FINAL

Corrective Action Plan for the Risk-Based Remediation of Site SS-15A



Homestead Air Force Base
Florida

Prepared For

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

and

Air Force Base Conversion Agency
Homestead Air Force Base, Florida

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From: Hansen, Jerry E, Mr, HQAFCEE [Jerry.Hansen@HQAFCEE.brooks.af.mil]
Sent: Tuesday, August 08, 2000 10:16 AM
To: 'nwalton@dtic.mil'
Subject: Distribution statement for AFCEE/ERT reports

Norman, This is a followup to our phone call. The eight boxes of reports you received from us are all for unlimited distribution. If you have any questions, you can contact me at DSN 240-4353.

DEPARTMENT OF THE AIR FORCE
AIR FORCE BASE CONVERSION AGENCY

18 September 1998

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ATTN: Mr. Jorge R. Caspary, P.G.

RE: Final Corrective Action Plan for the Risk-Based Remediation of Site SS-15A
Homestead Air Force Base, Florida

The reference document is now final. Attached are responses to FDEP and DERM comments on the draft document. If you have any questions, please contact Rita Chan at (305) 224-7119.

THOMAS J. BARTOL
BRAC Environmental Coordinator

Attachment:
1. Response to Comments
2. Final CAP for SS-15A

cc: USEPA, Doyle Brittain
DERM, James Carter/Charles Hallas (2)
Montgomery Watson, Jerry Gaccetta
HQ AFBCA/DD, Andrew Mendoza
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MEMORANDUM

August 28, 1998

To: Mr. Sam Taffinder (AFCEE/ERT), Mr. Tom Bartol (AFBCA/DD-Homestead), and Ms. Rita Chan (AFBCA/DD-Homestead)

From: Doug Downey and John Hicks, Parsons Engineering Science, Inc.

Subject: Responses to FDEP and DERM Review Comments on the Draft Final Corrective Action Plan for the Risk-Based Remediation of Site SS-15A, Homestead AFB, Florida

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Response to Comments Received from the Florida Department of Environmental Protection on the Draft Final Corrective Action Plan for the Risk-Based Remediation of Site SS-15A

The following verbal comments were received during the BRAC Cleanup Team (BCT) meeting held on 13 May 1998 at Homestead AFB, FL. The comments were taken directly from the meeting minutes. Our response to each comment follows.

1. Comment: *Mr. Greg Brown, FDEP, said the range of cleanup alternatives for risk at the site all seemed to be reasonable and acceptable approaches. He asked that the timeframes be calculated for the three alternatives to attain Tier 1 criteria just as they have been calculated for Tier 2 criteria.*

Response: Concur. The time frame for natural attenuation alone to attain Tier 1 target cleanup levels for groundwater were estimated for benzo(a)pyrene (27 years) and benzene (6 years). This information was presented in Section 6.6.3.4. At FDEP's request, the estimated timeframe for natural attenuation alone to achieve Tier 1 criteria will also be included in the discussion of Alternative 1 on pages 9-3 and 9-10. (Note: Because the Tier 2 SSTLs calculated for benzo(a)pyrene are essentially the same as the Tier 1 criteria, the timeframes for each alternative to attain Tier 1 will not change from the current estimates.)

2. Comment: *Mr. Brown suggested that the long-term monitoring plan include a condition for the short-term significant hydrologic impact of exceptional storm events (e.g. tropical storms).*

Response: The long-term monitoring plan (Section 10.3.5.3) will be modified to include a sentence stating that "In the event of a hurricane, the groundwater and nearby surface water will be monitored within six-months following the storm to assess the impact on this otherwise stable plume."

3. Comment: *In response to DERM's request for data to support the 30-day construction exposure scenario, Mr. Brown suggested that Parsons ES contact Captain McLain at Eglin AFB. Eglin AFB has an approved and validated construction scenario that has FDEP's approval (for active bases).*

- **Response:** Mr. Downey contacted Capt McLain and obtained a copy of the approved construction worker exposure scenarios. Since these exposure criteria already have FDEP approval for active installations, they will be used to recalculate construction worker target levels for soils and groundwater in Section 7 of the document. Per telephone conversations with FDEP's Mr. Caspary, these target levels can still be used to focus remediation efforts for areas that will remain under Air Force control, but should not be used as final cleanup criteria for areas that will be transferred out of Air Force control. FDEP's position is that it will be difficult to control the duration of exposure for construction workers after the land transfers from Air Force control.

The Air Force agrees to use the Eglin AFB construction exposure scenario to determine site specific target levels for property retained by the Florida Air National Guard (FANG). A discussion and a map will be added to Section 10 of the CAP to delineate:

- the area to be retained by the FANG where Tier 2 SSTLs will be applied as cleanup criteria.
- Areas that do not meet Tier 1 industrial cleanup criteria and will require engineering/institutional controls until Tier 1 criteria are attained through natural attenuation.

- Areas that currently meet Tier 1 cleanup criteria and can be transferred with minimal industrial land use engineering/institutional controls.

The following additional comments were extracted from the 15 July 1998 letter from FDEP to Mr. Tom Bartol on the subject of the applicability of Tier 2 cleanup criteria at this site.

4. Comment: *"The Department felt that the proposed exposure durations and frequency and other parameters (see attached letter from Steve Roberts dated 6/11/98) lacked proper justification and more importantly, FDEP's contract toxicologists felt that the applicability of the chronic exposure equation for soils could not be readily extrapolated for short-term exposures as those addressed in the subject document."*

Response: Two issues are raised by this comment. The first issue is providing justification for the exposure assumptions used for the construction worker scenario. Parsons ES intends to use the construction worker exposure assumptions that have been approved for active Air Force facilities (i.e. the Eglin AFB exposure assumptions that have FDEP approval). The second issue has to do with the appropriateness of using the EPA chronic exposure equations to determine the risk of soil contaminants during short-term exposures. Parsons ES understands this concern. The risk of soil and groundwater contaminants could also be estimated by using acute exposure criteria that are available for some contaminants and generally fit under the OSHA workplace safe exposure umbrella. FDEP's desire to rely on engineering and institutional controls (such as OSHA worker safety standards) rather than calculated SSTLs. We believe that this response adequately addresses the concerns raised in the University of Florida letter.

5. Comment: *"The Department has opted, and communicated to the AFBCA's personnel and consultants, that it prefers the issue (of site-specific cleanup levels for future construction workers) be shifted to the arena of engineering and institutional controls. In other words, due to the uncertainties with regard to risk calculations for construction worker scenarios, the Department would rather rely on institutional/engineering controls for those areas where the health risk from exposure to contaminated soil is for short term exposures only due to (a disturbance) to the asphalt/concrete cap..."*

Response: Based on FDEP's Petroleum Contamination Site Cleanup Criteria (Chapter 62-770.680) a "No Further Action With Conditions" may be granted at a site that has engineering controls such as a permanent cover and where groundwater contamination is limited to the immediate vicinity of the source area and at least one year of monitoring data has documented plume stability. Based on FDEP's 15 July 1998 letter, we assume that this justification could be used to pursue a "No Further Action With Conditions" closure at Site SS-15A.

6. Comment: "*As discussed in our 13 June 1998 teleconference, this decision should not impede the AFBCA from proceeding with remediation of soil and groundwater in those areas on the flightline deemed by Parsons ES as exceeding the 30-day exposure criteria (for construction workers). As discussed, once the soil and groundwater removal operation is accomplished, then the Department expects that the transfer document for the flightline will include language indicating that should the asphalt/concrete cover need to be disturbed, that construction workers will be notified that petroleum contamination is present at the site and that they need to use proper protective equipment based on OSHA requirements.*"

Response: Based on this comment, Parsons ES intends to retain Section 7 of the existing CAP but modify it so that 1) soil and groundwater target levels are based on the Eglin AFB exposure assumptions; 2) explain that these target levels are intended to guide the cleanup of areas with higher risk and will be used as cleanup criteria for areas which will remain under Air Force control (FANG area).

Parsons ES intends to demonstrate that the Tier 1 cleanup criteria of 2500 mg/kg for Total Recoverable Petroleum Hydrocarbons (TRPH) should be waived at this site due to the highly weathered nature of the fuel residuals. The following text will be added to Section 4.3.1.1 "Based on the precedent set for adjacent Site SS-15B, the Air Force is requesting a waiver to the Tier I TRPH TCLs for Site SS-15A. The TRPH found in Site SS-15A should be of the same as Site SS-15B. SS-15B contains the jet fuel pumphouses that feed fuel into the Site SS-15A fuel distribution lines. The Tier 1 Direct Exposure II TCL for TRPH in soil (industrial worker exposure scenario) is based on the most conservative and health protective carbon range that can be detected by the FL-PRO analytical method, the $>C_8$ to C_{10} range. To assess whether the Tier 1 TCL was an appropriate cleanup goal for the adjacent Site SS-15B, 44 soil samples were collected at Site SS-15B in October 1997 and analyzed TRPH using the FL-PRO method (OHM, 1997). The TRPH concentrations were broken down by the analytical laboratory into five carbon-group classes, including C_8-C_{10}, $>C_{10}$-C_{12}, $>C_{12}$-C_{16}, $>C_{16}$-C_{21}, and $>C_{21}$. TRPH concentrations detected in 11 of the 44 Site SS-15B soil

samples exceeded the Direct Exposure II TCL of 2,500 mg/kg; concentrations in these 11 samples ranged from 2,800 mg/kg to 7,600 mg/kg. However, total concentrations of C_8-C_{10} hydrocarbons in these 11 samples ranged from 126 mg/kg to 403 mg/kg, and did not exceed the Direct Exposure II TCL . The analytical results indicate that C_8-C_{10} hydrocarbons represented 4.1 percent to 9.8 percent of the TRPH. The low percentage of volatile, low-molecular-weight aromatics present in the fuel is confirmed by the low magnitude of the total BTEX concentrations, which constituted less than 0.1 percent to 0.5 percent (average 0.3 percent) of the TRPH by mass . Based on the TRPH classification, the primary TRPH was $>C_{12}$-C_{16}, which have relatively low toxicities (FDEP, 1997). The OHM (1997) report concluded that, based on the TRPH carbon group classification, TRPH did not appear to be a cleanup driver for the site.

A total of 20 TRPH concentrations detected in soil samples at Site SS-15A have exceeded the Tier 1 TCL of 2,500 mg/kg. With the exception of soil from AP8-SB6 (TRPH = 15,000 mg/kg), TRPH concentrations detected in these samples (2,600 mg/kg to 9,600 mg/kg) are similar to those detected in the Site SS15B samples. Although the TRPH concentrations determined for Site SS-15A in March 1994 and October 1997 were not broken down by carbon-group classes, very low total BTEX concentrations were observed relative to the TRPH concentrations. This indicates that, similar to Site SS-15B, C_8-C_{10} hydrocarbons in Site SS-15A soils are also insignificant. Total BTEX concentrations in Site SS-15A soil samples collected in 1994 ranged from less than 0.1 to 4.4 percent of the TRPH concentrations by mass (average 0.6 percent).

Four soil samples collected at Site SS-15A in October 1997 contained detectable concentrations of TRPH that ranged from 21 mg/kg to 200 mg/kg. The maximum total BTEX concentration detected in these four samples was 0.0197 mg/kg, which is approximately 0.1 percent of the TRPH concentration detected in the same sample (see Section 5). The 1997 data indicate that the percentage of TRPH consisting of low-molecular-weight, volatile compounds (e.g., BTEX) is decreasing over time at Site SS-15A due to preferential attenuation (via biodegradation and volatilization) of the more volatile compounds. Based on the detailed analysis of TRPH completed at Site SS-15B, and the supporting results at Site SS-15A, the Air Force does not consider the Tier 1 TCL of 2500 mg/kg to be valid indicator of risk for this highly weathered jet fuel. Specific analysis of VOCs, SVOCs, and PAHs at the site have been used to more accurately identify Tier 1 soil chemicals of potential concern."

Based on this TRPH waiver, AFBCA intends to identify areas of SS-15A which meet all other Tier 1 soil criteria. The institutional controls recommended for these areas should be less restrictive than in areas where soils exceed Tier 1 industrial criteria. General institutional controls will be included in land transfer documents to ensure future construction worker protection. The exact language will be worked out by AFBCA's legal counsel.

Response to Comments from Dade Environmental Resource Management Group letter dated 15 May 1998

Risk-Based Issues

A. Groundwater

1. Comment: *Please provide the rationale for not including incidental ingestion and inhalation of volatile organic compounds from groundwater.*

Response: The Tier 2 site-specific target levels (SSTLs) will be recalculated using construction worker exposure assumptions developed for use at Eglin AFB, Florida (McLain, 1998). The exposure pathways that will be incorporated in the new SSTLs include dermal exposure and incidental ingestion. Section 7 of the final Corrective Action Plan (CAP) will explain that the SSTLs will be used as cleanup criteria for areas that are to remain under Air Force control. They can also be used to guide the cleanup of areas that will be transferred from Air Force control, but are not intended to be final cleanup criteria. The Tier 1 target cleanup levels (TCLs) listed in Section 4 of the CAP will be considered as the final cleanup criteria for transferred land.

2. Comment: *Vinyl Chloride and/or TCE levels higher than primary drinking water standards have been consistently detected in the groundwater throughout the monitoring period. These compounds must be addressed.*

Response: During the 4 sampling events performed from January 1997 to January 1998 (year 2 quarter 1 to year 2 quarter 4), vinyl chloride (VC) concentrations exceeded 1 µg/L at least once in four wells at apron lines AP15 and AP17. Detected VC concentrations ranged up to 5 µg/L. During the same time period, the maximum detected TCE concentration was 3 µg/L at apron lines AP17 and AP18. These chlorinated aliphatic hydrocarbons (CAHs) are not typical fuel constituents, and therefore do not appear to be related to the jet fuel distribution system. The concurrent detections of *cis*-1,2-DCE (a common daughter product resulting from the reductive dechlorination of TCE) and VC (a daughter product resulting from the reductive dechlorination of DCE) in groundwater indicate that anaerobic, microbially-mediated, reductive dechlorination of CAHs is occurring. Under highly reducing, methanogenic conditions, VC may be reductively transformed to ethene, a non-toxic end-product. As described in Section 6.4.8 of the draft final CAP, evidence of localized methanogenic conditions in Site SS-15A groundwater is present. Given the isolated occurrence and low magnitude of the CAH concentrations, the evidence that reductive dechlorination is occurring, and the lack of clearly-defined sources, remediation by natural attenuation (RNA) is the preferred remedial alternative for these compounds. Biannual analysis for CAHs is recommended

at wells AP15-MW37 and AP17-MW40 and will be included in the long-term monitoring (LTM) plan.

3. Comment: *In addition, TRPH levels higher than Groundwater Target Cleanup Levels developed in Chapter 62-770. F.A.C., have been detected in the groundwater and must be addressed.*

Response: During the January 1997 sampling event (the last event that included analysis of TRPH), TRPH concentrations exceeded the Table V Target Cleanup Level (TCL) and Table IX Natural Attenuation Source Default Value in two wells (AP11-MW14 and AP26-MW75) and 1 well (AP11-MW14), respectively. Engineered remediation has been recommended for the area surrounding AP26-MW75; therefore, only TRPH at AP11-MW14 remains of potential concern. Groundwater from this well has been analyzed for TRPH five times since monitoring began in October 1995. The most recent analysis result (January 1997, 76 mg/L) was the only value that exceeded the Natural Attenuation Source Default value of 50 mg/L. This well will not be included in the LTM program. A single exceedence of the Natural Attenuation Source Default Value is not sufficient justification for continued monitoring at this location given the future industrial use of the site, the presence of institutional controls, and the relative immobility of the dissolved contaminants.

B. Soil

4. Comment: *The use of alternative soil cleanup target levels is justified based on the presence of an engineering control (pavement) in accordance with Rule 62-770-680(2)c4. Be advised, however, that an institutional control in the form of a Deed Restriction is required, which prohibits removal of the engineering control. Removal of institutional and engineering controls require prior departmental approval and must be accompanied by active cleanup, unless the required reassessment reveals that the applicable cleanup target levels have been achieved.*

Response: The Air Force is aware of the Deed Restriction requirement.

5. Comment: *The FDEP industrial worker default values for exposed skin surface area and soil ingestion rates may not be appropriate for the construction worker. The industrial worker is assumed to be an indoor/office worker. The construction worker could potentially intake greater amounts of soil and would likely wear different type of clothing, exposing a greater skin surface area. DERM recommends using an ingestion rate of 480 mg/kg (Hawley, J.K., 1985) and an exposed skin surface area for the head, hands and forearms, minimally. However, alternate values may be proposed with the appropriate references.*

Response: As described in the response to comment 1, the SSTLs will be recalculated using the Eglin AFB exposure assumptions; these assumptions have been reviewed and approved by the FDEP. For soil exposure, an exposed skin surface area of 5,300 cm^2 and an ingestion rate of 480 mg/day will be used to compute reasonable maximum exposure (RME) SSTLs. For groundwater exposure, a skin surface area of 5,300 cm^2 and an ingestion rate of 0.005 L/hr will be used.

6. Comment: *As indicated in all previous MPO Quarterly review letters, the soil assessment/delineation for TRPH is incomplete and must be addressed.*

In addition, it is recommended that areas with TRPH concentrations exceeding Industrial Direct Exposure Soil Cleanup Target Levels identified during the initial assessment using EPA Method 9071 are re-sampled utilizing FL-PRO. Use of the FL-PRO including carbon range speciation will present a more accurate representation of TRPH contaminant concerns on site and may provide for the development of more cost effective solutions (i.e., reduction in the areal extent of the TRPH plume exceeding Chapter 62-770, F.A.C. soil cleanup target levels). In addition, leachability concerns must be addressed if Soil Cleanup Target Levels for leachability are exceeded. This may be addressed through SPLP sampling or through engineering controls (i.e., maintaining the surface seal) in conjunction with institutional controls.

Response: See the response to FDEP comment No. 6 for discussion of requested waiver of Tier 1 TRPH criteria. Soil TRPH concentrations exceeded the Tier 1 leachability TCL numerous times, indicating that groundwater impacts may be unacceptable. However, in January 1997 (the last event that included analysis of TRPH), groundwater TRPH concentrations in only two wells exceeded the Tier 1 Table V TCL (one of these detections was in an area that will be remediated), and concentrations in only 1 well exceeded the natural attenuation source default value (although not all samples were analyzed for TRPH). The TRPH consists primarily of heavy, longer-chained PAHs that are relatively immobile in the subsurface, and migration risks are negligible. The available data indicate that the detected soil TRPH concentrations are not having significant adverse impacts on groundwater quality. Given the strong evidence that biodegradation of petroleum hydrocarbon compounds is occurring in the subsurface beneath the site, TRPH concentrations will decrease over time. Maintenance of the pavement cap and use of other institutional controls and deed restrictions will minimize leaching and prevent improper exposure to contaminated media. Further definition of the extent of soil TRPH contamination will not alter these conclusions.

7. Comment: *Please provide the rationale for selecting exposure frequencies of 60, 30 and 5 days/year and an exposure duration of 1 year. The values for these variables must be based on site-specific, historical information and must consider the potential for cumulative exposure of an individual contractor to multiple contaminated sites within the HARB.*

Response: The SSTLs will be recalculated using exposure frequencies derived for use at Eglin AFB and accepted by the FDEP (180 days/yr for soil and 46 days/yr for groundwater) (McLain, 1998). These values reportedly are based on studies of actual conditions during typical construction activities. (Reference: McLain, Captain. Tables received from Eglin AFB, Florida with construction worker exposure assumptions. June 12, 1998).

Source Reduction Issues

8. Comment: *Details of the procedures to be implemented during any soil removal must be submitted in a Remedial Action Plan prepared in accordance with Chapter 62-770 F.A.C. These details must include but not be limited to:*

1. *The frequency of samples using a field screening technique (OVA), and the endpoint goals of the field screening during soil excavation.*

2. *The frequency of confirmatory analytical samples and proposed parameters, etc.*

3. *The design calculations for the treatment of the water to be pumped from the excavations must be included in the Remedial Action Plan.*

Be advised that in all cases where groundwater is withdrawn from the aquifer, the DERM strongly recommends the use of on site recharge in order to conserve the groundwater resources of Miami-Dade County. If sanitary sewer is the only feasible or cost effective alternative, the location and construction details of the connection must be submitted in order to determine if this alternative is acceptable.

Response: A remedial action plan outlining excavation procedures will be submitted for review prior to any soil removal. The use of on-site recharge will be considered. However, the selected remedial alternative includes aggressive pumping from a 30- by 30-foot excavation for 2 weeks (estimated total of 300,000 gallons to be extracted). Recharge of this water would be technically infeasible without concurrent construction of an extensive recharge gallery given the large volume of water that will potentially be removed during a short time period. Construction of such a gallery would add significantly to the cost of the remedial action and is not warranted given the short-term nature of the remedial action.

FINAL

CORRECTIVE ACTION PLAN
FOR THE RISK-BASED REMEDIATION OF SITE SS-15A

HOMESTEAD AIR FORCE BASE
FLORIDA

September 1998

Prepared for

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

and

Air Force Base Conversion Agency
Homestead Air Force Base, Florida

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EXECUTIVE SUMMARY

GENERAL OVERVIEW

A limited site investigation addressing soil and groundwater contaminated with fuel hydrocarbons at Site SS-15A, Homestead Air Force Base (AFB), Florida, was conducted by Parsons Engineering Science, Inc. (Parsons ES). Field work was conducted to supplement previous investigations and to complete the corrective action plan (CAP) presented in this report in support of a risk-based remediation decision for Site SS-15A. Characterization field efforts for this investigation were conducted in October 1997. An *in situ* bioventing pilot test also was performed at Site SS-15A to determine the effectiveness of this remedial technique in treating site-related contamination.

The risk-based demonstration at Site SS-15A is sponsored by the United States (US) Air Force Center for Environmental Excellence (AFCEE) at Brooks Air Force Base, Texas under Air Mobility Command (AMC) contract F11623-94-D-0024, Delivery Order RL39, and is a component of a multi-site AFCEE initiative. The purpose of this initiative is to demonstrate how quantitative fate and transport calculations and risk evaluation, based on site-specific data, can be integrated. Consequently, this integration allows for rapid determination of the type and magnitude of corrective action required at a site to minimize contaminant migration, receptor exposure, and subsequent risks to potential receptors. Risk-based remediation is designed to combine natural physical, chemical, and biological processes with low-cost source reduction technologies such as limited excavation and *in situ* bioventing to economically reduce potential risks to human health and the environment posed by subsurface petroleum fuel spills.

Site SS-15A is a flightline apron located in the southeastern portion of the Base and encompasses an asphalt and concrete covered area approximately 7,600 feet long and 1,130 feet wide. The site contains 26 abandoned underground jet fuel distribution lines

(AP-4 through AP-29). The lines were installed beginning in 1956, and were abandoned in late 1993 and early 1994. The fuel hydrocarbon contamination in soil and groundwater at Site SS-15A (primarily JP-4 jet fuel) occurs in a number of isolated areas beneath the flightline apron and generally in the vicinity of fuel line valve boxes. Because of the flat groundwater hydraulic gradient, migration of dissolved contaminant plumes does not appear to have occurred to any appreciable extent. Analytical results for vertical extent wells indicate that the dissolved contamination is limited to the shallow portion of the surficial aquifer.

One objective of the CAP is to document any potential current risks to human health and the environment (i.e., ecological receptors) due to exposure to chemical contaminants originating from Site SS-15A. The CAP also addresses the potential future risks to human and ecological receptors due to exposure to chemical contaminants over time, accounting for the effects of natural chemical attenuation processes. The overall objective of the CAP is to develop and present a recommended risk-based remedial approach for fuel hydrocarbon contamination in soils and groundwater at Site SS-15A that is protective of both human health and the environment.

OVERVIEW OF PROJECT ACTIVITIES

It is the intent of the Air Force to pursue a risk-based remediation of Site SS-15A in conformance with the tiered-approach framework established by the Florida Department of Environmental Protection (FDEP) (1997). The activities conducted pursuant to 1) determining the need for and type of any interim corrective action, and 2) establishing the level of evaluation necessary to define risk-reduction requirements at this site included characterizing:

- The nature and extent of fuel hydrocarbon contamination in selected portions of the site;
- The locations of potential groundwater discharge areas;

- The local geology and hydrogeology that may affect contaminant transport;
- The proximity of the site to drinking water aquifers, surface water, and other sensitive environmental resources;
- The expected persistence, mobility, chemical form, and environmental fate of contaminants in soils and groundwater under the influence of natural physical, chemical, and biological processes;
- The current and potential future uses of the site and its vicinity, including groundwater, and the likelihood of exposure of receptors to other potentially impacted environmental media over time;
- The potential risks associated with chemical contamination under current and foreseeable future conditions;
- The long-term target remedial objectives and chemical-specific concentration goals required to protect human health and the environment; and
- The treatability of residual fuel hydrocarbon contamination using low-cost source-reduction technologies such as limited excavation and bioventing.

RESULTS OF RISK-BASED ANALYSIS

Several remedial approaches that rely both on natural processes and on engineered solutions were evaluated for the site. A site-specific exposure pathways analysis involving environmental media impacted by chemical contamination at Site SS-15A was completed to assess whether existing and predicted future concentrations of hazardous substances would pose a threat to current and foreseeable future onsite or offsite receptors. The site-specific exposure pathways analysis indicates that only onsite intrusive workers could reasonably be exposed to significant concentrations of site-related contamination.

Concentrations of several fuel hydrocarbons measured at Site SS-15A slightly exceed applicable Tier 1 target cleanup levels (TCLs) (FDEP, 1997). Tier 1 TCLs are generic risk-based concentrations that are used as a screening tool to initially determine what chemicals of potential concern (COPCs) might exist in an unrestricted industrial land use scenario. Because the long-term remediation objective of this site is to use this property for unrestricted industrial use, FDEP has requested that the ultimate cleanup goal for this site is to achieve Tier 1 TCLs. The analytes with Site SS-15A concentrations above the Tier 1 screening levels include benzene, ethylbenzene, xylenes, methyl tert-butyl ether (MTBE), naphthalene, several polyaromatic hydrocarbons (PAHs) and total recoverable petroleum hydrocarbons (TRPH). This CAP requests a waiver from Tier 1 TCLs for TRPH based on the low mass fraction of BTEX and other $C_8 - C_{10}$ compounds remaining in these jet fuel residuals.

The Florida Air National Guard (FANG) will continue to control and operate from the northern end of Site SS-15A. This continuation of Air Force control allows for more oversight of future construction workers in the FANG area, and limitations on their exposure to any contaminated soil or groundwater. In addition to the generic Tier 1 evaluation, a Tier 2 evaluation was conducted to develop alternate site-specific target levels (SSTLs) to guide corrective actions to be implemented in the FANG area. These SSTLs are based upon construction worker exposure scenarios that have been approved by FDEP for active Air Force installations. SSTLs were also used to determine if there were other areas within Site SS-15A that posed a significant threat to intrusive construction workers. Comparison of Site SS-15A contaminant concentrations to site-specific Tier 2 SSTLs indicated that the maximum detected concentrations of benzo(a)anthracene, benzo(a)pyrene, and benzo(b)fluoranthene measured in groundwater between December 1996 and October 1997 exceeded their respective health-based groundwater SSTLs. These exceedences were concentrated within the FANG area indicating a potential need for remediation to protect future construction workers. Minor exceedences of Tier 2 soil SSTLs were detected for

benzo(a)pyrene and dibenz(a,h) anthracene, but these were scattered and only appeared to impact groundwater in the FANG area.

A site-specific chemical fate assessment was completed to identify the potential for, and risks associated with, exposure to chemical contamination over time at the site. The potential for receptor exposure to chemical contamination at Site SS-15A over time depends on future site conditions and the persistence, mobility, chemical form, toxicity, and fate of site-related contaminants. Site characterization data relevant to documenting natural chemical attenuation, specifically bioattenuation, were collected and are documented in this CAP. Fate and transport model results were used to predict the exposure-point concentrations of indicator compounds (benzene and benzo(a)pyrene) over time at the site.

Although site-specific data indicate that groundwater COPCs are being reduced in mass, concentration, and toxicity by natural chemical attenuation processes, the BIOSCREEN model developed for the site suggests that concentrations of dissolved benzene and benzo(a)pyrene will not be reduced below their Tier 1 TCLs or SSTLs at every point at the site for up to 6 years and 27 years, respectively, unless some type of source removal is undertaken in the FANG area. Additionally, this model predicts that benzene, which is the most mobile of the simulated COPCs, will not migrate more than approximately 50 feet from the source area. Therefore, attainment of Tier 1 TCLs in groundwater could take up to 27 years if only natural chemical attenuation with LTM were implemented at this site.

RECOMMENDED REMEDIAL ALTERNATIVE

The recommended remedial alternative for all areas of Site SS-15A with Tier 1 exceedences is continued institutional controls to ensure the protection of any future workers involved in excavation activities, and continued groundwater monitoring to confirm that natural attenuation is reducing COPC concentrations and limiting migration. These controls should be included in land transfer documents for areas of the site that will be transferred from Air Force control.

Because soils and groundwater within the FANG area exhibited a greater number of Tier 1 and SSTL exceedences, two remedial alternatives that incorporate engineered source reduction were developed to more rapidly achieve the desired contaminant reductions. The comparative remedial analysis presented in this CAP indicates that the best combination of risk reduction and low cost remediation can be achieved by excavating source area soils in two FANG areas (AP-26 and AP-27) and pumping groundwater from the excavations for a limited period (approximately 2 weeks per excavation area). Excavation of source area soils would rapidly and relatively inexpensively remove the source of dissolved groundwater contamination. This activity, in combination with intensive short-term groundwater extraction, would remove both residual and dissolved contaminants, and has the potential to achieve health-protective Tier 1 TCLs and SSTLs for groundwater within 3 years of implementation of this alternative. To confirm that the predicted degree of remediation is being attained and to ensure that no unacceptable receptor exposures to chemical contamination could occur at the site, a long-term monitoring plan is included in this CAP.

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LIST OF ACRONYMS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AMC	Air Mobility Command
bgs	below ground surface
BRAC	Base Realignment and Closure
BTEX	benzene, toluene, ethylbenzene, xylenes
CAP	corrective action plan
CO_2	carbon dioxide
COC	chemical of concern
COPC	chemical of potential concern
CSM	conceptual site model
°C	degrees Celsius
DERM	Miami-Dade Department of Environmental Resources Management
DOT	Department of Transportation
FAC	Florida Administrative Code
FANG	Florida Air National Guard
FDEP	Florida Department of Environmental Protection
F_{oc}	fractional organic carbon content
ft/day	foot per day
ft/ft	foot per foot
ft/sec	foot per second
ft/yr	feet per year
GAC	granular activated carbon
gpm	gallons per minute
HDPE	high-density polyethylene
IDW	investigation-derived waste
IWWTP	industrial wastewater treatment plant
IRIS	Integrated Risk Information System
K_d	distribution coefficient
kg	kilogram
kg/L	kilograms per liter
L/kg	liters per kilogram
LNAPL	light nonaqueous-phase liquid
LTM	long-term monitoring
MDL	method detection limit
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mm/Hg	millimeters of mercury
MO	monitoring only

MS/MSDs	matrix spikes/matrix spike duplicates
MTBE	methyl tert butyl ether
mV	millivolts
N	nitrogen
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanographic and Atmospheric Administration
O_2	oxygen
ORP	oxidation/reduction potential
OSHA	Occupational Safety and Health Administration
OSWER	USEPA Office of Solid Waste and Emergency Response
OU9	Operable Unit 9
PAH	polynuclear aromatic hydrocarbon
Parsons ES	Parsons Engineering Science, Inc.
PEL	permissible exposure limit
PID	photoionization detector
ppmv	parts per million, volume per volume
POA	point-of-action
PQL	practical quantitation limit
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RI	remedial investigation
RNA	remediation by natural attenuation
SAP	sampling and analysis plan
scfm	standard cubic feet per minute
SCTLs	soil cleanup target levels
SSTL	site-specific target level
SVE	soil vapor extraction
TCLs	target cleanup levels
TMWs	temporary monitoring wells
TOC	total organic carbon
TRPH	total recoverable petroleum hydrocarbons
TVH	total volatile hydrocarbons
US	United States
USEPA	U.S. Environmental Protection Agency
VMPs	vapor monitoring points
VOAs	volatile organic aromatics
VOC	volatile organic compound
VOHs	volatile organic halogenateds
VW	vent well

P.E. CERTIFICATION

The initial corrective action plan for Site SS-15A located at Homestead Air Force Base (AFB), Florida has been reviewed. The Florida Department of Environmental Protection (FDEP) facility ID number for this site is 138521996.

I hereby certify that, in my professional judgment, the components of this initial corrective action plan satisfy the requirements set forth in Chapter 62-770, Florida Administrative Code (FAC). The engineering design features incorporated in this plan provide reasonable assurances of achieving the alternative, site-specific cleanup levels for groundwater derived for this site per Chapter 62-770.650. To the best of my knowledge, this plan is free of errors and omissions.

Signature

Florida 31941

P.E. Registration

9/16/98

Date

SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

Parsons Engineering Science, Inc. (Parsons ES) was retained by the United States (US) Air Force Center for Environmental Excellence (AFCEE) to prepare a corrective action plan (CAP) in support of a risk-based remediation decision for soil and groundwater contaminated with fuel hydrocarbons at Site SS-15A at Homestead Air Force Base (AFB), Florida. Site SS-15A, the Flightline Apron, encompasses an asphalt- and concrete-covered area approximately 7,600 feet long and 1,130 feet wide. The site contains 26 abandoned underground jet fuel distribution lines (AP-4 through AP-29). Fuel releases from leaking underground fuel distribution lines and re/defueling valve boxes located along these lines, have contaminated site soil and groundwater with fuel hydrocarbons.

Risk-based remediation is designed to combine natural physical, chemical, and biological processes with low-cost source reduction technologies such as limited excavation and *in situ* bioventing, as necessary, to economically reduce potential risks to human health and the environment posed by subsurface petroleum fuel spills. For any chemical to pose a risk, four elements must exist at the site:

- A source of chemical contamination that exceeds or could generate chemical contamination above health-protective or aesthetic standards;
- A mechanism of contaminant release;
- A human or ecological receptor and a receptor exposure point; and

- A completed pathway through which that receptor will contact the chemical.

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

The goal of this CAP is to find and document the most cost-effective method of reducing present and future risk by combining, as necessary, three risk-reduction techniques:

- Chemical Source Reduction - Achieved by natural attenuation processes over time and/or by engineered removals such as limited excavation, soil vapor extraction (SVE), or *in situ* bioventing.

- Chemical Migration Control - Examples include the natural attenuation of a groundwater plume, and SVE to prevent migration of hazardous vapors to a receptor exposure point.

- Receptor Restriction – Institutional/engineering controls (e.g., excavation precautions, impermeable cap) to limit receptor exposure to site contaminants until natural attenuation and/or engineered remediation can reduce the chemical source and/or eliminate the potential for chemical migration to an exposure point.

The major tasks that have been performed in support of this risk-based project are:

- Assessing available data and collecting supplemental site characterization data necessary to define the nature, magnitude, and extent of soil, soil gas, and groundwater contamination and to document to what degree natural attenuation processes are operating at the site;

- Determining whether an unacceptable risk to human health or the environment currently exists or may exist in the foreseeable future using reasonable exposure

scenarios, quantitative contaminant fate and transport models, and exposure concentration estimates; and

- Evaluating and recommending a remedial alternative that both reduces the source of contamination and minimizes or eliminates risks to potential receptors.

This CAP was prepared in accordance with the final Petroleum Contamination Site Cleanup Criteria rule (Chapter 62.770 of the Florida Administrative Code [FAC]) (Florida Department of Environmental Protection [FDEP], 1997). This rule provides guidance for determining the remedial requirements for closure of petroleum-contaminated sites, including several methods for determining matrix-specific cleanup criteria.

Once a petroleum-contaminated site has been characterized, the site may be subjected to a Tier 1 risk evaluation. A Tier 1 evaluation is a screening-level assessment where contaminant concentrations measured in site media are compared to generic target cleanup levels (TCLs) that are based on conservative receptor exposure factors, potentially completed receptor exposure pathways, and land use assumptions, to identify appropriate corrective actions. FDEP (1997) presents Tier 1 TCLs for various receptor exposure scenarios in lookup tables.

In the event that measured site concentrations exceed the applicable Tier 1 TCLs, either an interim corrective action or a Tier 2 (site-specific) evaluation may be pursued. If an interim corrective action is deemed unnecessary, a Tier 2 evaluation may be conducted to establish reasonable, risk-based target cleanup objectives for a specific site. A Tier 2 evaluation is more comprehensive than a Tier 1 analysis because it requires quantitative contaminant fate and transport calculations and the development of site-specific remediation goals for potential receptor exposure pathways based on reasonable exposure assumptions and actual land use considerations. Tier 2 site-specific target levels (SSTLs) are based on the outcome of a predictive exposure pathways analysis to evaluate current and potential future human health risks and short-

term and long-term contaminant fate at the site. Although Tier 2 evaluations usually involve more rigorous analysis and may require use of long-term institutional controls, they should result in a more focused remediation of those contaminants that may actually pose a risk to potential receptors.

This CAP estimates potential risks to human health and the environment (i.e., ecological receptors) from exposure to chemical contaminants originating from Site SS-15A under current conditions. The CAP also estimates the potential risks to future human and ecological receptors due to exposure to chemical contaminants over time, accounting for the effects of natural chemical attenuation processes. Finally, the CAP develops and describes a recommended remedial approach for fuel hydrocarbon contamination in soils, groundwater, and soil gas at Site SS-15A that ultimately can achieve the Tier 1 TCLs. This CAP is being submitted for review and approval in accordance with FDEP (1997) program requirements.

1.2 REPORT ORGANIZATION

This CAP consists of 11 sections, including this introduction (Volume I), and six appendices (Volume II). Site background, including operating history and a review of environmental site investigations conducted to date, is provided in the remainder of this section. Section 2 summarizes the 1997 site characterization activities performed by Parsons ES. Physical characteristics of Site SS-15A and surrounding environs are described in Section 3. A Tier 1 evaluation is completed in Section 4 to identify those site contaminants that are considered chemicals of potential concern (COPCs). Section 5 summarizes the nature and extent of COPC contamination at the site. Section 6 addresses the effects of natural chemical attenuation processes that are documented to be occurring at the site, and presents quantitative chemical fate and transport and receptor exposure analyses. The comprehensive Tier 2 evaluation, including the development of SSTLs, is detailed in Section 7. Section 8 presents contaminant treatability pilot test results for bioventing, and evaluates this low-cost source reduction technology. Section 9 presents a comparative analysis of three candidate remedial

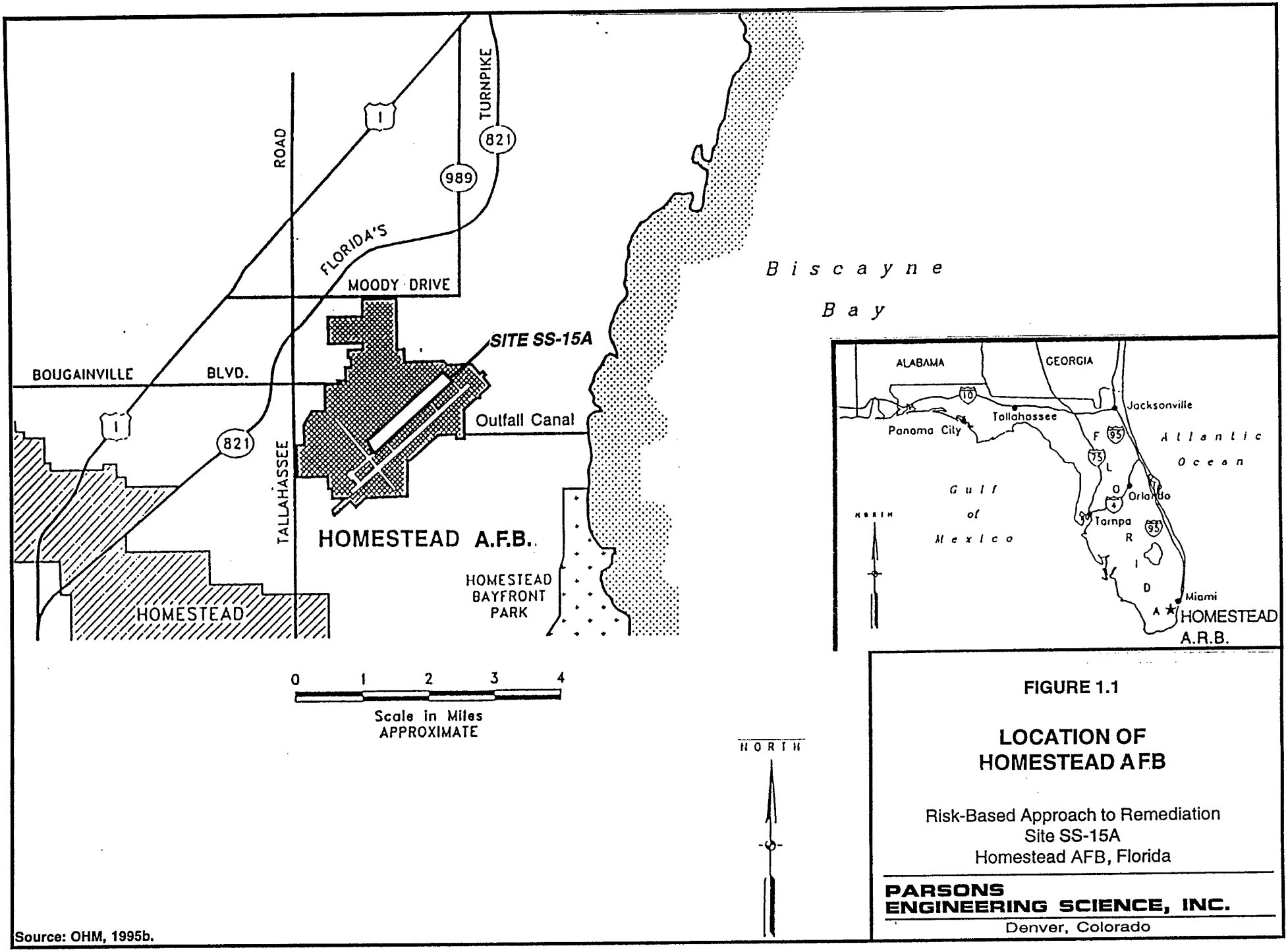
alternatives. Section 10 is a more detailed implementation plan for the recommended remedial alternative, including a detailed long-term monitoring plan (LTMP). Section 11 presents references used in preparing this CAP. Sections 1 through 11 are presented in Volume I of this CAP.

Boring logs, groundwater sampling forms, and well construction diagrams for all sampling activities completed by Parsons ES at Site SS-15A are included in Appendix A. Appendix B includes the quantitative calculations and fate and transport model results used in the predictive chemical fate assessment. Appendix C presents the site-specific (Tier 2) SSTL derivations and toxicity profiles for COPCs. Appendix D presents the source-reduction treatability pilot test data and calculations, and Appendix E summarizes the screening, development, and cost analyses of remedial alternatives considered in detail within this CAP. Appendix F presents a site-specific sampling and analysis plan (SAP) for the LTM at the site. The six appendices to this CAP are included in Volume II.

1.3 SITE BACKGROUND

Homestead AFB is currently the headquarters for the 482nd Air Force Reserve Fighter Wing which, along with the Florida Air National Guard (FANG), occupies approximately one-third of the Base property (the cantonment area). Site SS-15A, the Flightline Apron, is located mostly outside of the cantonment area. Site SS-15A is expected to be transferred to the Dade County Aviation Department, with the exception of the northern corner of the site that is used by the FANG.

Homestead AFB is located in Dade County, Florida, approximately 25 miles south of the City of Miami and 1.5 miles west of Biscayne Bay (Figure 1.1). The FDEP facility designation for Site SS-15A is No. 138521996, and the Dade County



Source: OHM, 1995b.

FIGURE 1.1

LOCATION OF HOMESTEAD AFB

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

Department of Environmental Resources (DERM) identifier is No. UT-5272. Site SS-15A is located in the southeastern portion of the Base and encompasses a 197-acre asphalt- and concrete-covered area measuring approximately 7,600 feet long and 1,130 feet wide (Figure 1.2). The site contains 26 abandoned underground jet fuel distribution lines (AP-4 through AP-29, Figure 1.3). The adjacent Site SS-15B, located southeast of Site SS-15A, is the location of nine former pumphouses and fuel tank farms that supplied fuel to pipelines within Site SS-15A.

The 26 4-inch (AP-19) to 6-inch-diameter (all others) steel distribution lines extend northwest beneath the Flightline Apron from the former pumphouses. The lines are spaced on 293-foot centers, and six valve boxes, spaced at 136-foot intervals, are located along each distribution line (Figure 1.3). The lines were installed beginning in 1956, were removed from service in the early 1960s, and were abandoned, along with the fuel farm tanks, in late 1993 and early 1994 (OHM, 1997). The fuel storage tanks were removed by OHM (1995a) during December 1993 through February 1994. The fuel hydrant system (FHS) piping was purged of fuel, tested, and 25 of the 26 distribution lines were grouted in early 1994 (OHM 1995a). Line AP-4 was left open after purging for possible future use.

1.4 PREVIOUS REMEDIAL INVESTIGATIONS AND INTERIM REMEDIAL ACTIONS

Several phases of environmental investigations and quarterly groundwater monitoring events have been conducted at Sites SS-15 from 1986 through 1997. Geraghty & Miller, Inc. (1992) performed IRP Phase II (1986) and IV (1988/1989) investigations in the fuel pumphouses area (Site SS-15B), including soil vapor surveys, monitoring well installation, and environmental media analyses. After abandoning and grouting the fuel distribution lines in 1994, OHM conducted several phases of soil and groundwater investigations at Site SS-15A, including seven quarters of groundwater monitoring. Interim remedial actions, consisting of overdeveloping selected wells to

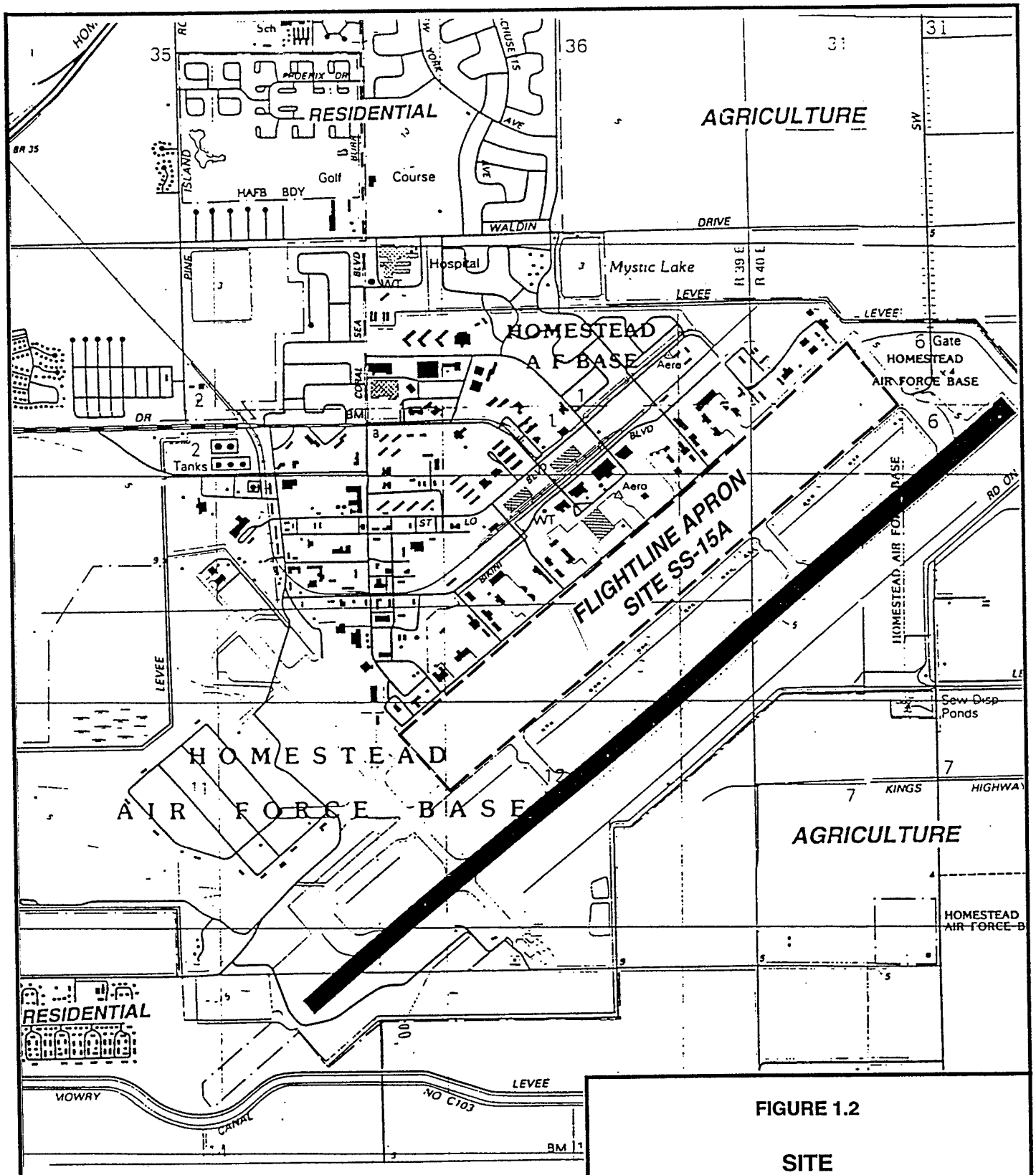


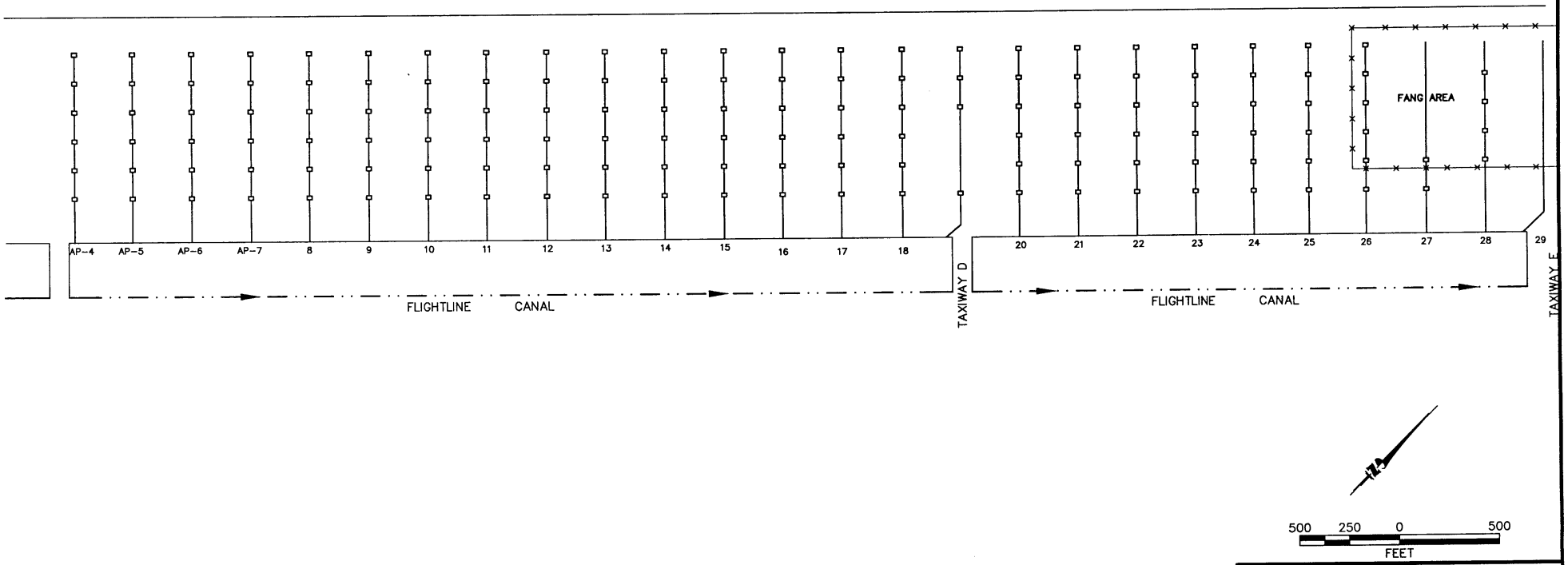
FIGURE 1.2

SITE LOCATION

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado



500 250 0 500

FEET

LEGEND

APRON FUEL LINE AND VALVE BOXES

FIGURE 1.3

SITE LAYOUT

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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reduce concentrations of dissolved fuel hydrocarbons, were implemented. Other investigation and interim remedial action activities at Site SS-15A have included:

- Collection and analysis of soil samples from 232 boreholes along and between the fuel distribution piping beneath the Flightline Apron in March 1994; installation and sampling of 84 temporary monitoring wells (TMWs); installation and sampling of 103 permanent monitoring wells; and performance of 11 aquifer slug tests (OHM, 1995a);

- Installation of 15 shallow monitoring wells, overdevelopment of 32 shallow monitoring wells, and collection and analysis of groundwater samples from 69 shallow monitoring wells during September/October 1995 (first quarterly monitoring-only [MO] event) (OHM, 1995b);

- Installation of 3 shallow monitoring wells, overdevelopment of 6 shallow monitoring wells, and collection and analysis of groundwater samples from 73 shallow monitoring wells during January 1996 (second quarterly MO event) (OHM, 1996a);

- Overdevelopment of 1 shallow monitoring well, and the collection and analysis of groundwater samples from 76 shallow monitoring wells during April 1996 (third quarterly MO event) (OHM, 1996b);

- Installation of 5 shallow and 2 intermediate-depth monitoring wells, and collection and analysis of groundwater samples from 81 shallow and 2 intermediate-depth monitoring wells during July 1996 (fourth quarterly MO event) (OHM, 1996c);

- Installation of 2 shallow monitoring wells, and collection and analysis of groundwater samples from 51 shallow monitoring wells during December 1996-January 1997 (year two first-quarter MO event) (OHM, 1997a);

- Installation of two pilot-scale bioventing systems, soil and soil gas sampling, air permeability testing and *in situ* respiration testing were performed at Site SS-15B by OHM and Parsons ES in October and November 1996 and February 1997 (Parsons ES, 1997a);

- Collection and analysis of groundwater samples from 40 shallow monitoring wells during July 1997 (year two second-quarter MO event) (OHM, 1997b);

- Collection and analysis of groundwater samples from 40 shallow monitoring wells during October 1997 (year two third-quarter MO event) (OHM, 1997c); and

- Collection and analysis of groundwater samples from shallow monitoring wells during January 1998 (year two fourth-quarter MO event) (OHM, report pending).

SECTION 2

SITE CHARACTERIZATION ACTIVITIES

Since 1994, several soil and groundwater investigations have been conducted at Site SS-15A by OHM. These investigations focused on characterizing and delineating dissolved hydrocarbons in groundwater and residual fuel hydrocarbons in soils. Parsons ES conducted a limited investigation at Site SS-15A during October 1997 to collect site-specific data relevant to quantifying the effects of natural contaminant attenuation processes and to facilitate development and implementation of a risk-based remedial action for Site SS-15A. Soil gas, soil, and groundwater were sampled to:

- Further delineate the extent of contamination in selected areas;
- Assess temporal trends in soil and groundwater contaminant concentrations;
- Support contaminant fate and transport analyses;
- Develop appropriate exposure-point concentrations to compare to final remediation goals; and
- Evaluate and design an appropriate remedial alternative for the site (if necessary).

A detailed investigation was performed at the north end of Flightline Apron Line AP-26 (valve box 1), where previous investigation results indicated relatively high soil and groundwater contaminant concentrations. Numerous groundwater monitoring wells are present at this location, facilitating a detailed assessment of the distribution of dissolved contaminants and pertinent geochemical analytes. The intent of the detailed

investigation was to enable use of line AP-26 as a microcosm of natural attenuation mechanisms occurring at the overall site. Sampling also was performed at other fuel distribution lines where elevated contaminant concentrations in soil and/or groundwater had been documented in order to:

- Confirm that geochemical conditions are sufficiently homogenous across Site SS-15A to allow extrapolation of the results of the detailed analysis performed at the AP-26 area to other site areas;
- Evaluate temporal trends in soil contaminant concentrations; and
- Support the performance of a bioventing pilot test.

To the extent practicable, data collected during previous investigations were used to augment this study. Emphasis was placed on collecting data documenting the natural biodegradation and attenuation of fuel hydrocarbons in soils and groundwater at the site.

The October 1997 supplemental site characterization activities performed by Parsons ES at Site SS-15A are briefly described in the remainder of this section. Most site characterization procedures (i.e., soil, soil gas, and groundwater sampling procedures) are described in detail in the project SAP (Parsons ES, 1997b).

2.1 SCOPE OF DATA COLLECTION ACTIVITIES

As part of the risk-based remedial approach for Site SS-15A, field data collection efforts focused on investigating specific chemical constituents that potentially pose a threat to human health or the environment. The chemicals targeted for study at this site were identified from previous site investigations and the chemical composition of the primary contaminant source (i.e., release(s) of JP-4 jet fuel from the former fueling/defueling system). The petroleum hydrocarbon chemicals identified and addressed as part of this study include benzene, toluene, ethylbenzene, and xylenes

(BTEX); polynuclear aromatic hydrocarbons (PAHs); and methyl tert butyl ether (MTBE). Selected samples also were analyzed for total recoverable petroleum hydrocarbons (TRPH). These analytes were targeted based on previous site assessment results and FDEP (1997) analytical requirements for petroleum UST sites.

Generally, laboratory analytical methods used during previous sampling events (e.g., quarterly groundwater monitoring events) were used during the risk-based field investigation. The only exception was the use of US Environmental Protection Agency (USEPA) Method SW8310 instead of SW8270 for the analyses of PAHs, because Method SW8270 reporting limits for some PAHs exceed generic FDEP TCLs. Soil and groundwater samples were analyzed by Quanterra, Inc. of Arvada, Colorado; Austin, Texas; and Tampa Florida. Soil gas samples were analyzed by Air Toxics, Ltd. of Folsom, California. Field analyses and measurements were performed for various inorganic, geochemical, and physical parameters to document natural biodegradation processes and to assess the potential effectiveness of low-cost source reduction technologies.

The risk-based investigation for Site SS-15A was conducted according to the methodologies presented in the *Draft Work Plan For the Risk-Based Remediation of Site SS-15A* (Parsons ES, 1997), hereafter referred to as the work plan. The work plan was developed according to available guidelines and minimum requirements to support site closure under one of several scenarios (FDEP, 1997), including:

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

The following sampling and testing activities were performed by Parsons ES during October 1997 at Site SS-15A as part of this investigation:

- Drilling 8 soil borings along fuel lines AP-15, AP18, AP-20, and AP-26;
- Collection of 10 subsurface soil samples for fixed-base laboratory analysis from the eight boreholes;
- Installation of one air-injection vent well (VW) and two vapor monitoring points (VMPs) at AP-18;
- Collection of groundwater samples from 23 existing groundwater monitoring wells along AP-10, AP-11, AP-17, AP-22, and AP-26;
- Collection and field screening of soil gas samples from 15 locations along AP-18 and AP-26;
- Collection of four soil gas samples for laboratory analysis from existing groundwater monitoring wells (with screens extending above the saturated zone) along AP-18 and AP-26; and
- Conducting a bioventing treatability pilot test at AP-18, including an air permeability test and *in situ* biorespiration tests.

Analytical method detection limit (MDL) requirements were considered before site characterization work was initiated under the risk-based remediation investigation. Suitable analytical methods and quality control (QC) procedures were selected (Parsons ES, 1997b) to ensure that the data collected under this program are of sufficient quality to be used in a quantitative risk assessment.

Table 2.1 summarizes the methods used to analyze the environmental samples collected under this program. This table also lists the laboratory-specified MDLs and practical quantitation limits (PQLs) for each analytical method by analyte and environmental sample matrix. The MDL is the lowest concentration at which a particular chemical can be measured and distinguished with 99-percent confidence from

TABLE 2.1
ANALYTE REPORTING LIMITS
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Analyte	Analytical Method	Field or Fixed-Base	Soil Gas MDL [a]	Soil Gas Units	Soil MDL	Soil PQL [b]	Soil Units	Ground Water MDL	Ground Water PQL	Ground Water Units
SOIL GAS										
Benzene	TO3	Fixed-Base	0.052-0.1	ppmv [c]						
Toluene	TO3	Fixed-Base	0.052-0.1	ppmv						
Ethylbenzene	TO3	Fixed-Base	0.052-0.1	ppmv						
Xylene (Total)	TO3	Fixed-Base	0.052-0.1	ppmv						
TPH [d] (C5+ Hydrocarbons)	TO3	Fixed-Base	0.52-1.0	ppmv						
C2-C4 Hydrocarbons	TO3	Fixed-Base	0.52-1.0	ppmv						
SOIL AND GROUNDWATER										
TRPH [e]	FL-PRO	Fixed-Base			9	10	mg/kg [f]	0.19	0.5	mg/L [g]
Benzene	SW8020A	Fixed-Base			0.5	5	µg/kg [h]	0.056	2	µg/L [i]
Toluene	SW8020A	Fixed-Base			1.24	5	µg/kg	0.15	2	µg/L
Ethylbenzene	SW8020A	Fixed-Base			0.5	2	µg/kg	0.054	2	µg/L
Xylene (Total)	SW8020A	Fixed-Base			1.5	5	µg/kg	0.15	2	µg/L
MTBE [j]	SW8020A	Fixed-Base			1.5	5	µg/kg	0.01	5	µg/L
Chlorobenzene	SW8020A	Fixed-Base			0.5	2	µg/kg	0.085	2	µg/L
1,2-Dichlorobenzene	SW8020A	Fixed-Base			0.5	4	µg/kg	0.18	4	µg/L
1,3-Dichlorobenzene	SW8020A	Fixed-Base			0.5	4	µg/kg	0.09	4	µg/L
1,4-Dichlorobenzene	SW8020A	Fixed-Base			0.5	3	µg/kg	0.33	4	µg/L
Acenaphthene	SW8310	Fixed-Base			0.036	0.2	mg/kg	0.093	1	µg/L
Acenaphthylene	SW8310	Fixed-Base			0.049	0.2	mg/kg	0.04	1	µg/L
Anthracene	SW8310	Fixed-Base			0.0026	0.02	mg/kg	0.03	0.1	µg/L
Benzo(a)anthracene	SW8310	Fixed-Base			0.0034	0.02	mg/kg	0.06	0.13	µg/L
Benzo(a)pyrene	SW8310	Fixed-Base			0.0022	0.015	mg/kg	0.065	0.23	µg/L
Benzo(b)fluoranthene	SW8310	Fixed-Base			0.0025	0.012	mg/kg	0.059	0.18	µg/L
Benzo(g,h,i)perylene	SW8310	Fixed-Base			0.003	0.05	mg/kg	0.071	0.2	µg/L
Benzo(k)fluoranthene	SW8310	Fixed-Base			0.0035	0.011	mg/kg	0.059	0.17	µg/L
Chrysene	SW8310	Fixed-Base			0.002	0.04	mg/kg	0.073	0.2	µg/L
Dibenz(a,h)anthracene	SW8310	Fixed-Base			0.0034	0.02	mg/kg	0.076	0.3	µg/L
Fluoranthene	SW8310	Fixed-Base			0.0024	0.04	mg/kg	0.036	0.2	µg/L
Fluorene	SW8310	Fixed-Base			0.0064	0.04	mg/kg	0.035	0.2	µg/L
Indeno(1,2,3-cd)pyrene	SW8310	Fixed-Base			0.003	0.03	mg/kg	0.055	0.43	µg/L
Naphthalene	SW8310	Fixed-Base			0.046	0.2	mg/kg	0.059	1	µg/L
Phenanthrene	SW8310	Fixed-Base			0.0055	0.04	mg/kg	0.03	0.2	µg/L
Pyrene	SW8310	Fixed-Base			0.0026	0.04	mg/kg	0.043	0.2	µg/L
SOIL ONLY										
Total Organic Carbon	SW9060	Fixed-Base			0.055	0.2	%			
GROUNDWATER ONLY										
Electrical Conductivity	DRM [j]	Field							0.02	mmhos/cm [k]
Dissolved Oxygen	DRM	Field							0.5	mg/L
pH	DRM	Field							0.1	pH Units
Redox Potential	DRM	Field							20	mv [l]
Temperature	DRM	Field							1	°C
Alkalinity (as $CaCO_3$)	E310.1	Fixed-Base						0.69	5	mg/L
Amonia	CHEMetrics 1510	Field							0.1	mg/L
Carbon Dioxide	CHEMetrics 4500	Field							100	mg/L
Iron, Ferrous	Hach 8146	Field							0.024	mg/L
Manganese	Hach Manganese	Field							0.05	mg/L
Methane	RSKSOP175	Fixed-Base						0.000052	0.0005	mg/L
Nitrate	E300	Fixed-Base						0.05	0.5	mg/L
Nitrite	E300	Fixed-Base						0.05	0.5	mg/L
Nitrogen, nitrate/nitrite	E353.2	Fixed-Base						0.016	0.1	mg/L
Sulfate	Hach 8051	Field							7	mg/L
Sulfide	Hach 8131	Field							0.01	mg/L

[a] MDL = Method Detection Limit

[b] PQL = Practical Quantitation Limit

[c] ppmv = parts per million, volume per volume

[d] TPH = Total Petroleum Hydrocarbon

[e] TRPH = Total Recoverable Petroleum Hydrocarbons

[f] mg/kg = milligrams per kilogram

[g] mg/L = milligrams per liter

[h] µg/kg = micrograms per kilogram

[i] µg/L = micrograms per liter

[j] DRM = direct reading meter

[k] mmhos/cm = millimhos per centimeter

[l] mv = millivolts

the normal "noise" of an analytical instrument or method. The PQL is the lowest level at which a chemical can be accurately and reproducibly quantitated. Table 2.2 summarizes the field and fixed-base laboratory analyses performed by sampling location.

2.2 SOIL GAS MEASUREMENTS

Soil gas sampling was performed at Site SS-15A using both field (semi-quantitative) and fixed-base laboratory (quantitative) analyses. The purpose of soil gas sampling was to assess the potential risk to future workers at the site from inhalation of volatilized contaminants, and to determine whether or not sufficient oxygen is available in the soil gas to sustain aerobic fuel hydrocarbon biodegradation. If oxygen (O_2) concentrations are significantly lower than background values, and carbon dioxide (CO_2) concentrations are higher than background levels, then the occurrence of aerobic fuel hydrocarbon biodegradation can be inferred. In addition, the oxygen levels allow an assessment of whether there is sufficient oxygen to sustain continuing aerobic biodegradation without engineered addition of oxygen via *in situ* bioventing.

Soil gas samples were collected at the 15 locations shown on Figure 2.1. All soil gas samples except those from VW1, AP26-MW76, and AP26-MW104 were screened using field instruments to measure O_2, CO_2, and total volatile hydrocarbon (TVH) concentrations. Soil gas samples from four locations (AP18-MW41, AP18-MW43, AP26-MW75, and AP26-MW114), selected based on field screening results, were collected in SUMMA® canisters and submitted to Air Toxics, Ltd. in Folsom, California for analysis of TVH and BTEX using USEPA Method TO-3. All samples were field screened using the test equipment and methods specified in the AFCEE protocol documents *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee *et al.*, 1992) and *Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing: Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential* (Downey and Hall,

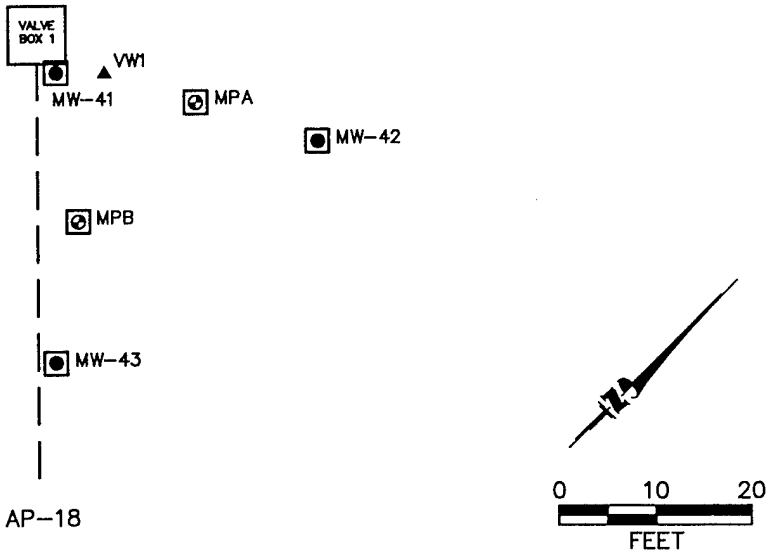
TABLE 2.2
SAMPLE ANALYSIS BY SAMPLING LOCATION
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

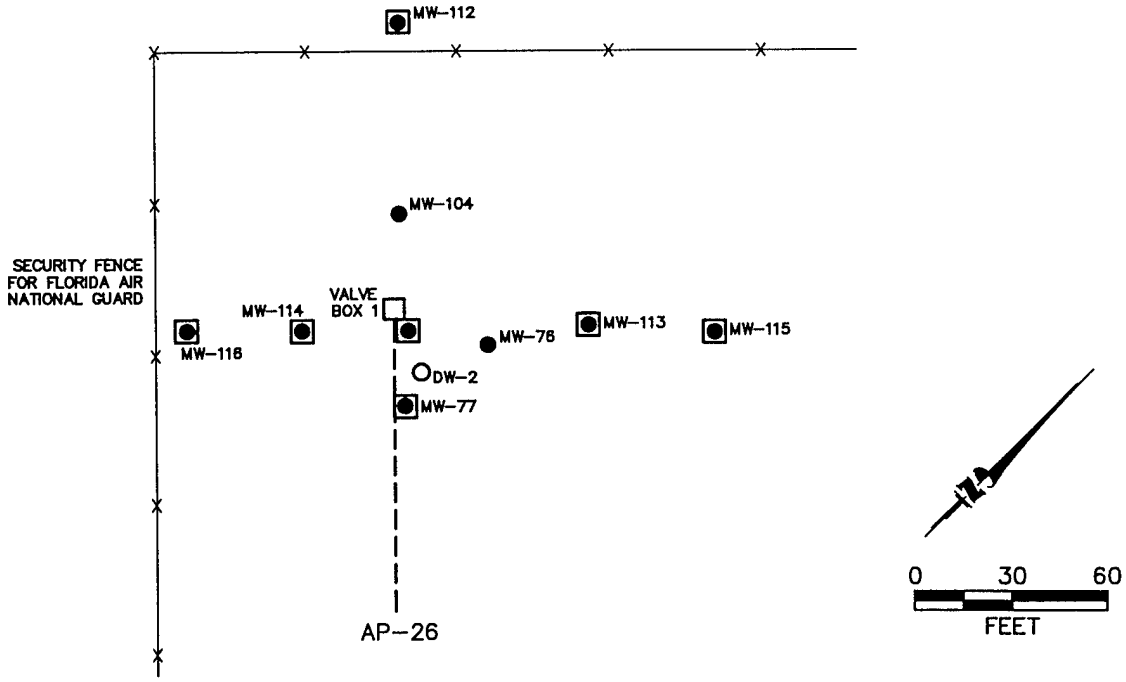
Sampling Location	Sample Matrix	Sample Depth (feet bgs[b/])	Laboratory Analytes[a/]								Field Screening Analytes[a/]					
			VOCs [c/]	TRPH [d/]	PAH [e/]	Alkalinity	Groundwater Suite [f/]	TOC [g/]	TPH [h/]	BTEX [i/]	TVH [j/]	O_2/CO_2 [k/]	Groundwater Suite [l/]	Conductivity	Temperature	Redox Potential
AP-10																
MW-9	groundwater	NA			X	X	X						X	X	X	X
MW-10	groundwater	NA	X	X	X	X	X [m/]						X	X	X	X
MW-11	groundwater	NA	X	X	X	X	X [m/]						X	X	X	X
MW-110	groundwater	NA			X	X	X						X	X	X	X
AP-11																
MW-14	groundwater	NA			X	X	X [m/]						X	X		X
MW-15	groundwater	NA	X	X	X	X	X [m/]						X	X	X	X
MW-16	groundwater	NA	X	X	X	X	X [m/]						X	X	X	X
MW-95	groundwater	NA			X	X	X [m/]						X	X	X	X
AP-15																
SB1	soil	2 - 4	X	X	X											
AP-17																
MW-40	groundwater	NA		X	X	X	X [m/]			X			X	X	X	X
MW-99	groundwater	NA			X	X	X [m/]						X	X	X	X
AP-18																
SBI (VW1)	soil	3 - 5	X	X	X											
SBI (VW1)	soil gas	3 - 5.5									X	X				
MPA	soil gas										X	X				
MPB	soil gas										X	X				
MW-41	soil gas	4 - 5.5							X	X	X	X				
MW-42	soil gas	4 - 5.5									X	X				
MW-43	soil gas	4 - 5.5							X	X	X	X				
AP-20																
SB1	soil	3 - 5	X	X	X											
AP-22																
MW-63	groundwater	NA			X	X	X						X	X	X	X
MW-64	groundwater	NA	X	X	X	X	X [m/]						X	X	X	X
MW-111	groundwater	NA	X	X	X	X	X						X	X	X	X

TABLE 2.2
SAMPLE ANALYSIS BY SAMPLING LOCATION
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Sampling Location	Sample Matrix	Sample Depth (feet bgs[b/])	Laboratory Analytes[a/]								Field Screening Analytes[a/]					
			VOCs [c/]	TRPH [d/]	PAH [e/]	Alkalinity	Groundwater Suite [f/]	TOC [g/]	TPH [h/]	BTEX [i/]	TVH [j/]	O_2/CO_2 [k/]	Groundwater Suite [l/]	Conductivity	Temperature	Redox Potential
AP-26																
MW-75	groundwater	NA			X	X	X						X	X	X	X
MW-75	soil gas	3 - 5.5							X	X	X	X				
MW-76	groundwater	NA			X	X	X						X	X	X	X
MW-76	soil gas	3 - 5.5														
MW-77	groundwater	NA	X	X	X	X	X						X	X	X	X
MW-77	soil gas	3 - 5.5									X	X				
MW-104	groundwater	NA			X	X	X						X	X		X
MW-104	soil gas	3 - 5.5														
MW-112	groundwater	NA	X	X	X	X	X [m/]						X	X	X	X
MW-112	soil gas	3 - 5.5									X	X				
MW-113	groundwater	NA			X	X	X [m/]						X	X	X	X
MW-113	soil gas	3 - 5.5									X	X				
MW-114	groundwater	NA			X	X	X						X	X	X	X
MW-114	soil gas	3 - 5.5							X	X	X	X				
MW-115	groundwater	NA			X	X	X [m/]						X	X	X	X
MW-115	soil gas	4 - 5.5									X	X				
MW-116	groundwater	NA			X	X	X						X	X	X	X
MW-116	soil gas	3 - 5.5									X	X				
DW-2	groundwater	NA					X						X	X	X	X
SB1	soil	5 - 7	X	X	X											
SB2	soil	3 - 5	X	X	X											
SB3	soil	5 - 7	X	X	X											
SB4	soil	3 - 5	X	X	X											
SB4	soil	5 - 7	X	X	X											
SB5	soil	5 - 7						X								
SB5	soil	6 - 8						X								

a/ Refer to Table 2.1 for analytical methods and reporting limits.
b/ bgs = below ground surface
c/ VOC = volatile organic carbon
d/ TRPH = total recoverable petroleum hydrocarbon
e/ PAH = polynuclear aromatic hydrocarbon
f/ analytical suite includes: nitrate, nitrite, nitrate + nitrite, and methane
g/ TOC = total organic carbon
h/ TPH = total petroleum hydrocarbon
i/ BTEX = benzene, toluene, ethylbenzene, and xylene
j/ TVH = total volatile hydrocarbon
k/ O_2/CO_2 = oxygen and carbon dioxide
l/ analytical suite includes: pH, ammonia, ferrous iron, manganese, sulfide, and sulfate
m/ nitrate + nitrite was not analyzed





LEGEND

- SHALLOW MONITORING WELL
- NEW VAPOR MONITORING POINT
- NEW AIR INJECTION VENT WELL
- INTERMEDIATE MONITORING WELL
- SOIL GAS SAMPLING LOCATION
- APRON LINE RE/DEFUELING VALVE BOX AND ABANDONED, UNDERGROUND FUEL LINE

FIGURE 2.1

SOIL GAS SAMPLING LOCATIONS OCTOBER 1997

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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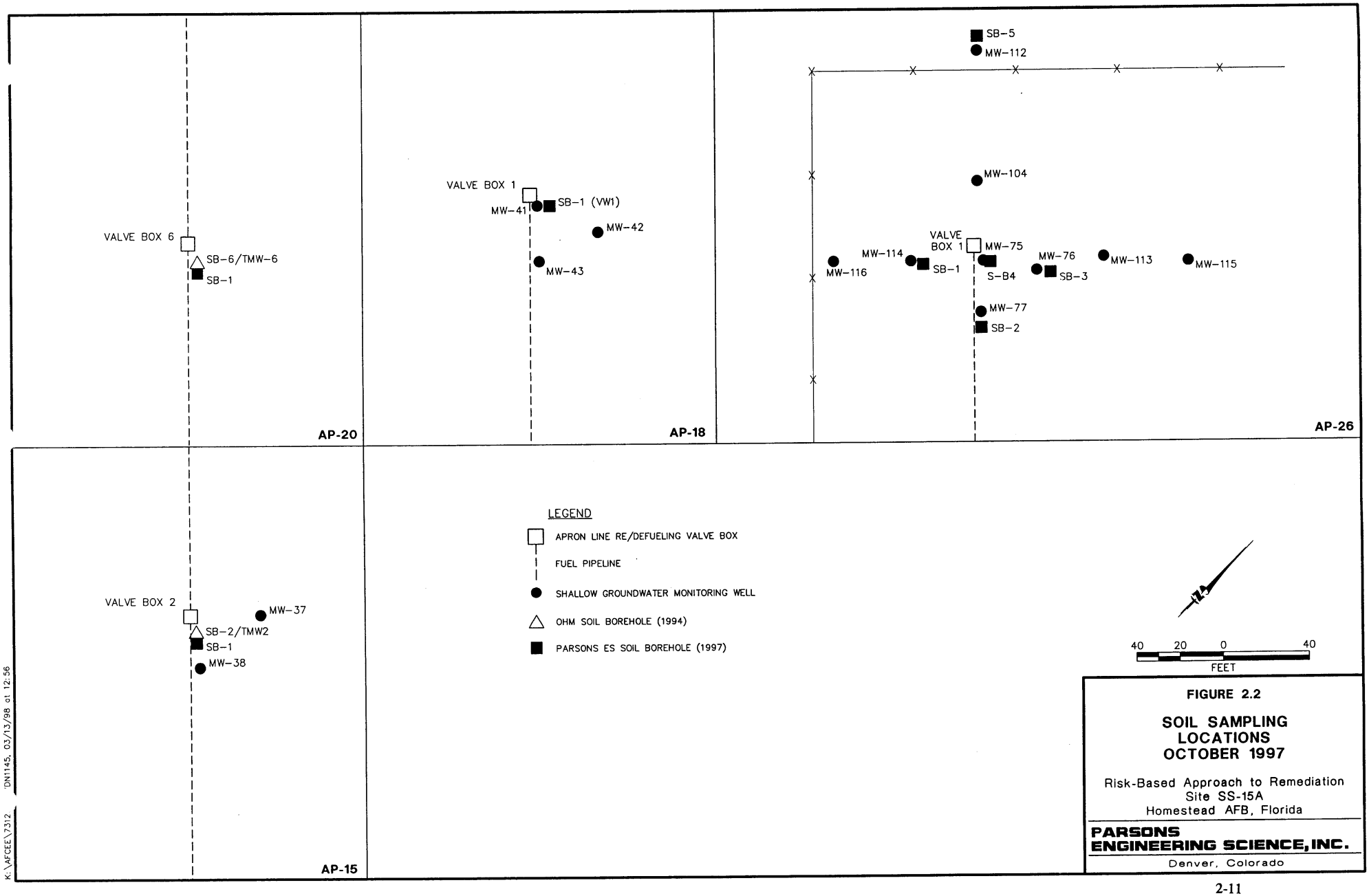
1994). All sample handling and field quality assurance (QA)/QC procedures for soil gas are specified in Appendix A of the work plan (Parsons ES, 1997b). Analytical results for soil gas samples are summarized in Section 5.

2.3 SUBSURFACE SOIL SAMPLING

Soil samples were collected from eight soil boreholes to obtain soil total organic carbon (TOC) data and to further characterize soil contamination at selected areas at fuel lines AP-15, AP-18, AP-20, and AP-26, where previous investigations indicated relatively high soil contaminant concentrations (Figure 2.2). Soils were sampled to facilitate evaluation of the potential for contaminant partitioning from soil into groundwater and soil gas, and to assess the magnitude of any changes in contaminant concentrations that have occurred over time. Many of these "soil" samples were collected from the weathered limestone bedrock.

Soil samples for laboratory or field analysis were collected at regular intervals from all boreholes, both above and below the groundwater surface. A total of 10 soil samples from 8 boreholes were submitted for fixed-base laboratory analysis. Samples from all 8 boreholes were described for lithology and field screened for ionizable organic vapors using a TVH meter. With the exception of soil borings for the VW and VMPs (Figure 2.3), soil boreholes were located within approximately 3 feet of previously-drilled and sampled soil boreholes to allow assessment of the potential temporal variation in contaminant concentrations.

All boreholes were drilled using a truck-mounted auger rig. Two methods were used to collect subsurface soil samples, based on the sampling location and analyses to be performed. Soil samples from all locations other than AP18-MPA and AP18-MPB were collected by advancing 2.5-inch-diameter split-spoon sampling barrels to total depth. Hollow-stem augers were not used to advance the boreholes prior to split-spoon



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FIGURE 2.2

SOIL SAMPLING LOCATIONS OCTOBER 1997

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

sampling because of the shallow depths of the boreholes and competent nature of the weathered bedrock. Samples from MPA and MPB were obtained by collecting soil cuttings from the outside of the augers as they were removed from the respective borings. These cutting samples were used for field screening purposes only. Split-spoon barrels lined with four pre-cleaned, 6-inch-long brass sampling tubes were used to collect the soil samples that were submitted to the fixed-base laboratory for analysis. After recovering the sample, the ends of the brass tubes were covered with Teflon® patches and capped, and the tubes were labeled prior shipment to the laboratory. The sampling tubes were used to preserve the integrity of the soil samples and to minimize potential losses of VOCs that can occur during transfer of soil to jars.

A total of 10 soil samples were submitted to Quantera Inc. for laboratory analysis. Replicate samples were not collected because of the difficulty obtaining a sufficient quantity of sample from individual sampling intervals. One trip blank, one temperature blank, and one decontamination water source blank were collected as part of the soil sampling QC program. Table 2.2 presents the locations and depth intervals for all soil samples collected as part of the risk-based remediation study.

All boreholes not completed as a VW or VMP were abandoned by filling them with bentonite chips from the bottom of the borehole to approximately 1 foot below the pavement surface. The remainder of each borehole was sealed with 10,000 pounds per square-inch, non-shrinking grout placed to match the existing pavement surface. Soil borehole logs and completion diagrams for the VW and VMPs are included in Appendix A. The borehole logs indicate the intervals at which soil samples were collected for field headspace screening and laboratory analyses. Soil analytical results are summarized and discussed in Sections 4 and 5.

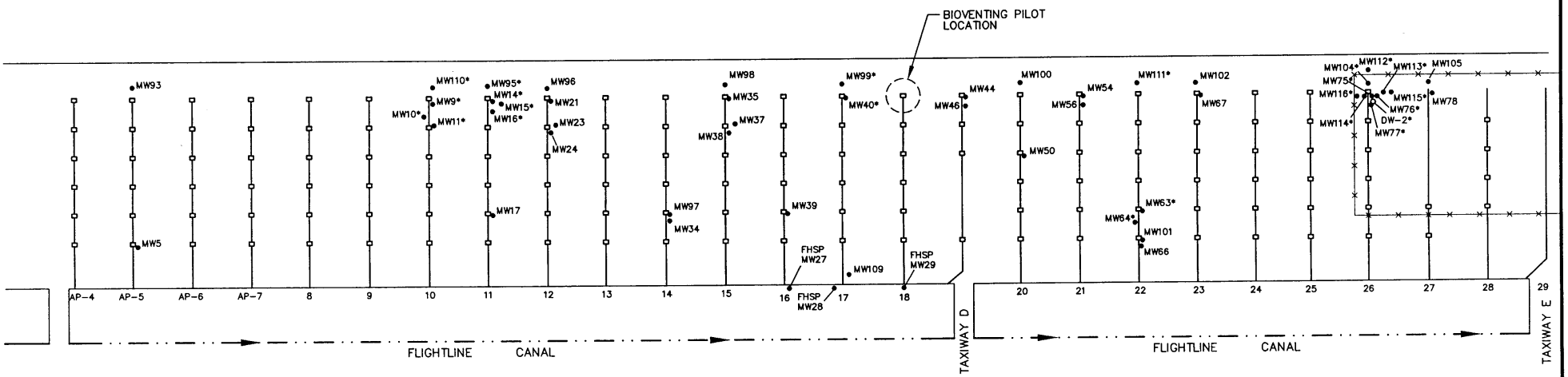
2.4 VENT WELL AND VAPOR MONITORING POINT INSTALLATION

One VW and two VMPs were installed at Flightline Apron line AP-18 near valve box 1 in preparation for a bioventing pilot test. Details of VW and VMP installation are described in Section 8.

2.5 GROUNDWATER SAMPLING

Groundwater samples were collected from 23 existing monitoring wells at Site SS-15A in October 1997. The groundwater sampling locations are shown on Figure 2.3. Samples collected from 10 wells in the apron line AP-26 area were analyzed for fuel-related contaminants and for various inorganic and geochemical indicators to evaluate natural chemical and physical attenuation processes that are occurring at the site. A total of 13 additional groundwater samples were collected from wells along 4 other fuel lines where elevated concentrations of dissolved contaminants have been detected in the past (AP-10, AP-11, AP-17, and AP-22). These additional groundwater samples were collected primarily to confirm that geochemical conditions are sufficiently homogeneous across Site SS-15A to allow the results of the focused risk-based analysis performed for the AP-26 area to be extrapolated to the rest of the site. Field and laboratory analytical data collected at each groundwater sampling location are summarized in Table 2.2. A product sheen was detected in well MW-14 along AP-11, but was of insufficient quantity to collect a sample for laboratory analysis. A measurable thickness of mobile LNAPL has been encountered only one time in one well (a thickness of 0.01 foot was measured in well AP20-MW50 during October 1995).

Groundwater samples were collected using the procedures described in the work plan (Parsons ES, 1997b). One duplicate sample, and one combination equipment/ambient condition/decontamination water blank were collected during the groundwater sampling event. Field QC samples also included one trip blank for each cooler of samples sent to the laboratory for volatile organic compound (VOC) analysis.





LEGEND

APRON FUEL LINE AND VALVE BOXES

MW40 ● SHALLOW GROUNDWATER MONITORING WELL SAMPLED BY OHM IN OCTOBER 1997

MW40* ● SHALLOW GROUNDWATER MONITORING WELL SAMPLED BY PARSONS ES IN OCTOBER 1997

DW-2* ○ INTERMEDIATE-DEPTH GROUNDWATER MONITORING WELL SAMPLED BY PARSONS ES IN OCTOBER 1997

FIGURE 2.3

GROUNDWATER SAMPLING LOCATIONS OCTOBER 1997

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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Field and laboratory groundwater analytical results are discussed in Section 5 of this report. These analytical results are used in Section 6 to evaluate the natural physical, chemical, and biological processes that are affecting the contaminants at this site.

2.6 SOURCE-REDUCTION FEASIBILITY TESTING

In situ bioventing was identified as a potentially appropriate source reduction technology for Site SS-15A. A bioventing pilot test was performed in the vicinity of valve box 1 on apron line AP-18 in October 1997 to assess the feasibility of using shallow *in situ* bioventing to add oxygen to unsaturated, fuel-contaminated soils, thereby promoting *in situ* biodegradation. Although bioventing pilot testing was recently performed at adjacent Site SS-15B (Parsons ES, 1997a), the conditions at Site SS-15A are sufficiently different from those at SS-15B (thicker vadose zone and a continuous pavement cover at SS-15A) to warrant additional testing. The location of the bioventing pilot test performed at Site SS-15A is shown on Figure 2.3. Installation of bioventing pilot test wells, testing equipment and procedures, and bioventing pilot test results are discussed in Section 8 of this CAP.

2.7 EQUIPMENT DECONTAMINATION PROCEDURES

All downhole soil sampling tools (e.g., split-spoon samplers) were cleaned prior to collection of each sample with a clean water/phosphate-free detergent mix followed by a clean water rinse. Hollow-stem augers were used only to ream the borings for the VW and VMPs. Decontaminated augers were used for each of the VW and VMP boreholes, and the bit was decontaminated between each of these boreholes using the same procedure used for the split-spoon samplers .

New, disposable high-density polyethylene (HDPE) and Teflon® tubing was used to collect the groundwater sample from each well. The only other groundwater sampling equipment requiring decontamination was the water level indicator probe. The probe

was decontaminated prior to each use with a clean water/phosphate-free detergent mix followed by a distilled water rinse.

2.8 INVESTIGATION-DERIVED WASTES (IDW)

Soil cuttings and unused soil samples were collected into 55-gallon, US Department of Transportation (DOT)-approved drums and transported to a drum storage area near the OHM field trailers. Decontamination and purge water also was placed into 55-gallon, DOT-approved drums and transported to the same storage area. All drums were labeled with the contractor's name, date, contents, and sampling location. One composite sample for each medium was collected from the waste drums. Both samples were submitted to the laboratory for the analyses listed in the OHM (1996d) Technical Memorandum *Soil Disposal Profile Analytical Project Requirements*. As directed by AFCEE, IDW profiling results were forwarded to OHM, which arranged for the proper waste disposal.

2.9 ANALYTICAL DATA QUALITY ASSESSMENT

2.9.1 Procedures

A Level III validation was performed on the October 1997 analytical results obtained from the fixed-base laboratories. The validation included internal data checks and application of data qualifiers to the analytical results based on adherence to method protocols and project-specific QA/QC control limits. Method protocols reviewed included:

- Analytical holding times,
- Method blanks,
- Trip blanks,
- Surrogate spikes,

- Matrix spikes/matrix spike duplicates (MS/MSDs),
- Laboratory control samples (LCSs), and
- Sample temperatures during shipping and storage.

A Level IV validation, including an evaluation of initial calibrations, continuing calibrations, instrument performance criteria, and second-column confirmations, and a review of analytical raw data and calculation checks was performed on 10 percent of the data.

Data qualifiers were applied to analytical results during the data validation process. All data were validated using method applicable guidelines and in accordance with the *National Functional Guidelines for Organic Data Review* (USEPA 1994a) and the *National Functional Guidelines for Inorganic Data Review* (USEPA 1994b). The following definitions provide explanations of the USEPA (1994a and 1994b) qualifiers assigned to analytical results during data validation. The data qualifiers described were applied to both inorganic and organic results.

U - The analyte was not present above the reported sample quantitation limit (SQL).

J - The analyte was positively identified, but the associated numerical value may not be consistent with the amount actually present in the environmental sample. The data should be considered acceptable as a basis for decision-making.

UJ - The analyte was not present above the reported SQL. The associated numerical value may not accurately or precisely represent the concentration necessary to detect the analyte in the sample.

J1 The analyte is qualified as an estimated value solely because it is greater than the MDL and less than the PQL, indicating no laboratory quality issues.

2.9.2 Results

Data quality for each QC parameter where exceptions were noted during the validation is summarized in this section. Only results that exceeded QA/QC criteria are presented. All frequency requirements for field sample collection of QA/QC samples (MS/MSDs and blanks) were met. The frequency requirements for laboratory specific method criteria QA/QC also were met.

2.9.2.1 Holding Time

Twenty-two water nitrate (as nitrogen [N]) (Method E300), 22 nitrite (as N) (Method E300), and one soil aromatic VOC (Method SW8020) samples were qualified as estimated for holding time exceedances. To assess the usability of the nitrate/nitrite data, eight samples were recollected and analyzed for nitrate plus nitrite (as N) within holding time using Method E353.2. The aromatic VOC sample also was recollected and reanalyzed using Method SW8020.

2.9.2.2 Blank Contamination

Blank contamination was reported at concentrations representative of normal laboratory and field procedures with the exception of the method blanks. One aromatic volatile (Method SW8020) sample reporting limit was elevated in accordance with the validation criteria based on the toluene detection in the blank. The blank result was detected at a concentration which was between the MDL and PQL. Therefore, the sample reporting limit was never elevated above the PQL, and sample data quality was not adversely affected.

2.9.2.3 Conclusions

All sample results qualified as "U, UJ, J, or J1" are usable for the purposes intended. Results qualified as such represent an association to non-compliant QC criteria which has caused the reported concentration to be estimated. Project data quality objectives do not exclude the use of estimated concentrations.

Analytical accuracy and precision were within control limits and are considered acceptable. All method-specific criteria were within control limits with the exception of holding time. Critical project samples that failed holding-time criteria were resampled and reanalyzed. All blank contamination was at concentrations less than the target PQL. Because PQLs were not exceeded, the impact of blank contamination to the project is minimal.

SECTION 3

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

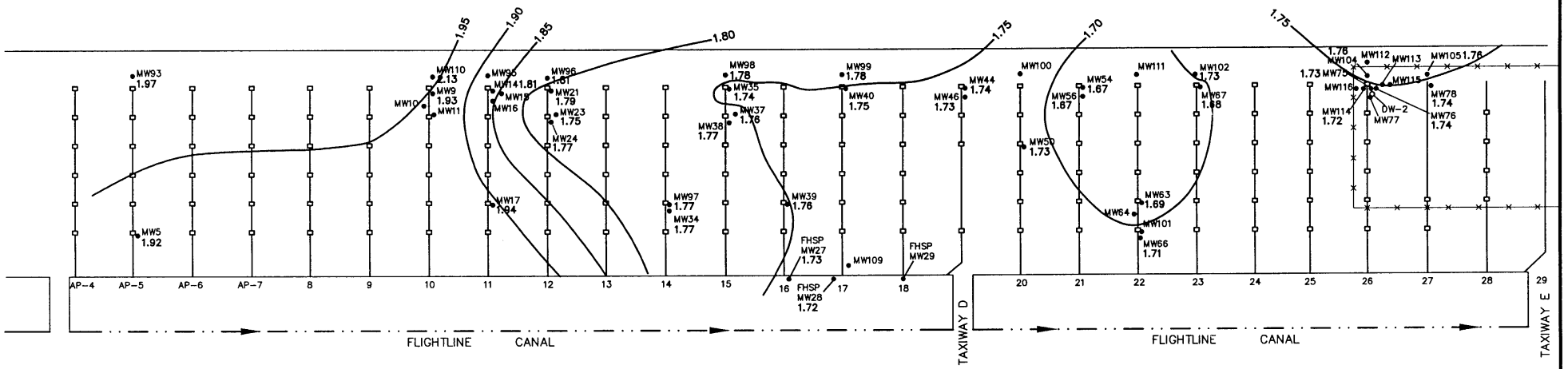
This section describes the physical characteristics of Site SS-15A and adjacent environs at Homestead AFB, as determined from data collected during previous site investigations and by Parsons ES in October 1997 as part of the risk-based remediation field investigation. Information presented is based on the results of earlier Base-wide and/or site-specific investigations (Geraghty & Miller, Inc. 1993; OHM, 1995 through 1997c). A summary of site characterization activities completed by Parsons ES to supplement existing data is presented in Section 2 of this CAP.

3.1 SITE TOPOGRAPHY AND SURFACE WATER HYDROLOGY

Site SS-15A and the surrounding area has relatively flat topography, with elevations at Site SS-15A ranging from approximately 6 to 8 feet above the national geodetic vertical datum (NGVD). The site slopes gently toward the southeast. Surface runoff from the flightline apron area flows into the flightline canal, which is located approximately 265 feet southeast of the southeastern edge of the apron area and is oriented parallel to the apron and runway (Figure 3.1). Surface water in the flightline canal flows northeast into Biscayne Bay via other canals.

3.2 SITE GEOLOGY AND HYDROGEOLOGY

The uppermost geologic strata underlying Site SS-15A consist of approximately 2 to 3 feet of sand and limestone fragments overlying limestone bedrock of the Miami Oolite



LEGEND

APRON FUEL LINE AND VALVE BOXES

MW40 1.92 — SHALLOW GROUNDWATER MONITORING WELL SAMPLED BY PARSONS ES AND/OR OHM IN OCTOBER 1997
GROUNDWATER ELEVATION (FEET ABOVE NGVD)

DW-2 — INTERMEDIATE-DEPTH GROUNDWATER MONITORING WELL SAMPLED BY PARSONS ES AND/OR OHM IN OCTOBER 1997

1.75 — INFERRED LINE OF EQUAL GROUNDWATER ELEVATION (Feet Above NGVD)
GROUNDWATER ELEVATIONS FROM OHM (1997c)

500 250 0 500
FEET

FIGURE 3.1

GROUNDWATER ELEVATIONS OCTOBER 1997

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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Formation. The Miami Oolite consists of soft, oolitic limestone interbedded with sandy limestone and thin layers of hard limestone. Solution features and pockets of silty sand and shell fragments are common (OHM, 1995a). The thickness of the Miami Oolite beneath Homestead AFB ranges from 15 to 20 feet. The Miami Oolite and underlying Fort Thompson Formation are highly permeable, and are the principal components of the Biscayne Aquifer in the Homestead AFB area (OHM, 1995a). Native surficial sands at the site are covered with asphalt or concrete pavement.

Groundwater beneath the site occurs in the Miami Oolite, and the water table surface generally is encountered at depths between 5 and 6 feet below ground surface (bgs). Groundwater surface elevations measured in October 1997 are included in Appendix A and plotted on Figure 3.1. With local exceptions, groundwater elevations indicate that, in October 1997, the overall groundwater flow direction was to the east or southeast, consistent with the regional southeasterly flow direction identified by OHM (1995a). However, groundwater elevations measured at AP-26 in October 1997 indicate that the local flow direction may be toward south or southwest at the northwest end of the apron line. In the remedial investigation (RI) report, OHM (1995a) notes that groundwater flow directions may be locally variable at the site. The irregular groundwater surface may result from local variations in recharge and discharge such as may be caused by the presence of pavement areas with higher-than-average infiltration rates or the presence of drainage ditches. The hydraulic gradient beneath the site is very flat, averaging about 0.00009 foot per foot (ft/ft) (OHM, 1995a), and vary depending on the location and time at which water levels were measured.

The hydraulic conductivity of the surficial water-bearing zone at Site SS-15A was estimated during previous investigations using slug test data. Hydraulic conductivity values determined for the surficial aquifer range from 6.5 to 98 feet per day (ft/day). Using the average horizontal hydraulic gradient of 0.00009 ft/ft and an estimated

effective porosity of 20 percent, the horizontal groundwater flow velocity has been calculated to be 0.014 ft/day or 5.1 feet per year (ft/yr) (OHM, 1995a).

3.3 CLIMATOLOGICAL CHARACTERISTICS

The climate of south Florida is subtropical with warm summers and mild winters. For Miami, the average daily temperature ranges from 66°F in January to 82°F in July (National Oceanic and Atmospheric Administration [NOAA], 1973). Based on meteorological data compiled by Homestead AFB personnel for the period from January through November 1994, the average annual temperature at Homestead AFB ranged from 69°F in January to 84°F in July (OHM, 1995a). The recorded high and low temperatures for this time period ranged from 95°F on June 10 to 48°F on March 4.

Rainfall in southern Florida occurs in distinct cycles. The rainy season typically extends from May through October, with the remaining 6 months being relatively dry. The average annual precipitation is approximately 58 inches. The highest monthly precipitation typically occurs in September (9.5 inches), and the lowest monthly precipitation occurs in December (1.7 inches) (NOAA, 1973). Much of the annual precipitation occurs during thunderstorms in the months of July through September. A total of 65.4 inches of precipitation was recorded at Homestead AFB during the time period referenced above (OHM, 1995a). Approximately 62 percent of the precipitation occurred during the 6-month rainy season (May through October, 1994). During the highest rainfall event in the above-referenced 1994 period, 12.8 inches of rainfall was recorded between 12 and 16 November, during Tropical Storm Gordon.

3.4 LAND USE

3.4.1 Site Access

Site SS-15A is located adjacent to and services the runway at Homestead AFB. The entire extent of Site SS-15A is within the fenced Base boundaries (Figure 1.2). The

Base is under manned guard 24 hours per day, 7 days per week. The site is located within the designated flightline area, and access to this area is restricted. Access to the FANG area (which includes portions of apron lines AP-26 through AP-29) is further restricted by a chainlink fence (Figure 3.1) with motion detectors and armed guards. Additionally, the site is capped by 6 to 18 inches of asphalt and concrete pavement, which precludes direct exposure of onsite receptors (e.g., Base personnel) to potentially impacted soils and groundwater.

3.4.2 Current and Proposed Land Use

Portions of the site are currently used by FANG and the Air Force Reserve Command (OHM, 1995a). Much of the aircraft apron is currently inactive. Based on a 1993 Base Realignment and Closure (BRAC) recommendation, approximately one-third of the Base will continue to be used for FANG or Air Force Reserve operations, including the area containing portions of apron lines AP-26 through AP-29 in the northeastern corner of Site SS-15A and AP-1 through AP-3 in the southwestern corner. Once environmental restoration is completed, the remainder of the Base will be leased and/or sold. The Dade County Aviation Department is expected to be the primary lessee of the non-cantonment portion of the Base (i.e., the portion that will not be used for Air Force Reserve operations) (OHM, 1995a). Areas of SS-15A that are not used by the FANG or the Air Force Reserve are reportedly designated for light industrial use. Figure 1.2 shows the location of Site SS-15A relative to Homestead AFB and indicates adjacent land uses.

The downgradient Base boundary is approximately 2,000 feet from Site SS-15A. Offsite lands adjacent to the Base to the east, southeast, and west are used primarily for agricultural purposes. There is a small residential area southwest of the Base, and additional residential areas to the north. Unless all aviation activities at the Base cease, it is highly unlikely that Site SS-15A would be available for residential use. Therefore,

future onsite land use is expected to remain industrial (e.g., associated with aviation support activities).

3.4.3 Water Resources

The Biscayne Aquifer underlies Homestead AFB and all of Dade County, and is the sole source of fresh water for these areas. This is the only aquifer system potentially impacted by fuel releases at Homestead AFB.

A water supply well survey was completed as part of the 1995 corrective action report (OHM, 1995a). Active, on-Base potable wells are located 8,000 feet west-northwest of (upgradient from) the flightline apron, and wells used for emergency backup of the Base's normal wellfield are located 4,500 feet northwest of the flightline apron, but are currently inactive. No public water supply wells are located within a 0.5-mile radius of the Base. Three non-potable water wells are located southwest of Site SS-15A, the closest of which is approximately 5,000 feet away (Geraghty & Miller, Inc. 1993).

3.5 POPULATION DEMOGRAPHICS

Site SS-15A is located entirely within a controlled-access portion of the Base. Base workers include civilians and Air Force and FANG personnel. The general public is excluded from Site SS-15A.

3.6 ECOLOGICAL RESOURCES

Although numerous plant and wildlife species are known to occur on and near Homestead AFB, Site SS-15A is in a heavily developed, active industrial portion of the Base that is covered with asphalt and concrete. The industrial setting and operational activity levels in the immediate vicinity, coupled with a lack of suitable wildlife habitat, essentially preclude the presence of terrestrial and aquatic wildlife populations at the site.

The Flightline Canal, which is part of the Operable Unit 9 (OU-9) Boundary Canal System, is located within the adjacent Site SS-15B. A number of potential ecological receptors were identified for the Flightline Canal as part of the RI for OU-9 (Woodward-Clyde Consultants, 1995). Although the Flightline Canal is not within Site SS-15A, the potential ecological receptors identified for OU-9 are included as potential receptors for contamination migrating from Site SS-15A because of the proximity of the Flightline Canal to the Site. Following is a summary of potential ecological receptors and exposure media identified in the OU-9 RI (Woodward-Clyde Consultants, 1995):

Exposed Group (potential receptors)	Exposure Medium
Aquatic vegetation	Surface water, sediment
Benthos	Surface water, sediment
Fish and amphibians	Surface water, sediment, aquatic biota
Birds	Surface water, sediment, aquatic biota
Mammals	Surface water, sediment, aquatic biota
Reptiles	Surface water, sediment, aquatic biota

These media have not been sampled as part of the Site SS-15A investigation.

SECTION 4

TIER 1 ANALYSIS AND IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

This section provides an overview of the regulatory requirements for a risk-based, tiered approach to identification of COPCs, and reviews the preliminary conceptual site model (CSM) developed for Site SS-15A in the CAP work plan (Parsons ES, 1997b) as a means of selecting appropriate regulatory screening criteria to identify COPCs in affected site media (i.e., chemicals present at concentrations that could pose a risk to human and/or ecological receptors exposed to the affected media). This section also presents a screening-level Tier 1 analysis used to select the COPCs that are the focus of this CAP. The COPCs for Site SS-15A are identified in the Tier 1 analysis based on estimated risks to human health posed by maximum detected contaminant concentrations. Conservative land use and exposure assumptions are used in the Tier 1 screening analysis to ensure that the nature and extent of any COPCs that could pose a risk to human receptors at or near the site are fully described (Section 5), and that these chemicals are fully evaluated in subsequent analyses through quantitative fate and transport and receptor exposure evaluations (Sections 6 and 7).

4.1 REGULATORY REVIEW OF THE TIER 1 SCREENING PROCESS

As an initial step in determining the necessity for remedial action, representative concentrations of site contaminants are compared to the NFA-Without-Conditions generic TCLs for soil and groundwater presented in Tables IV and V of the *Petroleum*

Contamination Site Cleanup Criteria (FDEP, 1997). Contaminant soil concentrations must be below the Direct Exposure I and the leachibility target levels presented in Table IV (based on applicable groundwater criteria specified in 62-770.680 (1)(c), FAC). Concentrations of COPCs in groundwater must be below background concentrations or less than levels presented in Table V. If the groundwater is impacting, or may impact, surface water, the TCLs presented for surface water in Table VI also applies.

If representative concentrations of petroleum contaminants exceed the NFA-Without-Conditions TCLs, the concentrations are then compared to the NFA-With-Conditions TCLs presented in the Rule. Contaminant soil concentrations must be less than the Direct-Exposure II levels and the leachability target levels presented in Table IV (based on applicable groundwater criteria, as specified in 62-770.680 (1)(c), FAC). Concentrations of COPCs in groundwater also are compared to the same criteria applicable to an NFA proposal.

Maximum dissolved site contaminant concentrations also are compared to the Table IX Natural Attenuation Source Default Values. This comparison provides an initial assessment of the potential appropriateness of monitored natural attenuation as a remedial alternative.

Those analytes with site concentrations that exceed the appropriate TCLs for soil and groundwater are considered to be COPCs, and are retained for further analysis concerning the risk-reduction requirements for the site. The nature and extent of these COPCs are described more fully in Section 5. Quantitative fate and transport analyses and site-specific exposure estimates are conducted and presented in Sections 6. Section 7 develops site-specific Tier 2 SSTLs that are sufficient to protect human health and the environment given the current and future use of the FANG area which will remain under Air Force control (i.e., industrial use only).

4.2 PRELIMINARY CONCEPTUAL SITE MODEL REVIEW

Figure 4.1 presents the preliminary CSM developed for Site SS-15A. The CSM was developed using data collected during all relevant site investigations and is based on a review of potential receptors and feasible exposure scenarios. The purpose of developing a CSM is to guide the evaluation of available site information and to determine potential data gaps, including:

- Potential contaminant sources;
- Media affected by contaminant releases;
- Mechanisms of contaminant release (e.g., leaching and volatilization);
- Potential human and ecological receptors;
- Potential receptor exposure points based on conservative, reasonable land use assumptions; and
- Routes of possible receptor exposure (e.g., inhalation, ingestion, or dermal contact).

Figure 4.1 was developed to provide an outline for addressing all matrix-specific, current and future exposure scenarios at Site SS-15A.

4.2.1 Contamination Source Assessment

Based on previous site investigations, soil, soil gas, and groundwater beneath the flightline apron have been contaminated with petroleum hydrocarbons as the result of past spills and leaks in the JP-4 fueling system. Soil contamination occurs in a number

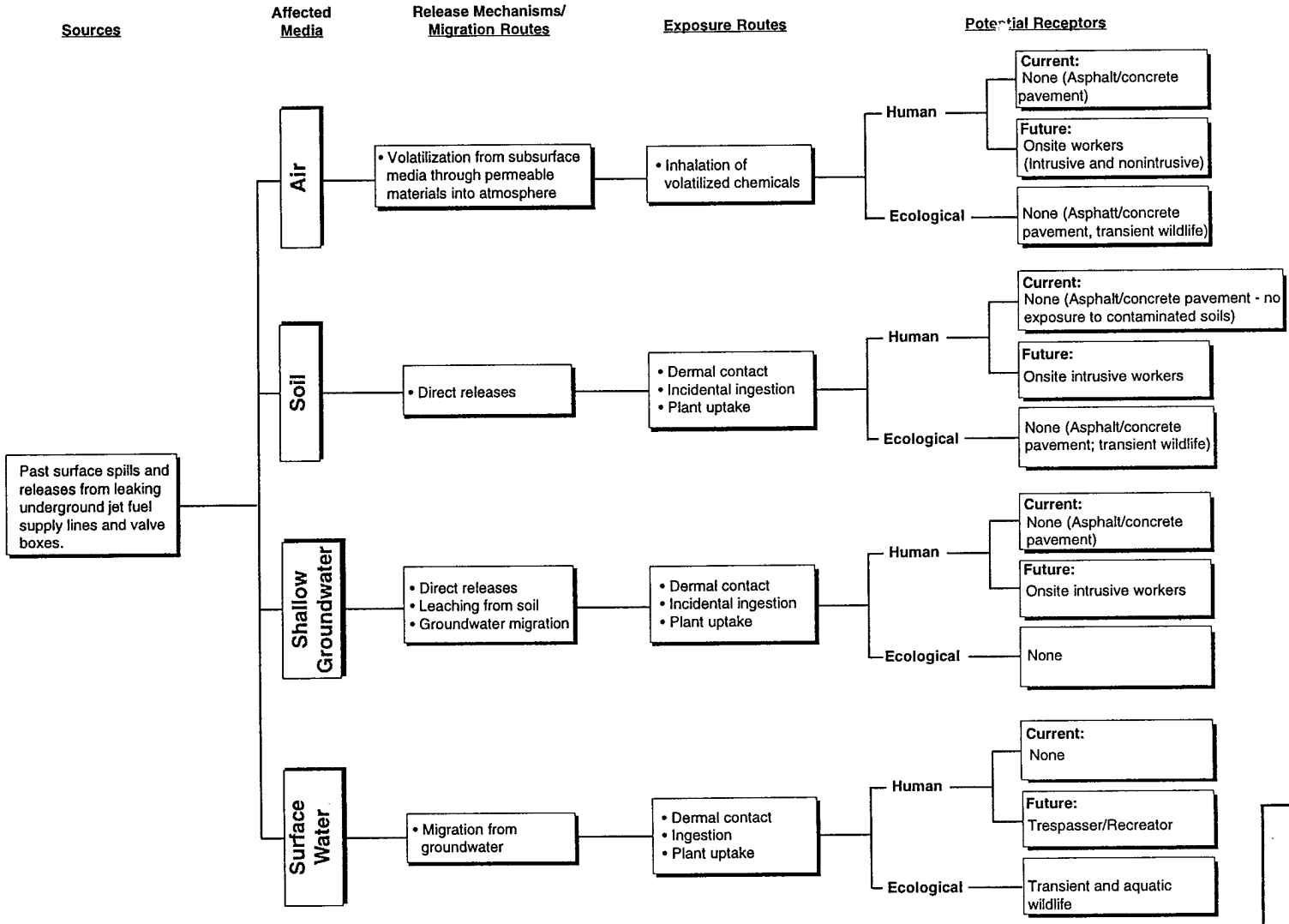


FIGURE 4.1

PRELIMINARY CONCEPTUAL SITE MODEL

Risk-Based Approach to Remediation
Site SS-15A
Homested ARB, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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of discrete areas, primarily as residual light nonaqueous-phase liquid (LNAPL) in the thin vadose (unsaturated) zone and within the uppermost portion of the saturated zone. The absence of measurable mobile LNAPL (free product) detections at the site indicate that mobile LNAPL is not a significant, continuing source of groundwater contamination. PAHs also have been detected in soil and groundwater at Site SS-15A. Naphthalenes are the only PAH compounds found in JP-4 fuel (**Reference**). PAHs may have leached into soil and groundwater from the asphalt pavement covering much of the site. If the fuel pipelines are coated with a tar-like substance, then exposure of the coating to JP-4 could have caused leaching of the high molecular weight PAHs into the surrounding soil and groundwater.

Historical groundwater quality data suggest that concentrations of dissolved fuel constituents in groundwater are decreasing, indicating that the contaminant sources also are dwindling due to the effects of leaching, volatilization, and biodegradation. Rates of contaminant mass reduction are evaluated in Section 6 to determine whether or not the applicable FDEP (1997) NFA criteria are likely to be achieved within 5 years, per Rule 62-770.690, FAC.

The contaminant release mechanisms considered in this CAP include partitioning from residual LNAPL into groundwater and into soil gas, possible discharge of contaminated groundwater into surface water in the Flightline Canal, and leaching of PAHs into soils and groundwater. This approach is consistent with the nature of contamination detected at the site, the physical characteristics of the surrounding area, and the physiochemical properties of the COPCs.

4.2.2 Land Use and Potential Receptors

Based on the information presented in Sections 3.4 through 3.6, potential current and human future populations that could be exposed to contaminated media include onsite non-intrusive industrial workers, onsite intrusive industrial workers, and offsite

recreators and trespassers (via contact with potentially impacted surface water in the Flightline Canal at Site SS-15B). The only contamination at Site SS-15A that could impact ecological receptors is dissolved contaminants which migrate and discharge to the flightline canal; based on available groundwater monitoring data, this pathway is currently incomplete.

4.2.3 Exposure Pathways

An understanding of receptor potential exposure pathways is important in determining how potential receptors could contact contaminated media and how that contact could result in the uptake of chemicals. An exposure pathways analysis reviews the contaminant sources, locations, and types of environmental releases in relation to population locations and activity patterns to determine the potentially significant pathways and routes of receptor exposure. A completed exposure pathway consists of four necessary elements:

- A source and mechanism of chemical release,
- An environmental transport medium,
- A point of potential contact with a receptor, and
- A feasible route of exposure at the exposure point.

If one or more of these elements is missing, the pathway is incomplete and there is no exposure (and therefore, no risk).

The concrete/asphalt covering limits both the contaminant transport mechanisms and the potential exposure points at Site SS-15A. This barrier prevents contact with contaminated soil or groundwater by current onsite personnel, prevents contact between contaminated media and surface water runoff, reduces the potential for leaching, and acts as a barrier to migration of soil or soil gas contaminants into the ambient

atmosphere. There are currently no buildings at Site SS-15A. Therefore, infiltration of organic vapors into structures is an incomplete pathway for current receptors. However, if future land use at the Base involves construction of buildings at the site, then this pathway could potentially become completed.

Site hydrogeology is described in Section 3.2. The flat hydraulic gradient indicates that the horizontal groundwater and plume migration rate should be slow, reducing the likelihood that site contaminants could impact surface water or potable water wells via groundwater migration and discharge. Based on the information presented in Section 3.4.3, migration of contaminated groundwater to potable drinking water sources is considered to be an incomplete pathway. Based on available groundwater monitoring data, contaminated groundwater is not currently impacting surface water. Site hydrogeologic information suggests that it is highly unlikely that groundwater will impact surface water (i.e., the Flightline Canal) in the future. Modeling to assess the potential for groundwater to impact surface water is performed in Section 6.

Based on the industrial land use scenario and site-specific contaminated media information, the following human receptor exposure routes may potentially be completed and were evaluated during the data analysis process:

- Dermal contact with or incidental ingestion of contaminated soil by future onsite intrusive workers (e.g., during future excavation activities);
- Dermal contact with contaminated groundwater by future onsite intrusive workers (e.g., during future excavation activities);
- Inhalation of volatilized contaminants by future onsite intrusive workers (e.g., during future excavation activities); and
- Incidental ingestion of and dermal contact with surface water by future offsite recreators or trespassers.

Available information indicates that none of these pathways currently is completed. Therefore, only potential future exposures are assessed.

4.3 TIER 1 SCREENING ANALYSIS

It is the intention of the Air Force to obtain FDEP approval for a corrective action for Site SS-15A that will protect potential receptors from unacceptable exposures to site-related chemicals. To accomplish this objective, the COPCs that drive potential risks and impact the final remedial requirements at this site were identified.

FDEP (1997) Tier 1 TCLs are based on 1) analyte-specific toxicity data; 2) an exposure-pathway-specific cancer target risk limit of 10^{-6} (i.e., there is an added lifetime cancer risk for people near the site of 1 additional cancer above the normal background level in 1 million people, expressed as 10^{-6} or 1 in 1 million) and a noncancer hazard quotient less than or equal to 1; and 3) conservative receptor exposure assumptions.

4.3.1 Tier 1 Screening Analysis for Soil

TCLs for direct exposure of industrial workers (Direct Exposure II) were selected as the appropriate set of Tier 1 screening values for soil at Site SS-15A. The FDEP (1997) guidance provides industrial-scenario TCLs for petroleum constituents in soil that incorporate risks posed by the dermal contact, ingestion, and inhalation exposure pathways. Table 4.1 compares the maximum site concentrations for each compound measured in soil at Site SS-15A during the 1994 contamination assessment investigation (OHM, 1995a) and the 1997 risk-based sampling event to the Direct-Exposure II TCLs. Based on these comparisons, TRPH, benzo(a)anthracene, benzo(a)pyrene, and benzo(b)fluoranthene are identified as potential COPCs in soil.

TABLE 4.1
COMPARISON OF MAXIMUM SITE SOIL CONCENTRATIONS TO TARGET CLEANUP LEVELS
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Chemical Name	Units	Maximum Concentration Detected (1994)[a/]	Location of Maximum Detection (1994)	Maximum Concentration Detected (1997)[b/]	Location of Maximum Detection (1997)	Direct Exposure II[c/] TCL	Number of Times Exceeded (1994)	Number of Times Exceeded (1997)
Acenaphthene	mg/kg[d/]	8.1	AP20-SB6	11 J1[e/]	AP26-SB1-5	22,000	0	0
Acenaphthylene	mg/kg	9.3	AP18-SB1	ND[f/]	---	11,000	0	--
Anthracene	mg/kg	NA[g/]	--	8.1	AP26-SB1-5	290,000	0	0
Benzo(a)anthracene	mg/kg	NA	--	11	AP26-SB1-5	5.1	NA	1
Benzo(a)pyrene	mg/kg	16	AP20-SB6	7.4	AP26-SB1-5	0.5	21	4
Benzo(b)fluoranthene	mg/kg	NA	--	7.4	AP26-SB1-5	5	NA	1
Benzo (g,h,i)perylene	mg/kg	9	AP20-SB6	0.35J1	AP26-SB4-3	45,000	0	0
Benzo(k)fluoranthene	mg/kg	NA	--	2.8	AP26-SB1-5	52	0	0
Chrysene	mg/kg	NA	--	12	AP26-SB1-5	490	0	0
Dibenzo(a,h)anthracene	mg/kg	NA	--	ND	---	0.5	NA	--
Fluoranthene	mg/kg	85	AP20-SB6	20	AP26-SB1-5	45,000	0	0
Fluorene	mg/kg	13	AP20-SB6	9.3	AP26-SB1-5	24,000	0	0
Indeno(1,2,3-cd)pyrene	mg/kg	NA	--	4.3	AP26-SB1-5	5.2	NA	0
Naphthalene	mg/kg	60	AP18-SB1	4.6	AP26-SB4-3	8,600	0	0
Phenanthrene	mg/kg	NA	--	29	AP26-SB1-5	29,000	0	0
Pyrene	mg/kg	64	AP20-SB6	14	AP26-SB1-5	40,000	0	0
Phenanthrene + Anthracene	mg/kg	120	AP20-SB6	--	--	29,000/22,000[h/]	0/0[h/]	--
Chrysene + Benzo(a)anthracene	mg/kg	65	AP20-SB6	--	--	490/5.1[i/]	0/NA[i/]	--
Indeno(1,2,3-cd)pyrene + Dibenzo(a,h)anthracene	mgkg	18	AP20-SB6	--	--	5.2/0.5[j/]	NA/NA[j/]	--
Benzo(b)fluoranthene + Benzo(k)fluoranthene	mg/kg	37	AP20-SB6	--	--	5/52[k/]	NA/0[k/]	--
Benzene	mg/kg	ND	---	0.0027	AP26-SB4-3	1.50	--	0
Ethylbenzene	mg/kg	39	AP18-SB1	0.018	AP26-SB4-3	240	0	0
Toluene	mg/kg	170	AP29-SB6	0.0034	AP26-SB4-5	2,000	0	0
Xylenes, Total	mg/kg	110	AP18-SB1	ND	---	290	0	--
MTBE[l/]	mg/kg	ND	---	ND	---	6,100	--	--
TRPH[m/]	mg/kg	15,000	AP8-SB6	200	AP15-SB1-2	2,500	20	0

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

[a/] Data from samples collected in 1994 by OHM.

[b/] Data from samples collected in October 1997 by Parsons ES.

[c/] Direct Exposure II is for No Further Action With Conditions (industrial worker scenario).

[d/] mg/kg = Milligrams per kilogram.

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

[f/] ND = Analyte not detected.

[g/] NA = Not available.

[h/] Phenanthrene value/anthracene value.

[i/] Chrysene value/benzo(a)anthracene value.

[j/] Indeno(1,2,3-cd)pyrene value/dibenzo(a,h)anthracene value.

[k/] Benzo(b)fluoranthene value/benzo(k)fluoranthene value.

[l/] MTBE = Methyl tertbutyl ether.

[m/] TRPH = Total recoverable petroleum hydrocarbons.

4.3.1.1 Request for Waiver to Tier 1 TRPH Target Cleanup Levels

Based on the precedent set for adjacent Site SS-15B, the Air Force is requesting a waiver to the Tier I TRPH TCLs for Site SS-15A. The TRPH found in Site SS-15A should be of the same as Site SS-15B. SS-15B contains the jet fuel pumphouses that feed fuel into the Site SS-15A fuel distribution lines. The Tier 1 Direct Exposure II TCL for TRPH in soil (industrial worker exposure scenario) is based on the most conservative and health protective carbon range that can be detected by the FL-PRO analytical method, the $>C_8$ to C_{10} range. To assess whether the Tier 1 TCL was an appropriate cleanup goal for the adjacent Site SS-15B, 44 soil samples were collected at Site SS-15B in October 1997 and analyzed TRPH using the FL-PRO method (OHM, 1997). The TRPH concentrations were broken down by the analytical laboratory into five carbon-group classes, including C_8-C_{10}, $>C_{10}$-C_{12}, $>C_{12}$-C_{16}, $>C_{16}$-C_{21}, and $>C_{21}$. TRPH concentrations detected in 11 of the 44 Site SS-15B soil samples exceeded the Direct Exposure II TCL of 2,500 mg/kg; concentrations in these 11 samples ranged from 2,800 mg/kg to 7,600 mg/kg. However, total concentrations of C_8-C_{10} hydrocarbons in these 11 samples ranged from 126 mg/kg to 403 mg/kg, and did not exceed the Direct Exposure II TCL . The analytical results indicate that C_8-C_{10} hydrocarbons represented 4.1 percent to 9.8 percent of the TRPH. The low percentage of volatile, low-molecular-weight aromatics present in the fuel is confirmed by the low magnitude of the total BTEX concentrations, which constituted less than 0.1 percent to 0.5 percent (average 0.3 percent) of the TRPH by mass . Based on the TRPH classification, the primary TRPH was $>C_{12}$-C_{16}, which have relatively low toxicities (FDEP, 1997). The OHM (1997) report concluded that, based on the TRPH carbon group classification, TRPH did not appear to be a cleanup driver for the site.

A total of 20 TRPH concentrations detected in soil samples at Site SS-15A have exceeded the Tier 1 TCL of 2,500 mg/kg. With the exception of soil from AP8-SB6 (TRPH = 15,000 mg/kg), TRPH concentrations detected in these samples (2,600

mg/kg to 9,600 mg/kg) are similar to those detected in the Site SS15B samples. Although the TRPH concentrations determined for Site SS-15A in March 1994 and October 1997 were not broken down by carbon-group classes, very low total BTEX concentrations were observed relative to the TRPH concentrations. This indicates that, similar to Site SS-15B, C_8-C_{10} hydrocarbons in Site SS-15A soils are also insignificant. Total BTEX concentrations in Site SS-15A soil samples collected in 1994 ranged from less than 0.1 to 4.4 percent of the TRPH concentrations by mass (average 0.6 percent).

Four soil samples collected at Site SS-15A in October 1997 contained detectable concentrations of TRPH that ranged from 21 mg/kg to 200 mg/kg. The maximum total BTEX concentration detected in these four samples was 0.0197 mg/kg, which is approximately 0.1 percent of the TRPH concentration detected in the same sample (see Section 5). The 1997 data indicate that the percentage of TRPH consisting of low-molecular-weight, volatile compounds (e.g., BTEX) is decreasing over time at Site SS-15A due to preferential attenuation (via biodegradation and volatilization) of the more volatile compounds. Based on the detailed analysis of TRPH completed at Site SS-15B, and the supporting results at Site SS-15A, the Air Force does not consider the Tier 1 TCL of 2500 mg/kg to be valid indicator of risk for this highly weathered jet fuel. Specific analysis of VOCs, SVOCs, and PAHs at the site have been used to more accurately identify Tier 1 soil chemicals of potential concern.

4.3.1.2 PAHs Exceeding Tier 1 Target Cleanup Levels

Concentrations of the PAHs benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene and benzo(b)fluoranthene detected in 1994 were not reported individually in the contamination assessment report (OHM, 1995a). Instead, combined concentrations for PAH pairs were reported (i.e., benzo(a)anthracene + chrysene, dibenzo(a,h)anthracene + indeno(1,2,3-cd)pyrene, phenanthrene + anthracene, and benzo(b)anthracene + benzo(k)anthracene) because

the analytical method used (USEPA SW8100) could not resolve individual concentrations of these analytes. In some cases, the maximum combined concentration of the PAH pair detected in soils was less than the Direct-Exposure II TCL for one or both individual PAHs, indicating that one or both of the PAHs should not be considered a COPC. However, the maximum combined concentration of indeno(1,2,3-cd)pyrene + dibenzo(a,h)anthracene detected in 1994 (18 micrograms per kilogram [µg/kg] exceeded the Direct Exposure II TCLs for these compounds (5.2 µg/kg and 0.5 µg/kg, respectively); therefore, these PAHs were not eliminated from further consideration. Similarly, the combined concentration of benzo(b)fluoranthene + benzo(k)fluoranthene (37 µg/kg) exceeded the Direct Exposure II TCL for benzo(b)fluoranthene (5 µg/kg). Because, the maximum concentration of benzo(b)fluoranthene detected in October 1997 also exceeded the TCL, this analyte was retained as a COPC.

The October 1997 soil quality data were examined to assess the relative frequency of detection of indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene in site soils. At least one of the two compounds were detected in five of the eight samples collected. Assuming that the non-detected compound was present at a concentration equal to one-half the MDL, the ratio of indeno(1,2,3-cd)pyrene to benzo(a,h)anthracene in the five samples ranged from 22:1 to 335:1 and averaged 167:1. These ratios suggest that indeno(1,2,3-cd)pyrene is substantially more abundant in petroleum-contaminated site soils than dibenzo(a,h)anthracene, and that dibenzo(a,h)anthracene may not be a COPC in soil at Site SS-15A.

The maximum soil contaminant concentrations were not compared to the leachability TCLs presented in Table IV of FDEP (1997). The leachability criteria were established to ensure that leaching of residual contamination adsorbed to soil particles will not result in significant impairment of groundwater quality. At Site SS-15A, the vadose zone is thin (approximately 5 feet thick), the pavement limits percolation of precipitation through site soils, and groundwater is continually or seasonally in direct

contact with contaminated soil, minimizing the significance of downward leaching of contaminants from the vadose zone to the water table. In addition, the contamination has been present for more than 30 years (the SS-15A distribution lines have not been in service since the early 1960s), and the impacts of site contamination on groundwater quality have been fully demonstrated by the results of several years of groundwater monitoring. The gradual desorption of residual fuel contaminants from the soils and dissolution into the groundwater is significant to the extent that the contaminants in soils represent a continuing source of groundwater contamination. The length of time that the soil contamination will continue to cause dissolved contaminant concentrations to exceed Tier 1 TCLs (Table V levels in Chapter 62-770) is addressed in Section 6.

4.3.2 Tier 1 Screening Analysis for Groundwater

The Tier 1 groundwater TCLs presented by the FDEP (1997) and used in this CAP are based on the conservative assumption of unrestricted future use of groundwater (e.g., use as a drinking water source). Comparisons of the TCLs for unrestricted groundwater use to maximum concentrations of compounds detected in groundwater samples collected between December 1996 and October 1997 are presented in Table 4.2. Based on these comparisons, benzene, ethylbenzene, MTBE, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, naphthalene, and TRPH are identified as the COPCs in site groundwater. It should be noted that, for most of the analytes, the concentrations exceeding Tier 1 TCLs were limited to 3 or fewer of the 23 wells sampled, and therefore appear to be localized occurrences at the site.

Maximum dissolved contaminant concentrations also are compared to Table IX Natural Attenuation Source Default Values in Table 4.2. During the period from December 1996 to October 1997, only naphthalene and TRPH exceeded their default values at four wells (AP11-MW14, AP17-MW40, AP23-MW67, and AP26-MW75) and one well (AP11-MW14), respectively. The limited number of default value

TABLE 4.2
COMPARISON OF MAXIMUM SITE GROUNDWATER CONCENTRATIONS TO TARGET CLEANUP LEVELS
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Chemical Name	Units	Maximum Concentration Detected [a]	Location of Maximum Detection	Date of Maximum Detection	Table V Target Cleanup Level [b]	Number of Wells Exceeded [c]	Table IX Natural Attenuation Source Default [d]	Number of Wells Exceeded [c]
Benzene	µg/L [e]	28	AP16-MW39/AP12-MW24	Oct 97/Jan 97	1	22	100	0
Ethylbenzene	µg/L	130	AP10-MW9	Dec 96	30	3	300	0
Toluene	µg/L	4	AP26-MW114	July 97	40	0	400	0
Xylenes, Total	µg/L	11J* [f]	AP23-MW67	Oct 97	20	0	200	0
MTBE [g]	µg/L	80J*	AP23-MW67	Oct 97	35	3	350	0
Acenaphthene	µg/L	25	AP26-MW76	Oct 97	20	3	200	0
Acenaphthylene	µg/L	2.1	AP10-MW-9	Oct 97	210	0	2,100	0
Anthracene	µg/L	12	AP26-MW76	Oct 97	2,100	0	21,000	0
Benzo(a)anthracene	µg/L	7	AP27-MW78	Oct 97	0.2	5	20	0
Benzo(a)pyrene	µg/L	5	AP27-MW78	Oct 97	0.2	2	20	0
Benzo(b)fluoranthene	µg/L	5	AP27-MW78	Jul & Oct 97	0.2	1	20	0
Benzo (g,h,i)perylene	µg/L	ND	---	---	210	0	2,100	0
Benzo(k)fluoranthene	µg/L	5	AP27-MW78	Oct 97	0.5	2	50	0
Chrysene	µg/L	5	AP27-MW78	Oct 97	5	0	500	0
Dibenzo(a,h)anthracene	µg/L	ND	---	---	0.2	0	20	0
Fluoranthene	µg/L	17	AP27-MW78	Oct 97	280	0	2,800	0
Fluorene	µg/L	31	AP26-MW76	Oct 97	280	0	2,800	0
Indeno(1,2,3-cd)pyrene	µg/L	ND	---	---	0.2	0	20	0
Naphthalene	µg/L	330	AP23-MW67	Jul 97	20	15	200	4
Phenanthrene	µg/L	46	AP26-MW114	Jan 97	210	0	2,100	0
Pyrene	µg/L	15	AP27-MW78	Oct 97	210	0	2,100	0
TRPH [h]	mg/L	76	AP11-MW14	Jan 97	5	2	50	1

[a] Maximum detection at Site SS-15A during December 1996-January 1997, July 1997, and October 1997 sampling events.

[b] Cleanup level for No Further Action With or Without Conditions (FDEP, 1997).

[c] Number of wells with analyte concentrations exceeding target cleanup level at least once during January 1997, July 1997, and October 1997 sampling events.

[d] Allowable maximum concentration for remediation by natural attenuation with monitoring (FDEP, 1997).

[e] µg/L = Micrograms per liter.

[f] J* = Estimated value, due to elevated surrogate recovery.

[g] MTBE = Methyl tert-butyl ether.

[h] TRPH = Total recoverable petroleum hydrocarbons.

exceedences suggests that natural attenuation is an appropriate remedial alternative for site groundwater.

4.3.3 Tier 1 Screening Analysis for Soil Gas

FDEP (1997) guidance does not provide TCLs for screening soil gas concentrations or for directly screening ambient air values. FDEP guidance accounts for the potential for volatilization of contaminants from soils into ambient air in the calculation of the Tier 1 TCLs for direct contact with soil. TRPH was the only volatile COPC detected above Tier 1 TCLs in soil, indicating that exposure via volatilization from soil into ambient air will not present appreciable risks. The Tier 1 TCLs do not account for the presence of the concrete/asphalt cover at the site, which would act to further minimize the potential for exposure via the inhalation pathway.

As a secondary means of assessing the potential for exposure via inhalation of volatiles, soil gas samples collected in October 1997 were analyzed for BTEX, and maximum detections of each compound were compared to the chemical-specific Occupational Safety and Health Administration (NIOSH, 1997) 8-hour time-weighted average Permissible Exposure Limits (PELs). Table 4.3 presents the results of this comparison. Xylene was detected above the OSHA PEL in the sample collected at MW-41. However, the analytical result is qualified as being biased due to matrix interference. All other detections of xylene were below the PEL. No other compounds were detected at concentrations above the PELs. The comparison of soil gas values to ambient air PELs is weighted averages, whereas the maximum detected value represents a worse-case scenario at a localized hotspot. Subsurface soil gas concentrations are not represent of potential ambient air exposure concentrations because they do not account for the presence of the asphalt/concrete cover, or the dilution which would occur as volatiles moved through the soil column and into ambient air. Neither are subsurface soil gas concentrations representative of an exposure concentration for onsite intrusive workers engaged in excavation activities

TABLE 4.3
COMPARISON OF MAXIMUM SITE SOIL GAS CONCENTRATIONS TO OSHA PERMISSIBLE EXPOSURE LIMITS
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Chemical	Maximum Detected Concentration (ppmv [a/])	OSHA PEL (ppmv) [b/]	Maximum Concentration Above PEL?
Benzene	ND [c/]	1	No
Toluene	65M [d/]	200	No
Ethylbenzene	54M	100	No
Xylenes	240M	100	Yes
TVH [e/]	22,000	-- [f/]	--

[a/] ppmv = Parts per million, volume per volume.

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

[c/] ND = Not detected above reporting limits.

[d/] M data qualifier indicates potential bias due to matrix interferences.

[e/] TVH = Total volatile hydrocarbons.

[f/] "--" = No PEL available.

because they do not account for the volatilization that could occur during excavation of soils or for the dilution of soil gas concentrations in ambient air. Nonetheless, if future excavation of contaminated soils proves to be necessary, appropriate air monitoring and personal protective equipment should be required to ensure that construction workers in trenches are not exposed to adverse soil gas levels.

Based on the single detection of xylene above the OSHO PEL, the highly conservative nature of the screen, and the fact that no detections of xylene in soil exceeded the Direct Exposure II TCL (which incorporate the inhalation pathway), the inhalation pathway will not be further developed in this report.

4.3.4 Summary of Site SS-15A COPCs

Table 4.4 summarizes the COPCs identified for soil, groundwater, and soil gas at Site SS-15A. Based on comparisons of the maximum soil concentrations to FDEP (1997) TCLs for ingestion, dermal exposure, and inhalation (of volatilized compounds and soil particulates) (Table 4.1), benzo(a)anthracene, benzo(a)pyrene, and benzo(b)fluoranthene, are identified as site COPCs in soil. As discussed in Section 4.3.1.1, Tier 1 TRPH target cleanup levels are not appropriate for the highly weathered jet fuel residuals which remain on the site. Although the concentrations of indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene detected in October 1997 did not exceed the Tier 1 TCLs for these compounds, they were not eliminated from further consideration because the 1994 soil quality analyses did not resolve individual concentrations of these analytes.

Based on comparisons of the maximum detected site chemical concentrations to the Tier 1 TCLs for groundwater, benzene, ethylbenzene, MTBE, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, naphthalene, and TRPH are identified as the groundwater COPCs (Table 4.4).

TABLE 4.4
SUMMARY OF CHEMICALS OF POTENTIAL CONCERN
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Chemicals of Potential Concern	Rationale [a/]
Soil	
Benzo(a)anthracene	Maximum concentration in 1994 or 1997 exceeded Direct Exposure II Target Cleanup Level
Benzo(a)pyrene	Maximum concentration in 1994 or 1997 exceeded Direct Exposure II Target Cleanup Level
Benzo(b)flouranthene	Maximum concentration in 1994 or 1997 exceeded Direct Exposure II Target Cleanup Level
Indeno(1,2,3-cd)pyrene	Possible COPC; maximum combined concentration of indeno(1,2,3-cd)pyrene plus dibenzo(a,h)anthracene exceeded Direct Exposure II Target Cleanup Levels for these compounds
Dibenzo(a,h)anthracene	Possible COPC; maximum combined concentration of indeno(1,2,3-cd)pyrene plus dibenzo(a,h)anthracene exceeded Direct Exposure II Target Cleanup Levels for these compounds
Groundwater	
Benzene	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
Ethylbenzene	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
MTBE	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
Naphthalene	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
Acenapthene	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
Benzo(a)anthracene	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
Benzo(a)pyrene	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
Benzo(b)fluoranthene	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
Benzo(k)flouranthene	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
TRPH	Maximum concentration in December 1996 to October 1997 exceeded Table V Target Cleanup Level
Air	
Xylenes	Maximum 1997 concentration exceeded OSHA 8-hour time-weighted average Permissible Exposure Limit

[a/] See Tables 4.1 through 4.3.

SECTION 5

NATURE AND EXTENT OF CHEMICALS OF POTENTIAL CONCERN

5.1 OVERVIEW

This section summarizes the nature and extent of COPC contamination in soil, soil gas, and groundwater at Site SS-15A. Data from earlier site characterization activities (OHM 1995a, 1995b, 1996a, 1996b, 1996c, 1997a, 1997b, and 1997c) and the 1997 risk-based remediation field investigations are included in this discussion. Based on the OHM data, contamination in soil and groundwater resulting from fuel releases at valve boxes and leaks in the distribution piping, occurs in a number of isolated areas beneath the Flightline Apron. Discussion in this section is limited to those chemicals that were identified as COPCs based on the Tier 1 screening analysis presented in Section 4. The COPCs are listed in Table 4.4. In addition, the areal extent of PAHs that are possible COPCs in soil [indeno-(1,2,3-cd)pyrene and dibenzo(a,h)anthracene] is presented (see Section 4.3.1).

5.2 SOURCES OF CONTAMINATION

Subsurface contamination at Site SS-15A is the result of leaking underground jet fuel (JP-4) distribution pipelines and fueling/defueling valve boxes. The lines were installed beginning in 1956, were removed from service in the 1960s, and were abandoned in place in early 1994 (OHM, 1995a). The FHS piping was purged of fuel, tested, and grouted (OHM 1995a). Line AP-4 was left open for possible future use. The quantity of fuel released from the FHS has not been determined.

According to (reference), the only PAH compounds in JP-4 are naphthalenes. Therefore, the higher molecular weight COPCs detected in groundwater (e.g., benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene) may have a different source than the naphthalenes and aromatic VOCs. If the fuel pipelines are coated with a tar-like substance, then exposure of the tar coating to JP-4 could have caused leaching of the higher molecular weight PAHs into the surrounding soil and groundwater. Alternatively, low levels of PAHs may have leached into soil and groundwater from the asphalt pavement covering much of the site.

5.3 SOIL GAS SAMPLING RESULTS

Soil gas samples were collected at Site SS-15A to facilitate assessment of the potential risk to future workers at the site from inhalation of VOCs, and to determine whether or not sufficient O_2 is available in the soil gas to sustain aerobic fuel hydrocarbon biodegradation. Nine soil gas samples were collected from the AP-26 area, which was the focus of the risk-based field investigation, and six samples were collected from the northern end of AP-18, which had high soil VOC results (maximum of 176 mg/kg) during the 1994 investigation (OHM, 1995_). The samples were analyzed in the field for concentrations of O_2, CO_2, and TVH, and four soil gas samples from locations that exhibited relatively elevated TVH levels also were submitted to Quanterra, Inc. for analysis of BTEX and TVH (referenced to jet fuel).

Field and laboratory analytical results for 1997 soil gas samples are summarized in Table 5.1. Comparison of maximum soil gas BTEX concentrations to OSHA 8-hour time-weighted average PELs (Table 4.3) indicated that xylenes at AP18-MW41 pose a potential inhalation risk to future intrusive workers. This is the same location where significantly elevated total VOC concentrations were detected in soil in 1994. The field screening data indicate that soil gas O_2 levels in areas of fuel-contaminated soils have been depleted due to microbial respiration during aerobic biodegradation of the fuel compounds. Concentrations of CO_2, which is a metabolic byproduct of biodegradation

TABLE 5.1
FIELD AND LABORATORY ANALYTICAL RESULTS FOR SOIL GAS
OCTOBER 1997
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

		Field Screening Data			Laboratory Analytical Data[a/]				
Sample Location	Sample Depth (ft bgs)[b/]	Oxygen (percent)	Carbon Dioxide (percent)	TVH (ppmv)[c/]	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethyl-benzene (ppmv)	Xylenes (ppmv)
AP-18									
VW-1	2.5-5.3	NA[d/]	NA	NA	NA	NA	NA	NA	NA
MPA	4.0-4.5	0.0	16.8	> 20,000	NA	NA	NA	NA	NA
MPB	4.0-4.5	0.0	16.0	1,900	NA	NA	NA	NA	NA
MW-41	3.25-5.3	0.0	13.5	9,200	22,000	<1[e/]	65M[f/]	54M	240M
MW-42	3.25-5.3	0.0	16.3	680	NA	NA	NA	NA	NA
MW-43	3.25-5.3	0.0	16.0	840	1,500	<0.052	4.7M	2.7	24M
AP-26									
MW-75	3.0-5.3	0.0	17.8	5,600	7,300	<0.54	25M	30M	84
MW-76	2.5-5.3	WATER[g/]			NA	NA	NA	NA	NA
MW-77	2.5-5.3	0.0	15.5	3,600	NA	NA	NA	NA	NA
MW-104	2.5-5.3	WATER			NA	NA	NA	NA	NA
	3.0-5.3	19.0	1.5	72	NA	NA	NA	NA	NA
V-113	3.0-5.3	5.0	8.5	3,800	NA	NA	NA	NA	NA
MW-114	3.0-5.3	0.0	8.2	>20,000	8,900	<0.27	24	31M	95
MW-115	3.5-5.3	13.5	6.0	440	NA	NA	NA	NA	NA
MW-116	3.0-5.3	0.0	8.2	600	NA	NA	NA	NA	NA

[a/] Laboratory analysis of soil gas performed using USEPA Method TO-3. C5+ hydrocarbons referenced to jet fuel (MW=156); C2-C4 hydrocarbons referenced to propane (MW=44).

[b/] ft bgs = feet below ground surface.

[c/] TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume.

[d/] NA = Sample not analyzed.

[e/] < = compound analyzed for, but not detected. Number shown represents the laboratory method detection limit.

[f/] M = Reported value may be biased due to apparent matrix interferences.

[g/] Unable to collect soil gas sample due to saturated condtions.

reactions, are correspondingly elevated. These data indicate that the addition of oxygen to contaminated soils (e.g., bioventing) would be effective in reducing the source of dissolved groundwater contamination. The soil gas analytical results are discussed further in Section 7 of this CAP.

5.4 SOIL SAMPLING RESULTS

Soil sampling was performed at Site SS-15A during 1994 (OHM, 1995a) and as part of the recent risk-based investigation. In 1994, OHM drilled 232 soil boreholes along and between the fuel distribution lines located beneath the Flightline Apron to identify potential "hotspots" of fuel contamination. Parsons ES drilled and sampled an additional 8 soil boreholes along Apron Lines AP-15, AP-18, AP-20, and AP-26 in October 1997. Soil samples at Site SS-15A have been analyzed for TRPH, aromatic VOCs including BTEX and MTBE, and PAHs. The compounds initially identified as soil COPCs as a result of the Tier 1 analysis include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and TRPH. As discussed in Section 4.3.1.1, Tier 1 TRPH criteria were not deemed appropriate for this highly weathered fuel residual. Soil quality data obtained for this risk-based project in October 1997 are summarized in Tables 5.2 and 5.3, and 1994 data are presented in Appendix A.

Available soil analytical data indicate that soil COPCs are generally confined to isolated areas of shallow soils at depths less than 5 to 7 feet bgs. Soil COPCs with maximum concentrations exceeding Tier 1 screening levels are listed in Table 4.4, and Figure 5.1 presents the concentrations and distribution of COPCs exceeding the Tier 1 screening levels. The Tier 1 (Direct Exposure II) TCL of 0.5 mg/kg for benzo(a)pyrene was exceeded in 21 samples (maximum concentration of 16 mg/kg at location AP20-SB6) in 1994 and in 4 samples (maximum concentration of 7.4 mg/kg at location AP26-SB1-5) in 1997. Benzo(a)anthracene and benzo(b)fluoranthene concentrations (maximum concentrations of 11 mg/kg and 7.4 mg/kg, respectively at

TABLE 5.2
AROMATIC VOLATILE ORGANICS, TRPH, AND TOC IN SOIL
OCTOBER 1997
RISKED-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

			1,2-Dichloro-benzene (mg/kg)[a]	1,3-Dichloro-benzene (mg/kg)	1,4-Dichloro-benzene (mg/kg)	Benzene (mg/kg)	Chloro-benzene (mg/kg)	Ethyl-benzene (mg/kg)	Methyl Tert-butyl Ether (mg/kg)	Toluene (mg/kg)	Total Xylenes (mg/kg)	TRPH[b] (mg/kg)	TOC[c] (mg/kg)
FDEP TCL[d]			--	--	--	*1.5*	--	*240*	*6100*	*2000*	*290*	*2500*	--
Sample Location	**Date**	**Depth (feet)**											
AP15-SB1-2	10/24/97	2 - 4	0.0047 U[e]	0.0047 U	0.0035 U	0.00075 J1[f]	0.0024 U	0.0024 U	0.0059 U	0.0059 U	0.0059 U	200	NA[g]
AP18-VW1-3	10/24/97	3 - 5	0.62 U	0.62 U	0.58 U	0.77 U	1.8	0.31 U	0.77 U	0.77 U	0.77 U	36	NA
AP20-SB1-3	10/24/97	3 - 5	0.0047 U	0.0047 U	0.0035 U	0.0059 U	0.0024 U	0.0024 U	0.0059 U	0.0015 J1	0.0059 U	12 U	NA
AP26-SB1-5	10/24/97	5 - 7	0.0047 U	0.0047 U	0.0035 U	0.0059 U	0.049	0.0024 U	0.0059 U	0.0059 U	0.0059 U	NA	NA
AP26-SB2-3	10/24/97	3 - 5	0.0047 U	0.0047 U	0.0035 U	0.0058 U	0.0079	0.0023 U	0.0058 U	0.0058 U	0.0058 U	NA	NA
AP26-SB3-5	10/24/97	5 - 7	0.0047 U	0.0047 U	0.0035 U	0.0059 U	0.01	0.0024 U	0.0059 U	0.0018 J1	0.0059 U	22	NA
AP26-SB4-3	10/24/97	3 - 5	0.0013 J1	0.00053 J1	0.0035 U	0.0027 J1	0.023	0.018	0.0058 U	0.0017 J1	0.0058 U	21	NA
AP26-SB4-5	10/24/97	5 - 7	0.0048 U	0.0048 U	0.0036 U	0.006 U	0.021	0.0024 U	0.006 U	0.0034 J1	0.006 U	NA	NA
AP26-SB5-6	10/24/97	6 - 8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	780 J1
AP26-SB5-8	10/24/97	8 - 10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	800 J1

[a] mg/kg = Milligrams per kilogram.

[b] TRPH = Total recoverable petroleum hydrocarbons.

[c] TOC = Total organic carbon.

[d] Florida Department of Environmental Protection (1997) target cleanup level for direct exposure (industrial scenario) (62-770).

[e] U = The analyte was analyzed for and is not present above the reporting limit.

[f] J1 = The analyte was positively identified at a concentration between the method detection limit and the reporting limit.

[g] NA = Not analyzed.

Note: Analysis methods are SW8020 for aromatic volatiles, FL-PRO for TRPH, and SW9060 for TOC.

TABLE 5.3
POLYNUCLEAR AROMATIC HYDROCARBONS IN SOIL (OCTOBER 1997)
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

			Ace-naphthene (mg/kg)[a]	Ace-naphthylene (mg/kg)	An-thracene (mg/kg)	Benzo(a) anthracene (mg/kg)	Benzo(a) pyrene (mg/kg)	Benzo(b) fluor-anthene (mg/kg)	Benzo(g,h,i) perylene (mg/kg)	Benzo(k) fluor-anthene (mg/kg)	Chrysene (mg/kg)	Dibenz(a,h) anthracene (mg/kg)	Fluor-anthene (mg/kg)	Fluorene (mg/kg)	Indeno (1,2,3-c,d) pyrene (mg/kg)	Naphthalene (mg/kg)	Phenan-threne (mg/kg)	Pyrene (mg/kg)
FDEP TCL[b]			*22000*	*11000*	*290000*	*5.1*	*0.5*	*5*	*45000*	*52*	*490*	*0.5*	*45000*	*24000*	*5.2*	*8600*	*29000*	*40000*
Sample Location	**Depth (feet)**	**Sample Date**																
AP15-SB1-2	2 - 4	10/24/97	0.24 U[c]	0.24 U	0.021 J1[d]	0.014 J1	0.018 U	0.0056 J1	0.0037 J1	0.013 U	0.022 J1	0.024 U	0.065	0.026 J1	0.035 U	0.24 U	0.11	0.065
AP18-VW1-3	3 - 5	10/24/97	0.31 U	0.31 U	0.054	0.031 U	0.0089 J1	0.008 J1	0.0079 J1	0.017 U	0.062 U	0.031 U	0.078	0.11	0.046 U	3.8	0.33	0.055 J1
AP20-SB1-3	3 - 5	10/24/97	0.24 U	0.24 U	0.024 U	0.024 U	0.018 U	0.014 U	0.059 U	0.013 U	0.047 U	0.024 U	0.047 U	0.047 U	0.035 U	0.24 U	0.047 U	0.047 U
AP26-SB1-5	5 - 7	10/24/97	11 J1	24 U	8.1	11	7.4	7.4	5.9 U	2.8	12	2.4 U	20	9.3	4.3	24 U	29	14
AP26-SB2-3	3 - 5	10/24/97	0.23 U	0.23 U	0.22	0.037	0.061	0.053	0.043 J1	0.017	0.058	0.023 U	0.41	0.19	0.037	0.23 U	0.87	0.39
AP26-SB3-5	5 - 7	10/24/97	1.8	2.4 U	1.7	1.5	0.85	0.78	0.59 U	0.29	1.5	0.24 U	3.5	1.5	0.47	2.4 U	6.5	3
AP26-SB4-3	3 - 5	10/24/97	2.3 U	2.3 U	0.77	1.5	0.81	0.65	0.35 J1	0.26	0.88	0.23 U	2.7	0.68	0.3 J1	4.6	2.4	2.7
AP26-SB4-5	5 - 7	10/24/97	2.4 U	2.4 U	0.55	1.4	1.1	0.87	0.6 U	0.32	1.1	0.24 U	1.7	0.56	0.57	2.4 U	1.5	1.7

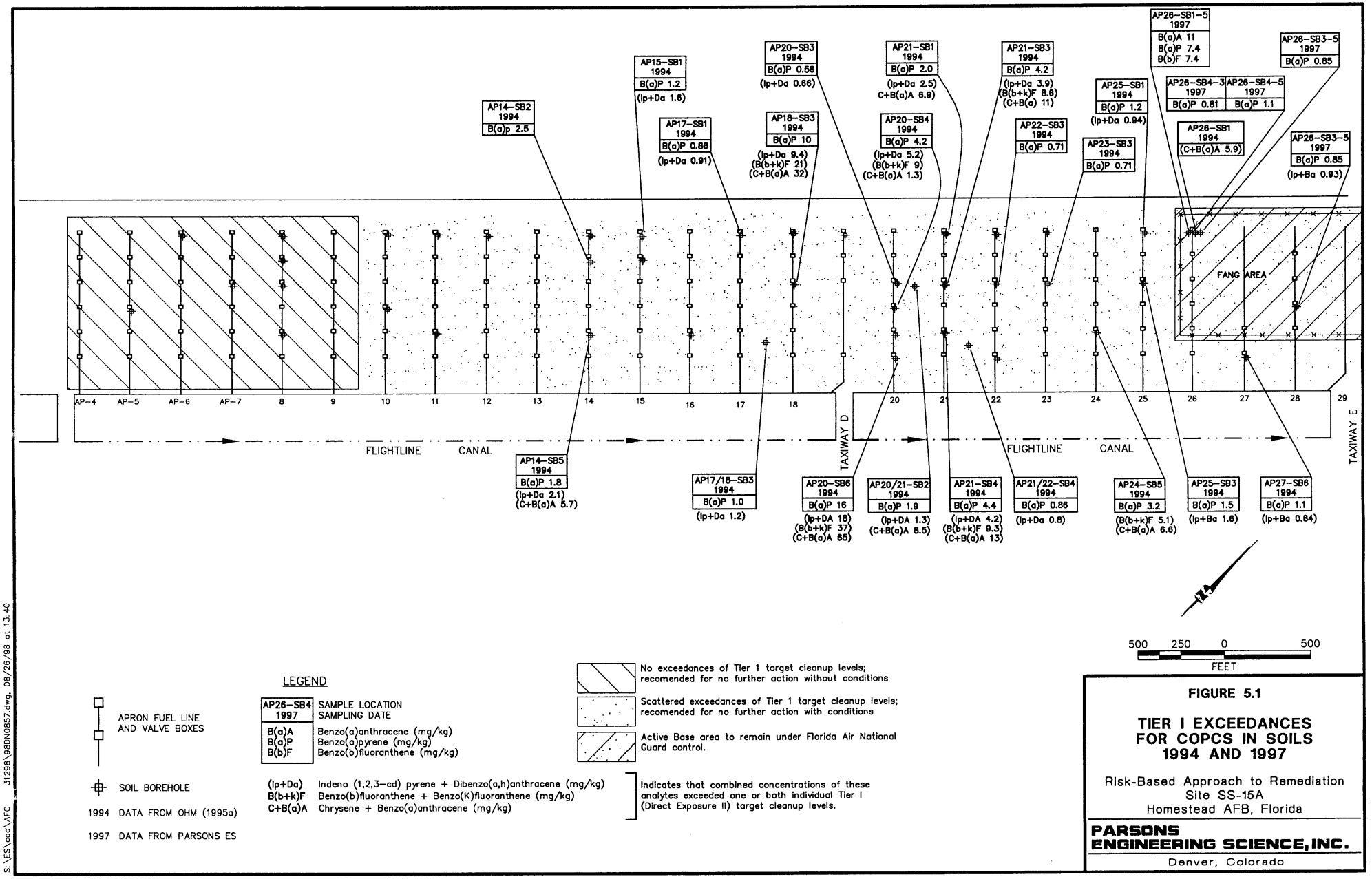
[a] mg/kg = Milligrams per kilogram.

[b] Florida Department of Environmental Protection (1997) target cleanup level for direct exposure (industrial scenario) (62-770).

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

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

Note: Analysis method is SW8310.



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FIGURE 5.1

TIER I EXCEEDANCES FOR COPCS IN SOILS 1994 AND 1997

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

location AP26-SB1-5) exceeded their respective screening levels of 5.1 mg/kg and 5 mg/kg at only one location in 1997.

The degree to which benzo(a)anthracene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, and dibenzo(a,h)anthracene exceeded their respective soil screening levels in 1994 is not known because the analytical method used (SW8100) could not resolve individual concentrations of these analytes. Combined concentrations for PAH pairs that exceeded the individual Tier 1 (Direct Exposure II) TCL for one or both of the individual PAHs also are shown on Figure 5.1. The long-term impacts of soil contamination on underlying groundwater at this site, accounting for site-specific conditions, are considered in Section 6.

5.5 GROUNDWATER SAMPLING RESULTS

This subsection summarizes the results of groundwater sampling events conducted during previous site investigations, quarterly MO events, and the 1997 focused field investigation performed in support of risk-based remediation of Site SS-15A. The analytes identified as groundwater COPCs based on the Tier 1 screening are benzene, ethylbenzene, MTBE, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, naphthalene, and TRPH. Groundwater quality data obtained by Parsons ES in 1997 is summarized in Tables 5.4 and 5.5, and all available analytical results for groundwater samples obtained by OHM since 1994 are presented in Appendix A.

Similar to the distribution of soil contamination, groundwater contamination occurs in a number of isolated locations beneath the Flightline Apron, likely due in part to the flat groundwater gradient and estimated low flow rate (see Section 3.2). Areas with groundwater contamination roughly coincide with the source areas characterized by contaminated soils; therefore, significant migration of dissolved contaminant plumes

TABLE 5.4
VOLATILE ORGANICS AND TRPH IN GROUNDWATER
OCTOBER 1997
RISKED-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

		1,2-Dichloro-benzene (µg/L)[a]	1,3-Dichloro-benzene (µg/L)	1,4-Dichloro-benzene (µg/L)	Benzene (µg/L)	Chloro-benzene (µg/L)	Ethyl-benzene (µg/L)	Methyl Tert butyl Ether (µg/L)	Toluene (µg/L)	Total Xylenes (µgL)	Total BTEX (µgL)	TRPH[b] (mg/L)[c]
FDEP NFA TCL[d]		--	--	--	1	--	30	35	40	20	--	5
FDEP NA TCL[e]		--	--	--	100	--	300	350	400	200	--	50
Sample Location	**Date**											
Field Blank	10/27/97	4 U[f]	4 U	3 U	2 U	2 U	2 U	5 U	0.75 J1[g]	2 U	0.75 J1	0.5 U
AP-10 MW-10	10/27/97	4 U	4 U	3 U	2 U	2 U	2 U	5 U	2 U	2 U	<RL[i]	0.5 U
AP-10 MW-10 DUP[j]	10/27/97	4 U	4 U	3 U	2 U	2 U	2 U	5 U	2 U	2 U	<RL	0.5 U
AP-10 MW-11	10/27/97	4 U	4 U	3 U	2 U	2 U	2 U	5 U	2 U	2 U	<RL	0.5 U
AP-11 MW-15	10/26/97	4 U	4 U	3 U	2 U	2 U	2 U	5 U	2 U	2 U	<RL	0.5 U
AP-11 MW-16	10/26/97	4 U	4 U	3 U	1.4 J1	1.2 J1	2 U	5 U	2 U	2 U	1.4 J1	0.78
AP-17 MW-40	10/23/97	NA	NA	NA	15**	NA	11**	25U	4U**	4U**	26**	5
AP-22 MW-64	10/28/97	4 U	4 U	3 U	2 U	2 U	2 U	5 U	2 U	2 U	<RL	0.5 U
AP-26 MW-77	10/29/97	4 U	4 U	3 U	2 U	2 U	2 U	5 U	2 U	2 U	<RL	0.5 U
AP-22 MW-111	10/27/97	4 U	4 U	3 U	2 U	2 U	2 U	5 U	2 U	2 U	<RL	0.5 U
AP-26 MW-112	10/28/97	4 U	4 U	3 U	2 U	2 U	2 U	5 U	0.25 U	2 U	<RL	0.5 U

[a] µg/L = Micrograms per liter.

[b] TRPH = Total recoverable petroleum hydrocarbons.

[c] mg/L = milligrams per liter.

[d] Florida Deptartment of Environmental Protection (1997) no further action target cleanup level for Resource Protection/Recovery (Table V, 62-770).

[e] Florida Department of Environmental Protection (1997) natural attenuation source default value (62-770).

[f] U = The analyte was analyzed for and is not present above the reporting limit.

[g] J1 = The analyte was positively identified and has a concentration between the method detection limit and the reporting limit.

[h] NA = Not analyzed.

[i] RL = Reporting limit.

[j] DUP = Field duplicate.

** Sample results were supplied by OHM.

Note: Analysis methods are SW8020A for aromatic VOCs, FL-PRO for TRPH, and SW8010A for halogenated VOCs.

TABLE 5.5
POLYNUCLEAR AROMATIC HYDROCARBONS IN GROUNDWATER
OCTOBER 1997
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

		Ace-naphthene (µg/L)[a]	Ace-naphthylene (µg/L)	An-thracene (µg/L)	Benzo(a) anthracene (µg/L)	Benzo(a) pyrene (µg/L)	Benzo(b) fluor-anthene (µg/L)	Benzo (g,h,i) perylene (µg/L)	Benzo(k) fluor-anthene (µg/L)	Chrysene (µg/L)	Dibenz(a,h) anthracene (µg/L)	Flour-anthene (µg/L)	Fluorene (µg/L)	Indeno (1,2,3-c,d) pyrene (µg/L)	Naph-thalene (µg/L)	Phenan-threne (µg/L)	Pyrene (µg/L)
FDEP NFA TCL[b]		*20*	*210*	*2100*	*0.2*	*0.2*	*0.2*	*210*	*0.5*	*5*	*0.2*	*280*	*280*	*0.2*	*20*	*210*	*210*
FDEP NA TCL[c]		*200*	--	*21000*	*20*	*20*	*50*	*2100*	*50*	*500*	*20*	*2800*	*2800*	*20*	*200*	*2100*	*2100*
Sample Location	**Date**																
Field Blank	10/27/97	0.98 U[d]	0.98 U	0.098 U	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.29 U	0.2 U	0.2 U	0.42 U	0.98 U	0.2 U	0.2 U
AP-10 MW-9	10/27/97	1.6	2.1	0.33	0.13 U	0.22 U	0.17 U	0.19 U	0.16 U	0.19 U	0.29 U	0.63	0.6	0.41 U	16	0.22	0.7
AP-10 MW-10	10/27/97	0.98 U	0.98 U	0.098 U	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.29 U	0.2 U	0.2 U	0.42 U	0.98 U	0.2 U	0.2 U
AP-10 MW-10 DUP[e]	10/27/97	0.97 U	0.97 U	0.097 U	0.13 U	0.22 U	0.17 U	0.19 U	0.17 U	0.19 U	0.29 U	0.19 U	0.19 U	0.42 U	0.97 U	0.19 U	0.19 U
AP-10 MW-11	10/27/97	0.98 U	0.98 U	0.098 U	0.13 U	0.22 U	0.18 U	0.2 U	0.17 U	0.2 U	0.29 U	0.2 U	0.2 U	0.42 U	0.98 U	0.2 U	0.2 U
AP-10 MW-110	10/27/97	0.98 U	0.98 U	0.098 U	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.29 U	0.2 U	0.2 U	0.42 U	0.98 U	0.2 U	0.2 U
AP-11 MW-14	10/26/97	0.98 U	0.98 U	0.098 U	0.13 U	0.22 U	0.18 U	0.2 U	0.17 U	0.2 U	0.29 U	0.039 J1[f]	0.2 U	0.42 U	12	0.2 U	0.2 U
AP-11 MW-15	10/26/97	0.98 U	0.98 U	0.098 U	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.3 U	0.2 U	0.2 U	0.42 U	0.98 U	0.2 U	0.2 U
AP-11 MW-16	10/26/97	0.98 U	0.98 U	0.13	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.3 U	0.2 U	2	0.42 U	6.9	0.98	0.2 U
AP-11 MW-95	10/27/97	0.99 U	0.99 U	0.099 U	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.3 U	0.2 U	0.2 U	0.43 U	0.99 U	0.2 U	0.2 U
AP-17 MW-40	10/23/97	4.9 U	4.9 U	0.38 J1	0.64 U	1.1 U	0.89 U	0.99 U	0.84 U	0.99 U	1.5 U	0.6 J1	1.4	2.1 U	120	1.8	0.7 J1
AP-17 MW-99	10/23/97	0.23 J1	0.98 U	0.098 U	0.13 U	0.22 U	0.18 U	0.2 U	0.17 U	0.2 U	0.29 U	0.2 U	0.094 J1	0.42 U	0.98 U	0.2 U	0.2 U
AP-22 MW-63	10/27/97	1 U	1 U	0.079 J1	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.3 U	0.2 U	0.2 U	0.43 U	0.99 J1	0.2 U	0.062 J1
AP-22 MW-64	10/28/97	0.98 U	0.98 U	0.098 U	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.29 U	0.068 J1	0.2 U	0.42 U	0.98 U	0.2 U	0.094 J1
AP-22 MW-111	10/27/97	0.98 U	0.98 U	0.098 U	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.29 U	0.083 J1	0.2 U	0.42 U	0.98 U	0.2 U	0.2 U
AP-26 MW-75	10/29/97	18	2 U	4.3	0.32	0.45 U	0.35 U	0.39 U	0.33 U	0.39 U	0.59 U	4.7	12	0.84 U	2 U	16	3.7
AP-26 MW-76	10/29/97	20	4.9 U	6.5	0.63 U	1.1 U	0.87 U	0.97 U	0.83 U	0.97 U	1.5 U	9.6	22	2.1 U	8.1	25	7.2
AP-26 MW-77	10/29/97	4	0.99 U	0.12	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.3 U	2.8	4.3	0.43 U	0.99 U	0.2 U	1.9
AP-26 MW-104	10/29/97	1 U	1 U	3.8	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.3 U	4.4	8.5	0.43 U	44	20	3
AP-26 MW-112	10/28/97	0.97 U	0.97 U	0.15	0.13 U	0.22 U	0.17 U	0.19 U	0.17 U	0.19 U	0.29 U	0.19 U	0.97	0.42 U	0.97 U	0.19 U	0.1 J1
AP-26 MW-113	10/28/97	17	0.52 J1	0.91	0.24 J1	0.45 U	0.35 U	0.39 U	0.33 U	0.39 U	0.59 U	6.6	22	0.84 U	2 U	3.2	4.4
AP-26 MW-114	10/29/97	12	1 U	2.8	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.3 U	5.8	8.2	0.43 U	24	14	5.4
AP-26 MW-115	10/28/97	6.1	1 U	0.21	0.13 U	0.23 U	0.18 U	0.2 U	0.17 U	0.2 U	0.3 U	0.56	5.6	0.43 U	1 U	0.2 U	0.37
AP-26 MW-116	10/29/97	8.3	0.98 U	1.2	0.22	0.23 U	0.18 U	0.2 U	0.17 U	0.2	0.29 U	5.4	11	0.42 U	0.98 U	0.33	3.6

[a] µg/L = Micrograms per liter.

[b] Florida Deptartment of Environmental Protection (1997) no further action target cleanup level for Resource Protection/Recovery (Table V, 62-770).

[c] Florida Deptartment of Environmental Protection (1997) natural attenuation source default value (62-770).

[d] U = The analyte was analyzed for and is not present above the reporting limit.

[e] Dup = Field duplicate.

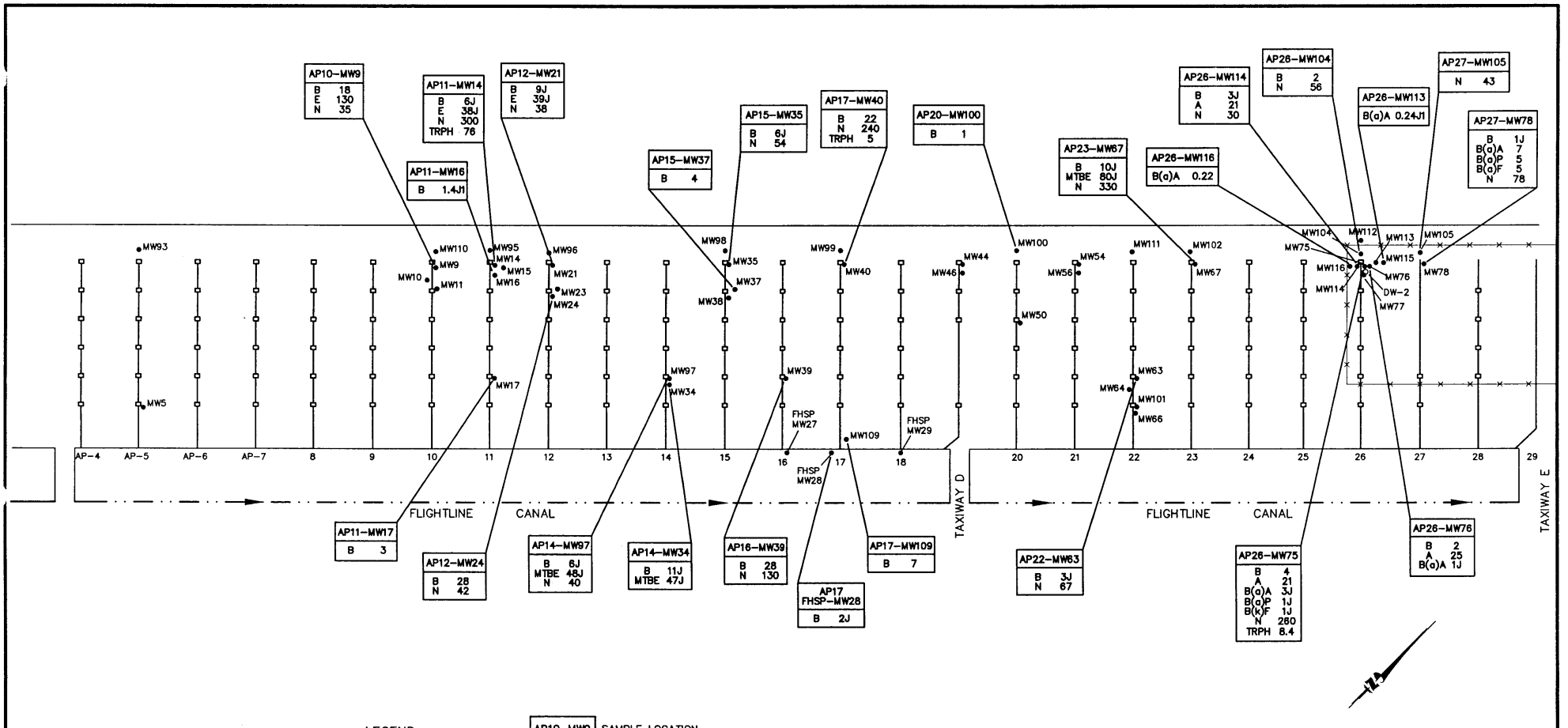
[f] J1 = The analyte was positively identified and has a concentration between the method detection limit and the reporting limit.

Note: Analysis method is SW8310.

has not been observed. The maximum migration distance observed to date was at Apron Line AP-26 in the vicinity of valve box 1, where contaminants appear to have migrated approximately 70 feet from the source area (valve box 1). Additionally, groundwater contamination is limited to the shallow portion of the surficial aquifer (less than 25 feet bgs) (OHM, 1996c; Geraghty & Miller, Inc., 1993).

Shallow groundwater contamination was detected at Site SS-15A during groundwater investigations conducted in 1994 (OHM, 1995a). During these investigations, 103 permanent wells were installed and sampled at Site SS-15A and analyzed for aromatic VOCs and halogenated VOCs (VOHs), ethylene dibromide, PAHs, TRPH, and total and dissolved lead. Subsequently, a quarterly MO program has been conducted, with seven sampling events having been completed to date. During the MO period, 27 additional monitoring wells were installed. The number of wells sampled and analyses performed during the monitoring period has varied; during the most recent event for which data are available (October 1997), 40 wells were sampled and analyzed for VOHs, VOAs, and PAHs. Groundwater samples from 23 existing wells also were collected during the October 1997 risk-based field investigation performed by Parsons ES. These samples were analyzed for VOAs, PAHs, TRPH, and various inorganic and geochemical indicator parameters to evaluate natural chemical and physical attenuation processes that are occurring at the site. The analytes targeted at each well were varied to avoid duplication of OHM's October 1997 MO sampling. For example, well AP26-MW75 was targeted to be sampled during the same time period by both OHM (MO event) and Parsons ES (risk-based remedial investigation). Therefore, the risk-based analytical suite for this well was tailored where feasible to avoid duplication of analyses.

Based on the results of MO sampling events performed in December 1996-January 1997, July 1997, and October 1997, one or more COPCs exceeded their respective Tier 1 (Table V) TCLs at a total of 25 locations. Figure 5.2 presents the maximum



LEGEND

APRON FUEL LINE AND VALVE BOXES

MW40 ● SHALLOW GROUNDWATER MONITORING WELL SAMPLED BY PARSONS ES AND/OR OHM IN OCTOBER 1997

DW-2 ○ INTERMEDIATE-DEPTH GROUNDWATER MONITORING WELL SAMPLED BY PARSONS ES AND/OR OHM IN OCTOBER 1997

AP10–MW9	SAMPLE LOCATION
B	BENZENE (µg/L)
E	ETHYLBENZENE (µg/L)
MTBE	METHYL TERT BUTYL ETHER (µg/L)
A	ACENAPHTHENE (µg/L)
B(a)A	BENZO(a)ANTHRACENE (µg/L)
B(a)P	BENZO(a)PYRENE (µg/L)
B(a)F	BENZO(b)FLUORANTHENE (µg/L)
B(k)F	BENZO(k)FLUORANTHENE (µg/L)
N	NAPHTHALENE (µg/L0
TRPH	TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/L)

J THE ANALYTE WAS ANALYZED FOR AND WAS POSITIVELY IDENTIFIED, BUT THE ASSOCIATED NUMERICAL VALUE MAY NOT BE CONSISTENT WITH THE AMOUNT ACTUALLY PRESENT IN THE ENVIRONMENTAL SAMPLE. THE DATA SHOULD BE CONSIDERED AS A BASIS FOR DECISION-MAKING AND ARE USABLE FOR MANY PURPOSES.

J1 THE ANALYTE IS QUALIFIED AS AN ESTIMATED VALUE SOLELY BECAUSE IT IS GREATER THAN THE METHOD DETECTION LIMIT AND LESS THAN THE PRACTICAL QUANTITATION LIMIT, INDICATING NO LABORATORY QUALITY ISSUES.

FIGURE 5.2

TIER I EXCEEDANCES FOR COPCS IN GROUNDWATER DECEMBER 1996-OCTOBER 1997

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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concentrations of groundwater COPCs detected above their respective Tier 1 screening levels at each of the sampled monitoring wells during the three recent monitoring events described above. The Table V TCLs for the volatile COPCs benzene, ethylbenzene, and MTBE were exceeded at 22 wells, 3 wells, and 3 wells, respectively. The Table V TCLs for the following PAHs also were exceeded: acenaphthene (3 wells), benzo(a)anthracene (5 wells), benzo(a)pyrene and benzo(k)fluoranthene (2 wells each), benzo(b)fluoranthene (1 well), and naphthalene (15 wells). The Table V TCL for TRPH was exceeded at 2 wells. The maximum concentrations of COPCs detected during the three monitoring events performed from December 1996 through October 1997 were benzene (28 μg/L), ethylbenzene (130 μg/L), MTBE (80J* μg/L), acenaphthene (25 μg/L), benzo(a)anthracene (7 μg/L), benzo(a)pyrene (5 μg/L), benzo(b)fluoranthene (5 μg/L), benzo(k)fluoranthene (5 μg/L) naphthalene (330 μg/L), and TRPH (76 mg/L). The J* qualifier indicates that the value is estimated due to elevated surrogate recovery.

It should be noted that the MDLs for historical groundwater quality results have not always been lower than the Tier 1 TCLs. For example, the MDL for benzo(a)pyrene using USEPA Method SW8270 (the method used by OHM to analyze for PAHs) is 5 μg/L, compared to a Tier 1 TCL of 0.2 μg/L. Therefore, it is conceivable that benzo(a)pyrene was present in groundwater samples at a concentration between 0.2 μg/L and 5 μg/L, but was not detected during previous analysis.

The effects of the chemical characteristics and site-specific characteristics of each of the groundwater COPCs on their fate and transport within the shallow groundwater are examined in Section 6. Emphasis is placed on documenting the effects of natural physical, chemical, and biological processes on COPC mass, concentration, persistence, toxicity, and mobility.

SECTION 6

QUANTITATIVE TIER 2 CHEMICAL FATE ASSESSMENT

6.1 INTRODUCTION

The fate and transport of COPCs in environmental media at Site SS-15A must be considered when assessing the need for and feasibility of certain remedial approaches to mitigate potentially unacceptable risks to human or ecological receptors. The purpose of this section is to quantitatively estimate the effects of various site-specific natural attenuation processes on the fate and transport of COPCs. These processes include leaching, dispersion, diffusion, adsorption, and biodegradation. Particular emphasis is given to documenting verifiable COPC biodegradation in both soils and groundwater. This section summarizes and interprets specific site characterization data relevant to documenting the effectiveness of natural chemical, physical, and biological processes that are minimizing COPC migration and reducing COPC concentration, mass, and toxicity over time. This quantitative fate assessment is used to estimate the timeframe to attain Tier 1 cleanup criteria using natural attenuation, and to determine whether natural attenuation will be effective in controlling the migration of contaminants from the site.

As discussed in Section 4, a number of PAHs [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and possibly also indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene] detected in soil at Site SS-15A exceeded their respective health-protective Tier 1 (Direct-Exposure II) TCLs designed to be protective of possible future site workers (Table 4.1). In addition, several site-related compounds were detected in groundwater during recent sampling events at concentrations above health-protective

Tier 1 (Table V) TCLs. Benzene, ethylbenzene, MTBE, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, naphthalene, and TRPH were measured in groundwater during the December 1996 through October 1997 sampling events at concentrations above the most restrictive groundwater TCLs (Table 4.2). Based on available groundwater monitoring data, surface water is not impacted by contaminated groundwater from Site SS15A. Therefore, there are no site-related COPCs for surface water. The short- and long-term fate and transport of these COPCs within affected environmental media at Site SS-15A is discussed in the following sections.

6.2 OPERATIVE MECHANISMS OF CONTAMINANT ATTENUATION

Understanding the fate of COPCs in environmental media is critical to evaluating and predicting contaminant distribution patterns. There are several physical, chemical, and biological processes that influence how a chemical behaves in soil and groundwater. The following sections present a brief overview of the major chemical and physical characteristics that define the fate of COPCs in soil and groundwater at Site SS-15A. These characteristics ultimately determine if the mass of contaminants in the environment can be eliminated or rendered immobile by natural processes. The positive effects of these natural processes on reducing the actual mass of COPCs and/or minimizing leaching or the extent of migration in groundwater are termed natural attenuation, or intrinsic remediation.

6.2.1 Nondestructive Chemical Attenuation Processes

Nondestructive attenuation processes can be described as those physical and chemical processes that may prohibit significant contaminant migration but will not result in a permanent reduction in contaminant mass. Examples of nondestructive attenuation processes include volatilization, sorption, advection, and hydrodynamic dispersion. These processes must be evaluated when determining whether some type of remediation is warranted because chemical contamination poses or has the potential to

pose a risk to human or ecological receptors. If contamination cannot reach a potential receptor exposure point, the contamination poses no risk.

6.2.1.1 Solubility

The water solubility of a chemical species defines how that particular chemical could partition (leach) from a contaminant source (e.g., LNAPL, contaminated soils) and dissolve into and migrate with groundwater. In general, lighter hydrocarbon chains tend to be more water soluble than heavier hydrocarbon chains. For example, the water solubilities of the soil COPCs are as follow: benzo(a)anthracene, 5.7 μg/L to 16.8 μg/L (Davis *et al.*, 1942; Klevens, 1950; Mackay and Shiu, 1977; May *et al.*, 1978; Smith *et al.*, 1978; Walters and Luthy, 1984); benzo(b)fluoranthene, 1.2 to 14 μg/L (USEPA, 1980 and 1982); benzo(a)pyrene, 0.5 μg/L to 4.5 μg/L (Billington *et al.*, 1988; Davis and Parke, 1942; Davis *et al.*, 1942; Eadie *et al.*, 1990; Mackay and Shiu, 1977; and Schwarz and Wasik, 1976). The water solubilities of the potential soil COPCs indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene are 62 μg/L (Sims *et al.*, 1988) and 0.5 to 2.5 μg/L, respectively (Davis *et al.*, 1942 and Means *et al.*, 1980).

In contrast to these PAHs, the BTEX compounds have solubilities ranging from approximately 152 mg/L (ethylbenzene and xylenes) to 1,780 mg/L (benzene) (Bohon and Claussen, 1951; Mackay and Shiu, 1981; Verschueren, 1983; Isnard and Lambert, 1988). Consequently, even though the lighter hydrocarbons such as the BTEX compounds may comprise a low mass fraction of the initial source of contamination (e.g., about 4 percent of fresh JP-4 jet fuel), these compounds preferentially leach from contaminated soil and LNAPL into groundwater and migrate as dissolved contamination (Lyman *et al.*, 1992).

6.2.1.2 Sorptive Properties

Another chemical characteristic that can govern how a compound may migrate (or become attenuated or occluded) within soil and groundwater is its sorptive properties.

Organic contaminants like the COPCs at Site SS-15A sorb to that portion of the soil matrix that is composed of organic carbon and clay particles. If a contaminant can be strongly sorbed to organic carbon and/or clay particles in either unsaturated or saturated soils, the compound will be less mobile and less likely to be transported great distances from the source area. Benzene does not sorb readily to soil and is considered the most mobile of the BTEX compounds (Abdul *et al.*, 1987). MTBE also is relatively mobile in groundwater systems. In comparison, naphthalene and other PAHs sorb much more strongly to the soil matrix, and migration is limited in both soil and groundwater (Verschueren, 1983; Wiedemeier et al., 1995).

The TOC content of saturated soils was measured as part of the 1997 sampling event at Site SS-15A. The TOC contents measured in two uncontaminated saturated soil samples from SB5, collected upgradient from valve box 1 at apron line AP-26, were 0.078 and 0.080 percent, respectively. The presence of TOC in the aquifer matrix indicates that sorption of fuel contaminants to soil particles is most likely retarding the mobility of the COPCs relative to that of groundwater.

6.2.1.3 Volatility

The volatility of each COPC also can affect how the chemical behaves in the environment. The volatile COPCs detected in soil and/or groundwater at Site SS-15A include BTEX and MTBE. These compounds have vapor pressures ranging from about 6.6 millimeters of mercury (mm Hg) for xylene to 249 mm Hg for MTBE (Montgomery and Welkom, 1990; Daubert and Danner, 1989). The detection of BTEX in soil gas samples collected at the site confirms that these compounds are partitioning from soil and groundwater into the vapor phase. The potential pathway involving volatilization from subsurface environmental media was not directly investigated as a mass transport mechanism at Site SS-15A. The site is covered by up to 18 inches of concrete and/or asphalt pavement, which eliminates effective mass transfer via volatilization into the outdoor atmosphere.

6.2.1.4 Advection and Hydrodynamic Dispersion

Advective transport is the transport of contaminants by the bulk movement of groundwater. As described in Section 3.2, the advective groundwater flow velocity at Site SS-15A is relatively slow (average of approximately 5 ft/yr); the advective migration velocity of most dissolved contaminants is anticipated to be even slower due to the effects of retardation (Section 6.2.1.2). The slow contaminant migration velocity is significant in that microorganisms have more time to biodegrade the contaminants before they can reach a receptor exposure point.

Hydrodynamic dispersion, which includes mechanical dispersion and diffusion, is another important process causing dilution of contaminants dissolved in groundwater. Whereas advection is controlled by macroscopic movement of groundwater, hydrodynamic dispersion is typically governed by molecular diffusion and/or tortuosity of groundwater flow through pore spaces. Advection and hydrodynamic dispersion of dissolved contaminants in groundwater underlying Site SS-15A will tend to reduce measurable concentrations over time but will not bring about a reduction in overall contaminant mass. The long-term fate and transport of dissolved contaminants, accounting for the influence of these hydrogeologic characteristics, is quantitatively investigated in Section 6.6.4. This information is used to determine if natural attenuation will prevent potential unacceptable exposure of receptors, should an exposure pathway involving groundwater be completed in the future.

6.2.2 Destructive Chemical Attenuation Processes

In comparison to nondestructive chemical attenuation processes, destructive chemical attenuation processes result in the permanent removal of contaminant mass from the environment. Primarily as a result of the operation of destructive chemical attenuation properties, Tier 1 TCLs will be attained. Documenting and distinguishing the effects of destructive attenuation processes, such as biodegradation, from nondestructive attenuation processes is critical to evaluating the potential for RNA to bring about a

reduction in contaminant mass over time. The effectiveness of destructive attenuation processes at reducing contaminant mass at a site depends on how susceptible the chemical is to biodegradation and whether the site is characterized by physical, chemical, and biological conditions favorable to such processes.

Numerous laboratory and field studies have shown that hydrocarbon-degrading bacteria can participate in the degradation of many of the chemical components of different types of fuels (e.g., JP-4 jet fuel) under both aerobic and anaerobic conditions (e.g., Jobson *et al.*, 1972; Perry, 1977; Atlas, 1981, 1984, and 1988; Gibson, 1984; Reinhard *et al.*, 1984; Young, 1984; Bartha, 1986; Wilson *et al.*, 1986, 1987, and 1990; Baedecker *et al.*, 1988; Lee, 1988; Chiang *et al.*, 1989; Grbic-Galic, 1989 and 1990; Leahy and Colwell, 1990; Parker *et al.*, 1990; Stieber *et al.*, 1990, 1994; Altenschmidt and Fuchs, 1991; Alvarez and Vogel, 1991; Baedecker and Cozzarelli, 1991; Bauman, 1991; Borden, 1991; Brown *et al.*, 1991a; Haag *et al.*, 1991; Hutchins and Wilson, 1991; Beller *et al.*, 1992; Bouwer, 1992; Edwards and Grbic-Galic, 1992; Thierrin *et al.*, 1992; Malone *et al.*, 1993; Davis *et al.*, 1994). Biodegradation of fuel hydrocarbons will occur when an indigenous population of hydrocarbon-degrading microorganisms is present in the soil and groundwater, and sufficient concentrations of electron acceptors and nutrients, including fuel hydrocarbons, are available to these organisms. Soils and groundwater with a history of exposure to fuel hydrocarbon compounds, such as at Site SS-15A, generally contain microbial populations capable of facilitating biodegradation reactions (Zobell, 1946; Litchfield and Clark, 1973; Borden, 1994; Seech *et al.*, 1994; Simpkin and Giesbrecht, 1994). The chemical basis for the biodegradation of each of the COPCs is described in more detail in Section 6.4, where geochemical data relevant to documenting biodegradation at the field scale at Site SS-15A are presented.

6.3 EVIDENCE OF CONTAMINANT BIODEGRADATION OVER TIME

The first step in determining whether site data indicate that COPCs are biodegrading in soils and groundwater at Site SS-15A was to compare contaminant concentrations at selected sampling locations over time. The purpose of this comparison was to assess the evidence of field-scale contaminant mass loss. Decreases in the magnitude of contaminant concentrations at a site over time that cannot be explained by physical processes (e.g., source removal, mass transport in groundwater) may be the first indication that contaminants are biodegrading at the site.

6.3.1 Observed Contaminant Loss From Soil

There is evidence for natural attenuation of contaminants in soil at Site SS-15A. As discussed in Section 4.3.1.1, remaining fuel residuals at this site are highly weathered and contain less than 5 percent of their original BTEX content. Comparison of maximum soil concentrations detected in 1994 and 1997 at three locations (OHM soil boring locations AP15-SB2, AP20-SB6, and AP26-SB1), presented on Table 6.1, indicates that contaminant concentrations generally decreased at AP15-SB2 and AP20-SB6. Conversely, 1997 contaminant concentrations at AP26-SB1 were generally higher than those detected at the same location in 1994. It should be noted that the relatively high PQLs for the 1994 data from AP15-SB2 make direct comparison of 1994 and 1997 data infeasible for many of the target analytes.

Biodegradation of soil COPCs present in the vadose zone can proceed if the soil particles to which the contaminants are adsorbed are covered with a water film to support microbial populations. The presence of abundant soil moisture in the vadose zone can be inferred from the shallow water table depth, the relatively warm ambient air temperature, and presence of the asphalt/concrete cap that would inhibit evaporation of subsurface moisture into the atmosphere. These conditions are favorable to the growth of fuel-degrading microorganisms, and most likely result in anaerobic

TABLE 6.1
COMPARISON OF SOIL ANALYTICAL DATA FROM OHM (1994) AND PARSONS ES (1997)
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Compound	Units	AP26-SB1 5'-7' (1994)	AP26-SB1-5 5'-7' (1997)	AP20-SB6 3'-5' (1994)	AP20-SB1-3 3'-5' (1997)	AP15-SB2 2'-4' (1994)	AP15-SB2 2'-4' (1997)
Acenaphthene	mg/kg [a/]	<4.0	11 J1 [b/]	8.1	0.24 U [c/]	<12	0.24 U
Acenaphthylene	mg/kg	<4.0	24 U	0.85	0.24 U	<12	0.24 U
Anthracene	mg/kg	7.5	8.1	120	0.024 U	<12	0.021 J1
Benzo(a)anthracene	mg/kg	5.9	11	65	0.024 U	<12	0.014 J1
Benzo(a)pyrene	mg/kg	<4.0	7.4	16	0.018 U	<12	0.018 U
Benzo(b)fluoranthene	mg/kg	4.3	7.4	37	0.014 U	<12	0.0056 J1
Benzo (g,h,i)perylene	mg/kg	<4.0	5.9 U	9	0.059 U	<12	0.0037 J1
Benzo(k)fluoranthene	mg/kg	4.3	2.8	37	0.013 U	<12	0.013 U
Chrysene	mg/kg	5.9	12	65	0.047 U	<12	0.022 J1
Dibenzo(a,h)anthracene	mg/kg	<4.0	2.4 U	18	0.024 U	<12	0.024 U
Fluoranthene	mg/kg	7.1	20	85	0.047 U	<12	0.065
Fluorene	mg/kg	<4.0	9.3	13	0.047 U	<12	0.026 J1
Indeno(1,2,3-cd)pyrene	mg/kg	<4.0	4.3	18	0.035 U	<12	0.035 U
Naphthalene	mg/kg	13	24 U	1.4	0.24 U	29	0.24 U
Phenanthrene	mg/kg	7.5	29	120	0.047 U	<12	0.11
Pyrene	mg/kg	5.9	14	64	0.047 U	<12	0.065
Benzene	mg/kg	<2.9	0.0059 U	<5.8	0.0059 U	<0.74	0.00075 J1
Ethylbenzene	mg/kg	3.2	0.0024 U	<5.8	0.0024 U	4.9	0.0024 U
Toluene	mg/kg	3.7	0.0059 U	<5.8	0.0015 J1	<0.74	0.0059 U
Xylenes, Total	mg/kg	17	0.0059 U	<5.8	0.0059 U	12	0.0059 U
1,2-Dichlorobenzene	mg/kg	NA [d/]	0.0047 U	NA	0.0047 U	NA	0.0047 U
1,3-Dichlorobenzene	mg/kg	NA	0.0047 U	NA	0.0047 U	NA	0.0047 U
1,4-Dichlorobenzene	mg/kg	NA	0.0035 U	NA	0.0035 U	NA	0.0035 U
Chlorobenzene	mg/kg	NA	0.049	NA	0.0024 U	NA	0.0024 U
MTBE [e/]	mg/kg	<2.9	0.0059 U	<58	0.0059 U	<7.4	0.0059 U
1,2-Dichloroethane	mg/kg	<2.9	NA	<5.8	NA	<0.75	NA
1,2-Dibromoethane	mg/kg	<2.9	NA	<5.8	NA	<0.75	NA
TRPH [f/]	mg/kg	1400	NA	90	12 U	5300	200

a/ mg/kg = milligrams per kilogram.
b/ J1 = The analyte was positively identified and has a concentration between the method detection limit and the reporting limit.
c/ U = The analyte was analyzed for and is not present above the reporting limit.
d/ NA = Not available.
e/ MTBE = Methyl tert butyl ether.
f/ TRPH = Total recoverable petroleum hydrocarbons.

biodegradation of vadose zone contaminants over time. However, because of the limited amount of data and the inherent variability of soil sampling, no meaningful conclusions can be made from the data presentation in Table 6.1 regarding the degree to which significant reduction of contaminant mass has occurred in site soils between 1994 and 1997.

The declining concentrations of dissolved contaminants measured in source area wells provides indirect evidence of declining residual LNAPL concentrations in saturated soils. Under equilibrium conditions, the amount of contaminant in saturated soils that will dissolve in groundwater can be determined by a linear, site-specific distribution partitioning coefficient (K_d). Because of the low groundwater flow velocity at the site (estimated at 5.1 ft/yr [OHM 1995a]), dissolved contamination in groundwater in the source areas can be assumed to be in equilibrium with the contamination sorbed to the soil. Therefore, the decrease in dissolved contaminant concentrations measured in groundwater from source area wells should be proportional to the decrease in contaminant concentrations in saturated soils. Loss of contaminant mass from groundwater is discussed in Section 6.3.2, and quantitative estimates for rates of destructive contaminant loss from saturated soils and groundwater are presented in Section 6.3.3.

6.3.2 Observed Contaminant Loss from Groundwater

Analytical data from permanent groundwater monitoring wells that were sampled and analyzed for several of the groundwater COPCs during multiple sampling events were compared to assess whether dissolved contaminant concentrations appear to be decreasing over time. Table 6.2 presents the analytical results for groundwater COPCs that exceeded their respective Tier 1 (Table V) TCLs during the time periods from August 1994 through October 1995, and from December 1996 through October 1997. This comparison is considered valid because the plume size is not increasing over time (i.e., reductions in the site average concentration are not due to physical

TABLE 6.2
SUMMARY OF 1994-1995 AND 1996-1997 COPCS
IN GROUNDWATER
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Chemical Name	Location	August 1994 through October 1995	December 1996 Through October 1997		Table V Target Cleanup Level[a]
		Maximum Concentration Exceeding TCL	Maximum Concentration Exceeding TCL	Monitoring Only Event[b]	
Benzene (µg/L)[c]	AP5-MW1	19	-----[d]		1
	AP10-MW9	13	18	Y2Q1	
	AP10-MW11	2.8	NS		
	AP11-MW14	27	6J[e]	Y2Q1	
	AP11-MW16	2.8	1.4J	Y2Q3	
	AP11-MW-17	4	3	Y2Q1	
	AP12-MW21	32	9J	Y2Q1	
	AP12-MW24	47	28	Y2Q1	
	AP13-MW28	1.4	NS[f]		
	AP13-MW29	1.5	NS		
	AP14-MW31	9.2	NS		
	AP14-MW34	12	12	Y2Q1	
	AP14-MW-97	3	6J	Y2Q1	
	AP15-MW35	14	6J	Y2Q3	
	AP15-MW36	2.3	NS		
	AP15-MW37	15	4	Y2Q2	
	AP15-MW38	24	-----		
	AP16-MW39	23	28	Y2Q3	
	AP16-FHSP-MW27	1	-----		
	AP17-MW40	16	22	Y2Q1	
	AP17-MW99	1	-----		
	AP17-MW109	NI	7	Y2Q1	
	AP17-FHSP-MW28	10	2J	Y2Q2	
	AP18-MW41	2.6	-----		
	AP18-FHSP-MW29	2	-----		
	AP19-MW44	22	-----		
	AP19-MW46	2.8	-----		
	AP20-MW47	2.7	NS		
	AP20-MW100	3	1	Y2Q3	
	AP21-MW54	9	-----		
	AP21-MW57	15	NS		
	AP21-MW59	12	NS		
	AP22-MW63	20	3J	Y2Q1	
	AP22-MW101	61	-----		
	AP23-MW67	-----	10J	Y2Q3	
	AP26-MW75	2	4	Y2Q3	
	AP26-MW76	2	2	Y2Q3	
	AP26-MW104	-----	2	Y2Q3	
	AP26-MW114	NI	3J	Y2Q1	
	AP27-MW78	2	1J	Y2Q1	
Ethylbenzene (µg/L)	AP10-MW9	140	130	Y2Q1	30
	AP11-MW14	-----	38J	Y2Q1	
	AP12-MW21	120	39J	Y2Q1	
	AP12-MW24	43	-----		
MTBE (µg/L)	AP14-MW34	-----	47J	Y2Q3	35
	AP14-MW-97	-----	48J	Y2Q2	
	AP23-MW67	38	80J	Y2Q3	
Acenaphthene (µg/L)	AP12-MW21	26	-----		20
	AP16-MW39	22	-----		
	AP22-MW101	69	-----		
	AP26-MW75	21	20	Y2Q1	
	AP26-MW76	-----	25	Y2Q3	
	AP26-MW114	NI[g]	21	Y2Q1	
	AP26-MW116	NI	33	Y2Q1	
Benzo(a)anthracene (µg/L)	AP22-MW101	7	-----		0.2
	AP26-MW75	-----	3J	Y2Q2	
	AP26-MW76	-----	1J	Y2Q3	
	AP26-MW113	NI	0.024J	Y2Q3	
	AP26-MW116	NI	1J	Y2Q1	
	AP27-MW78	-----	7	Y2Q3	

TABLE 6.2 (Continued)
SUMMARY OF 1994-1995 AND 1996-1997 COPCS
IN GROUNDWATER
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Chemical Name	Location	August 1994 through October 1995	December 1996 Through October 1997		Table V Target Cleanup Level[a/]
		Maximum Concentration Exceeding TCL	Maximum Concentration Exceeding TCL	Monitoring Only Event[b/]	
Benzo(a)anthracene (µg/L)	AP22-MW101	7	-----		0.2
	AP26-MW75	-----	3J	Y2Q2	
	AP26-MW76	-----	1J	Y2Q3	
	AP26-MW113	NI	0.024J	Y2Q3	
	AP26-MW116	NI	1J	Y2Q1	
	AP27-MW78	-----	7	Y2Q3	
Benzo(a)pyrene (µg/L)	AP26-MW75	NA	1J	Y2Q2	0.2
	AP27-MW78	NA	5	Y2Q3	
Benzo(b)fluoranthene (µg/L)	AP27-MW78	NA	5	Y2Q3	0.2
Benzo(k)fluoranthene (µg/L)	AP27-MW78	NA	5	Y2Q3	0.5
	AP26-MW75	NA	1J	Y2Q2	
Naphthalene (µg/L)	AP5-MW1	20	-----		20
	AP8-MW6	120	-----		
	AP10-MW9	110	35	Y2Q3	
	AP10-MW13	34	NS		
	AP11-MW14	240	300	Y2Q1	
	AP11-MW16	2.8	-----		
	AP11-MW-17	61	-----		
	AP12-MW21	230	38	Y2Q1	
	AP12-MW24	21	42	Y2Q3	
	AP13-MW28	48	NS		
	AP13-MW29	68	NS		
	AP14-MW30	240	-----		
	AP14-MW34	48	-----		
	AP14-MW97	-----	40	Y2Q1	
	AP15-MW35	150	54	Y2Q3	
	AP16-MW39	240	76	Y2Q1	
	AP17-MW40	350	180	Y2Q1	
	AP17-FHSP-MW28	56	-----		
	AP18-MW41	24	-----		
	AP19-MW44	33	-----		
	AP20-MW47	96	NS		
	AP20-MW50	38	-----		
	AP21-MW54	39	-----		
	AP22-MW63	75	67	Y2Q1	
	AP22-MW101	160	-----		
	AP22-MW60	56	NS		
	AP23-MW67	660	330	Y2Q2	
	AP23-MW68	68	NS		
	AP26-MW75	180	260	Y2Q3	
	AP26-MW76	37	-----		
	AP26-MW104	31	56	Y2Q3	
	AP26-MW114	37	30	Y2Q1	
	AP27-MW78	120	78	Y2Q1, Y2Q2	
	AP27-MW105	98	43	Y2Q1	
TRPH (mg/L)[i/]	AP11-MW14	57	76J	Y2Q1	5
	AP15-MW35	9.1	-----		
	AP20-MW50	7	-----		
	AP17-MW40	-----	5	Y2Q1	
	AP26-MW75	-----	8.4	Y2Q1	
	AP27-MW78	8	-----		

a/ Cleanup level for No Further Action With or Without Conditions.
b/ Y2Q1=year two, first quarter (December 1996-January 1997); Y2Q2=year two, second quarter (July 1997);
c/ mg/L = micrograms per liter.
d/ ----- = Compound below asociated TCL.
e/ J = Estimated value.
f/ NS = Not sampled.
g/ NI = Well not installed.
h/ NA = Not applicable because PQL greater than TCL.
i/ mg/L = milligrams per liter.

dispersion/diffusion of the plume). Available data suggest that the areal extent of dissolved contamination at Site SS-15A has not changed significantly from 1994 to 1997. Therefore, reductions in groundwater COPC concentrations in the source area over time may be a good first indicator that contaminant mass loss is occurring.

Based on analytical data obtained at the same sampling locations over time (September-October 1995 and October 1997, from 27 wells for benzene, ethylbenzene, and MTBE, and 17 wells for acenaphthene and naphthalene), the average concentrations of dissolved COPCs near and within source areas has decreased significantly, with the exception of MTBE. Average benzene, ethylbenzene, acenaphthene, and naphthalene concentrations were reduced by 77 percent, 60 percent, 30 percent, and 44 percent, respectively. In contrast, the average concentration of MTBE increased by 14 percent during the same period. Because the PQLs for benzo(a)anthracene, benzo(a)pyrene, and benzo(k)fluoranthene for samples collected in 1995 were, with only one exception, greater than the concentrations measured in 1997, average reductions for these compounds could not be calculated. Mass losses for benzo(b)fluoranthrene could not be assessed because results for this compound were not reported in the 1995 data.

Further evidence for COPC mass loss is indicated by the reduction in the number of locations where dissolved COPC concentrations exceeded their respective Tier 1 screening levels. The number of locations where one or more COPCs exceeded their respective Tier 1 screening levels was reduced from 30 in August 1994-October 1995 to 24 in December 1996-October 1997. These numbers probably underestimate the reduction in numbers of locations with exceedances, because some wells where exceedances of Tier 1 TCLs occurred in December 1996-October 1997 were not yet installed during the August 1994-October 1995 sampling events. If only the wells that were installed at the time of the initial sampling time period (August 1994-October

1995) are considered, COPCs exceeded their respective Tier 1 screening levels at 18 locations during the December 1996-October 1997 time period.

6.3.3 Estimating Site-Specific Contaminant Biodegradation Rates

It is important to distinguish between the effects of nondestructive attenuation processes (i.e., advection, dispersion, and sorption) and of destructive attenuation processes (i.e., biodegradation) on the mass of dissolved groundwater COPCs in the groundwater at Site SS-15A. Comparison of analytical data from several sampling events suggest that most of the groundwater COPCs are being removed from saturated soils and groundwater by mechanisms other than dispersion, advection, and sorption. To quantify these effects, an exponential regression method can be used to derive degradation rates from concentration reduction data versus time (Buscheck and Alcantar, 1996). The reduction in COPC concentrations at specific sampling points can be easily used to estimate a first-order attenuation rate, provided the plume size is relatively stable or decreasing. It is commonly assumed that biodegradation rates for fuel hydrocarbons in saturated media can be approximated by a first-order decay constant (Chapelle, 1993). Using the equation:

$$C_{(t)} = C_i e^{(-kt)}$$

Where: $C_{(t)}$ = concentration at time t

C_i = initial concentration

k = decay rate (T^{-1})

t = time

Table 6.3 summarizes the calculated biodegradation rates for each of the groundwater COPCs. The calculated rates are based on reductions in contaminant concentrations measured at specific sampling points over time. These degradation rates express the quantity of the contaminant mass being removed from the saturated media

TABLE 6.3
COMPOUND-SPECIFIC BIODEGRADATION RATES
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Chemical	Degradation Rate (day^{-1})[a/]		Average Site-Specific Half-Life (days)	Number of Wells Used for Rate Calculation[b/]
	Range	Average		
Benzene	0.0011-0.0048	0.0024	284	4
Ethylbenzene	NC[c/]	NC	NC	--
Total BTEX	0.0012-0.013	0.0022	321	5
MTBE	NC	NC	NC	--
Acenaphthene	0.0040-0.0063	0.0039	177	4
Benzo(a)anthracene	0.0085	0.0085	82	1
Benzo(a)pyrene	0.0079	0.0079	88	1
Benzo(b)fluoranthene	0.0075	0.0075	92	1
Benzo(k)fluoranthene	NC	NC	NC	--
Naphthalene	0.0008-0.0069	0.0021	323	8

[a/] Degradation rate estimated using first-order decay equation described in text.

[b/] Only rates that had a correlation coefficient (R^2 value) of 0.8 or greater were used.

[c/] NC = not calculated due to insufficient data.

that cannot be explained by nondestructive attenuation processes such as dispersion and adsorption. The effects of both aerobic and anaerobic destructive attenuation processes are included in these site-specific biodegradation rate estimates. The potential for additional hydrocarbons to leach from "smeared" contaminants in soils and LNAPL into groundwater was not factored into the rate estimates. As a result, the rates may underestimate the effectiveness of biodegradation processes at the site. Only rates having an associated correlation coefficient (R^2 value) of 0.8 or greater are included in Table 6.3.

Because dissolved contamination concentrations vary with groundwater levels (generally higher concentrations at times of high water levels and lower concentrations at times of lower water levels [OHM, 1996c]) as well as with time, three different sets of data were analyzed where sufficient data were available. For the wells that were overdeveloped, only the data collected subsequent to overdevelopment were analyzed. One set of degradation rates was calculated using data from all seven quarterly groundwater monitoring events; a second set included data from four events during times of low water levels (average site water levels between 1.45 and 1.79 feet above NGVD); and a third set using data from three events during times of high water levels (average site water levels between 2.13 and 2.38 feet above NGVD).

Based on these estimated degradation rates, the average half-life calculated for benzene in saturated soils and groundwater at Site SS-15A is about 280 days. The half-life of naphthalene ranged from approximately 100 days to approximately 866 days and averaged about 323 days. All half-lives calculated for ethylbenzene had correlation coefficients less than 0.8, and therefore are not reported in Table 6.3. Wiedemeier *et al.* (1995a) reports rates for ethylbenzene ranging from 0.0012 day^{-1} to 0.0038 day^{-1}, which yield half-lives of 180 to 600 days. Due to insufficient data, site-specific degradation rates and half-lives for MTBE, benzo(a)pyrene, benzo(a)anthracene,

benzo(k)fluoranthene, and benzo(b)fluoranthene could not be calculated with confidence.

6.4 EVIDENCE OF CONTAMINANT BIODEGRADATION VIA MICROBIALLY MEDIATED REDOX REACTIONS

Available site data suggest that TRPH, BTEX, and PAHs are biodegrading in saturated soils and groundwater at Site SS-15A. There were measurable decreases in the concentrations of these compounds at select sampling locations and in the site average concentrations of each specific compound over the course of several sampling events. A simple exponential regression method (i.e., first-order decay) was used to estimate site-specific destructive degradation rates for benzene, ethylbenzene, total BTEX, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and naphthalene. On the basis of this evaluation, and a large body of evidence in the literature that demonstrates that biodegradation of fuel hydrocarbons in groundwater is ubiquitous throughout a large variety of hydrogeologic settings, it can be inferred that the groundwater COPCs are biodegrading at Site SS-15A.

There is another line of evidence that can be used to show that these contaminants are biodegrading in saturated soil and groundwater at Site SS-15A. The fuel hydrocarbon groundwater COPCs (i.e., benzene, ethylbenzene, MTBE, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, naphthalene, and TRPH) are typically utilized as electron donors in biologically mediated redox reactions under a wide range of geochemical conditions. Therefore, analytical data on potential electron acceptors can be used as geochemical indicators of COPC biodegradation (Salanitro, 1993; McCallister and Chiang, 1994; Wiedemeier *et al.*, 1995; Borden *et al.*, 1995). Reductions in the concentrations of oxidized chemical species that are used by microorganisms to facilitate the oxidation of fuel hydrocarbon compounds within contaminated media are an indication that contaminants are biodegrading. Alternately, an increase in the metabolic byproducts resulting from the reduction of

electron acceptors can be used as an indicator of contaminant biodegradation. The availability of potential electron acceptors to participate in contaminant biodegradation reactions can be used to estimate the total contaminant mass that can be biodegraded over time at this site. Coupled with the biodegradation rates described earlier, this information can be used to predict how much and how quickly groundwater COPCs can be removed from saturated soils and groundwater at Site SS-15A as a result of natural processes.

6.4.1 Relevance of Redox Couples in Biodegradation

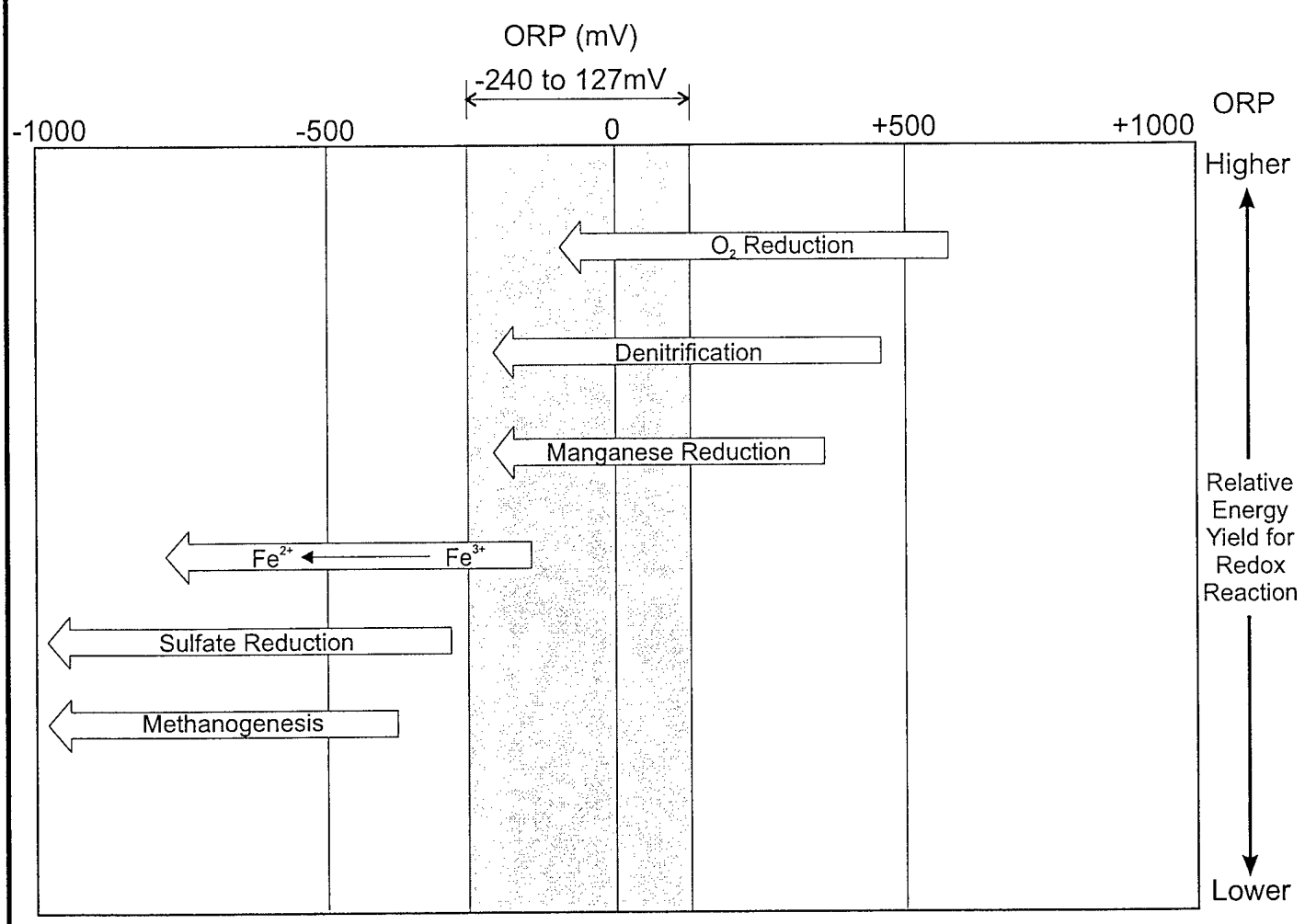
Microorganisms obtain energy to replenish enzymatic systems and to reproduce by oxidizing organic matter. Biodegradation of all of the groundwater COPCs is the result of a series of redox reactions that maintain the charge balance within the natural environment. Microorganisms facilitate the degradation of these organic compounds by transferring electrons from the electron donor (i.e., COPCs and native organic carbon) to available electron acceptors. Electron acceptors are elements or compounds that occur in relatively oxidized states and can participate in redox reactions involving these available electron donors. Electron acceptors known to be present in saturated soil and groundwater at Site SS-15A are oxygen, nitrate/nitrite, manganese, sulfate, ferric iron, and carbon dioxide.

Microorganisms facilitate fuel hydrocarbon biodegradation to produce energy for their use. The amount of energy that can be released when a reaction occurs or is required to drive the reaction to completion is quantified by the free energy of the reaction (Stumm and Morgan, 1981; Bouwer, 1994; Chapelle, 1993; Godsey, 1994; Mueller *et al.*, 1994; Berg *et al.*, 1994). Microorganisms are able to utilize electron transport systems and chemiosmosis to combine energetically favorable and unfavorable reactions to produce energy for life processes (i.e., cell production and maintenance). Microorganisms will facilitate only those redox reactions that will yield energy. By coupling the oxidation of fuel hydrocarbon compounds, which requires energy, to the

reduction of other compounds (e.g., oxygen, nitrate/nitrite, manganese, ferric iron, sulfate, and carbon dioxide), which yields energy, the overall reaction will yield energy. Detailed information on the redox reactions required to biodegrade each of the groundwater COPCs is included in Appendix B. The reader is encouraged to review this information to more fully understand the chemical basis of biodegradation.

Figure 6.1 illustrates the sequence of microbially mediated redox processes based on the amount of free energy released for microbial use. In general, reactions yielding more energy tend to take precedence over processes that yield less energy (Stumm and Morgan, 1981; Godsey, 1994; Reinhard, 1994). As Figure 6.1 shows, oxygen reduction would be expected to occur in an aerobic environment with microorganisms capable of aerobic respiration because oxygen reduction yields significant energy (Bouwer, 1992; Chapelle, 1993). However, once the available oxygen is depleted and anaerobic conditions dominate the interior regions of the contaminant plume, anaerobic microorganisms can utilize other electron acceptors in the following order of preference: nitrate/nitrite, manganese, ferric iron, sulfate, and finally carbon dioxide. Each successive redox reaction provides less energy to the system, and each step down in redox energy yield would have to be paralleled by an ecological succession of microorganisms capable of facilitating the pertinent redox reactions.

The expected sequence of redox processes can be estimated by the oxidation/reduction potential (ORP) of the groundwater. The ORP measures the relative tendency of a solution or chemical reaction to accept or transfer electrons. The ORP of the groundwater can be measured in the field. This measurement can be used as a crude indicator of which redox reactions may be operating at a site. High ORPs mean that the solution (or available redox couple) has a relatively high oxidizing potential.



Notes

ORP = Oxidation Reduction Potential

Range of ORP measured at Site SS-15A

1. These reactions would be expected to occur in sequence if the system is moving toward equilibrium.

2. These redox processes occur in order of their energy-yielding potential (provided microorganisms are available to mediate a specific reaction). Reduction of a highly oxidized species decreases the ORP of the system.

3. The ORP of the system determines which electron acceptors are available for organic carbon oxidation.

4. Redox reaction sequence is paralleled by an ecological succession of biological mediators.

Adapted from Stumm and Morgan, 1981.

FIGURE 6.1

SEQUENCE OF MICROBIALLY MEDIATED REDOX PROCESSES

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Microorganisms can only facilitate the biodegradation (oxidation) of the fuel hydrocarbon compounds using redox couples that have a higher ORP than the contaminants. Appendix B includes tables that show that redox couples including nitrate, oxygen, ferric iron, sulfate, and carbon dioxide all have higher oxidizing potentials than the redox couples including the fuel hydrocarbon COPCs. This is why these electron acceptors can be used to oxidize the fuel hydrocarbon compounds. The reduction of highly oxidized species results in an overall decrease in the ORP of the groundwater. As shown in Figure 6.1, the reduction of oxygen and nitrate will reduce the oxidizing potential to levels at which ferric iron (Fe^{3+}) reduction can occur. As each chemical species that can be used to oxidize the contaminants is exhausted, the microorganisms are forced to use other available electron acceptors with lower oxidizing capacity. When sufficiently low (negative) ORP levels have been developed as a result of these redox reactions, sulfate reduction, and methanogenesis can occur almost simultaneously (Stumm and Morgan, 1981).

ORP values measured in shallow groundwater at Site SS-15A in October 1997 ranged from +127 to -240 millivolts (mV) (Figures 6.1 and 6.2 and Table 6.4). Areas with the lowest ORP measurements generally coincided with the presence of fuel-contaminated groundwater, indicating that the progressive use of electron acceptors in the order shown on Figure 6.1 has caused the groundwater in the contaminated areas to become more reducing. These data imply that oxygen, nitrate, manganese, and ferric iron may be used to biodegrade fuel hydrocarbon contaminants at this site. However, many authors have noted that field ORP data alone cannot be used to reliably predict all of the electron acceptors that may be operating at a site, because the platinum electrode probes are not sensitive to some redox couples (e.g., sulfate/sulfide) (Stumm and Morgan, 1981; Godsey, 1994; Lovley *et al.*, 1994). Analytical data on oxidized and reduced species are presented in the following subsections to verify which electron

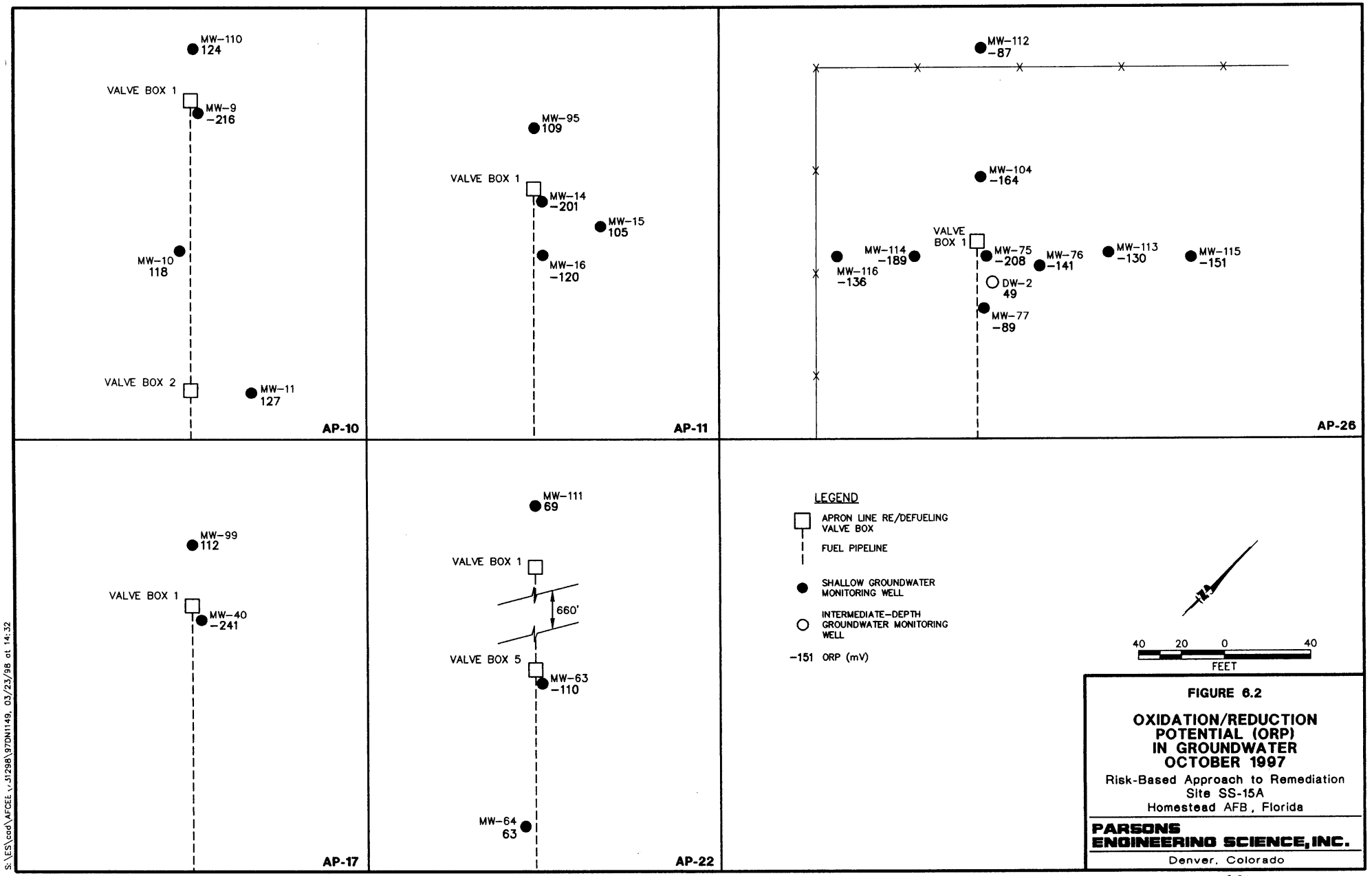


FIGURE 6.2

OXIDATION/REDUCTION POTENTIAL (ORP) IN GROUNDWATER OCTOBER 1997

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Site SS-15A
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TABLE 6.4
GROUNDWATER GEOCHEMICAL DATA
OCTOBER 1997
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Sample Number	ORP (mV)[a]	Dissolved Oxygen (mg/L)[b]	Nitrate as N[c] (mg/L)	Nitrite as N[c] (mg/L)	Nitrate + Nitrite(as N)[d] (mg/L)	Ammonia (mg/L)	Manganese (mg/L)	Ferrous Iron (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	Methane (µg/L)[e]	pH	Temperature (°C)[f]	Carbon Dioxide (mg/L)	Alkalinity, Total (as CaCO3) (mg/L)	Electrical Conductivity (µs/cm)[g]
AP-26																
MW-75	-208.2	0.1	0.058J[h]	0.5UJ[i]	0.074J1[j]	22.5	0.024U[k]	3.05	3.90	0.303	860	6.83	30.4	12.5	354	730
MW-76	-141.0	0.2	0.5UJ	0.5UJ	0.13	14.0	0.024U	2.16	3.61	0.067	840	6.96	29.5	14.0	322	705
MW-77	-89.0	0.1	0.5UJ	0.5UJ	0.40	14.0	0.024U	1.57	12.57	0.000	360	6.83	30.3	13.5	337	730
MW-104	-163.6	0.2	0.5UJ	0.5UJ	0.28	24.0	0.024U	2.74	2.97	0.074	1500	6.90	NA[l]	13.0	346	684
MW-112	-87.3	0.2	0.18J	0.5UJ	NA	16.0	0.024U	2.40	19.25	0.010	1600	6.85	29.2	14.0	346	792
MW-113	-130.4	0.2	0.11J	0.5UJ	NA	16.0	0.024U	2.95	2.39	0.065	1100	6.80	28.7	13.0	349	679
MW-114	-188.5	0.1	0.5UJ	0.5UJ	0.10	7.0	0.024U	0.74	2.53	0.057	640	7.03	30.2	19.0	252	486
MW-115	-150.5	0.1	0.15J	0.5UJ	NA	14.0	0.024U	1.18	3.12	0.081	740	6.78	28.8	14.0	360	751
MW-116	-136.0	0.2	0.5UJ	0.5UJ	0.19	12.0	0.024U	1.67	2.05	0.052	590	6.95	30.2	16.0	295	598
DW-2	49.3	0.0	3.5J	0.5UJ	3.90	0.4	0.024U	0.024U	43.86	0.012	0.28J	7.07	26.9	17.0	NA	705
AP-10																
MW-9	-215.6	0.2	0.077J1	0.5U	0.14	0.8	0.1	0.05	3.61	0.719	2500	6.90	29.5	19.0	277	556
MW-10	118.1	2.1	1.7J	0.5U	NA	0.1U	0.024U	0.15	23.00	0.000	0.05U	7.18	28.8	60.0	190	446
MW-11	127.2	0.5	2.0J	0.5U	NA	0.2	0.024U	1.17	29.14	0.010	0.05U	6.89	29.0	19.0	260	623
MW110	124.4	0.4	0.98J	0.5U	1.20	0.1	0.024U	0.36	23.78	0.032	0.05U	7.18	29.2	>100	192	442
AP-11																
MW-14	-200.7	0.6	0.1J	0.5U	NA	1.0	0.2	0.05	33.28	0.719	2000	7.17	NA	19.0	260	591
MW-15	105.2	0.7	1.9J	0.5U	NA	0.1	0.2	0.01	23.29	0.000	14	7.14	29.2	23.0	233	550
MW-16	-119.8	0.5	0.18J	0.5U	NA	0.6	0.1	1.26	5.36	0.034	2100	6.76	29.0	12.0	369	732
MW-95	108.9	0.6	0.44J	0.5U	NA	0.1	0.024U	0.18	23.88	0.000	12	7.17	28.7	40.0	206	494
AP-17																
MW-40	-240.6	0.2	0.14J	0.5U	NA	10.0	0.024U	0.52	3.27	0.719	1800	6.71	29.2	13.0	402	810
MW-99	112.2	0.2	0.21J	0.5UJ	NA	>10	0.024U	0.42	24.71	0.008	240	6.68	29.4	13.5	336	744
AP-22																
MW-63	-109.5	0.2	0.98J	0.5U	0.98	3.0	0.1	0.35	28.46	0.032	61	6.94	28.6	21.0	261	672
MW-64	62.9	0.2	1.2J	0.5UJ	NA	3.0	0.024U	0.03	35.19	0.019	41	7.03	27.6	18.0	259	694
MW-111	69.3	0.2	2.0	0.5U	2.30	2.0	0.024U	0.19	37.09	0.016	3.6	6.91	29.5	18.0	256	681

a/ mV = millivolts, ORP = oxidation-reduction potential.
b/ mg/L = milligrams per liter.
c/ Analysis method is E300, N = nitrogen.
d/ Analysis method is E353.2, N = nitrogen.
e/ µg/L = micrograms per liter.
f/ °C = degrees Celsius.
g/ µs/cm = microsiemens per centimeter.
h/ J = The analyte was positively identified, but the associated numerical value may not be consistent with the amount actually present in the environment. The data should be considered as a basis of decision-making and are usable.
i/ UJ = The analyte was analyzed for and is not present above the reporting limit. The associated numerical value may not accurately represent the concentration necessary to detect the analyte.
j/ J1 = The analyte was positively identified and has a concentration between the method detection limit and the reporting limit.
k/ U = The analyte was analyzed for and is not present above the reporting limit.
l/ NA = Not available.

acceptors are actually being used to biodegrade the groundwater COPCs in saturated soil and groundwater at Site SS-15A.

6.4.2 Dissolved Oxygen Concentrations

Almost all types of fuel hydrocarbons can be biodegraded under aerobic conditions (Borden, 1994). Mineralization of fuel hydrocarbons to carbon dioxide and water under aerobic conditions involves the use of oxygen as a cosubstrate during the initial stages of metabolism, and as a terminal electron acceptor during the later stages of metabolism for energy production (Higgins and Gilbert, 1978; Gibson and Subramanian, 1984; Young, 1984). The reduction of molecular oxygen during the oxidation of the fuel hydrocarbon compounds yields a significant amount of free energy that the microorganisms could utilize.

DO concentrations were measured at groundwater sampling locations in October 1997. Table 6.4 and Figure 6.3 present the analytical results for DO by sampling location. As shown on the figure, DO concentrations were uniformly low at all sampling locations, with the highest concentration (2.1 mg/L) measured at AP10-10. The low magnitude of DO concentrations in upgradient monitoring wells (located northwest of the apron lines) indicates that background DO concentrations in shallow groundwater are low (0.2 to 0.6 mg/L), and that oxygen is not currently a significant electron acceptor during microbially mediated degradation of fuel hydrocarbons at Site SS-15A.

6.4.3 Dissolved Nitrate Concentrations

Because anaerobic conditions generally prevail in the site groundwater, nitrate can be used as an electron acceptor by indigenous facultative anaerobes mineralize fuel hydrocarbon compounds via either denitrification or nitrate reduction processes. Concentrations of nitrate (as nitrogen [N]) measured at the site in October 1997 are summarized in Table 6.4 and depicted on Figure 6.4. Background nitrate (as N)

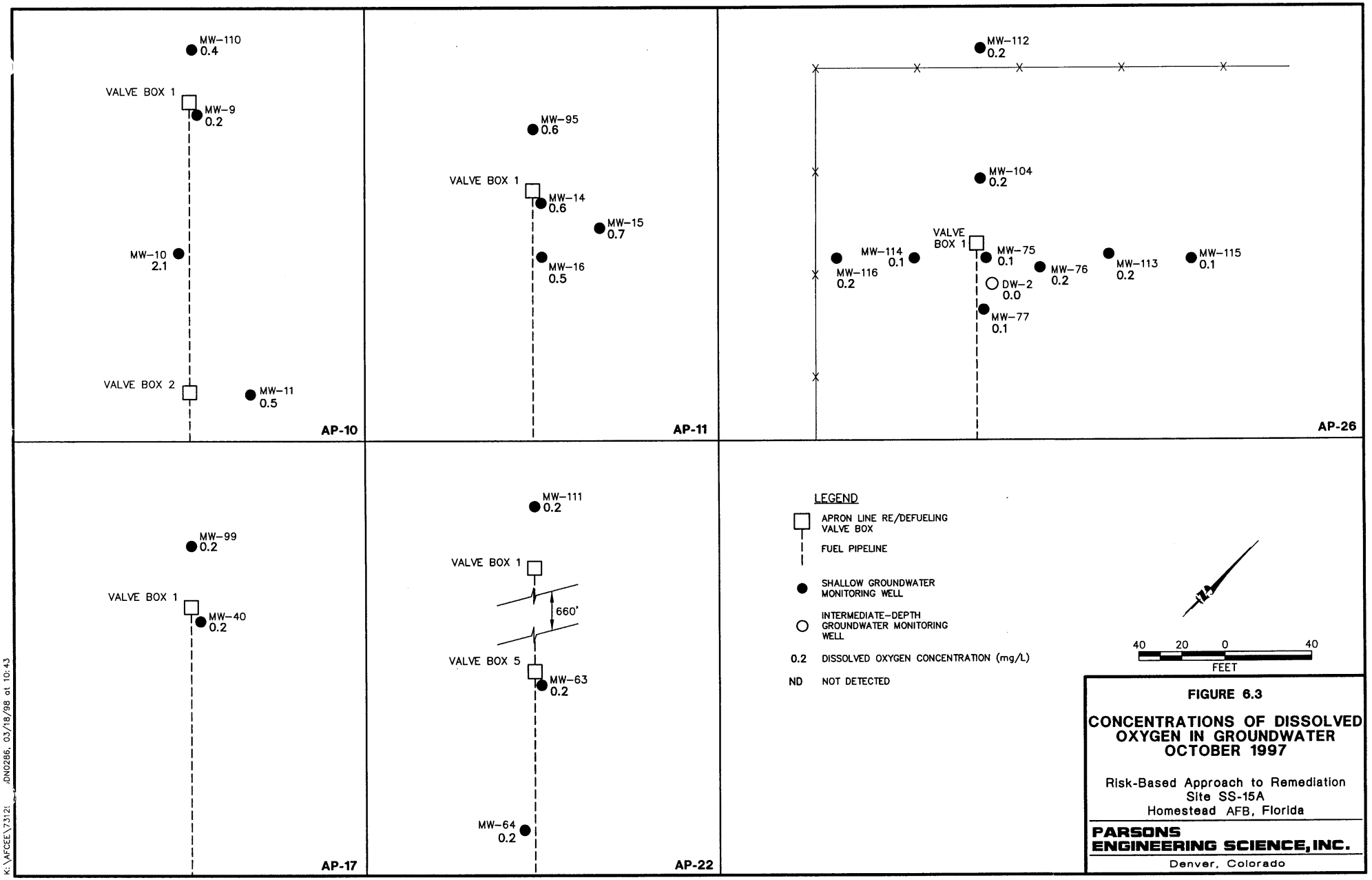


FIGURE 6.3

CONCENTRATIONS OF DISSOLVED OXYGEN IN GROUNDWATER OCTOBER 1997

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

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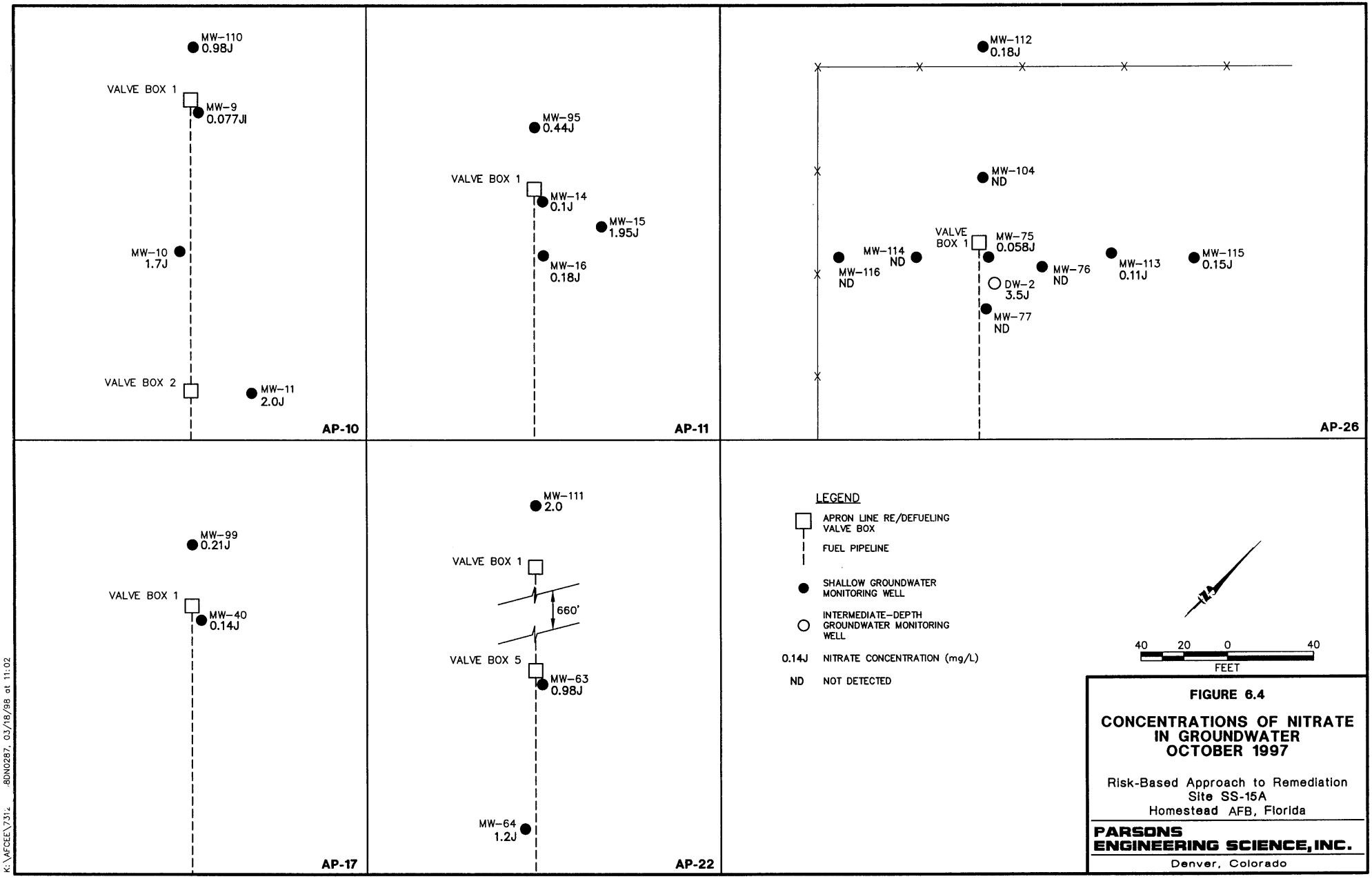


FIGURE 6.4

CONCENTRATIONS OF NITRATE IN GROUNDWATER OCTOBER 1997

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Site SS-15A
Homestead AFB, Florida

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concentrations measured in upgradient to cross-gradient wells AP10-MW110, AP11-MW95, AP17-MW99, AP22-MW111, and AP26-MW112 ranged from 0.18J mg/L to 2.0 mg/L and averaged 0.76 mg/L. Conversely, nitrate (as N) concentrations measured in source area wells exhibiting dissolved fuel contamination (AP10-MW9, AP11-MW14, AP17-MW40, AP22-MW63, and AP26-MW75) ranged from 0.058J mg/L to 0.98 mg/L and averaged 0.27 mg/L. These data indicate that dissolved nitrate concentrations within the contaminant plumes are slightly depleted relative to measured background concentrations at the five apron lines sampled. The results indicate that nitrate is being used to oxidize fuel hydrocarbons in the anaerobic core of the dissolved plumes via denitrification or nitrate reduction. The use of nitrate as an electron acceptor in microbially facilitated redox reactions is consistent with the range of ORP values measured at the sampled apron lines (Figure 6.1). However, the low background nitrate (as N) concentrations appear to limit the importance of this degradation reaction at Site SS-15A.

6.4.4 Ammonia

The presence of ammonia in groundwater can result from either nitrate reduction (facilitated by microbes) or fixing of atmospheric nitrogen (also a microbial process). Nitrate is not widespread in groundwater within the aquifer; however, the fixation of atmospheric nitrogen may occur under the anaerobic, methanogenic conditions observed at the site. The presence of ammonia in groundwater is a strong indication of microbial activity.

Ammonia concentrations measured in groundwater samples collected in October 1997 are summarized in Table 6.4. Ammonia was detected in all but one (AP10-MW10) of the samples analyzed. Ammonia concentrations detected in shallow groundwater varied across the site, with generally elevated ammonia concentrations occurring in (but not limited to) source areas. Therefore, production of ammonia

appears to be occurring at higher rates in the source areas due to increased microbial activity stimulated by the relative abundance of organic carbon (fuel hydrocarbons).

As described in Section 6.4.3, nitrate concentrations detected in October 1997 did not exceed 2 mg/L, while ammonia concentrations ranged up to 24 mg/L. The disparity between these values indicates that the nitrate deficit at the site in shallow portions of the surficial aquifer is being overcome by microbial communities that fix atmospheric nitrogen.

Ammonia was detected at a low concentration (0.4 mg/L) in the intermediate depth well AP26-DW2. The low magnitude of this detection indicates that little microbial activity is occurring in the deeper groundwater, which is consistent with the results of other electron acceptor and metabolic byproduct measurements at this well. These results also indicate that little organic substrate (including fuel hydrocarbons) is present in the deeper groundwater at this location, consistent with previous groundwater sampling results for this location (OHM, 1996a).

6.4.5 Manganese Concentrations

Manganese also can be used as an electron acceptor to facilitate the oxidation of the fuel hydrocarbon groundwater COPCs under anaerobic and slightly reducing conditions. As shown on Figure 6.1, manganese reduction can be microbially facilitated in groundwater conditions similar to those required to support denitrification. The reduction of manganese during the oxidation of fuel hydrocarbon compounds yields essentially as much free energy to the system as aerobic respiration. Under anaerobic and slightly reducing groundwater conditions, manganese reduction is the second-most energetically favorable redox reaction that can be used to oxidize (degrade) fuel hydrocarbon compounds.

Reduced forms of manganese were measured at groundwater sampling locations in October 1997. Reduced forms of manganese would be produced locally if oxidized

forms of manganese were being used as electron acceptors to oxidize other compounds, such as fuel hydrocarbons. As shown on Table 6.4, reduced manganese was detected at only low concentrations (maximum 0.2 mg/L). Although the ORP data collected at the site imply that manganese could be involved in fuel hydrocarbon degradation reactions, the lack of significant background concentrations of manganese minimizes the potential importance of this degradation reaction at Site ST-15A.

6.4.6 Ferrous Iron Concentrations

Although relatively little is known about the anaerobic metabolic pathways involving the reduction of ferric iron (Fe^{3+}), this process has been shown to be a major metabolic pathway for some microorganisms (Lovley and Phillips, 1988; Chapelle, 1993). Elevated concentrations of ferrous iron (Fe^{2+}) often are found in anaerobic, fuel-contaminated groundwater systems. Concentrations of dissolved ferrous iron once were attributed to the spontaneous and reversible reduction of ferric oxyhydroxides, which are thermodynamically unstable in the presence of organic compounds such as benzene. However, more recent studies suggest that the reduction of ferric iron cannot proceed at all without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.,* 1991; Chapelle, 1993). None of the common organic compounds found in low-temperature, neutral, reducing groundwater could reduce ferric oxyhydroxides to ferrous iron under sterile laboratory conditions (Lovley *et al.,* 1991). This means that the reduction of ferric iron to ferrous iron requires mediation by microorganisms with the appropriate enzymatic capabilities.

To determine if ferric iron is being used as an electron acceptor for fuel biodegradation at Site SS-15A, ferrous (reduced) iron concentrations were measured at groundwater sampling locations. Figure 6.5 presents the analytical results for ferrous iron in groundwater at this site. Slightly elevated ferrous iron concentrations (relative to background concentrations measured northwest of the apron lines) were detected in wells AP11-MW16, AP26-MW75, and AP22-MW63. These wells are located adjacent

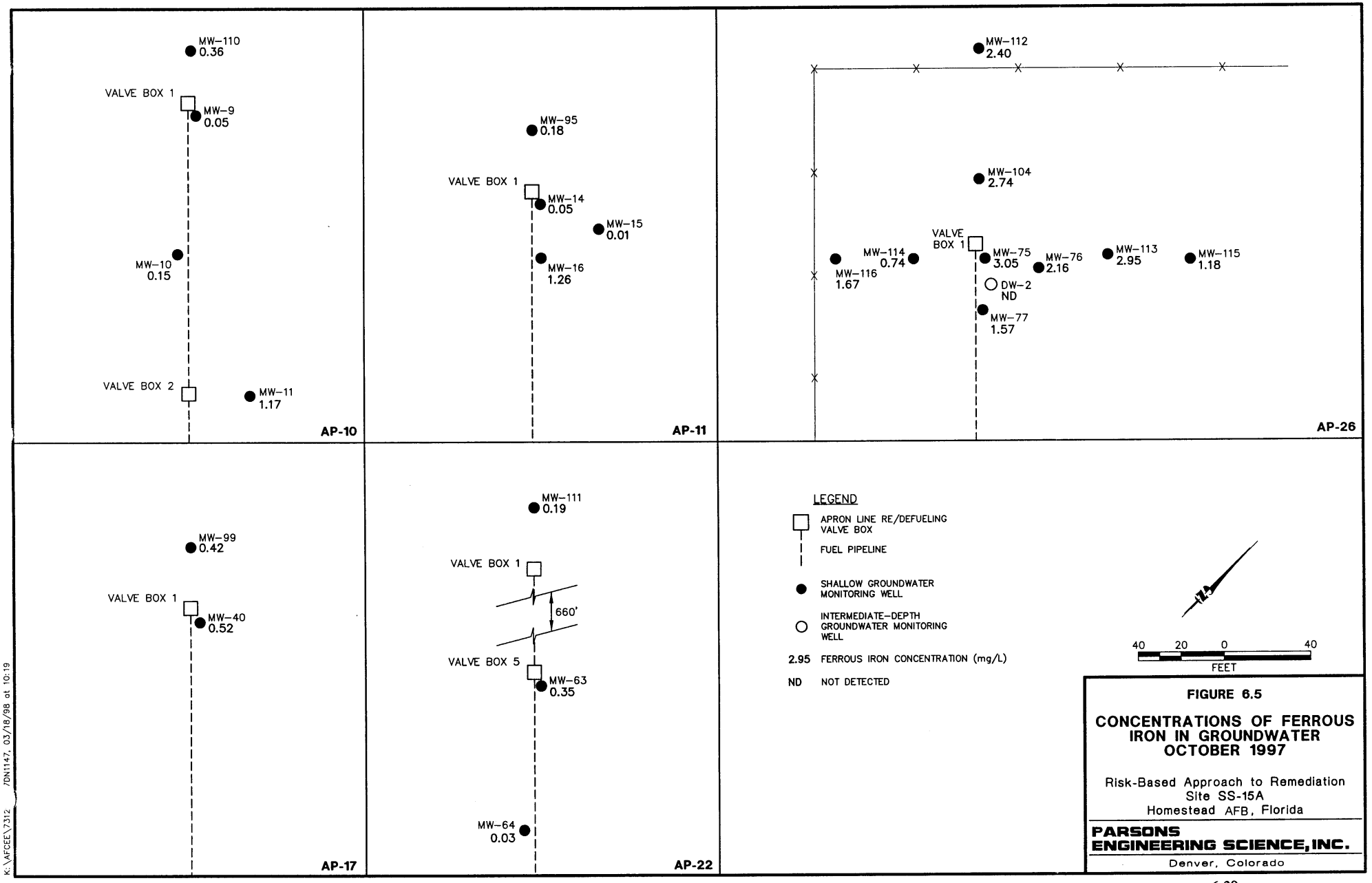


FIGURE 6.5

CONCENTRATIONS OF FERROUS IRON IN GROUNDWATER OCTOBER 1997

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Site SS-15A
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to or near valve boxes and contained dissolved fuel contamination. The detected ferrous iron concentrations ranged from 0.35 mg/L to 3.05 mg/L and averaged 1.55 mg/L. Background ferrous iron concentrations, inferred using analytical results from wells AP11-MW95, AP26-MW112, and AP22-MW111, ranged from 0.18 to 2.40 mg/L and averaged 0.92 mg/L. Background ferrous iron concentrations measured at apron lines AP-10 and AP-17 were similar to those measured near valve boxes. The occurrence of elevated ferrous iron concentrations measured within contaminated areas indicates that ferric iron is acting as an electron acceptor at these locations. In addition, the measured ORP of the groundwater at this site are within the range that would be expected for the ferric iron-reducing conditions implied by the observed ferrous iron distributions (Figure 6.1).

6.4.7 Sulfate Concentrations

Sulfate also may be used as an electron acceptor during microbial degradation of the fuel hydrocarbon COPCs under anaerobic conditions (Grbic-Galic, 1990). Sulfate can be reduced to sulfide during the oxidation of the fuel hydrocarbon compounds. The presence of decreased concentrations of sulfate (and possibly increased concentrations of sulfide) in the source area relative to background concentrations indicates that sulfate may be participating in redox reactions at the site. To investigate the potential for sulfate reduction at Site SS-15A, sulfate and sulfide concentrations were measured during the October 1997 groundwater sampling event.

Table 6.4 and Figure 6.6 show the analytical results for sulfate and sulfide in groundwater at Site SS-15A. In general, areas characterized by elevated concentrations of dissolved COPCs are depleted in sulfate concentrations relative to measured background concentrations. Significant depletion of sulfate in source area well AP22-MW63 was not observed, however. Background concentrations of sulfate at the site ranged from 19.25 mg/L at well AP26-MW112 to 37.1 mg/L at AP22-MW111. With the exception of well AP22-MW3, sulfate concentrations measured at wells having

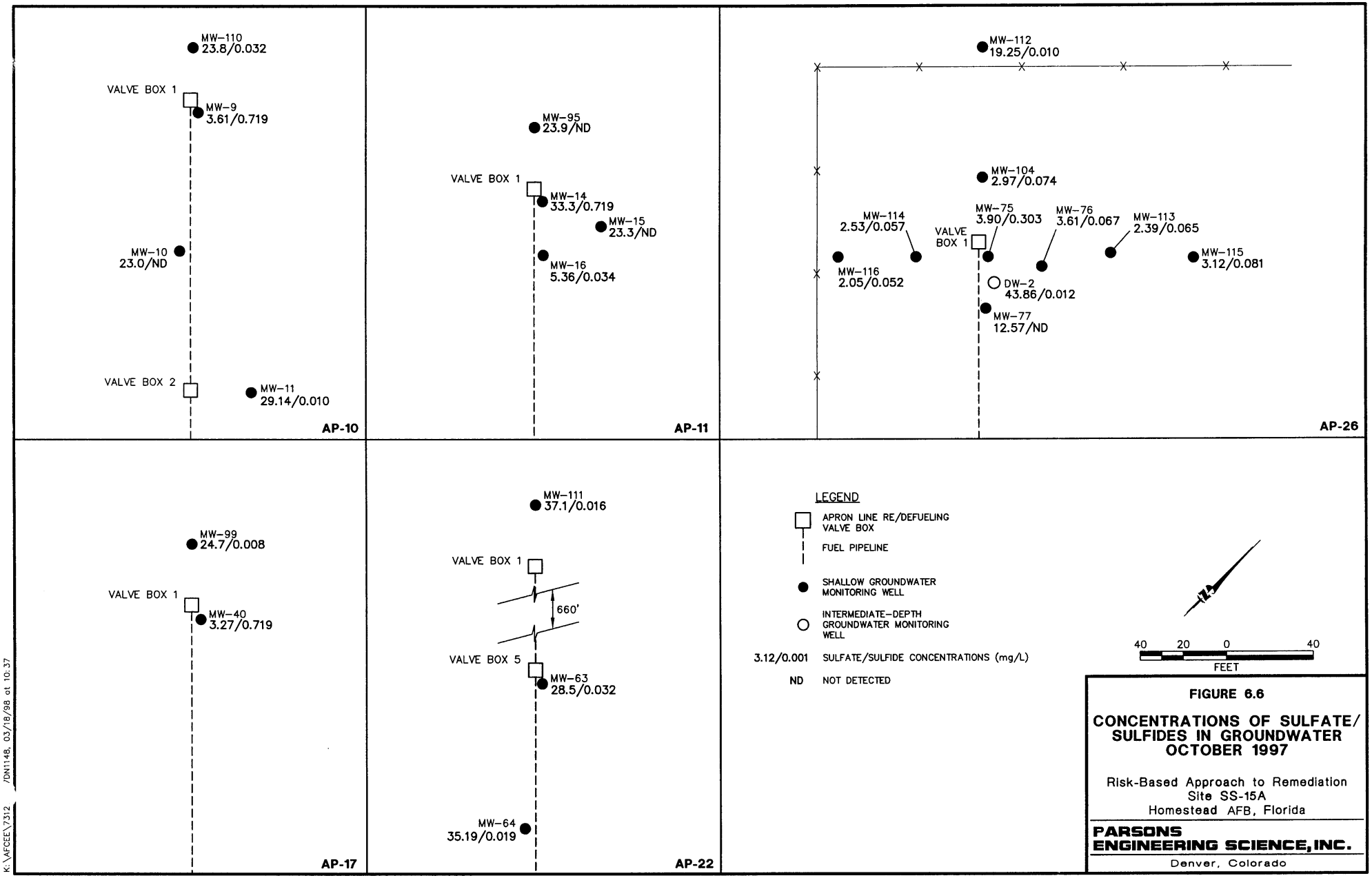


FIGURE 6.6

CONCENTRATIONS OF SULFATE/ SULFIDES IN GROUNDWATER OCTOBER 1997

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

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detectable levels of dissolved fuel hydrocarbons ranged from 5.36 mg/L at well AP11-MW16 to 2.05 mg/L at well AP26-MW116. This general depletion of sulfate within the contaminated areas indicates that this compound is acting as an electron acceptor during fuel biodegradation reactions.

Figure 6.6 also shows that elevated concentrations of sulfide, which can be produced when sulfate is reduced during fuel hydrocarbon oxidation, generally coincide with depleted sulfate concentrations and elevated fuel hydrocarbon concentrations. The apparent production of sulfide within the contaminated area supports the observation that microbial populations are using sulfate to oxidize fuel hydrocarbons at the site.

The measured ORPs of the groundwater at this site are not within the range that would be expected for the sulfate-reducing conditions implied by the observed sulfate and sulfide distributions. However, as described in Section 6.4.1, field ORP data alone cannot be used to reliably predict the electron acceptors that may be operating at a site.

6.4.8 Dissolved Methane Concentrations

On the basis of free energy yield and the oxidizing potential of the site groundwater, the carbon dioxide/methane (CO_2/CH_4) redox couple also could be used to oxidize fuel hydrocarbon compounds to carbon dioxide and water once the groundwater is sufficiently reducing. To attain these reducing levels, other highly oxidizing chemical species such as oxygen, nitrate, ferric iron, and sulfate must first be reduced. This redox reaction is called methanogenesis or methane fermentation. Methanogenesis yields the least free energy to the system in comparison to other chemical species (Figure 6.1 and Appendix B). The presence of methane in groundwater at elevated concentrations relative to background concentrations is a good indicator of methane fermentation.

Dissolved methane was measured at groundwater monitoring wells sampled during the October 1997. Table 6.4 and Figure 6.7 present the analytical data for methane.

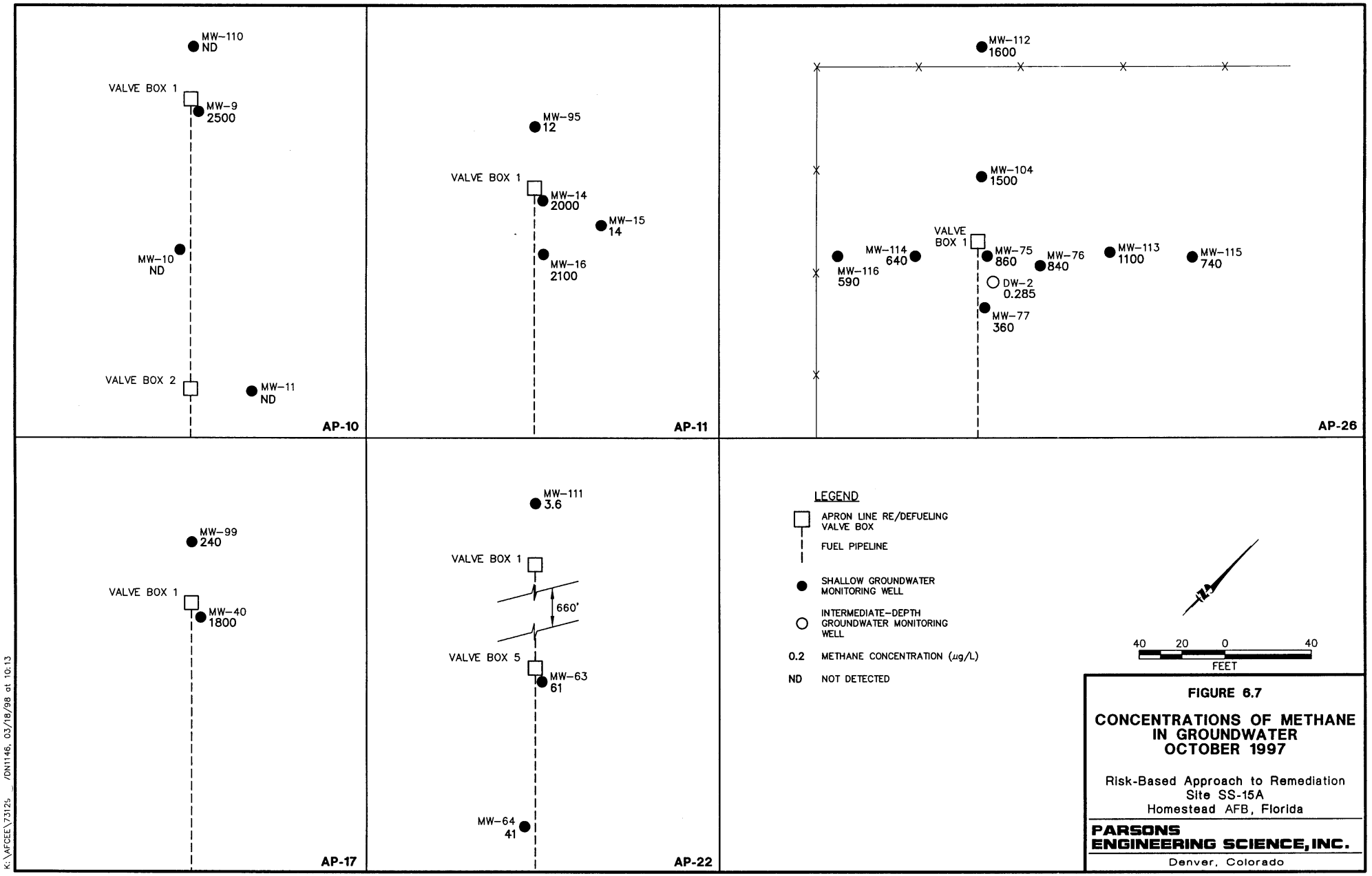


FIGURE 6.7

CONCENTRATIONS OF METHANE IN GROUNDWATER OCTOBER 1997

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\73125 /DN1146, 03/18/98 at 10:13

Methane concentrations detected at or adjacent to contaminant source areas at several apron lines were substantially elevated relative to background concentrations. At apron lines AP-10, AP-11, AP-17, and AP-22, maximum methane concentrations ranged from 61 µg/L to 2,500 µg/L and averaged 1,590 µg/L. In contrast, background concentrations at these same apron lines ranged from not detected (<0.05 µg/L) to 240 µg/L and averaged 64 µg/L. The presence of elevated methane levels in groundwater at Site SS-15A strongly indicates that biodegradation is occurring via methanogenesis.

Although well AP26-MW112 appears to be located hydraulically upgradient from the suspected source area (valve box 1), the groundwater sample from this well contained methane at 1,600 µg/L. However, the detection of low concentrations of several PAHs at this location in October 1997 indicates that some contamination has migrated from Valve Box 1 to this well, and may explain the presence of methane. The low concentration of methane (0.28J µg/L) detected at the intermediate-depth well DW-2 indicates that methanogenesis is not a significant process deeper in the surficial aquifer.

6.4.9 pH

The pH of groundwater samples collected from groundwater monitoring points and monitoring wells in October 1997 was measured (Table 6.4). The pH of a solution is the negative logarithm of the hydrogen ion concentration [H^+]. Groundwater pH values measured at the site were relatively neutral, ranging from 6.68 to 7.18 standard units. This range of pH is within the optimal range for fuel hydrocarbon-degrading microbes of 6 to 8. The limited and relatively neutral range of pHs also indicates that microbial reactions have a minimal effect on groundwater pH, likely due to the moderately high alkalinity of site groundwater.

6.4.10 Temperature

Groundwater temperature was measured at groundwater monitoring points and monitoring wells in October 1997 (Table 6.4). Temperature affects the types and growth rates of bacteria that can be supported in the groundwater environment, with higher temperatures generally resulting in higher growth rates. The temperature of groundwater samples collected from the shallow monitoring wells varied from 27.6 degrees Celsius (°C) to 30.4°C. These relatively warm temperatures should promote microbial growth and may enhance rates of hydrocarbon biodegradation.

6.5 THEORETICAL ASSIMILATIVE CAPACITY ESTIMATES

The preceding discussions have been devoted to determining if fuel hydrocarbon COPCs are biodegrading in saturated soils and groundwater at Site SS-15A. Analytical data on reduced and oxidized chemical species indicate that indigenous microorganisms are facilitating the oxidation of fuel hydrocarbons and the reduction of electron acceptors to generate free energy for cell maintenance and production. The question of how much contaminant mass can be biodegraded must be addressed to assess the full potential for long-term intrinsic bioremediation to minimize plume size and mass over time, and to eventually reduce COPC concentrations to at least Tier 2 SSTLs (Section 7).

Mass balance relationships can be used to determine how much contaminant mass can be degraded by each of the redox reactions that the microorganisms might use to make free energy available for cell maintenance and production. The stoichiometric relationship between the contaminant and the electron acceptor can be used to estimate the expressed assimilative capacity of the groundwater. Once the redox reactions operating at the site have been defined, it is possible to estimate how much contaminant mass can be assimilated or oxidized by available electron acceptors. This analysis, when coupled with the biodegradation rate information discussed earlier (Section

6.3.4), provides the basis for determining the potential for continued COPC mass reduction in saturated soils and groundwater at the site.

Appendix B presents the coupled redox reactions that represent the biodegradation of each of the groundwater COPCs, including the stoichiometric mass ratio of electron acceptors needed to oxidize each of the groundwater COPCs. These stoichiometric mass ratios can be used to estimate the assimilative capacity of the groundwater at Site SS-15A. This is accomplished by first determining the initial (background) mass of each electron acceptor available in the groundwater. Data on these chemical species were collected at sampling locations upgradient from and outside of the dissolved plume. As groundwater slowly migrates into the source area, electron acceptors are brought into contact with hydrocarbon-degrading microorganisms and site contamination. The change in the electron acceptor mass from upgradient sampling locations to sampling locations within the source area is divided by the mass of electron acceptors required to mineralize each of the fuel hydrocarbon COPCs to estimate the expressed intrinsic capacity of the groundwater to biodegrade these compounds.

Average estimates of the background concentrations, measured at five areas, of all of the electron acceptors that are being used at the site to biodegrade fuel hydrocarbon compounds are listed in Table 6.5. These concentrations are used to calculate the available or expressed assimilative capacity of each electron acceptor for benzene, ethylbenzene, MTBE, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and naphthalene based on the mass stoichiometric relationships presented in detail in Appendix B. Table 6.5 also presents the source area concentrations of reduced manganese, ferrous iron, and methane. These concentrations are used to "back-calculate" the expressed assimilative capacity that is attributable to manganese reduction, ferric iron reduction, and methanogenesis. On the basis of these calculations, the saturated soils and groundwater at Site SS-15A has the intrinsic capacity to eventually oxidize an average COPC concentration of

TABLE 6.5
ESTIMATED ASSIMILATIVE CAPACITY OF SATURATED SOIL AND GROUNDWATER
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Average for Site SS-15A

Electron Acceptor or Metabolic Byproduct	Background Concentration (mg/L)[b/]	Concentration in Core of Plume (mg/L)	BTEX Assimilative Capacity[a/] (mg/L)	Benzene Assimilative Capacity[a/] (mg/L)	Ethylbenzene Assimilative Capacity[a/] (mg/L)	Naphthlene Assimilative Capacity[a/] (mg/L)	Acenaphthene Assimilative Capacity[a/] (mg/L)	Benzo(a)anthracene Assimilative Capacity[a/] (mg/L)	Benzo(a)pyrene Assimilative Capacity[a/] (mg/L)	Benzo(b)fluoranthene Assimilative Capacity[a/] (mg/L)	Benzo(k)fluoranthene Assimilative Capacity[a/] (mg/L)	MTBE Assimilative Capacity[a/] (mg/L)
Oxygen	0.44	0.26	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07
Nitrate[c/]	4.53	1.31	0.66	0.67	0.65	0.69	0.69	0.70	0.71	0.71	0.71	0.76
Iron	0.73	0.69	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	25.99	12.06	2.96	3.02	2.93	3.10	3.08	3.15	3.18	3.18	3.18	3.41
Methane	0.37	1.42	1.35	1.36	1.33	1.40	1.40	1.42	1.44	1.44	1.44	1.54
Total			5.02	5.12	4.97	5.25	5.23	5.34	5.39	5.39	5.39	5.78
Max. 1997 Concentration				0.028	0.13	0.33	0.025	0.007	0.005	0.005	0.005	0.080J
											avg =	5.32

AP-10

Electron Acceptor or Metabolic Byproduct	Background Concentration (mg/L)[b/]	Concentration in Core of Plume (mg/L)	BTEX Assimilative Capacity[a/] mg/L	Benzene Assimilative Capacity[a/] mg/L	Ethylbenzene Assimilative Capacity[a/] mg/L	Naphthlene Assimilative Capacity[a/] mg/L	Acenaphthene Assimilative Capacity[a/] mg/L	Benzo(a)anthracene Assimilative Capacity[a/] mg/L	Benzo(a)pyrene Assimilative Capacity[a/] mg/L	Benzo(b)fluoranthene Assimilative Capacity[a/] mg/L	Benzo(k)fluoranthene Assimilative Capacity[a/] mg/L	MTBE Assimilative Capacity[a/] mg/L
Oxygen	1.00	0.20	0.25	0.26	0.25	0.27	0.27	0.27	0.27	0.27	0.27	0.29
Nitrate[c/]	6.90	0.34	1.34	1.38	1.33	1.41	1.40	1.44	1.45	1.45	1.45	1.55
Iron	0.56	0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	25.31	3.61	4.62	4.71	4.57	4.82	4.80	4.91	4.95	4.95	4.95	5.31
Methane	0.00	2.50	3.21	3.25	3.16	3.33	3.33	3.38	3.42	3.42	3.42	3.68
Total			9.42	9.59	9.32	9.83	9.80	9.99	10.10	10.10	10.10	10.83
Max. 1997 Concentration			0.173	0.028	0.013	0.330	0.025	0.007	0.005	0.005	0.005	0.080

AP-11

Electron Acceptor or Metabolic Byproduct	Background Concentration (mg/L)[b/]	Concentration in Core of Plume (mg/L)	BTEX Assimilative Capacity[a/] (mg/L)	Benzene Assimilative Capacity[a/] (mg/L)	Ethylbenzene Assimilative Capacity[a/] (mg/L)	Naphthlene Assimilative Capacity[a/] (mg/L)	Acenaphthene Assimilative Capacity[a/] (mg/L)	Benzo(a)anthracene Assimilative Capacity[a/] (mg/L)	Benzo(a)pyrene Assimilative Capacity[a/] (mg/L)	Benzo(b)fluoranthene Assimilative Capacity[a/] (mg/L)	Benzo(k)fluoranthene Assimilative Capacity[a/] (mg/L)	MTBE Assimilative Capacity[a/] (mg/L)
Oxygen	0.600	0.600	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate[c/]	5.170	1.240	0.80	0.82	0.80	0.85	0.84	0.86	0.87	0.87	0.87	0.93
Iron	0.090	0.650	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Sulfate	23.580	19.320	0.91	0.92	0.90	0.95	0.94	0.96	0.97	0.97	0.97	1.04
Methane	0.013	2.050	2.61	2.65	2.58	2.72	2.72	2.75	2.79	2.79	2.79	3.00
Total			4.35	4.42	4.30	4.52	4.51	4.59	4.64	4.64	4.64	4.98
Max. 1997 Concentration			0.078	0.003	0.075	0.012	ND	ND	ND	ND	ND	ND

TABLE 6.5 (Continued)
ESTIMATED ASSIMILATIVE CAPACITY OF
SATURATED SOIL AND GROUNDWATER
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

AP-17

Electron Acceptor or Metabolic Byproduct	Background Concentration (mg/L)[b/]	Concentration in Core of Plume (mg/L)	BTEX Assimilative Capacity[a/] (mg/L)	Benzene Assimilative Capacity[a/] (mg/L)	Ethylbenzene Assimilative Capacity[a/] (mg/L)	Naphthlene Assimilative Capacity[a/] (mg/L)	Acenaphthene Assimilative Capacity[a/] (mg/L)	Benzo(a)anthracene Assimilative Capacity[a/] (mg/L)	Benzo(a)pyrene Assimilative Capacity[a/] (mg/L)	Benzo(b)fluoranthene Assimilative Capacity[a/] (mg/L)	Benzo(k)fluoranthene Assimilative Capacity[a/] (mg/L)	MTBE Assimilative Capacity[a/] (mg/L)
Oxygen	0.20	0.20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate[c/]	0.93	0.62	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Iron	0.42	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfate	24.71	3.27	4.56	4.65	4.51	4.76	4.74	4.85	4.89	4.89	4.89	5.24
Methane	0.24	1.80	2.00	2.03	1.97	2.08	2.08	2.11	2.14	2.14	2.14	2.29
Total			6.63	6.75	6.56	6.91	6.89	7.03	7.10	7.10	7.10	7.61
Max. 1997 Concentration			0.03	0.022	0.011	0.24	0.011	<0.005	<0.005	<0.005	<0.005	0.025U

AP-22

Electron Acceptor or Metabolic Byproduct	Background Concentration (mg/L)[b/]	Concentration in Core of Plume (mg/L)	BTEX Assimilative Capacity[a/] (mg/L)	Benzene Assimilative Capacity[a/] (mg/L)	Ethylbenzene Assimilative Capacity[a/] (mg/L)	Naphthlene Assimilative Capacity[a/] (mg/L)	Acenaphthene Assimilative Capacity[a/] (mg/L)	Benzo(a)anthracene Assimilative Capacity[a/] (mg/L)	Benzo(a)pyrene Assimilative Capacity[a/] (mg/L)	Benzo(b)fluoranthene Assimilative Capacity[a/] (mg/L)	Benzo(k)fluoranthene Assimilative Capacity[a/] (mg/L)	MTBE Assimilative Capacity[a/] (mg/L)
Oxygen	0.20	0.20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate[c/]	8.84	4.33 J	0.92	0.95	0.92	0.97	0.97	0.99	0.99	1.00	1.00	1.00
Iron	0.19	0.35	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfate	37.09	28.46	1.84	1.87	1.82	1.92	1.91	1.95	1.97	1.97	1.97	2.11
Methane	0.004	0.061	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Total			2.84	2.90	2.81	2.97	2.96	3.02	3.04	3.05	3.05	3.19
Max. 1997 Concentration			<0.004	0.002U	<0.004	0.067	0.011	<0.005	<0.005	<0.005	<0.005	<0.025

AP-26

Electron Acceptor or Metabolic Byproduct	Background Concentration (mg/L)[b/]	Concentration in Core of Plume (mg/L)	BTEX Assimilative Capacity[a/] (mg/L)	Benzene Assimilative Capacity[a/] (mg/L)	Ethylbenzene Assimilative Capacity[a/] (mg/L)	Naphthlene Assimilative Capacity[a/] (mg/L)	Acenaphthene Assimilative Capacity[a/] (mg/L)	Benzo(a)anthracene Assimilative Capacity[a/] (mg/L)	Benzo(a)pyrene Assimilative Capacity[a/] (mg/L)	Benzo(b)fluoranthene Assimilative Capacity[a/] (mg/L)	Benzo(k)fluoranthene Assimilative Capacity[a/] (mg/L)	MTBE Assimilative Capacity[a/] (mg/L)
Oxygen	0.20	0.10	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04
Nitrate[c/]	0.80	0.04	0.16	0.16	0.15	0.16	0.16	0.17	0.17	0.17	0.17	0.18
Iron	2.40	1.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	19.25	5.65	2.89	2.95	2.86	3.02	3.01	3.08	3.11	3.11	3.11	3.33
Methane	1.60	0.68	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total			3.08	3.14	3.05	3.22	3.20	3.28	3.31	3.31	3.31	3.54
Max. 1997 Concentration			0.043	0.004	0.029	0.26	0.025	<0.005	<0.005	<0.005	<0.005	<0.025

[a/] Calculated based on the ratio of the total of the total mass of electron acceptor required to oxidize a given mass of contaminants.

[b/] mg/L = milligrams per liter.

[c/] Concentration of nitrate = concentration of nitrate reported as nitrogen x 4.42 to convert to nitrate as NO_3.

J* = Estimated value due to elevated surrogate recovery.

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

approximately 5,320 μg/L. As shown on Table 6.5, this capacity is substantially higher than the maximum COPC concentrations detected in groundwater at Site SS-15A.

This estimate essentially represents an upper-bound estimate of the intrinsic mass reduction capability of the groundwater at Site SS-15A. The estimate identifies how much contaminant mass can be theoretically oxidized as one pore volume travels through the plume core. So, although the capacity is expressed in μg/L, the capacity is actually an estimate of the micrograms of contaminant mass that can be degraded in the volume of groundwater traveling through the core plume.

A closed system containing 2 liters of water can be used to help visualize the physical meaning of assimilative capacity. Assume that the first liter contains no fuel hydrocarbons, but it contains fuel-degrading microorganisms and has an assimilative capacity of exactly "x" mg of fuel hydrocarbons. The second liter has no assimilative capacity; however, it contains fuel hydrocarbons. As long as these 2 liters of water are kept separate, the biodegradation of fuel hydrocarbons will not occur. If these 2 liters are combined in a closed system, biodegradation will commence and continue until the fuel hydrocarbons are depleted, the electron acceptors are depleted, or the environment becomes acutely toxic to the fuel-degrading microorganisms. Assuming a nonlethal environment, if less than "x" mg of fuel hydrocarbons are in the second liter, all of the fuel hydrocarbons will eventually degrade given a sufficient time; likewise, if greater than "x" mg of fuel hydrocarbons were in the second liter of water, only "x" mg of fuel hydrocarbons would ultimately degrade.

This example shows, that in a closed system, the measured expressed assimilative capacity eventually should be equivalent to the loss in contaminant mass; however, the groundwater beneath a site is an open system. Electron acceptors can continually enter the system from upgradient flow. Furthermore, contaminant mass can be added to the

system through dissolution or leaching from LNAPL or contaminated soils. This means that the assimilative capacity is not fixed as it would be in a closed system, and therefore should not be quantitatively compared to concentrations of dissolved contaminants in the groundwater. Rather, the expressed assimilative capacity of groundwater is intended to serve as a qualitative tool. The fate of COPCs in groundwater is dependent on the relationship between the kinetics of biodegradation and the solute transport velocities (Chapelle, 1994).

6.6 PREDICTING CONTAMINANT TRANSPORT AND FATE

Understanding the effects of natural physical, chemical, and biological processes on chemicals is an important step in determining potential long-term risks associated with chemical migration in the environment. The behavior of COPCs under the influence of these processes must be quantified to:

- Predict the rate at which soil COPCs could leach from residual LNAPL and dissolve into groundwater;
- Assess the expected persistence and concentration of dissolved COPCs over time at the site; and
- Estimate potential receptor exposure-point concentrations.

If destructive and nondestructive attenuation processes can minimize or eliminate the concentrations of COPCs to which a receptor could be exposed, engineered remedial action may not be warranted because no reasonable completed exposure pathway exists or completion of exposure pathways involving groundwater would not result in significant risks. The focus of this final subsection is to predict how COPCs will be transported and transformed over time in soil and groundwater based on site data and mathematical solute transport calculations assuming no engineered remedial action is undertaken at Site SS-15A.

6.6.1 Leaching from Contaminated Soils

Residual LNAPL in saturated or seasonally saturated soils at Site SS-15A represents a continuing source of dissolved groundwater contamination. Assessment of the long-term impacts of contaminant leaching from soil into groundwater is desirable to determine the type and magnitude of remedial action that is appropriate at the site. Defining how groundwater COPCs partition from saturated soil and dissolve into groundwater based on site conditions can provide valuable information on predicting the future persistence of COPC concentrations in groundwater that exceed the Tier 1 TCLs. The major physical release mechanism for soils at this site is leaching from contaminated soils in direct contact with groundwater, rather than downward percolation of precipitation through unsaturated soils because of the continuous site pavement.

To assess the potential for contaminants to desorb from contaminated soils and dissolve into underlying groundwater over time at Site SS-15A, a simple batch-flushing model was used. Two scenarios were considered based on site conditions. The first scenario assumes that the groundwater is in continual contact with contaminated soil. The second scenario assumes that the groundwater is in contact with contaminated soils for only 3 months each year, during periods of high groundwater levels. As discussed previously, the groundwater table fluctuates seasonally. Residual fuel contamination sorbed onto the soil matrix can be released to groundwater once the soils are saturated. However, once the groundwater recedes from these soils, any residual contamination that did not partition from the soil matrix and dissolve into pore water will be effectively occluded. In addition to providing a release mechanism for sorbed contaminants, the rising groundwater table also may contribute contaminant mass to the now-saturated soil. As a result, contamination is "smeared" across the soil during the seasonal fluctuations. The impact of residual LNAPL in terms of contributing contaminant mass to underlying groundwater (and soils) is discussed in Section 6.6.3.

A site-specific equilibrium partitioning relationship was used to model how the soil COPCs are expected to leach from soils seasonally saturated by a rising groundwater table and dissolve into groundwater. A chemical-specific distribution partitioning coefficient (K_d) that is based on site-specific soil data was used to describe how much COPC mass remains associated with the soil matrix and how much COPC mass will dissolve into adjacent pore water. This K_d was incorporated into the batch-flushing model in which the total volume of contaminated soil is flushed with groundwater. Contaminants sorbed to the soil matrix are predictively modeled to leach from the soil into the uncontaminated groundwater. Contaminants released into the groundwater also can migrate away or be removed from the release area via the advective bulk movement of groundwater and *in situ* degradation. As contaminant mass is removed from the groundwater in contact with soils, additional contaminant mass can desorb from the soils and dissolve into adjacent pore water. Additional details are contained in Appendix B.

The site-specific leaching calculations for both the seasonal flush and continuous flush are presented in Table 6.6. Benzene and benzo(a)pyrene were selected for modeling because they are the primary "risk-drivers" at the site. In addition, the mobility of these compounds in the subsurface environment differs greatly. Benzene does not adsorb strongly to soils; therefore, it readily leaches to groundwater and is relatively mobile when dissolved in groundwater. Conversely, benzo(a)pyrene adsorbs strongly to soils and does not easily leach to groundwater. This lack of mobility is evidenced by the frequent detection of benzo(a)pyrene in soil samples near the water table in 1994 (OHM, 1995a) and the corresponding lack of benzo(a)pyrene detections in groundwater at the same locations.

The model results suggest that the shallow soils at Site SS-15A will be a significant but diminishing source of soil benzene mass to underlying groundwater for 6 to 28 years. The shorter time frame (6 years) assumes continuous flushing of soils, while the

TABLE 6.6
BATCH FLUSHING MODEL RESULTS FOR BENZENE
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Pore Volume	Years	Benzene Soil Concentration (µg/kg)	Benzene Water Concentration (µg/L)
0.00	0	1.60	28.0
0.06	1	1.42	24.9
0.13	2	1.26	22.1
0.19	3	1.12	19.6
0.26	4	0.99	17.4
0.32	5	0.88	15.4
0.38	6	0.78	13.7
0.45	7	0.69	12.1
0.51	8	0.61	10.8
0.58	9	0.55	9.6
0.64	10	0.48	8.5
0.70	11	0.43	7.5
0.77	12	0.38	6.7
0.83	13	0.34	5.9
0.90	14	0.30	5.3
0.96	15	0.27	4.7
1.02	16	0.24	4.2
1.09	17	0.21	3.7
1.15	18	0.19	3.3
1.22	19	0.17	2.9
1.28	20	0.15	2.6
1.34	21	0.13	2.3
1.41	22	0.12	2.0
1.47	23	0.10	1.8
1.54	24	0.09	1.6
1.60	25	0.08	1.4
1.66	26	0.07	1.3
1.73	27	0.06	1.1
1.79	28	0.06	1.0

BFLUSH.XLS

longer time frame assumes seasonal flushing (3 months per year of saturation). It should be emphasized that the batch-flushing model simulates the decrease in soil benzene mass caused by physical flushing alone. In reality, the mass of benzene adsorbed to soil particles also will diminish due to the effects of biodegradation; therefore, the 6- to 28-year time frame predicted by the model is conservative and represents worst-case remedial time frames. A benzene source half-life that combines the effects of both physical flushing and biodegradation was used during the BIOSCREEN modeling effort described in Section 6.6.3.

The batch-flushing model results for benzo(a)pyrene indicate that residual soil concentrations of this analyte (resulting from physical flushing only) may be a significant source of contaminant mass to groundwater for substantially more than 1,000 years due to the relative insolubility of this compound. Therefore, biodegradation and not physical flushing will be the primary mechanism for reducing benzo(a)pyrene concentrations in soils over time.

6.6.2 Dissolution From Mobile LNAPL

Mobile LNAPL is not considered to be a significant source of dissolved groundwater contamination at Site SS-15A relative to residual LNAPL adsorbed to soil particles. A measurable thickness of mobile LNAPL was encountered only once in single well (a thickness of 0.01 foot was measured in well AP20-MW50 during October 1995). Since October 1995, only LNAPL sheens and/or globules have been detected at various times in four groundwater wells at Site SS-15A (OHM, 1997).

6.6.3 Fate and Transport Within Groundwater - BIOSCREEN Modeling

BIOSCREEN is a screening model that simulates RNA of dissolved hydrocarbons at petroleum fuel release sites (Newell *et al.*, 1997). The software is based on the Domenico (1987) analytical solute transport model and is designed to simulate advection, dispersion, adsorption, and aerobic decay as well as anaerobic reactions that

have been shown to be the dominant biodegradation processes at many petroleum release sites.

BIOSCREEN includes three different model types:

1. Solute transport without decay;

2. Solute transport with biodegradation modeled as a first-order decay process (simple, lumped parameter approach); and

3. Solute transport with biodegradation modeled as an "instantaneous" biodegradation reaction.

The first model is appropriate for predicting the movement of conservative (non-degrading) solutes such as chloride. The only attenuation mechanisms simulated are dispersion in the longitudinal, transverse, and vertical directions and adsorption of the contaminant to the soil matrix.

With the second model, the solute degradation rate is proportional to the solute concentration. This is a conventional method for simulating biodegradation in dissolved hydrocarbon plumes. With this method, dispersion, sorption, and biodegradation parameters are lumped together in a single calibration parameter. The first-order decay model does not account for site-specific information such as the availability of electron acceptors. In addition, it does not assume any biodegradation of dissolved constituents in the source zone. In other words, this model assumes biodegradation starts immediately downgradient from the source.

Biodegradation of organic contaminants in groundwater is more difficult to quantify using a first-order decay equation because electron acceptor limitations are not

considered. A more accurate prediction of biodegradation effects may be realized by incorporating the instantaneous reaction equation into a transport model. This is because the instantaneous reaction model uses site-specific data, including representative concentrations of electron acceptors such as DO, nitrate, and sulfate, and biodegradation by-products such as ferrous iron and methane.

6.6.3.1 Modeling Objectives

The BIOSCREEN modeling was performed for Site SS-15A to accomplish the following two objectives:

- To estimate the maximum migration distance of dissolved benzene at the site over time; and
- To estimate how long the maximum benzene and benzo(a)pyrene concentrations in the plumes will exceed Tier 1 groundwater screening levels.

The lateral migration potential of benzene was modeled because, of the groundwater COPCs identified in Section 4, benzene is both mobile in the groundwater environment and considered a toxic carcinogen (has the lowest Table V TCL of any of the volatile COPCs). Therefore, benzene will likely be a primary "risk-driver" at this site. The lateral migration potential of benzo(a)pyrene was also modeled. Benzo(a)pyrene also will likely be a "risk-driver" due to its relative recalcitrance.

6.6.3.2 Model Input Data

Input data for the BIOSCREEN model include groundwater velocity, aquifer dispersivity, a contaminant retardation factor, a contaminant decay coefficient, dissolved contaminant concentrations in the source area, a half-life of the contaminant source, and the dimensions of the source zone. Each of these input values is described in more detail below.

Groundwater Velocity. The advective groundwater velocity beneath the site is based on site-specific hydraulic conductivity and hydraulic gradient data, and an estimated effective porosity of 20 percent based on published values for sand (Driscoll, 1986). The hydraulic conductivity value used in the model (0.011 cm/sec) is the average value calculated from slug test data collected from 10 monitoring wells at Site SS-15A in December 1994 (OHM, 1995a). The average site-wide hydraulic gradient value used in the model (9×10^{-5} ft/ft) is derived from the groundwater elevation data collected in December 1994. The resulting value of advective groundwater velocity calculated by BIOSCREEN is 5.1 ft/yr.

Dispersivity. Dispersion refers to the process whereby a plume will spread out in a longitudinal direction (along the direction of groundwater flow), transversely (perpendicular to groundwater flow), and vertically downward due to mechanical mixing and chemical diffusion in the aquifer. The longitudinal and transverse dispersivities of 4.1 feet and 0.4 feet, respectively, used in the model were calculated by BIOSCREEN from an estimated plume length of 50 feet. The vertical dispersivity was set to 0.

Retardation. Retardation of contaminants relative to the advective velocity of the groundwater occurs when contaminant molecules are sorbed to organic carbon, silt, or clay particles in the aquifer matrix. Increasing the retardation coefficient decreases the contaminant migration velocity relative to the advective groundwater velocity, and allows more time for biodegradation to occur along a given travel path. The average TOC concentration in two soil samples collected upgradient from apron line AP26 is 0.072 percent. Using the site fraction organic carbon of 0.00072, an estimated soil bulk density of 1.7 kilograms per liter (kg/L), and a partition coefficient for benzene of 79 liters per kilogram (L/kg) (Wiedemeier *et al.*, 1996), an average retardation coefficient of approximately 1.5 was calculated for benzene at the site (Table 6.7). An average retardation coefficient of approximately 16,000 for benzo(a)pyrene was

TABLE 6.7
CALCULATION OF RETARDATION COEFFICIENTS
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Compound	K_{oc} (L/kg [a/])	Maximum Fraction Organic Carbon [b/]	Minimum Fraction Organic Carbon [b/]	Average Fraction Organic Carbon [b/]	Distribution Coefficient K_d (L/kg) Maximum [c1/]	Minimum [c2/]	Average [c3/]	Bulk Density (kg/L) [d/]	Effective Porosity [d/]	Coefficient of Retardation Maximum	Minimum	Average
Benzene	79	0.000747	0.000695	0.000721	0.059	0.055	0.057	2.00	0.20	1.59	1.55	1.57
Benzo(a)pyrene	2,570,396	0.000747	0.000695	0.000721	1920.086	1786.425	1853.256	2.00	0.20	19202	17865	18534

[a/] Benzene value from AFCEE technical protocol (Wiedemeier *et al.*, 1995); benzo(a)pyrene value from Montgomery (1996).

[b/] From laboratory analyses of site soil samples.

[c1/] K_d = Maximum Fraction Organic Carbon x K_{oc}.

[c2/] K_d = Minimum Fraction Organic Carbon x K_{oc}.

[c3/] K_d = Average Fraction Organic Carbon x K_{oc}.

[d/] Estimated Value.

calculated based on site-specific TOC data, the estimated bulk density and effective porosity values described above, and a compound-specific partitioning coefficient derived from the literature (Montgomery, 1996).

First-Order Decay Coefficient (Solute Half-Life). BIOSCREEN uses the first-order decay coefficient to simulate biodegradation of dissolved contaminants after they have migrated downgradient from the source area. The first-order decay coefficient equals the half-life of the contaminant divided by 0.693. The half-life of benzene published in literature typically ranges from 0.02 to 2 years (Newell *et al.*, 1996; Wiedemeier *et al.*, 1995). As described in Section 6.3.3, the method of Buschek and Alcantar (1995) for a shrinking plume (declining contaminant concentrations) was used to calculate first-order decay rates for benzene from site-specific data. Using groundwater monitoring data from 1995 through October 1997, calculated decay rates ranged from 0.0011 day^{-1} (half-life of 1.7 years) to 0.0048 day^{-1} (half-life of 0.4 year), with an average value of 0.002 day^{-1} (half-life of 0.8 year). The BIOSCREEN model was run once using the site-specific average benzene decay rate.

As described in Section 6.3.3, insufficient site-specific data were available to calculate a site-specific first-order decay coefficient for dissolved benzo(a)pyrene. Aronson and Howard (1997) report that, in general, PAHs are thought to be resistant to anaerobic biodegradation in groundwater. These authors cite the results of a field study (Godsey *et al.*, 1992) in Pensacola, Florida where an anaerobic decay rate of 0.004 day^{-1} was determined for acenaphthene in methanogenic groundwater (similar to Site SS-15A). A rate-constant range for acenaphthene of 0 (no degradation) to 0.004 day^{-1} was derived by Aronson and Howard (1997). For BIOSCREEN modeling purposes, a benzo(a)pyrene decay rate of 0.002 day^{-1} (the average site-specific decay coefficient determined for naphthalene, and the midpoint of the range for acenaphthene described above), was used for Site SS-15A. The BIOSCREEN model results are relatively insensitive to the precise magnitude of the solute decay coefficient because

the simulated solute concentrations over time are much more dependent on the source decay rate than the solute decay rate, which is the case for benzene and benzo(a)pyrene.

Source Area Dimensions and Concentrations. BIOSCREEN assumes a source represented by a vertical plane perpendicular to groundwater flow. The cross-sectional area of the vertical plane was estimated from the soil data collected in 1994 (OHM, 1995a). The width of the source area was estimated to be 20 feet, and the thickness of the contaminated soil interval was estimated to be 5 feet. The maximum benzene and benzo(a)pyrene concentrations (28 µg/L and 5 µg/L, respectively) detected in groundwater samples collected in October 1997 were used as model inputs for initial source concentrations.

Source Half-Life and Source Mass. BIOSCREEN incorporates an approximation for a declining source concentration over time. The declining source term assumes that the mass of contaminant in the source area dissolves slowly as fresh groundwater passes through, and that the change in source zone concentration can be approximated as a first-order decay process. The model will compute an estimated source half-life due to physical flushing (dissolution) of adsorbed contaminants into the groundwater over time given the estimated mass of contaminant present in the source area. However, this half-life does not account for the effects of source biodegradation, which also reduces the source mass via destructive attenuation processes. Therefore, the average site-specific solute biodegradation rate for benzene (0.002 day^{-1}) was combined with the source decay rate attributable to physical flushing derived from the batch-flushing model assuming 3 months of flushing per year (0.0003 day^{-1}) to derive a total source decay rate for use in the BIOSCREEN simulations.

Benzene was not detected in soil samples collected in 1994, and was detected at a estimated maximum concentration of 2.7 µg/kg in samples collected in 1997; however, the detection limit was often elevated due to sample dilution. Assuming that the

average benzene concentration in source area soils is equal to the regular reporting limit for this compound of 5 μg/kg, and assuming 36 cubic meters of contaminated soil in the source (equivalent to a cylinder with a diameter of 20 feet and a height of 4 feet), an initial source area benzene mass of 0.00036 kg was estimated.

A tota source decay rate incorporating the effects of biodegradation and physical flushing (negligible for this analyte) also was estimated for benzo(a)pyrene. The source decay rate could not be confidently estimated using the soil quality results for the three locations that were sampled in both 1994 and 1997 (see Section 5.4) due to the variability of the data. Howard (1991) reported half-lives for benzo(a)pyrene in anaerobic soils of 228 days to 5.8 years. The most conservative half-life (5.8 years) was used for the benzo(a)pyrene source half-life in the BIOSCREEN simulations.

An initial soil benzo(a)pyrene concentration was back-calculated from the maximum dissolved benzo(a)pyrene concentration in groundwater using a compound-specific distribution coefficient (Appendix B). Assuming 36 cubic meters of contaminated soil in the source (equivalent to a cyliner with a diameter of 20 feet and a height of 4 feet), the dissolvable mass of benzo(a)pyrene in the source areas in October 1997 was estimated to be 0.72 kg based on an estimated distribution coefficient of 2000 L/kg.

Instantaneous Reaction Data. The instantaneous reaction model in BIOSCREEN uses field data for electron acceptors to calculate a biodegradation rate. The input data include the change in DO, nitrate, and sulfate concentrations between the source areas of the plume and an upgradient, background area and the observed ferrous iron and methane concentrations in the source area of the plume. Assuming that the biodegradation of benzene has produced 25 percent of the reaction byproducts (and the biodegradation of toluene, ethylbenzene, and xylenes the other 75 percent), 25 percent of the average concentrations of the reaction by-products measured in October 1997 were used as input for the instantaneous reaction model. The reaction stoichiometry

used by the instantaneous reaction model to simulate the fate and transport of BTEX compounds was revised to include the appropriate values for benzo(a)pyrene prior to simulation of this compound.

6.6.3.3 Model Calibration

The model was calibrated by comparing simulation results for dissolved benzene in source areas with three years (1994 through 1997) of groundwater monitoring results. The model was run for three source area wells (AP12-MW21, AP12-MW24, and AP16-MW39) with relatively high benzene concentrations detected in groundwater samples collected during the year 1, first quarter, MO event (October 1995). Plots of both simulated and field-measured dissolved benzene concentrations versus time indicate a reasonable correlation in light of the relatively erratic temporal variations in dissolved benzene concentrations observed during the MO events. Field data from MO events performed during times of relatively high groundwater levels were selected for model calibration because dissolved contaminant concentrations are generally higher during times of high groundwater levels.

6.6.3.4 Model Results

Benzene. The model was run at one-year intervals from 1997 to estimate the future maximum downgradient extent of dissolved benzene concentrations exceeding the Tier 1 TCL of 1 μg/L, and to determine the time required for benzene concentrations in the source area to decrease below the TCL. Simulations were performed for the source areas with the highest detected 1997 dissolved benzene concentrations (wells AP12-MW24 and AP16-MW39) in order to provide conservative estimates for the entire site. Benzene was detected at 28 μg/L in groundwater samples collected at both locations in October 1997. The average estimated source and solute decay rates presented in Sections 6.3.3 and 6.6.3.2, respectively, were used in model simulations.

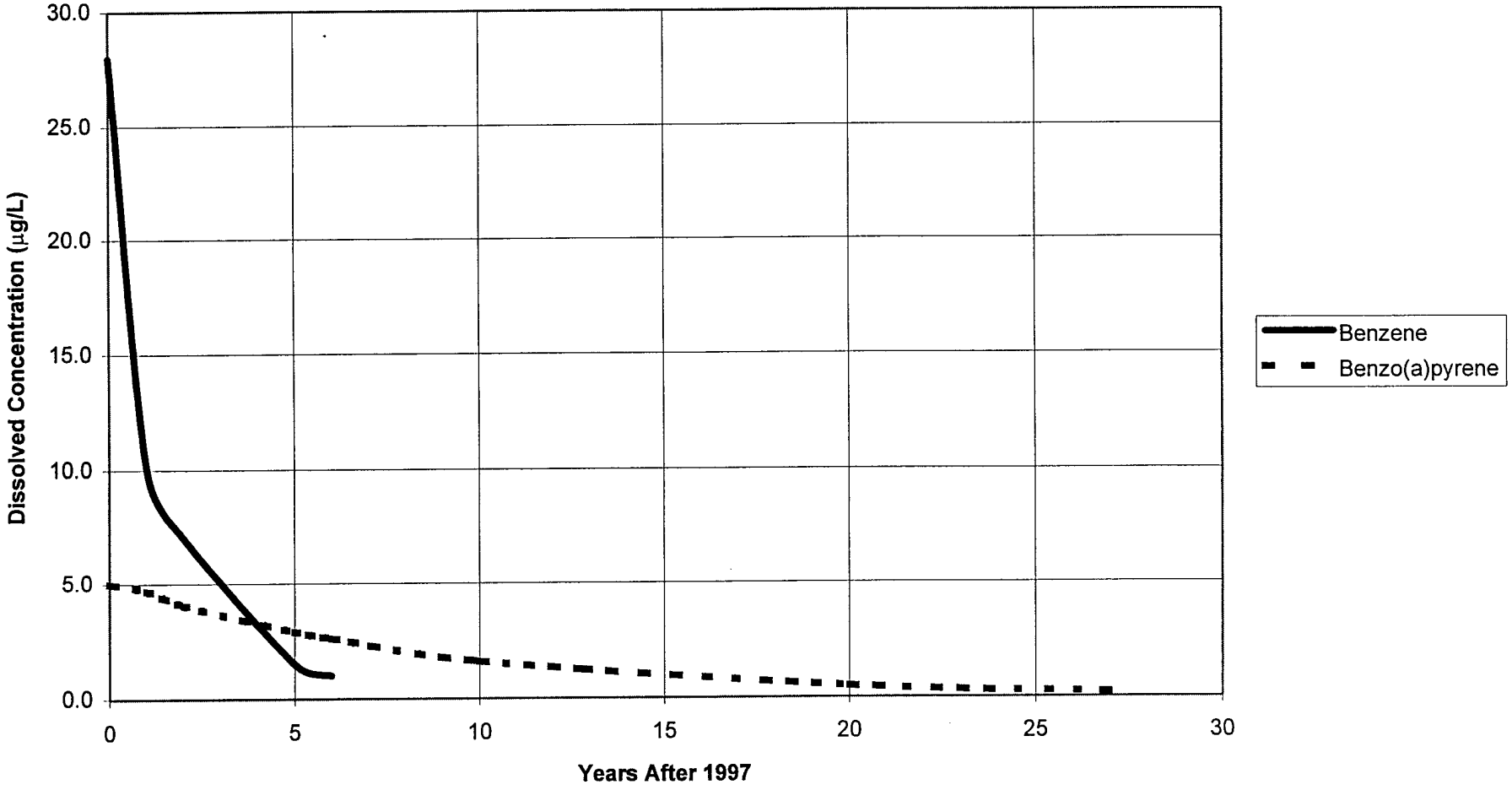
The first-order reaction model indicates that dissolved benzene concentrations will steadily decrease to below 1 μg/L within 6 years (Figure 6.8). The maximum predicted downgradient extent of dissolved benzene concentrations exceeding 1 μg/L was 35 to 40 feet from the source area.

Because of the low concentrations of dissolved benzene relative to the concentrations of electron acceptors in groundwater, results for the instantaneous reaction model indicate that benzene will be degraded at a faster rate than it is leached from source area soils. Therefore, the model predicts that benzene will be "instantaneously" degraded and will not persist in the groundwater. The presence of dissolved benzene in the groundwater at Site SS-15A demonstrates that this model is not adequately simulating site conditions, and that actual reaction rates in site groundwater are lower than the instantaneous rates simulated by the model.

Benzo(a)pyrene. The BIOSCREEN model was run at 2- to 5-year intervals from 1997 to estimate the time required for dissolved benzo(a)pyrene concentrations in source area groundwater to decrease below the Tier 1 TCL of 0.2 μg/L. Simulations were performed using the highest-detected 1997 concentration of dissolved benzo(a)pyrene (5 μg/L) in order to provide conservative estimates for the entire site. The simulation was performed using a source half-life of 5.8 years and an average solute half-life of 0.92 year.

Results of the first-order reaction simulation indicates that dissolved benzo(a)pyrene will steadily decrease to less than the Tier 1 TCL of 0.2 μg/L after approximately 27 years. Results also indicate that the lateral migration of dissolved benzo(a)pyrene will be minimal due to its extremely high retardation coefficient. The actual rates at which dissolved benzo(a)pyrene concentrations decrease may be more rapid than simulated, because the first-order decay rate decay rate may underpredict the rate of source depletion (Newell *et al.*, 1996). Similar to benzene, the instantaneous reaction model

FIGURE 6.8
SIMULATED TEMPORAL VARIATIONS IN DISSOLVED BENZENE AND BENZO(a)PYRENE CONCENTRATIONS--NATURAL ATTENUATION ONLY
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA



indicates that dissolved benzo(a)pyrene will not persist in the groundwater because the theoretical assimilative capacity of the groundwater exceeds the concentration of benzo(a)pyrene leaching from the source area soils.

6.6.3.5 Modeling Conclusions

Results of the BIOSCREEN model indicate that the maximum migration distance of dissolved benzene from any source area will be approximately 40 feet, and that concentrations of dissolved benzene will decrease below the Tier 1 TCL of 1 μg/L by approximately 2003. Results for dissolved benzo(a)pyrene suggest that maximum concentrations of this compound will persist in source area groundwater at concentrations exceeding 0.2 μg/L for up to approximately 27 years due to its potential biological recalcitrance.

SECTION 7

DEVELOPMENT OF TIER 2 TARGET LEVELS FOR CHEMICALS OF CONCERN IN THE FLORIDA AIR NATIONAL GUARD AREA

7.1 OBJECTIVE OF A TIER 2 SITE-SPECIFIC EVALUATION

The Tier 1 screening process is considered protective of human health because the Tier 1 risk-based screening criteria are based on conservative exposure assumptions that cover a wide range of commercial and industrial land uses. At FDEP's request, the Air Force has agreed to use Tier 1 industrial TCLs as the ultimate cleanup objective for parcels of Site SS-15A that will be transferred to non-Air Force entities. The Tier 1 analysis conducted in this CAP (Section 4) identified benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene as potential COPCs in soils; and identified benzene, ethylbenzene, MTBE, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, naphthalene, and TRPH as COPCs in groundwater. However, chemicals identified as COPCs in Section 4 of this CAP may not be present at levels that pose unacceptable threats to human health given the current and future exposure potential at this site. Section 6 described how natural attenuation will continue to limit migration and reduce future exposure concentrations. The future exposure potential at the site is also limited by actual land use, which can be controlled directly by the Air Force (in the FANG area) or by deed restrictions on land transferred to new land owners. The purpose of this section is to complete a Tier 2 analysis to determine appropriate site specific target levels (SSTLs) for contamination in the portion of Site SS-15A which will remain under Air Force control. A secondary purpose of SSTL development will be to determine if any other areas within Site SS-15A are likely to present a significant risk to future intrusive workers.

Development of site-specific exposure scenarios requires a reevaluation of the preliminary conceptual site model presented in Section 4. The revised CSM for Site SS-15A, which is presented in Section 7.2, identifies only those receptors and exposure pathways that realistically may be completed under current or hypothetical but realistic future exposure scenarios, considering land uses and the results of the chemical fate and transport assessment presented in Section 6.

Section 6 presented the results of fate and transport modeling used to predict the attenuation of the COPCs migrating away from the source areas. Tier 2 of the risk-based approach is completed in this section by comparing appropriate site concentrations (observed current, and predicted future) to reasonable matrix-specific SSTLs at receptor exposure points. These SSTLs are described as the Tier 2 risk-based criteria, and differ from the generic TCLs in that the conservative exposure assumptions used to derive the generic TCLs (e.g., exposure duration of 25 years) are replaced with more realistic site-specific exposure assumptions (e.g., exposure duration of one year). It is important to emphasize that the Tier 2 SSTLs are based on achieving levels of human health protection identical to those of the generic target cleanup levels (i.e., the site-specific criteria are based on a carcinogenic target risk limit of 10^{-6} and a noncarcinogenic hazard quotient of =1). The presence of various analytes at concentrations above the applicable generic TCLs also justifies the need for a Tier 2 evaluation to assist in the development of corrective actions that can achieve the desired level of risk reduction at the site.

One of the primary site-specific considerations that can be incorporated into development of the SSTLs is the demonstrated and predicted degree of attenuation of COPCs in affected environmental media. As mentioned above, the comprehensive chemical fate assessment, which emphasizes documenting biodegradation of the COPCs, concluded that natural chemical attenuation processes are effectively minimizing the mass and mobility of fuel hydrocarbon COPCs in soils and groundwater, and that these processes are expected to be sufficient to prevent

significant COPC migration beyond the immediate source areas (i.e., the limited "hotspot" locations of releases to soil). Based on this information, it can be concluded that migration of COPCs offsite or off Base will not occur. Furthermore, modeling indicates that groundwater contamination is not migrating appreciable distances from the location of the soil contamination source areas.

In summary, the objectives of developing SSTLs that include exposure assumptions more representative of actual site conditions are 1) to determine whether current or predicted future site concentrations of COPCs present an unacceptable risk to current and future receptors; and 2) to provide a mechanism or reference to assess the cost and time required to lower site concentrations to achieve adequate risk reduction at the site.

7.2 REVISED CONCEPTUAL SITE MODEL REVIEW

The preliminary CSM presented in Section 4 was used to qualitatively identify potential human and ecological receptors that may be exposed to site-related contaminants, and to define the types of these potential exposures at Site SS-15A (Figure 4.1). The preliminary CSM describes onsite release points, the affected physical media, the types of contaminant transport and fate mechanisms that may be involved at the site, each group of potentially exposed populations or receptors, and how each receptor group could come into contact with site-related contamination. This CSM was used to identify which of the exposure assumptions used to develop generic cleanup criteria most closely approximates site conditions. The exposure assumptions incorporated into the generic industrial TCLs (i.e., Table IV Direct-Exposure II and Table V TCLs) were identified as generally representative of the types of exposure that could occur at Site SS-15A, but greatly overestimate the magnitude of exposure specific to current and expected future site conditions within the FANG area. For example, Tier 1 screening of groundwater assumed unrestricted future use of groundwater. Therefore, the target cleanup criteria presented in Table V (FDEP, 1996) which were developed assuming potable use of groundwater, were used in the Tier 1 screening. The preliminary CSM exposure pathways are reevaluated in this section using the Tier

2 chemical fate information presented in Section 6. It is important to emphasize that the purpose of using the preliminary CSM and the conservative, nonsite-specific TCLs to identify COPCs was to ensure that all subsequent assessment activities beyond the Tier 1 screening evaluation address the full range of contaminants that may present some risk to current of future receptors.

The revised CSM for Site SS-15A, which is presented on Figure 7.1 and briefly reviewed in the following subsections, identifies only those receptors and exposure pathways that realistically may be considered given current and future land use within the FANG area. The outcome of the chemical fate assessment presented in Section 6 and the types of exposures likely to occur at this industrial site are reflected in this revised CSM. Justification for each site-specific exposure assumption is provided in subsequent discussions.

7.2.1 Revised Conceptual Model

7.2.1.1 Sources, Affected Media, Release Mechanisms, and Contaminant Environmental Transport

The likelihood of release from a source, the nature of the contaminants involved, the affected environmental media, and the probable magnitude of their release all are included in the revised CSM (Figure 7.1). As described in the preliminary CSM (Figure 4.1), releases from the below ground fuel distribution system have contaminated site soil, soil gas, and groundwater with fuel hydrocarbons. The predominant ongoing release mechanism for groundwater COPCs is leaching from contaminated soils in the smear zone. Soil contamination occurs in a number of discrete areas, primarily as residual LNAPL in the vadose (unsaturated) zone (i.e., shallower than 6 to 7 feet bgs). The general lack of mobile LNAPL (free product) detections at the site indicates that mobile LNAPL is not a significant, continuing source of groundwater contamination. The very flat groundwater gradient and low groundwater flow velocity (i.e., 0.014 ft/day or 5.1 ft/yr), and the potential for local multi-directional groundwater flow result in a lengthy groundwater residence time near

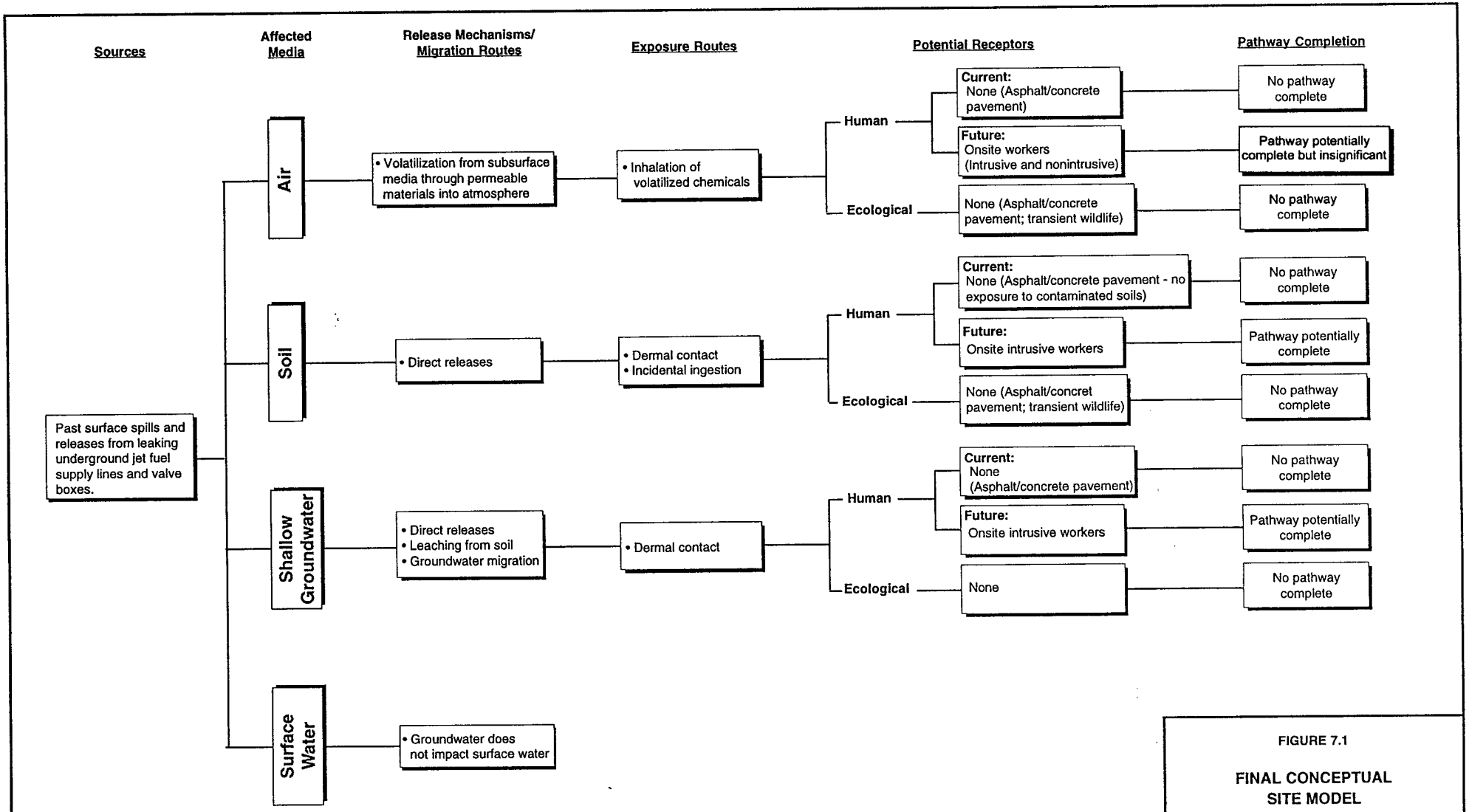


FIGURE 7.1

FINAL CONCEPTUAL SITE MODEL

Risk-Based Approach to Remediation
Site SS-15A
Homested ARB, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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the suspected source area. These hydrogeologic conditions act to minimize the horizontal migration of the dissolved plume. As site data and the modeling performed in Section 6.6 indicate, destructive and nondestructive attenuation rates are also acting to limit migration of contaminants in concentrations above the TCLs, to the vicinity of the "hotspot" soil source areas. Modeling also indicates that contaminants will not impact the flightline canal, and, therefore, groundwater contaminants from Site SS-15A will not impact surface water.

7.2.1.2 Potentially Exposed Receptors, Exposure Points, and Exposure Routes

The revised CSM also refines the identification of potentially exposed receptor populations, receptor exposure points, and exposure routes for realistic scenarios based on specific conditions within the FANG area. These components better reflect the likelihood and extent of human or ecological receptor contact with site-related contaminants. As described in Section 3, Site SS-15A is the flightline apron for the Homestead AFB runway. The entire extent of the site is within the boundaries of the Base, which is surrounded by a chainlink fence, and is under constant manned guard. An additional security fence surrounds the FANG area. Therefore, potential receptor groups are limited to Air Force authorized, onsite intrusive workers. There are no completed pathways to offsite receptors. Furthermore, the concrete/asphalt cover prevents contact with contaminated soil or groundwater by current Base personnel.

The industrial nature of the site, and the pavement covering the entire site, precludes the existence of suitable wildlife habitat. No resident ecological receptors were identified for which soils and/or groundwater are likely contaminant exposure media. No exposure pathways involving potential offsite ecological receptors are or will be complete based on the outcome of the quantitative chemical fate assessment presented in Section 6.

Using the most conservative exposure assumptions appropriate for the FANG area, the only realistic receptor that is likely to become exposed to site-related contaminants

is the onsite intrusive worker involved in demolition, removal, and/or construction activities. Inhalation of VOCs (partitioning from either contaminated soil or groundwater) in ambient air at the site could result in a completed pathway for the onsite intrusive worker. However, rapid dilution by ambient air will decrease xylene concentrations to levels that are well below the OSHA PEL; and therefore, this pathway is assumed to be insignificant. In addition, incidental ingestion of groundwater by the onsite intrusive worker was eliminated from further consideration. It is not reasonable to assume that intrusive workers could actually incidentally ingest a significant amount of contaminated groundwater during excavation activities.

7.2.2 Summary of Completed Exposure Pathways

Given the current and planned future uses of the FANG area (aircraft support), and the outcome of the Tier 2 quantitative chemical fate assessment presented in Section 6, only onsite intrusive workers could be exposed to site-related contamination during excavation activities (see Figure 7.1). Therefore, health-based Tier 2 SSTLs developed for the FANG area are those designed to protect hypothetical future onsite intrusive workers from carcinogenic risks and noncarcinogenic hazards via direct contact with soils and groundwater. Even onsite intrusive workers would be exposed to significant concentrations of contaminants only if the intrusive activities are located at or immediately adjacent to one of the areas of soil contamination. Based on extensive soil sampling, areas with elevated concentrations of contaminants are thought to comprise a relatively small proportion of the site.

7.3 DEVELOPMENT OF SITE-SPECIFIC TARGET LEVELS (SSTLS)

In order to develop representative SSTLs, realistic exposure assumptions for intrusive workers must be used. A detailed study of construction and underground utility workers was completed at Eglin AFB to estimate the average and maximum time that workers could be exposed to contaminated soils and groundwater during excavation activities (McLain, 1998). The results of this exposure study have been approved by

the FDEP as being representative of intrusive (excavation) worker exposures on active military bases. The Air Force believes that these exposure assumptions are valid for the FANG area of Site SS-15A, which will remain under Air Force control.

Tables 7.1 and 7.2 present the chemical-specific SSTLs for the FANG area within Site SS-15A. Note that two sets of SSTLs are calculated. Central tendency (CT) SSTLs are based on the average exposure timeframes expected for intrusive workers. Reasonable maximum exposure (RME) SSTLs are based on the maximum (worst case) exposure durations expected for intrusive workers. To ensure protection of human health under worst case conditions, the Air Force has selected RME SSTLs as cleanup target levels for the FANG Area. The RME values are based on a one-year, 180 days-per-year exposure to contaminated soils and a 46-day (2-hours-per-day) exposure to contaminated groundwater. Other exposure variables used to calculate the soil and groundwater SSTLs were taken from McClain (1998) and from FDEP values presented in *Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C., June 18, 1997.* COPC toxicity values used in the SSTL derivations are based on toxicity data reported in the Integrated Risk Information System (IRIS) (Micromedex, Inc., 1998) or used by FDEP to derive the generic Tier 1 target cleanup levels. Appendix C presents the exposure assumptions and derivation of the SSTLs for the FANG Area of Site SS-15A.

7.3.1 SSTLs for Soil

Table 7.1 presents the SSTLs for the soil COPCs found within the FANG Area at Site SS-15A. These SSTLs are calculated assuming direct contact with soil and include exposure via incidental ingestion of, dermal contact with, and inhalation of particulates and volatiles from site soils. The algorithm used to calculate the SSTLs is equivalent to that used by FDEP to calculate Tier 1 TCLs. The SSTLs differ from the Tier 1 target cleanup levels because several exposure parameters, as described above, are based on site-specific intrusive worker scenarios.

TABLE 7.1
COMPARISON OF MAXIMUM SOIL DETECTIONS TO SITE-SPECIFIC TARGET LEVELS (SSTLs)
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Chemical of Potential Concern	Units	Maximum Detected Concentration[a/]	Tier 2 Health-Based SSTL		Does Detected Site Maximum Concentration Exceed SSTL?	
			CT[e/]	RME[f/]	CT	RME
Benzo(a)anthracene	mg/kg [b/]	11	192	23	No	No
Benzo(a)pyrene	mg/kg	16 [c/]	19	2.3	No	Yes
Benzo(b)fluoranthene	mg/kg	7.4	192	23	No	No
Dibenz(a,h)anthracene	mg/kg	18 [c/d/]	19	2.3	No	Yes[d/]
Indeno(1,2,3-cd)pyrene	mg/kg	18 [c/d/]	192	23	No	No

[a/] Maximum concentrations were obtained from samples collected in 1994 by OHM or 1997 by Parsons ES.

[b/] mg/kg = milligrams per kilogram.

[c/] Maximum concentration based on 1994 data, 1997 concentrations were consistently lower:

Benzo(a)pyrene - 7.4 mg/kg
Dibenz(a,h)anthracene - ND (not detected)
Indeno(1,2,3-cd)pyrene - 4.3 mg/kg
TRPH - 200 mg/kg

[d/] Maximum concentration detected in 1994 was a combination of Dibenz(a,h)anthracene and Indeno(1,2,3-cd)pyrene.

[e/] Central tendency value.

[f/] Reasonable maximum exposure value.

TABLE 7.2
COMPARISON OF MAXIMUM GROUNDWATER DETECTIONS TO SITE-SPECIFIC TARGET LEVELS (SSTLs)
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Chemical of Potential Concern	Units	Detected Site Maximum Concentration[a/]	Tier 2 Health-Based SSTL		Does Detected Site Maximum Concentration Exceed SSTL?	
			CT	RME	CT	RME
Benzene	µg/L [b/]	28	42,000	2,990	No	No
Ethylbenzene	µg/L	130	609,000	53,300	No	No
Methyl tertbutyl ether (MTBE)	µg/L	80J	476,000	41,800	No	No
Acenaphthene	µg/L	25	129,000	11,300	No	No
Benzo(a)anthracene	µg/L	7	34.6	3.1	No	Yes [d/]
Benzo(a)pyrene	µg/L	5	2.3	0.21	Yes [d/]	Yes [c/]
Benzo(b)fluoranthene	µg/L	5	23	2.1	No	Yes [d/]
Benzo(k)fluoranthene	µg/L	5	234	20.9	No	No
Naphthalene	µg/L	330	308,000	26,000	No	No
TRPH [e/]	mg/L [f/]	76	-- [g/]	--	--	--

[a/] Maximum detection at Site SS-15A during December 1996-January 1997, July 1997, and October 1997 sampling events.

[b/] ug/L = micrograms per liter.

[c/] Detected concentrations at sampling locations AP26-MW75 and AP27-MW78 exceed SSTL.

[d/] Detected concentrations at sampling location AP27-MW78 exceeds SSTL.

[e/] TRPH = total recoverable petroleum hydrocarbon.

[f/] mg/L = milligrams per liter.

[g/] SSTL could not be calculated.

7.3.2 SSTLs for Groundwater

Table 7.2 presents SSTLs for the groundwater COPCs within the FANG Area at Site SS-15A. These SSTLs are calculated assuming dermal contact with and incidental ingestion of groundwater and inhalation of volatiles released from groundwater. The dermal contact algorithm is based on the general absorption intake equation for dermal contact with chemicals in water developed by USEPA (1989). The approach used to incorporate the inhalation pathway in the SSTL calculations was derived by toxicologists at the University of Florida (University of Florida, 1998). The groundwater SSTLs are health-based values calculated to protect onsite intrusive workers from health risks associated with dermal exposure, incidental ingestion, and inhalation of chemical contamination found in groundwater. As stated earlier, the generic health-based Tier 1 TCLs are calculated assuming purposeful ingestion of onsite groundwater by onsite workers under residential-type exposure conditions (i.e., 30-year exposure duration, 2 liters per day consumption rate, etc.). In reality, these TCLs would apply only if impacted groundwater from Site SS-15A migrated to offsite locations where a residential land use assumption is more representative of exposure conditions. The Tier 2 quantitative chemical fate assessment completed in Section 6 demonstrates that no groundwater COPC is expected to migrate to or beyond the site boundary.

7.4 COMPARISON OF EXPOSURE-POINT CONCENTRATIONS TO SSTLS

The maximum detected concentrations of soil and groundwater COPCs were conservatively assumed to represent the current and future exposure-point concentrations at Site SS-15A. However, it is important to note that the Tier 2 chemical fate assessment demonstrates that contaminant concentrations are rapidly reduced as groundwater moves away from the contaminant sources. In addition, the maximum detected site concentrations most likely do not represent the true exposure-point concentrations to which potential future workers would be exposed. Data suggest that much of Site SS-15A has little or no contamination, and that areas of greater

contamination are limited in extent. Furthermore, data indicate that destructive and nondestructive natural attenuation processes are operating at the site to reduce contaminant concentrations.

Table 7.1 compares maximum concentrations of soil COPCs to soil SSTLs. From the table it can be seen that two PAHs, benzo(a)pyrene and possibly dibenzo(a,h,)anthracene, have maximum detections that exceeded RME SSTLs. Of these two PAHs, only benzo(a)pyrene was detected above the RME SSTL in the 1997 sampling event; the detection of 7.4 mg/kg occurred in a soil sample collected at AP26-SB1-5 in the FANG Area.

Table 7.2 compares maximum detected concentrations of groundwater COPCs to groundwater SSTLs. Benzo(a)anthracene, benzo(a)pyrene, and benzo(b)fluoranthene were detected in groundwater at concentrations above the RME SSTLs. Benzo(a)pyrene wase detected above its RME SSTL at sampling locations within the FANG Area (AP26-MW75 and AP27-MW78) during 1997 sampling. Benzo(b)fluoranthene and benzo(a)anthracene were detected above their RME SSTLs during 1997 sampling events at sampling location AP27-MW78 only. These locations correspond to areas of relatively elevated soil contamination. Modeling results described in Section 6 and site data indicate that natural attenuation processes and the low groundwater flow rate will limit the areal extent of groundwater contaminated above the SSTLs.

7.5 SUMMARY OF RISK-REDUCTION REQUIREMENTS

Comparison of maximum detected COPC concentrations to SSTLs indicate that several PAH compounds exceed the SSTLs for soil and groundwater. Minor exceedences of SSTLs for soil are random throughout the site. These exceedances are caused by low levels of PAH compounds which are not directly related to fuel residuals but are likely residuals from asphalt pipe coatings or the asphalt covering the apron. Two locations at Site SS-15A (AP26-MW75 and AP27-MW78) showed consistent

groundwater contamination above RME SSTLs. Data collected on destructive and nondestructive attenuation at the site indicates that elevated concentrations of groundwater contaminants are not migrating appreciable distances from the source areas. No actions are needed to prevent migration.

Based on current levels of soil and groundwater contamination, two risk reduction requirements are evident:

1. Institutional controls that require proper protection for future excavation workers in all areas of Site SS-15A with contamination exceeding Tier 1 TCLs or SSTLs. These controls should be included in deed restrictions for all land that is transferred from Air Force control. Sections 9 and 10 discusses these institutional controls in greater detail.

2. Based on historical groundwater contamination exceeding SSTLs and soil leaching models, active remediation may be warranted at two "hotspots" within the FANG area to reduce the duration of elevated groundwater contaminant concentrations due to leaching from soil. Active remediation in this area will allow future intrusive workers to complete utility repairs, etc. without restrictions on the duration of exposure to soil and groundwater.

3. Continued monitoring of groundwater is recommended to ensure that contaminant concentrations continue to attenuate and will not pose a risk to surface waters in the Flightline Canal. Monitoring should continue until Tier 1 groundwater TCLs are achieved.

SECTION 8

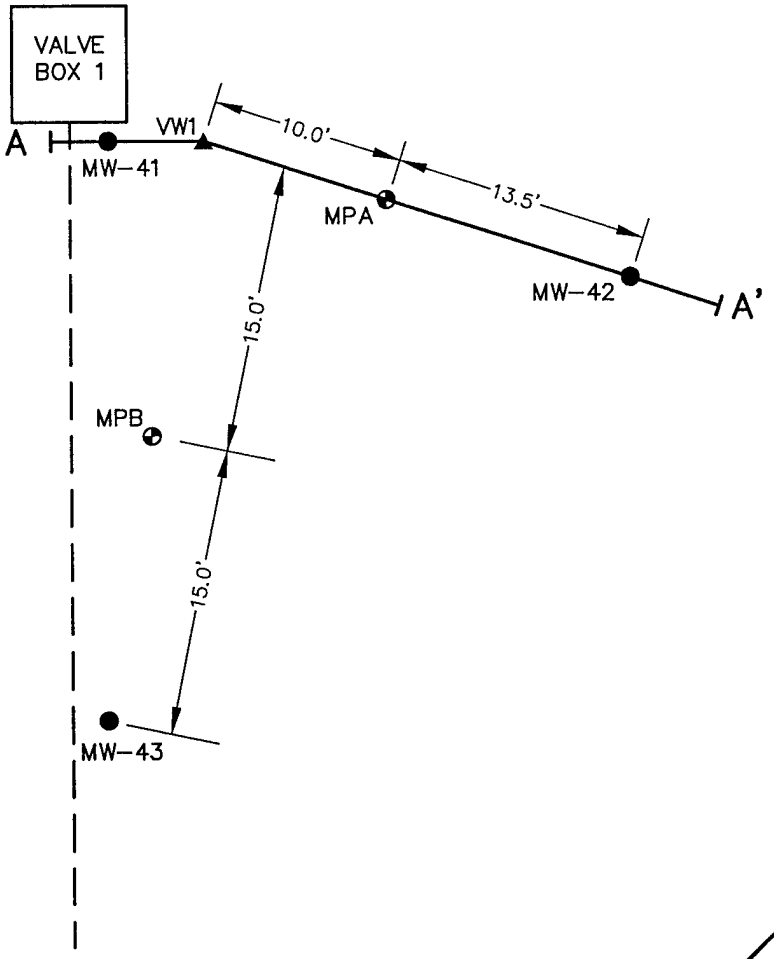
PILOT TESTING OF SOURCE REMOVAL TECHNOLOGIES

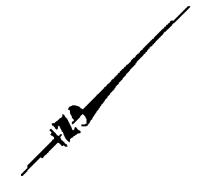
Section 6 of this CAP shows that both destructive and nondestructive attenuation processes should be effective at minimizing contaminant migration and reducing contaminant mass at Site SS-15A. This analysis was based on available site data for soil and groundwater. Selected source removal technologies also were evaluated at Site SS-15A in the event that engineered source removal is required to protect human health and the environment or to reduce the total time and cost of remediation. A pilot-scale bioventing test was conducted at Site SS-15A, apron line AP-18, by Parsons ES in October 1997. Results of bioventing pilot testing at apron line AP-18 are summarized in this section.

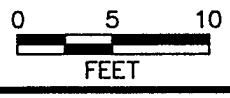
8.1 *IN SITU* BIOVENTING PILOT TEST DESIGN AND SYSTEM INSTALLATION

Bioventing pilot testing, including air permeability, oxygen influence, and *in situ* respiration testing, was conducted following procedures described in the Air Force bioventing protocol document (Hinchee *et al.*, 1992). In preparation for pilot testing, one air injection vent well (VW-1) and two vapor monitoring points (MPA and MPB) were installed near valve box 1 at the north end of Apron Line AP-18. Existing groundwater monitoring wells (MW-41, MW-42, and MW-43, which have well screens extending above the water table) also were utilized to monitor pressure response and soil gas chemistry during pilot testing.

Bioventing well VW-1 and vapor monitoring points MPA and MPB were installed on 24 October 1998. Figure 8.1 is a layout of the pilot testing area, and Figure 8.2 is a hydrogeologic cross-section showing the relationships of the screened intervals to







LEGEND

- EXISTING GROUNDWATER MONITORING WELL
- NEW VAPOR MONITORING POINT
- NEW AIR INJECTION VENT WELL
- ABANDONED, UNDERGROUND FUEL LINE
- A——A' HYDROGEOLOGIC CROSS-SECTION LINE

FIGURE 8.1

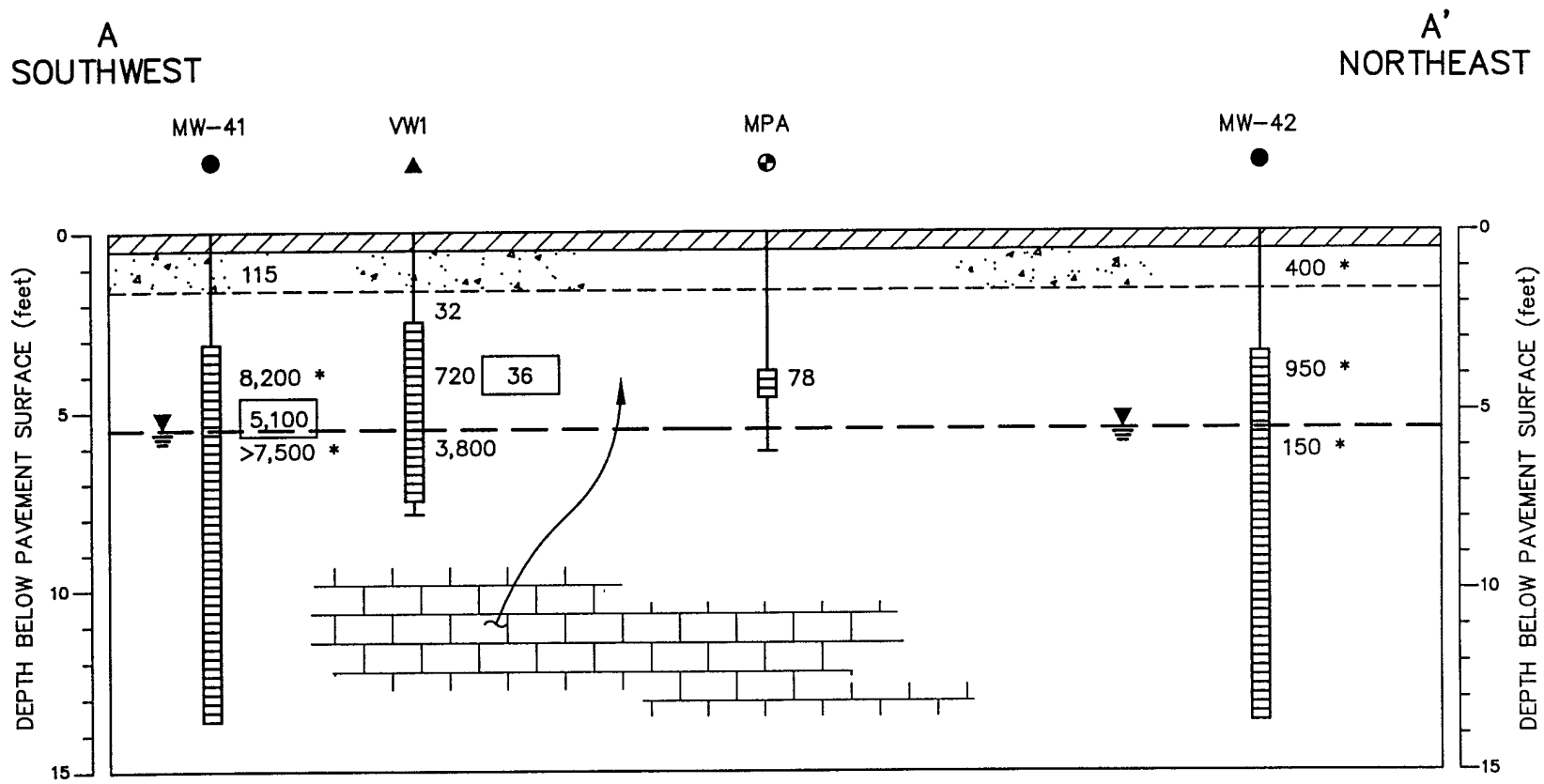
AS-BUILT VENT WELL AND VAPOR MONITORING POINT LOCATIONS APRON LINE AP-18

Risk-Based Approach to Remediation
SS 15-A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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LITHOLOGICAL DESCRIPTION

ASPHALT

SAND AND LIMESTONE FRAGMENTS

WEATHERED LIMESTONE

LEGEND

- GROUNDWATER MONITORING WELL
- VAPOR MONITORING POINT
- VENT WELL
- 720 * FIELD SCREENING RESULTS FOR TOTAL VOLATILE HYDROCARBONS (ppmv) (* VALUE CORRECTED FOR METHANE)
- 5,100 LABORATORY RESULTS FOR SOIL TOTAL PETROLEUM HYDROCARBONS (mg/kg)
- STATIC GROUNDWATER LEVEL
- GEOLOGIC CONTACT
- MONITORING POINT/WELL SCREENED INTERVAL

NOTE: FIELD SCREENING AND LABORATORY RESULTS FOR MW-41 AND MW-42 FROM OHM, 1995.

0 5 10
FEET

FIGURE 8.2

BIOVENTING SYSTEM HYDROGEOLOGIC CROSS SECTION APRON LINE AP-18

Risk-Based Approach to Remediation
Site SS 15-A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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subsurface soil intervals. Borehole logs and well construction diagrams for the bioventing system are included in Appendix A.

One 2-inch-diameter polyvinyl chloride (PVC) air injection vent well (VW-1) was installed in contaminated source area soils adjacent to valve box 1. VW-1 was screened in the limestone bedrock from 2.5 to 8.5 feet bgs. VW-1 was piped to three small test blowers which supplied a total air flow of 3 standard cubic feet per minute (scfm).

The two soil vapor monitoring points were screened in the unsaturated zone using 6-inch-long sections of 1-inch-diameter well screen, with the bottom of the screens placed at a depth of 4 feet bgs. A thermocouple was installed at the top of the MPA screen 5 to measure soil temperatures.

8.2 PILOT TEST RESULTS

8.2.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, soil gas collected from the MPs and existing groundwater monitoring wells was analyzed for initial oxygen, carbon dioxide, and TVH concentrations using portable gas analyzers, as described in the technical protocol document (Hinchee *et al.*, 1992). In addition, samples from wells MW-41 and MW-43 were submitted for laboratory analyses for TVH (referenced to JP-4 jet fuel) and BTEX. Table 8.1 summarizes the initial soil gas chemistry. Prior to collecting the soil gas samples, the MPs and groundwater monitoring wells were purged until oxygen levels stabilized to remove stagnant gas. At all locations, soil gas oxygen concentrations had been depleted to below the instrument detection limit. Depleted oxygen concentrations indicate significant biological activity and soil contamination. In comparison, oxygen concentrations at the upgradient well at AP26 (MW-112), which was constructed in clean soils, was 19.0 percent.

TVH field measurements at the MPs and groundwater monitoring wells ranged from 680 to over 20,000 parts per million, volume per volume (ppmv), and laboratory TVH

TABLE 8.1
INITIAL FIELD AND LABORATORY SOIL GAS ANALYTICAL RESULTS
BIOVENTING PILOT TEST, APRON LINE AP18
RISK-BASED APPROACH TO REMEDIATON
SITE SS-15A
HOMESTEAD AfB, FLORIDA

		Field Screening Data			Laboratory Analytical Data[a/]				
Sample Location	Sample Depth (ft bgs)[d/]	Oxygen (percent)	Carbon Dioxide (percent)	TVH[b/] (ppmv)[e/]	TPH[c/] (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethyl-benzene (ppmv)	Xylenes (ppmv)
VW-1	2.5-5.3	NA[f/]	NA	NA	NA	NA	NA	NA	NA
MPA	4.0	0.0	16.8	> 20,000	NA	NA	NA	NA	NA
MPB	4.0	0.0	16.0	1,900	NA	NA	NA	NA	NA
MW-41	3.5-5.3	0.0	13.5	9,200	22,000	<1[g/]	65M[h/]	54M	240M
MW-42	3.5-5.3	0.0	16.3	680	NA	NA	NA	NA	NA
MW-43	3.5-5.3	0.0	16.0	840	1,508	<0.052	4.7M	2.7	24M

[a/] Laboratory analysis of soil gas performed using USEPA Method TO-3. Laboratory TPH referenced to jet fuel (MW=156).

[b/] TVH = total volatile hydrocarbons.

[c/] TPH = total petroleum hydrocarbons. C5+ hydrocarbons referenced to jet fuel (MW=156); C2-C4 hydrocarbons referenced to propane (MW=44).

[d/] ft bgs = feet below ground surface.

[e/] ppmv = parts per million, volume per volume.

[f/] NA = Sample not analyzed.

[g/] < = compound analyzed for , but not detected. Number shown represents the laboratory method detection limit.

[h/] M = Reported value may be biased due to apparent matrix interferences.

results were 1,508 and 22,000 ppmv for soil gas samples from MW-43 and MW-41, respectively. These results indicate moderate to high levels of fuel contamination in the pilot test area.

8.2.2 Air Permeability and Oxygen Influence Testing

An air permeability test was conducted according to procedures outlined in the AFCEE bioventing protocol (Hinchee *et al.*, 1992). Air was injected into VW-1 for 60 minutes at a rate of approximately 3 scfm and an average pressure of 57 inches of water. Pressure measured at the MPs and groundwater monitoring wells gradually increased throughout the period of air injection. Due to the gradual increase in pressure response, the dynamic method of determining air permeability was selected. An average soil gas permeability value of 40 darcys, typical for sandy or porous soils, was calculated for this site. The maximum pressures measured at the MPs and groundwater monitoring wells, and calculated air permeability values are presented on Table 8.2. A radius of pressure influence of at least 30 feet was observed at the 3.5- to 5.5-foot depths.

The depth and radius of oxygen increase in the subsurface resulting from air injection during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 8.3 presents the change in soil gas oxygen levels that occurred during an 18-hour injection period with an air injection rate of 3 scfm. This period of air injection produced changes in soil gas oxygen levels at all the monitored screened intervals. Based on measured changes in oxygen levels, it is anticipated that the radius of influence for a long-term bioventing system would exceed 30 feet within the unsaturated limestone.

TABLE 8.2
MAXIMUM PRESSURE RESPONSE
AIR PERMEABILITY TEST
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD ARB, FLORIDA

TEST PARAMETERS:

Test Date: 10/25/97
Injection Well: VW1
Injection Pressure: 53-66 inches of water
Injection Flow Rate: 3 standard cubic feet per minute

Location	Distance From VW1 (feet)	Screen Depth (feet bgs) [a/]	Elapsed Time to Maximum Pressure (minutes)	Maximum Pressure Response (inches of water)	Air Permeability (darcy)
MPA	10.0	4.0	50	4.90	24
MPB	15.0	4.0	40	1.40	41
MW-42	23.5	3.5-5.3	40	1.60	39
MW-43	30.0	3.5-5.3	50	1.15	54

[a/] bgs = below ground surface.

TABLE 8.3
OXYGEN INFLUENCE IN SUBSURFACE DURING BIOVENTING PILOT TESTING
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD ARB, FLORIDA

Location	Distance From VW1 (feet)	Screen Depth (feet bgs) [a/]	Initial O_2 [b/] (percent)	Final O_2 [c/] (percent)
MW-41	5.3	3.5-5.3[d/]	0.0	21.0
MPA	10.0	4.0	0.0	20.3
MPB	15.0	4.0	0.0	15.5
MW-42	23.5	3.5-5.3[d/]	0.0	6.8
MW-43	30.0	3.5-5.3[d/]	0.0	6.0

[a/] bgs = below ground surface.
[b/] Measurements taken following MP installation and prior to permeability testing.
[c/] Measurements taken after approximately 18 hours of air injection (3scfm) at VW1.
[d/] Depth interval shown is from top of screed to groundwater surface.

The fairly uniform pattern of decreasing pressure response and oxygen influence with increasing distance from VW-1 indicates that the air flow through the weathered bedrock is relatively uniform and is not greatly influenced by fractures or other zones of higher permeability.

8.2.3 *In Situ* Respiration Testing

In situ respiration testing was performed at Apron Line AP-18 to determine oxygen utilization rates and potential biodegradation rates. Testing followed permeability and oxygen influence testing, which resulted in increased subsurface oxygen levels in the vicinity of valve box 1. At the completion of the oxygen influence test, the blower was turned off, and changes in soil gas composition over time were then measured at VW-1, MPA, and MPB. Oxygen, TVH, and carbon dioxide were measured for a period of approximately 48 hours following air injection. The measured oxygen losses then were used to calculate biological oxygen utilization rates. Table 8.4 provides a summary of the oxygen utilization rates.

Oxygen loss occurred at moderate rates, ranging from 0.289 percent per hour at MPA to 0.403 percent per hour at VW-1. At VW-1, oxygen levels dropped from 21.0 percent to 2.0 percent in approximately 48.5 hours (Table 8.4).

Based on these oxygen utilization rates, an estimated 462 to 652 mg of fuel per kg of soil can be degraded each year at this site. This conservative estimate is based on an average air-filled porosity of approximately 0.045 liter per kg of soil, and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. The air-filled porosity was calculated using laboratory soil moisture results for soil samples collected at the 2- to 4-foot and 3- to 5-foot intervals (collected at AP15 and AP20, respectively) and an estimated limestone porosity of 35 percent.

TABLE 8.4
OXYGEN UTILIZATION AND FUEL DEGRADATION RATES
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD ARB, FLORIDA

Location-Depth (feet bgs) [a/]	O_2 Loss [b/] (percent)	Test Duration[c/] (hours)	O_2 Utilization Rate[d/] (percent/hour)	Fuel Degradation Rate (mg TPH/kg/year)[e/]
VW-1	19.0	47.5	0.40	652
MPA	11.3	47.9	0.29	435
MPB	14.0	47.9	0.31	462

[a/] bgs = below ground surface.
[b/] Actual measured oxygen loss.
[c/] Elapsed time from beginning of test to time when minimum oxygen concentration was measured.
[d/] Values based on best-fit oxygen decay curves.
[e/] mg TPH/kg/year = milligrams of total petroleum hydrocarbons per kilogram of soil per year.

8.2.4 Pilot Test Results Summary

Treatabiliy testing indicates that *in situ* bioventing is a feasible method for remediating unsaturated, hydrocarbon-contaminated soil and weathered limestone bedrock within source areas at SS-15A. In contrast with the bioventing feasibility testing performed at Site SS-15B (Parsons ES, 1997a), results for the bioventing pilot test performed at Apron Line AP-18 indicate that relatively uniform distribution of air to the unsaturated soil and limestone is achievable with vertical air injection wells. The continuous asphalt and concrete pavement and thicker unsaturated zone at Site SS-15A (compared to Site SS-15B which has no pavement cover and a thinner unsaturated zone) likely account for the successful use of vertical air injection wells at Site SS-15A. Although bioventing is a technically feasible remediation technology for Site SS-15A, the distribution of contamination (numerous, widely-spaced, individual source areas) and lack of easily accessible electrical power would increase the cost of implementing this remedial technology at Site SS-15A.

SECTION 9

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Sections 6 and 8 provide scientific documentation of natural attenuation processes and the potential benefits of *in situ* bioventing in accelerating the remediation of source areas at Site SS-15A. An initial screening of remedial approaches and technologies was completed, and several technologies were identified for possible use at Site SS-15A. A complete review of the initial screening process is included in Appendix E. Three remedial alternatives were developed using various combinations of public education, land and groundwater use controls, LTM, natural attenuation, *in situ* bioventing, soil excavation, and groundwater extraction. The objectives of Section 9 are to summarize the remedial action objectives for Site SS-15A, review the remedial alternatives developed from the technologies screened in Appendix E and the primary evaluation criteria used to compare these alternatives, and to complete a more detailed comparative analysis of each alternative in an effort to identify the most logical approach for remediating Site SS-15A. Each alternative is more fully explained in terms of its effectiveness, technical and administrative implementability, and cost. Following this evaluation, an implementation plan and LTM plan for the recommended alternative are summarized in Section 10.

9.1 SUMMARY OF RISK REDUCTION REQUIREMENTS

Section 7 identified two primary risk reduction requirements based on a comparison of remaining site contaminants to Tier 1 industrial TCLs and SSTLs. These risk reduction requirements include:

1. A need to protect future intrusive workers in all areas of Site SS-15A with contamination exceeding Tier I TCLs or SSTLs for soil and groundwater. Protection from contaminated groundwater is particularly important since dermal contact with groundwater is the primary long-term risk driver for PAH contaminated sites. As a minimum, institutional controls requiring protection of excavation workers should be included in deed restrictions for all land transferred from Air Force control.

2. Based on historical groundwater contamination which exceeds both Tier 1 TCLs and SSTLs, and future predictions of soil leaching (Section 6), active remediation may be warranted at two "hot spots" within the FANG area (AP26-MW75 and AP27-MW78). Sampling of these areas has consistently revealed multiple contaminants which exceed the SSTLs that were developed for intrusive workers. Since this area will remain under Air Force control, the Air Force should consider the advantage of a focused remediation in these areas to eliminate future risks to intrusive utility or construction workers.

3. Continued monitoring of groundwater is recommended to ensure that contaminant concentrations continue to attenuate and will not pose a risk to surface waters in the Flightline Canal. Monitoring should continue until Tier 1 groundwater TCLs are achieved.

9.2 SUMMARY OF CANDIDATE REMEDIAL ALTERNATIVES

Based on the initial remedial screening process, which is summarized in Appendix H, several remedial approaches and technologies were retained for the development of remedial alternatives. These technologies were selected to provide a range of passive to more active response actions, all of which will minimize contaminant migration and diminish dissolved contaminant concentrations over time. The primary goal of all the candidate alternatives is to remediate Site SS-15A contaminant concentrations below Tier I groundwater TCLs. Long-term institutional controls (OSHA requirements) will

be used to ensure worker protection if soil excavation is required. The SSTLs developed for Site SS-15A have been used to identify areas where more immediate remediation will provide a protective work environment for intrusive workers. The goal of achieving Tier I TCLs and SSTLs (within the FANG Area) will be met in different time frames and at different costs under each alternative. The following remedial approaches and technologies were retained for evaluation:

- Long-term groundwater monitoring;
- Limited land use and engineering controls;
- Groundwater use controls;
- Public education;
- Natural attenuation of soil and groundwater contamination;
- *In situ* bioventing in selected source areas;
- Excavation of hot spots of contaminated soils; and
- Short-term groundwater extraction in plume "hotspots."

The primary objective of source reduction technologies would be to more rapidly remove contaminants from the shallow groundwater and unsaturated soils near wells AP26-MW75 and AP27-MW78, where the only exceedences of groundwater SSTLs occurred between December 1996 and October 1997 (Table 7.2).

Because natural attenuation has been effectively reducing dissolved contaminants in the groundwater and limiting downgradient migration (Section 6), this ongoing remediation process can best be enhanced through a reduction of the continuing source of contamination at Site SS-15A. Two candidate soil source reduction technologies (*in situ* bioventing for treatment of residual soil contamination and soil excavation) and one

groundwater treatment technology (short-term groundwater extraction and treatment) have been retained for additional analysis. Three candidate remedial alternatives were developed and are described in the following sections.

9.2.1 Alternative 1 - Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

Goal of Alternative 1: Attainment of SSTLs in the FANG Area and attainment of Tier I groundwater TCLs in all areas of Site SS-15A by the year 2024.

Remediation by natural attenuation (RNA) is achieved when natural attenuation mechanisms bring about a reduction in the total mass of, or restrict the migration of, a contaminant in the soil or dissolved in groundwater. RNA results from the integration of several subsurface attenuation mechanisms that are classified as either destructive or nondestructive. Destructive attenuation mechanisms include biodegradation, abiotic oxidation, and hydrolysis. Nondestructive attenuation mechanisms include sorption, dilution (caused by dispersion and infiltration), and volatilization. In some cases, RNA will reduce residual and dissolved contaminant concentrations below numerical concentration goals intended to be protective of human health and the environment. As indicated by the evidence of RNA described in Section 6, these processes are occurring in Site SS-15A soil and groundwater and will continue to reduce contaminant mass in the plume area.

Implementation of Alternative 1 would require the use of institutional controls such as land use restrictions and LTM. Land use restrictions may include placing long-term requirements for worker protection during soil excavation within the source area and long-term restrictions on groundwater well installations within and downgradient from the plume area. The intent of these restrictions would be to control potential receptor exposure to contaminants by protecting site workers and restricting activities within areas affected by site-related contamination.

LTM would be performed at a regular frequency and would consist of sampling a set of wells, including source area and sentry monitoring wells. The recommended site-specific LTM strategy is provided in Section 10. On the basis of predictive contaminant fate and transport modeling results (Section 6.6.3.4), it is unlikely that dissolved contaminant concentrations exceeding Tier 1 TCLs will migrate to the Flightline Canal, which represents the only potential receptor exposure point under current conditions. Nevertheless, LTM is the technical mechanism used to evaluate the progress of natural attenuation processes and to ensure that long-term risk reduction objectives are being met. Detection of dissolved contaminant concentrations exceeding risk-based action levels at a sentry well would indicate the need for additional evaluation of the probable extent of contaminant migration, and/or to determine if additional corrective action is necessary.

Public education on the selected alternative would be developed to inform Base personnel and potential new land owners of the scientific principles underlying source reduction and RNA. This education could be accomplished through public meetings, presentations, press releases, and posting of signs where appropriate. Periodic site reviews also could be conducted using data collected from the long-term groundwater monitoring program. The purpose of these reviews would be to evaluate the extent of contamination, assess contaminant migration and attenuation through time, and reevaluate the need for additional remedial actions.

9.2.2 Alternative 2 - *In Situ* Bioventing in Source Areas, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

Goal of Alternative 2: Attainment of SSTLs in the FANG Area by the year 2004 and attainment of Tier I groundwater TCLs in all areas of Site SS-15A by 2004.

Alternative 2 is similar to Alternative 1 except that *in situ* bioventing would be used to accelerate the reduction of residual contaminant concentrations in unsaturated soils in two source areas: AP26 valve box 1 and the northwest end of AP27. The Tier 2

health-based SSTLs for benzo(a)anthracene and benzo(a)pyrene in groundwater were exceeded at wells AP26-MW75 and AP27-MW78, and the SSTL for benzo(b)fluoranthene also was exceeded at well AP27-MW78.

Bioventing at these locations would reduce soil (and consequently groundwater) concentrations of these COPCs to below Tier 2 SSTLs more rapidly than with Alternative 1. An *in situ* pilot-scale bioventing test was performed by Parsons ES at Site SS-15A in October 1997. The detailed results of this test are presented in Section 8. As the test results indicate, bioventing can effectively remove fuel-related hydrocarbons from unsaturated soils at Site SS-15A. One existing groundwater monitoring well (with the screened interval extending above the saturated zone) at the northwestern ends of each of Apron Lines AP26 and AP27, would be converted to an air injection VW and manifolded using underground air lines to a common blower system located near the southeastern edge of the apron.

Land use and groundwater use controls for Alternative 2 would be identical to those described for Alternative 1. For areas of Site SS-15A to be transferred from Air Force control, deed restrictions would be required to ensure the protection of future intrusive workers until Tier I TCLs are achieved through natural attenuation. Additional site access would be required to maintain the bioventing systems. Long-term groundwater monitoring also would be the same as Alternative 1. Additional soil gas monitoring would be required for the full-scale bioventing systems to document the amount of contaminant mass being removed from the vadose zone and to ensure optimal system performance.

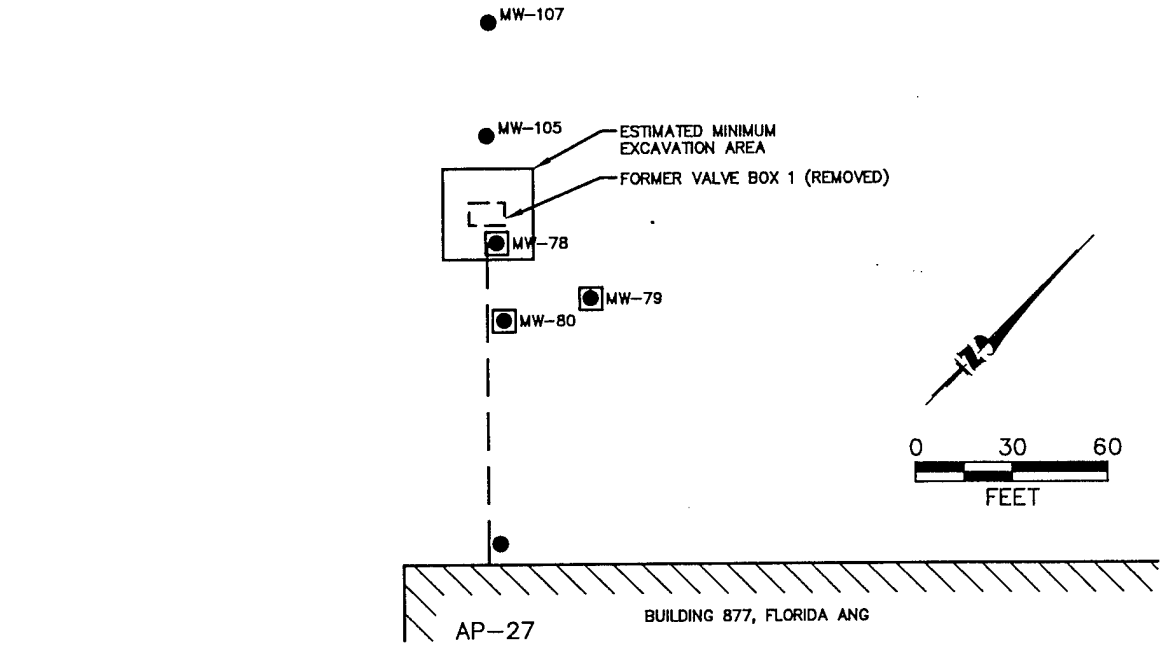
9.2.3 Alternative 3 - Source Area Soil Excavation, Short-Term Groundwater Extraction/Treatment, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

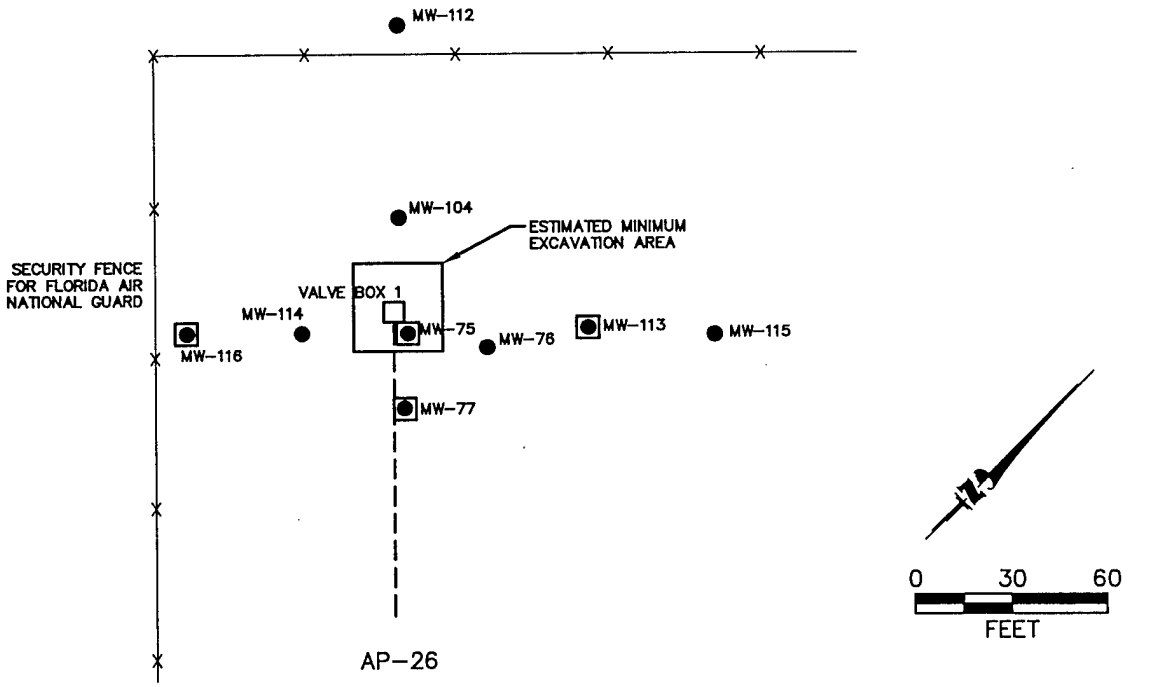
Goal of Alternative 3: Attainment of SSTLs in the FANG area by the year 2002 and attainment of Tier 1 groundwater TCLs in all areas of Site SS-15A by 2002.

The objective of this alternative is to remove contaminated soils that have consistently produced COPC concentrations in groundwater in excess of Tier 1 TCLs and SSTLs. The areas targeted for soil removal are at AP26 valve box 1 and the northwestern end of AP27. The specific objective of this limited excavation would be to remove soils that contain PAHs (including benzo(a)pyrene) at levels that are high enough to generate long-term groundwater contamination above the site-specific cleanup criteria. Excavation would immediately remove the source of contamination and could decrease the timeframe to attain Tier 1 groundwater TCLs from decades to less than 3 years. Once the source of long-term leaching is removed, any dissolved PAHs should degrade rapidly.

At each hot spot, approximately 250 cubic yards of unsaturated and saturated soil would be removed to a depth of approximately 8 feet bgs. The exact depth of excavation would be based on field observations of petroleum staining or product sheen. To accomplish this excavation at each hot spot, a 30-foot by 30-foot area of existing pavement would be saw cut, removed, and disposed of as construction rubble (Figure 9.1). A small excavator would remove all of the visibly contaminated soil and place it on plastic sheeting near the excavation. Soils would be allowed to drain, and would be sampled and transported to a local stationary thermal treatment facility which accepts petroleum-contaminated soils.

During excavation, a portable dewatering pump would be used to remove contaminated water from the pit. Rather than immediately backfilling the pit, groundwater would be allowed to flow into the pit for approximately 2 weeks and would be removed by the dewatering pump. Assuming a 20-gallon-per-minute (gpm) pumping rate and 8 hours of operation per day, approximately 150,000 gallons of groundwater could be removed from the vicinity of each hot spot. This equates to approximately ten pore volumes of water that would be removed from the excavation area. This intensive pumping should significantly enhance the removal of dissolved





LEGEND

- SHALLOW MONITORING WELL
- LONG-TERM MONITORING WELL
- APRON LINE RE/DEFUELING VALVE BOX AND ABANDONED, UNDERGROUND FUEL LINE

FIGURE 9.1

PROPOSED MINIMUM EXCAVATION AREAS AP26 AND AP27

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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COPCs and may be sufficient to rapidly reduce these compounds to Tier 1 cleanup criteria.

Recovered groundwater would be treated using skid-mounted carbon cannisters with an aeration pretreatment unit to oxidize and remove ferrous iron and prevent carbon fouling. Treated groundwater would be discharged directly to the sanitary sewer. Following 2 weeks of dewatering, the pit would be backfilled, compacted, and then resurfaced with asphalt. A 4-inch-diameter monitoring well would be installed in the center of each excavation area to facilitate future source area groundwater sampling.

9.3 REVIEW OF SCREENING AND EVALUATION CRITERIA

The evaluation criteria used to identify appropriate remedial alternatives for soil and groundwater contamination at Site SS-15A were adapted from those recommended by USEPA (1988) for selecting remedial actions for Superfund sites [Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-01]. These criteria include 1) anticipated effectiveness in meeting target cleanup criteria, 2) technical and administrative implementability, and 3) relative cost. An initial screening of remedial technologies was conducted using the three broad evaluation criteria (Appendix H). The following sections briefly describe the scope and purpose of each criterion.

9.3.1 Effectiveness

Each remedial approach or remedial alternative (which can be a combination of remedial technologies) was evaluated to determine how effectively it can attain the desired degree of cleanup. Remedial approaches that could not cost-effectively attain the desired level of remediation were eliminated from further consideration. The candidate alternatives were designed to attain Tier 1 groundwater TCLs for all of Site SS-15A and Tier 2 SSTLs for the FANG Area. Section 7 provides the rationale for and development of the SSTLs for the FANG Area, given the current and planned future land uses and the potential for receptor exposures to site-related contamination.

Remedial options retained for detailed evaluation are compared in terms of the expected effectiveness of each option to attain the desired degree of risk reduction at Site SS-15A, based on site-specific data supplemented with treatability test data collected at the site. The ability to minimize potentially adverse impacts on surrounding facilities and operations and other environmental resources is considered. Time to implementation and time until protection is achieved are described. Potentially adverse impacts that could be realized during implementation, the cost of necessary mitigation measures, and the potential for residual risks remaining following remedial action also are qualitatively considered. Long-term reliability for providing continued protection, including an assessment of potential for failure of the technology and the potential threats resulting from such a failure, also is evaluated.

9.3.2 Implementability

The technical feasibility, applicability, and reliability of each remedial approach were initially used as broad criteria to narrow the list of potentially applicable remedial approaches for the site. Technologies retained for detailed evaluation were evaluated in terms of engineering implementation, reliability, constructability, and technical/ logistical feasibility. Potential effects due to unanticipated site conditions or significant changes in site conditions were considered. The ability to monitor performance and public perception are discussed. Any prohibition of onsite activities that would be required to ensure successful implementation is described.

9.3.3 Cost

Relative cost of various remedial technologies was used as an initial screening tool (Appendix H). More detailed cost estimates were prepared for each remedial alternative developed for comparative analysis. The cost includes operation and maintenance costs over the time required for implementation. Present-worth cost estimates were prepared using a 7 percent annual adjustment factor in accordance with USEPA (1993) guidance.

9.4 DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

In this section, each of the candidate alternatives is evaluated using the criteria described in the previous section. Each alternative is more fully described in terms of its effectiveness, technical and administrative implementability, and cost.

9.4.1 Alternative 1 - Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

9.4.1.1 Effectiveness

Modeling results presented in Section 6 indicate that contaminant concentrations in soil and groundwater will decrease over time through both destructive and nondestructive attenuation processes. Natural chemical attenuation processes should be sufficient to reduce all dissolved COPCs to the Tier 1 TCLs and SSTLs by approximately year 2024. The assimilative capacity of the saturated media and the site-specific biodegradation rates will be sufficient to eventually transform fuel hydrocarbon compounds into carbon dioxide and water and to limit migration of the plume. It should be noted that the hydrogeology of the site also is responsible for the containment of the plume at the site. The very low horizontal hydraulic gradient at the site is preventing contaminants from migrating appreciable distances from the source area before they are attenuated.

Contaminant mass will slowly partition from residual LNAPL and dissolve into groundwater. However, the effects of biodegradation should cause the source to diminish significantly more rapidly than indicated by the batch-flushing model. When these two source reduction processes (leaching and biodegradation) are combined in the analytical model for the site, the maximum dissolved benzene and benzo(a)pyrene concentrations are predicted to decrease below the Tier 1 benzene TCL and the benzo(a)pyrene TCL within 6 years and 27 years, respectively. The downgradient migration of the dissolved contamination is predicted to be minimal (less than 50 feet

from the source area). LTM data would be used to better define contaminant half-lives and refine estimates for when Tier 1 TCLs would be uniformly attained.

Groundwater use controls are an important component of this alternative. The current restrictions on site access (Base perimeter fencing and fencing around the FANG area) provide a measure of protection against unauthorized site access and groundwater contact. The asphalt and concrete pavement that covers the site also limits the potential for onsite personnel exposure to contamination. The present industrial/uninhabited land use and nonuse of groundwater have effectively interrupted potential exposure pathways involving soil and groundwater at this site. As a part of this CAP, the Air Force proposes well permit restrictions to prevent withdrawal of groundwater from the shallow aquifer for drinking water applications within 500 feet of Site SS-15A until such time as the groundwater COPCs decrease below applicable Tier 1 criteria. Deed restrictions should also contain language requiring that any intrusive excavations below the current asphalt/concrete apron be completed with protective clothing and air monitoring in accordance with Occupational Safety and Health Administration (OSHA) standards. In general, excavation in the area of contaminated shallow groundwater also should be limited to prevent excessive incidental contact with contamination. These institutional controls should be a component of any future land use change or property exchange until such time as unrestricted Tier 1 TCLs have been achieved. This strategy will not interfere with the current or intended use of the site and affected physical media. In the unlikely event that the site is rezoned for unrestricted residential use within the next 27 years, groundwater use restrictions must be kept in place and enforced until such time as COPCs have been reduced to concentrations equal to or below unrestricted use (Tier 1) TCLs at every point.

Long-term groundwater monitoring is recommended under Alternative 1 as a method of measuring the effectiveness of natural chemical attenuation. The groundwater monitoring network would consist of existing and proposed groundwater monitoring

wells that would be sampled biennially for all COPCs. A sufficient historical groundwater quality database exists to demonstrate that the dissolved contaminant concentrations are not increasing, and hydrogeologic information and fate and transport modeling results indicate that plume migration will be minimal. Therefore, more frequent sampling is not required to monitor temporal changes in plume magnitude and extent. Sampling details are presented in the LTM plan presented in Section 10. Once Tier I TCLs are attained, 2 years of annual verification sampling is proposed to verify no adverse change in plume conditions before requesting regulatory approval for a Tier 2 closure (NFA with conditions).

For the purpose of cost estimation, groundwater sampling at AP26 and AP27 was assumed to occur biennially (every other year) for the first 27 years (i.e., from 1997 to 2024) and every year for the next 2 years (i.e., until 2026) to verify attainment of Tier 1 TCLs for all targeted analytes before requesting approval for a NFA with conditions site closure. Sampling of selected additional wells at other apron lines also was assumed to occur biennially to monitor reduction of COPC concentrations over time across the site.

A complete LTM plan is provided in Section 10 to assist the Base in implementing long-term groundwater monitoring. Parsons ES has been retained to complete the first year of groundwater monitoring at Site SS-15A. Data from each sampling event should be compared to model predictions to ensure that natural attenuation is preventing the contaminant plume from spreading further than was predicted by the model. In the event that remediation is not progressing as expected and/or the dissolved plume is migrating further or faster than expected, the following contingency actions are recommended:

- Resample selected monitoring wells to confirm initial results;

- Evaluate the results of the most recent groundwater sampling event to determine if there is a trend indicating more rapid contaminant migration due to a lack of natural attenuation or misinterpretation of site hydrogeology;

- Determine if the levels of groundwater contamination present an unacceptable risk to potential receptors given actual site and downgradient land use at the time of sampling (i.e., are exposure pathways complete?); and

- If a significant risk exists, reevaluate more active methods of remediation and implement the most effective risk-reduction method (e.g., the active remediation methods described for Alternatives 2 or 3).

9.4.1.2 Technical and Administrative Implementability

Alternative 1 is technically simple and easy to implement. Several existing wells are far enough downgradient to serve as sentry wells. Long-term groundwater sampling is a standard procedure involving minimal worker exposure to contaminated media.

Administrative implementation of this alternative would require that the Air Force clearly communicate plans regarding the future use of the Base and specifically Site SS-15A to the public, FDEP, and DERM. Any proposed change in land use that differs from industrial use, or any proposed groundwater pumping within 1,000 feet of the leading edge of the current contaminated areas, should be carefully evaluated. The existing access restrictions also should be maintained to prevent unauthorized access. Deed restrictions should also contain language requiring that any intrusive excavations below the current asphalt/concrete apron be completed with protective clothing and air monitoring in accordance with Occupational Safety and Health Administration (OSHA) standards. Any future construction or maintenance activities in this area should be planned to minimize excavations which extend into the groundwater until conservative Tier 1 TCLs have been achieved. Steps should be taken to protect the network of LTM wells. Wells should remain locked and protected against tampering or vandalism.

Public perception of Alternative 1 could be somewhat negative. This alternative should be adequately protective of human and ecological receptors if current institutional controls are maintained after land transfers. Although no unacceptable risk exists at this site, contaminant concentrations that exceed Tier 1 TCLs for groundwater would potentially persist onsite for a lengthy period of time. It is anticipated that public reaction to allowing contaminants in excess of Tier 1 TCLs to persist onsite with minimal engineered remediation may not be positive. To counteract potentially negative public opinion, public education would be a prominent part of this alternative and would focus on the site-specific risk analysis and cost savings. Human risk can be mitigated through institutional controls, and COPC reductions that are compatible with existing and future land uses would be achieved at minimum taxpayer expense. Routine LTM would provide verification of natural attenuation and ensure that site conditions do not change adversely over time.

9.4.1.3 Cost

The costs associated with Alternative 1 are presented in Table 9.1. Detailed cost calculations are presented in Appendix H. Annual or periodic costs would include groundwater monitoring and site management (to be provided by the Air Force and/or the property lessee), which would include evaluation of annual monitoring data, continued liaison with FDEP, DERM, and the public, and participation in future land use planning. Based on the conservative assumption that 27 years of natural chemical attenuation with 14 biennial LTM sampling events at AP26 and AP27 (i.e., 1998 to 2024, every other year) followed by 2 years of verification sampling would be required to achieve Tier 1 TCLs, the present-worth cost of Alternative 1 is estimated to be $184,913. The cost also includes 10 years of biennial monitoring of selected wells at other apron lines.

TABLE 9.1
COST ESTIMATE FOR CORRECTIVE ACTION ALTERNATIVE 1
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD ARB, FLORIDA

Implementation Tasks	Present Worth Cost[a/]
Groundwater sampling at 7 locations at AP26 and AP27 (Bienially for 27 years, then annually for 2 years)	$81,764
Groundwater sampling at 5 locations at other apron lines (Bienially for 10 years)	$29,483
Site Management (29 years)	$73,666
Present Worth of Proposed Corrective Action[b/]	**$184,913**

[a/] Sampling costs assume sampling performed by local, Miami-area personnel.

[b/] Based on an annual discount rate of 7 percent.

9.4.2 Alternative 2 - *In Situ* Bioventing in Source Area, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

9.4.2.1 Effectiveness

Bioventing would be implemented as the source area soil remediation technology for the immediate vicinities of AP26 valve box 1 and the northwestern end of AP27; at least one Tier 1 TCL for groundwater was exceeded at each of these locations. Based on the results of the pilot-scale bioventing test already performed at Site SS-15A, bioventing will efficiently remediate fuel-related contamination in unsaturated soils and reduce the overall mass of COPCs entering the groundwater. During periods of low groundwater elevation, LNAPL smeared in the soil will be more available for air (oxygen) contact and enhanced biodegradation. As with remedial Alternative 1, natural chemical attenuation would be the only remedial approach prescribed for dissolved contamination in groundwater at Site SS-15A under this alternative.

The anticipated impact of bioventing on reducing contaminant loading to groundwater from contaminated soils was incorporated into the analytical BIOSCREEN model by decreasing the benzene and benzo(a)pyrene source half-lives relative to the half-lives used in the Alternative 1 simulations. The half-lives used to simulate the effects of Alternative 2 are compared to those used for Alternative 1 in Table 9.2. For benzene, the estimated half-life due to flushing (leaching) of benzene from the aquifer matrix was combined with half-lives associated with aerobic and anaerobic biodegradation of this compound. It was assumed that aerobic and anaerobic conditions would each prevail for 6 months per year during bioventing system operation. For benzo(a)pyrene, the anaerobic and aerobic decay rates were estimated based on information provided by Howard (1991). The flushing rate was assumed to be negligible due to the relative insolubility of this compound.

The analytical model predicts that, if bioventing is implemented, dissolved benzo(a)pyrene concentrations would decrease below 0.2 µg/L (the Tier 1 TCL and

TABLE 9.2
SIMULATED SOURCE DECAY RATES FOR BIOSCREEN MODELING
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD ARB, FLORIDA

	Benzene		Benzo(a)Pyrene	
	Rate (day^{-1})	Half-Life (years)	Rate (day^{-1})	Half-Life (years)
Remedial Alternative 1				
Flushing Rate[a/]	0.00033	5.8	negligible	--
Anaerobic Decay Rate[b/]	0.0025	0.8	0.00033	5.8
Remedial Alternative 2				
Flushing Rate[a/]	0.00033	5.8	negligible	--
Anaerobic Decay Rate[c/]	0.0012	1.6	0.00033	5.8
Aerobic Decay Rate[d/]	0.0041	0.5	0.0013	1.45

[a/] From batch flushing model described in Section 6.6.1.

[b/] For benzene, the rate is the average solute decay rate derived from site-specific data; for benzo(a)pyrene, the rate is from Howard (1991).

[c/] Rate is equivalent to one-half the average anaerobic decay rate used in Alternative 1. The anaerobic rate was halved because it was assumed that the bioventing system would only be effective 6 months per year, and the anaerobic conditions would prevail the remaining 6 months.

[d/] Benzene rate is based on the assumption that 90% of the benzene is degraded after two years of bioventing system operation. Benzo(a)pyrene rate is from Howard (1991).

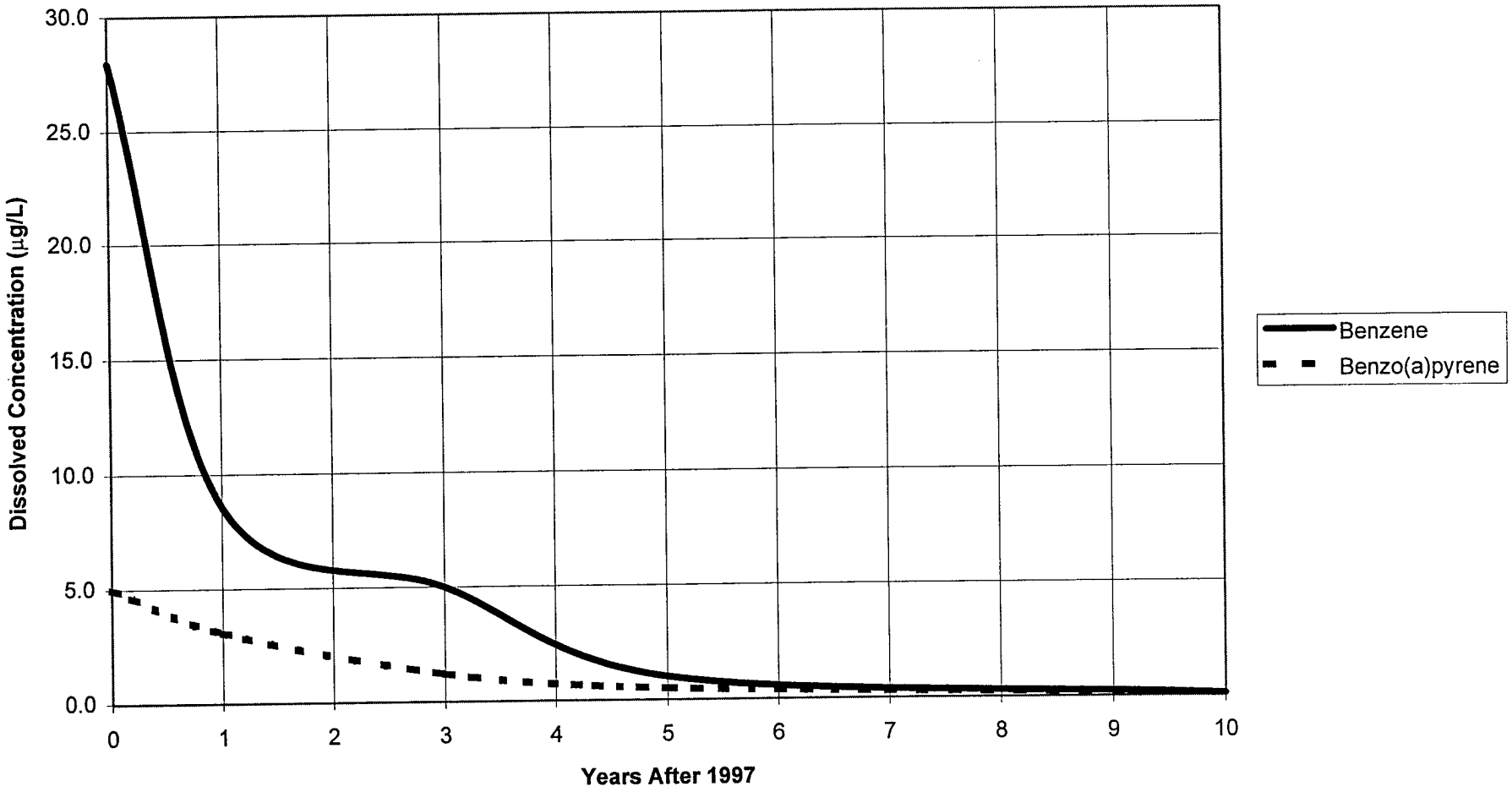
Tier 2 SSTL) within 7 years, compared to 27 years for Remedial Alternative 1 (Figure 9.2). The predicted migration distance of benzo(a)pyrene from the source area is negligible due to the extremely high retardation coefficient computed for this compound. Conversely, the model predicts that bioventing would not significantly decrease the time required for the maximum dissolved benzene concentration to decrease below the Tier 1 TCL of 1 μg/L (the projected time frame is 5 years, compared with 6 years for Alternative 1. This is because the limiting factor for benzene is the solute decay rate and not the source decay rate. Although the benzene source decay rate is more rapid in Alternative 2, the model predicts that dissolved benzene concentrations that have migrated downgradient from the source area will degrade at the same rate as in Alternative 1, and the decrease in these dissolved concentrations (controlled by the solute decay rate) will control the time required to achieve the Tier 1 TCL. The total volume of groundwater that could be impacted by the releases at Site SS-15A would not be significantly different under this alternative than would be expected if no engineered source reduction activities were conducted at this site.

The groundwater use controls for this alternative would be identical to those described for Alternative 1. The installation and operation of the bioventing system would require additional site access. The long-term groundwater monitoring proposed for Alternative 2 would be identical to Alternative 1. The bioventing system would require system maintenance checks every other week and annual respiration and oxygen influence testing to ensure proper operation and monitor remediation. Bioventing systems are relatively simple and require minimal maintenance during their operation.

9.4.2.2 Technical and Administrative Implementability

Implementation of bioventing would require the conversion of one existing groundwater monitoring well at each of the AP26 and AP27 source areas to air injection VWs. The VWs would be manifolded using underground air lines to a blower

FIGURE 9.2
SIMULATED TEMPORAL VARIATIONS IN DISSOLVED BENZENE AND BENZO(a)PYRENE CONCENTRATIONS--ALTERNATIVE 2
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA



alt2grph.xls

system located along the edge of the apron. The groundwater monitoring well conversions and installation of the bioventing system would not be technically difficult and would utilize standard construction techniques. One blower would be installed between AP26 and AP27 to supply approximately 5 standard cubic feet per minute (scfm) of air to each VW. Electrical service would be brought to the blower system from a source alongside the apron area. Electrical conductors likely would be buried to avoid interference with vehicular traffic and avoid the use of power poles which could possibly violate future height restrictions for the flightline area.

The general reliability and maintainability of bioventing systems is high. The bearings on the blower motor are sealed and do not require lubrication. In-line air filters and automatic pressure relief valves provide protection for the air injection blower. Filters generally require replacement after every 90 to 180 days of operation. It is estimated that the bioventing system for the AP26 and AP27 areas would operate for a maximum of 7 years to achieve Tier 1 TCLs for groundwater at all apron lines.

Administrative implementation of this alternative would be similar to that described for Alternative 1, and would require that Homestead AFB personnel communicate with the public and FDEP regarding the future use of the site (i.e., continued industrial use). Appropriate land use deed restrictions must be enforced to prevent unnecessary exposure of humans to contaminated soil and groundwater. Access to the site should continue to be restricted by the Base and FANG perimeter fences. Any future site development plans should protect the bioventing system, the VWs associated with the system, and the underground pipe manifolds and electrical utilities. Wells and the blower system enclosure should remain locked and protected against damage.

The public perception of Alternative 2 would be expected to be more positive than that of Alternative 1. This alternative could reduce all COPC concentrations to below Tier 1 TCLs and SSTLs relatively rapidly. Bioventing is expected to expedite the attenuation of dissolved contamination downgradient from the source area because less

contaminant mass will be added to groundwater over time. The primary advantage of Alternative 2 is that it would expedite attainment of both the Tier 1 groundwater TCLs and SSTLs at AP26 and AP27. LTM would verify the effectiveness of the implemented remedy, better define the time required for bioventing system operation, and ensure that site conditions do not change adversely over time.

9.4.2.3 Cost

The costs associated with Alternative 2 are presented in Table 9.3. Detailed cost calculations are presented in Appendix H. Annual or periodic costs would include operation and maintenance of the bioventing system for 7 years, groundwater monitoring, and site management (to be provided by the Air Force and/or the property lessee), which would include evaluation of annual monitoring data, continued liaison with FDEP, DERM, and the public, and participation in future land use planning. Based on the assumption that 7 years of natural chemical attenuation with 7 annual LTM sampling events (i.e., 1998 to 2004) followed by 2 years of annual verification sampling would be required to confirm attainment of Tier 1 TCLs and SSTLs, the present-worth cost of Alternative 2 is estimated to be $271,927.

9.4.3 Alternative 3 - Source Area Soil Excavation, Short-Term Groundwater Extraction/Treatment, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

9.4.3.1 Effectiveness

This alternative is identical to Alternative 1, with the addition of soil "hotspot" excavation and limited groundwater extraction in the source areas. The effectiveness of natural attenuation, institutional controls, and LTM is as described in Section 9.3.1. Groundwater extraction and treatment is an established technology for reducing source contamination and controlling plume migration. The goal of soil and groundwater extraction would be to aggressively target the removal of COPCs so that both the Tier 1 TCLs and SSTLs would be achieved more rapidly.

TABLE 9.3
COST ESTIMATE FOR CORRECTIVE ACTION ALTERNATIVE 2
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD ARB, FLORIDA

Implementation Tasks	Present Worth Cost[a/]
Groundwater sampling at 7 locations at AP26 and AP27 (Annually for 9 years)	$73,133
Groundwater sampling at 5 locations at other apron lines (Bienially for 10 years)	$29,483
Bioventing system installation (1998)	$60,148
Bioventing system O&M (7 years)	$57,617
Confirmation soil sampling and final reporting (2005)	$12,455
Site Management (9 years)	$39,091
Present Worth of Proposed Corrective Action[b/]	**$271,927**

[a/] Sampling costs assume sampling performed by local, Miami-area personnel.

[b/] Based on an annual discount rate of 7 percent.

The BIOSCREEN model was not used to simulate the effectiveness of this remedial alternative because simulation of nearly instantaneous removal of the benzo(a)pyrene source mass causes the model to predict that dissolved benzo(a)pyrene concentrations also will be removed instantaneously. In addition, BIOSCREEN does not have the ability to simulate extraction of groundwater and dissolved contaminants via pumping wells. However, it can reasonably be assumed that implementation of this alternative would decrease COPC concentrations in soil and groundwater to below Tier 1 TCLs relatively rapidly compared to Alternatives 1 and 2. Limited "hot spot" excavation would immediately remove the source of contamination and achieve Tier 1 soil TCLs and soil SSTLs. The influx of clean groundwater resulting from pumping would accelerate the partitioning of COPCs from saturated soils. Once the source of long-term leaching is removed, any dissolved COPCs that are not removed by pumping should degrade rapidly. Therefore, these actions could potentially decrease the time frame required to attain Tier 1 groundwater TCLs and SSTLs from a maximum of 7 years for Alternative 2 to less than 3 years.

There is a greater risk of exposure to fuel hydrocarbons to remediation workers during excavation of the contaminated soils. Therefore, this alternative would require enforcement of health and safety plans to reduce short-term risks from exposure to contaminated soils and shallow groundwater.

Extracted groundwater would likely require treatment prior to discharge. Activated carbon treatment is a standard process that should adequately remove dissolved contaminants and allow discharge of the treated water into the sanitary sewer. Alternative 3 should provide reliable, continuous protection with little risk from temporary system failures. However, this remedial alternative will result in the generation of wastes (pavement, soil, and groundwater) that will require transportation and treatment and/or disposal. This alternative does not comply with program goals to

the extent that the other two alternatives do due to the generation of an estimated 500 cubic yards of soil requiring off-Base treatment.

9.4.3.2 Implementability

The implementability considerations described for Alternative 1 in Section 9.3.1.2 also would be applicable to Alternative 3. Soil excavation and installing and operating a groundwater extraction system to reduce source area dissolved COPC concentrations in groundwater could present additional implementability concerns due to the short-term need for increased infrastructure and activity on the flightline apron. Groundwater extraction pumps and carbon canisters are readily available, and the technology used to construct the system is proven and reliable. Discharge of treated water to the Base sanitary sewer system should not present significant implementability problems. Off-Base thermal treatment facilities exist, and transportation of excavated soils to one of these facilities can be readily accomplished. The technical and administrative implementability concerns associated with the natural attenuation and LTM component of this remedial alternative are similar to those discussed for Alternative 1 (Section 6.4.1.2). Operation of a groundwater extraction and treatment system would require a significant commitment of man-hours and other resources to monitor the system during the projected 30-day operational period.

9.4.3.3 Cost

The estimated capital and operating costs of Alternative 3 are shown in Table 9.4. The total present worth cost of Alternative 3 is $195,654. The cost of Alternative 3 is increased from the costs of Alternative 1 by the addition of soil excavation, transport, and treatment and groundwater extraction and treatment. It is assumed that the groundwater extraction and treatment system would operate for 2 weeks at each excavation area. LTM would continue for at least 2 years after system shutdown to ensure that natural attenuation is reducing remaining COPC concentrations below

TABLE 9.4
COST ESTIMATE FOR CORRECTIVE ACTION ALTERNATIVE 3
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD ARB, FLORIDA

Implementation Tasks	Present Worth Cost[a/]
Groundwater sampling at 7 locations at AP26 and AP27 (Annually for 5 years)	$53,504
Groundwater sampling at 5 locations at other apron lines (Bienially for 10 years)	$34,111
Soil Excavation and Treatment (1998)	$46,790
Groundwater Extraction and Treatment (1998)	$32,650
Site Management (6 years)	$28,599
Present Worth of Proposed Corrective Action[b/]	**$195,654**

[a/] Sampling costs assume sampling performed by local, Miami-area personnel.

[b/] Based on an annual discount rate of 7 percent.

cleanup criteria throughout the site and to verify that excessive contamination does not migrate off-site.

9.5 RECOMMENDED ALTERNATIVE

Alternative 3 (Source Area Soil Excavation, Short-Term Groundwater Extraction/ Treatment, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls is recommended for remediation of Site SS-15A based on its expected effectiveness in attaining Tier 1 TCLs and SSTLs developed for the FANG Area, its relative simplicity with respect to technical and administrative implementation, and its relatively low overall cost. Table 9.5 provides a summary of the evaluation process for each alternative.

Implementation of soil excavation and short-term groundwater extraction in the AP26 and AP27 source areas would substantially reduce or eliminate the total mass of contaminants that could be introduced into the groundwater over time in these areas. The influx of clean groundwater resulting from pumping would accelerate the partitioning of COPCs from saturated soils. Once the source of long-term leaching is removed, any dissolved COPCs that are not removed by pumping should degrade rapidly. It is likely that significant concentrations of benzo(a)pyrene in groundwater are limited to the immediate vicinities of the AP26 and AP27 source areas. Therefore, the proposed excavation and pumping should effectively remove a high percentage of benzo(a)pyrene mass from the subsurface.

Groundwater monitoring will be used to verify the effectiveness of Alternative 3 at reducing COPC concentrations in groundwater and to assure that COPCs do not migrate beyond the area under reliable exposure controls. The short-term nature of the soil excavation and groundwater extraction indicates that implementation of this alternative should not affect future land use or operations.

TABLE 9.5
SUMMARY OF REMEDIAL ALTERNATIVE EVALUATION
CORRECTIVE ACTION PLAN
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A, HOMESTEAD ARB, FLORIDA

Remedial Alternative	Effectiveness	Implementability	Present Worth Cost Estimate
Alternative 1			$184,913
-Natural Attenuation -Long-Term Monitoring -Land and Groundwater Use Controls	Contaminant mass, volume, and toxicity will gradually be reduced by natural attenuation alone. 30-day Tier 2 SSTLs will be met in approximately 27 years.	Technically simple and easy to implement. Long-term groundwater monitoring for up to 29 years may be required. Groundwater use restrictions need to be implemented and would not incur any additional land use restriction beyond those currently in place at Site SS-15A. Requires public education.	
Alternative 2			$271,927
-*In Situ* Bioventing in Source Areas -Natural Attenuation -Long-Term Monitoring -Land and Groundwater Use Controls	Similar to Alternative 1, with the addition of bioventing to increase contaminant removal and degradation in the source area. Attainment of 30-day Tier 2 SSTLs in approximately 7 years. Pilot testing indicated bioventing will significantly remove petroleum compounds from unsaturated soils.	Long-term groundwater monitoring for up to 9 years is expected. The bioventing system is expected to operate for 7 years. This system will require weekly monitoring. Groundwater and land use restrictions would be the same as Alternative 1. Positive public perception.	
Alternative 3			$195,654
-Source Area Soil Excavation -Short-term Groundwater Pumping -Natural Attenuation -Long-Term Monitoring -Land and Groundwater Use Controls	Similar to Alternative 1, with the addition of soil excavation and groundwater extraction to readily remove adsorbed dissolved contaminants. 30-day Tier 2 SSTLs may be met in approximately 3 years.	Will result in short-term disruption of a portion of the site, but otherwise readily implementable. Long-term groundwater monitoring for an estimated 5 years will be required. Positive public perception.	

Although Alternative 1 (natural attenuation with monitoring and institutional controls) also would be protective of human health and would result in reduction of COPC concentrations in groundwater, this alternative is not recommended due to the potentially long timeframe (up to 27 years) required to attain the Tier 1 TCL and SSTL for benzo(a)pyrene in groundwater. In addition, the projected cost of Alternative 1 is very similar to that of Alternative 3.

BIOSCREEN model simulations indicate that, similar to Alternative 3, implementation of Alternative 2 (Alternative 1 plus *in situ* bioventing of source areas soils) also would result in rapid attainment of Tier 1 TCLs and SSTLs relative to Alternative 1. However, the projected cost of this alternative is substantially higher than that of Alternative 3, and the projected time to SSTL attainment is approximately double that of Alternative 3. Therefore, implementation of this alternative is not recommended.

On the basis of this evaluation, Alternative 3 provides the best combination of risk reduction and low cost without imposing additional land use restrictions. If, however, the temporary disruption of the site that would result from implementation of Alternative 3 is not acceptable, then Alternative 1 should be considered as a contingency. Section 10 provides additional details on the recommended implementation of this alternative.

SECTION 10

IMPLEMENTATION OF THE RECOMMENDED RISK-BASED CORRECTIVE ACTIONS

This section provides an implementation plan for the recommended risk-based corrective action for Site SS-15A (i.e., Alternative 3: source area soil excavation and short-term groundwater extraction in FANG Area, RNA with LTM and institutional controls in other areas with Tier 1 exceedences). This section presents the scope, schedule, and costs for the implementation of the selected remedial alternative.

10.1 SCOPE OF REMEDIAL ACTIVITIES

The recommended remedial action alternative will be implemented over an estimated 5-year period to ensure that contamination in groundwater at Site SS-15A is reduced sufficiently to attain and maintain the Tier 1 groundwater TCLs presented in Section 5 and SSTLs presented in Section 7. Once groundwater is reduced below Tier 1 TCLs, institutional controls on excavation can be reviewed to determine if they are still required. The following sequence of events is proposed to fully implement this remedial action.

10.1.1 Review and Approval of Corrective Action Plan

Approval of the draft final CAP is within the authority of Homestead AFB, FDEP, DERM, and AFCEE personnel. This group of environmental professionals has been briefed on the CAP contents by Parsons ES and the Air Force and completed a review of the draft final CAP. Their comments have been incorporated into this final CAP. This document will be distributed to each of the above organizations for final approval of the CAP. Following final approval, the Air Force intends to proceed with a design

of the proposed excavation and dewatering and implement the corrective actions described in this section.

10.1.2 Institutional Land and Groundwater Use Controls

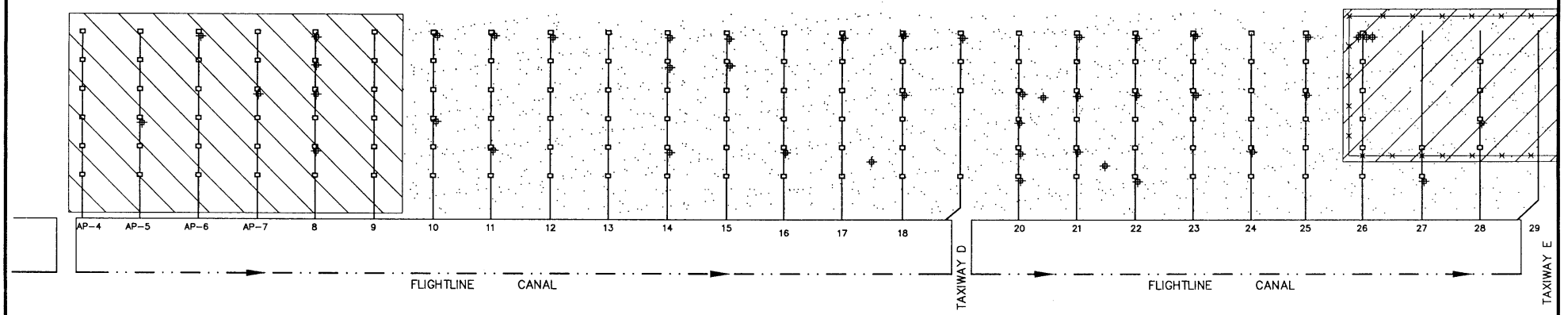
An important element of the recommended corrective action at Site SS-15A is land and groundwater use controls. Figure 10.1 illustrates three areas of Site SS-15A which require separate consideration when applying institutional controls. The first area encompasses apron fuel lines AP-4 through AP-9. Soil and groundwater sampling in this area has not revealed any Tier 1 exceedences. This area can be transferred with minimal institutional controls which state that the land will be used for general industrial use and any excavation will proceed following routine OSHA excavation standards.

The second area consists of apron lines AP-10 through AP-25 and the southern portions of AP-26 through AP-29. Soil and groundwater sampling in this area has revealed minor Tier 1 exceedences, primarily low levels of BTEX, and PAH compounds which may be associated with the asphalt cap. This area can be transferred from Air Force control with the following institutional controls recommended for the deed or other legal documents:

1. Land use will remain industrial/commercial;

2. Any excavation or removal of asphalt paving will be completed by workers who are wearing protective clothing and gloves in accordance with OSHA Level D requirements. Air monitoring will be conducted to ensure that no hazardous vapors are encountered (they are not expected, this is a precaution);

3. Prolonged contact with groundwater should be avoided until groundwater monitoring indicates that Tier 1 TCLs have been attained in the area.





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LEGEND

APRON FUEL LINE AND VALVE BOXES

SOIL BOREHOLE

No exceedances of Tier 1 target cleanup levels; recomended for no further action without conditions

Scattered exceedances of Tier 1 target cleanup levels; recomended for no further action with conditions

Active Base area to remain under Florida Air National Guard control.

FIGURE 10.1

INSTITUTIONAL CONTROL AREAS BASED ON TIER 1 EXCEEDANCES

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

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The third area consists of the active FANG area. Soil and groundwater sampling in this area has revealed consistent Tier 1 and SSTL exceedences. Excavation and short-term groundwater extraction have been recommended for two "hot spots" within the FANG area. This remedial action will ensure that future intrusive workers in this area are not exposed to contaminants at levels above protective SSTLs. The remedial actions are expected to also reduce contaminants below Tier 1 TCLs. Until such time as LTM verifies that Tier 1 TCLs have been achieved, institutional controls (1-3 above) should also be enforced for the FANG area. It is recommended that access to the site continue to be restricted. This action will prohibit unauthorized site access and unplanned ground disturbance.

The site cleanup objectives also are based on the assumption that future land use will not require extraction of shallow site groundwater for potable uses. Any future lease or new use of this property (or surrounding property) should stipulate that shallow groundwater will not be extracted within 500 feet of the site until COPC concentrations have been reduced below applicable concentrations.

10.1.3 Implementation of Long-Term Groundwater Monitoring

Section 10.2 of this CAP provides a complete LTM plan for Site SS-15A. Long-term groundwater monitoring is being proposed to verify that engineered source reduction technologies and natural chemical attenuation processes are sufficient to achieve the desired degree of remediation (i.e., to protect potential receptors). Careful implementation of the LTM plan is a key component of this CAP. The proposed remedial alternative for this site calls for groundwater sampling on an annual basis until Tier 1 groundwater TCLs are attained at every sampling location. Additionally, 2 years of verification sampling will be performed after TCLs are attained to confirm that dissolved contaminant concentrations are continuing to diminish. Wells will be purged in accordance with the SAP presented in Appendix F, and then sampled for groundwater COPCs and geochemical indicators of biodegradation.

Groundwater monitoring is recommended to begin in 1998 upon approval of the final CAP. Annual sampling is considered appropriate to monitor the relatively rapid reductions in groundwater contaminant concentrations that are expected to occur following excavation and groundwater extraction. Results of each groundwater sampling event should be provided to Homestead AFB, FDEP, DERM, and AFCEE to update all parties involved on remediation progress and to provide new information for pending land use decisions, as necessary.

10.1.4 Soil Excavation and Groundwater Extraction

As discussed in Section 9.1.3, an estimated 250 cubic yards of contaminated soil will be removed from each of the AP26 and AP27 source areas as part of the implementation of this alternative. Excavation of soils will be performed with a backhoe. It is anticipated that the excavations will be approximately 30 feet wide by 30 feet long by 8 feet deep. The actual extents of the two excavations will be determined in the field based on field headspace screening of grab samples collected from the sides and bottoms of the excavations. Confirmation soil samples will be submitted to a fixed-base laboratory for analysis of COPCs. A dewatering pump will be used as needed to remove groundwater that enters the excavation. Excavation will continue until all apparent contamination has been removed. Excavated soils will be placed on plastic sheeting on the flightline apron and allowed to drain, then transported to an off-Base thermal treatment facility for disposal. After soil removal, the dewatering system will continue to be operated for an estimated 2 weeks, 8 hours per day to remove dissolved COPCs. Extracted water will be treated in an aeration pretreatment unit followed by activated carbon filtration, and then discharged to the sanitary sewer. Samples of the extracted water will be analyzed at a fixed-base laboratory to confirm that COPC concentrations have been adequately reduced by the pumping.

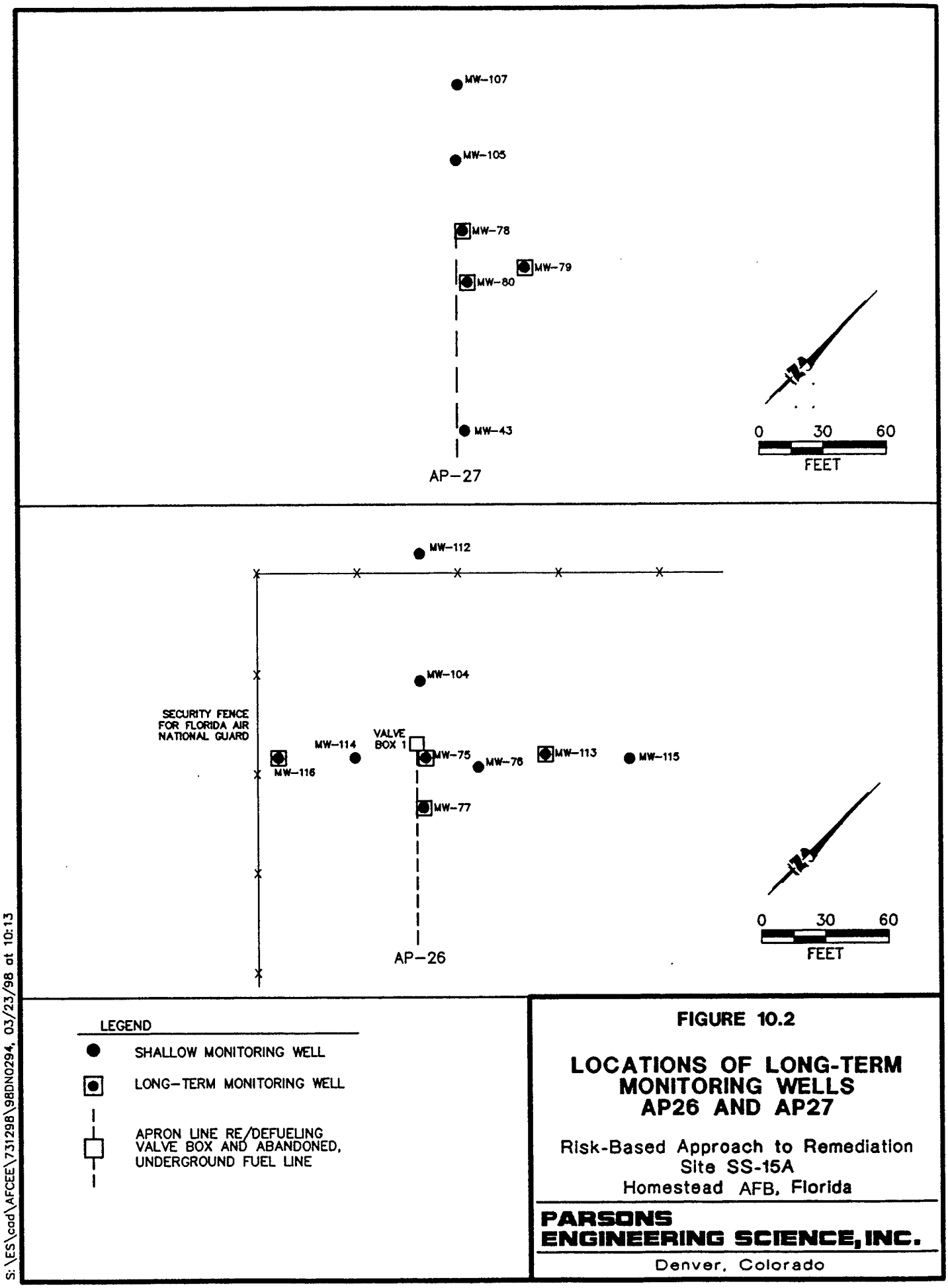
10.2 LONG-TERM MONITORING PLAN

The purpose of the LTM plan is to confirm the effectiveness of proposed engineered remediation and natural processes at achieving the desired level of risk reduction in a reasonable time frame. As part of this monitoring and compliance plan, contaminant behavior in groundwater will be monitored to verify that the proposed corrective action is sufficient to protect groundwater underlying the source area at Site SS-15A and to prevent significant downgradient migration. In the event that data collected under this program indicate that the selected alternative is insufficient to maintain plume stability and eventually achieve Tier 1 groundwater TCLs at Site SS-15A, contingency actions to augment the effects of the proposed corrective action will be evaluated.

10.2.1 Groundwater Monitoring

A total of seven wells will be sampled annually to monitor the fate and transport of COPCs in groundwater at AP26 and AP27 over time. The purpose of the monitoring events is to confirm that engineered remediation and natural chemical attenuation processes are reducing COPC concentrations and limiting mobility. These wells are located within and near the AP26 and AP27 source areas to ensure that implemented remedial actions and natural chemical attenuation processes are sufficient to eventually attain SSTLs and Tier 1 TCLs, and to minimize COPC transport in groundwater. The locations of all wells to be used for LTM at AP26 and AP27 are illustrated on Figure 10.2.

Source area wells AP26-MW75 and AP27-MW78 will be destroyed during the soil excavations. However, replacement wells will be installed in the excavation areas, and will serve as source area groundwater monitoring stations over time. In addition, wells AP26-MW113, AP26-MW77, and AP26-MW116 will act as sentry wells at AP26, and will be sampled to confirm that excessive migration of dissolved COPCs is not occurring. Wells AP27-MW79 and AP27-MW80 will act as sentry wells at AP27. If enlargement of the excavation areas necessitates the destruction of wells AP26-MW77



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FIGURE 10.2

LOCATIONS OF LONG-TERM MONITORING WELLS AP26 AND AP27

Risk-Based Approach to Remediation
Site SS-15A
Homestead AFB, Florida

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and AP27-MW80, then two new sentry wells should be installed near the fuel pipelines approximately 50 feet southeast of the source areas.

Biennial (every other year) sampling of seven additional wells scattered across Site SS-15A also is recommended to monitor temporal reductions in dissolved COPC concentrations over time. Dissolved COPC concentrations in these wells slightly exceed Tier 1 TCLs, which represent the long-term cleanup goals for the site. This monitoring will allow assessment of how rapidly natural physical and chemical attenuation processes are reducing dissolved COPC concentrations to below Tier 1 TCLs. The wells proposed for sampling include AP23-MW67 (elevated MTBE and naphthalene concentrations), AP16-MW39 and AP12-MW24 (elevated benzene concentrations), AP11-MW14 (elevated ethylbenzene, naphthalene, and TRPH concentrations, AP15-MW37 and AP17-MW40 (elevated benzene and vinyl chloride), and AP10-MW9 (elevated benzene and ethylbenzene concentrations).

The seven source area and sentry wells at AP26 and AP27 will be monitored for parameters listed in Table 10.1. Historical groundwater quality data, together with the aggressive removal of soil and contaminated groundwater, indicate that it is unlikely that site-related COPCs in excess of even the most stringent Tier 1 TCLs ever will be measured at the sentry wells. The detection of COPC contamination at concentrations exceeding Tier 1 criteria in any of the sentry wells will trigger the need to evaluate contingency actions. These actions could include resampling of sentry wells to confirm the presence of contaminants in excess of the Tier 1 target concentrations, and/or installing new sentry wells further downgradient from the source areas.

In addition to the geochemical parameters listed in Table 10.1, the seven additional LTM wells at apron lines AP23, AP15, AP16, AP17, AP12, AP11, and AP10 will be monitored for the constituents that have historically exceeded Tier 1 TCLs. These constituents are as follows:

TABLE 10.1

GROUNDWATER MONITORING ANALYTICAL PROTOCOL
CORRECTIVE ACTION PLAN
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A, HOMESTEAD AFB, FL

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Site -Specific Water MDL	Water Reporting Limit	Field or Fixed-Base Laboratory
Volatile hydrocarbons (BTEX, MTBE, Vinyl Chloride)	SW8260B (Gas Chromatography/ Mass Spectrometry method) or SW8021B (GC method)	As described in latest version of *Test Methods for Evaluating Solid Waste* (EPA SW-846)	BTEX compounds, MTBE and vinyl chloride have been identified as either groundwater COPCs or compounds that can affect biodegradation of groundwater COPCs	Every year at AP26 and AP27; every other year at other locations	Collect water samples in a 40 milliliter volatile organic analysis vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	See Appendix F	See Appendix F	Fixed-base
Polycylic aromatic hydrocarbons (PAHs)	SW8310 (HPLC method)	As described in latest version *of Test Methods for Evaluating Solid Waste* (EPA SW-846)	PAH compounds including naphthalene have been identified as a groundwater COPC	Every year at AP26 and AP27; every other year at other locations	Collect water samples in a 1-liter glass container; cool to 4°C	See Table 2.1 and Appendix F	See Table 2.1 and Appendix F	Fixed-base
Methane	RSKSOP-175 modified to analyze water samples for methane by headspace sampling with dual thermal conductivity and flame ionization detection.	Method published and used by the USEPA Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis)	Every year at AP26 and AP27; every other year at other locations	Collect water samples in a 40 milliliter volatile organic analysis vial with zero headspace; cool to 4°C; add hydrochloric acid to pH ≤2	See Table 2.1	See Table 2.1	Fixed-base
Redox potential	Direct-reading meter (Orion Model 290A with Orion Combination Redox 9678BN probe)	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of ground water influences and is influenced by biologically mediated reactions: can be used as an indicator of the terminal electron acceptor process involved in COPC biodegradation	Every year at AP26 and AP27; every other year at other locations	Measure directly using a flow-through cell with probe portals. Probe should be standardized against Zobel solution	NA[a]	0.0 pe units	Field

TABLE 10.1 (Continued)

GROUNDWATER MONITORING ANALYTICAL PROTOCOL
CORRECTIVE ACTION PLAN
RISK-BASED APPROACH TO REMEDIATION
SITE ST-27, CHARLESTON AFB, SOUTH CAROLINA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Site Specific Water MDL	Water Reporting Limit	Field or Fixed-Base Laboratory
Dissolved oxygen	Direct-reading meter (YSI Model 50B with YSI 5739 probe)	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	Reduced concentrations of dissolved oxygen indicate that microorganisms are facilitating oxygen reduction to biodegrade COPCs	Every year at AP26 and AP27; every other year at other locations	Measure directly using flow-through cell with probe portals. Probe should be calibrated with zero dissolved oxygen solution	NA	0.5 mg/L	Field
Ferrous iron (Fe^{2+})	Colorimetric HACH 8146	Field only	Elevated ferrous iron concentrations indicate that microorganisms are facilitating ferric iron reduction to biodegrade COPCs	Every year at AP26 and AP27; every other year at other locations	Collect 100 mL of water in a glass container; filter and use 10 mL aliquot for analysis	0.01 mg/L	0.024 mg/L	Field
Sulfate (SO_4^{2-})	Colorimetric HACH 8051	Field only	Reduced concentrations of sulfate indicate that microorganisms are facilitating sulfate reduction to biodegrade COPCs	Every year at AP26 and AP27; every other year at other locations	Collect 100 mL of water in a glass container; filter and use 10 mL aliquot for analysis	0.01 mg/L	0.01 mg/L	Field
Sulfide (S^{-2})	Colorimetric HACH 8131	Field only	Elevated concentrations of sulfide forms indicate that microorganisms are facilitating sulfate reduction to biodegrade COPCs	Every year at AP26 and AP27; every other year at other locations	Collect 100 mL of water in a glass container; filter and use 10 mL aliquot for analysis	NA	NA	Field
Nitrate	E300.0	Use E353.2 as alternate method	Substrate for microbial respiration	Every year at AP26 and AP27; every other year at other locations	Collect 40 mL of water in glass or plastic container. Cool to 4°C; analyze within 48 hours	See Table 2.1	See Table 2.1	Fixed-Base

TABLE 10.1 (Continued)

GROUNDWATER MONITORING ANALYTICAL PROTOCOL
CORRECTIVE ACTION PLAN
RISK-BASED APPROACH TO REMEDIATION
SITE ST-27, CHARLESTON AFB, SOUTH CAROLINA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Site-Specific Water MDL	Water Reporting Limit	Field or Fixed-Base Laboratory
pH	Direct-reading meter (Orion Model 140)	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	Aerobic and anaerobic processes are pH-sensitive	Every year at AP26 and AP27; every other year at other locations	Measure directly using a contained flow-through cell with probe portals. Probe should be calibrated using at least three pH standards	NA	0.00 pH units	Field
Temperature	Direct-reading meter	Field only	Metabolism rates for microorganisms depend on temperature	Every year at AP26 and AP27; every other year at other locations	Measure directly using a contained flow-through cell with probe portals	NA	1.0 °C	Field
Conductivity	Direct-reading meter (Orion Model 140 with Conductivity Cell 014050)	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	General water quality parameter used as a marker to verify that site samples are obtained from the same ground water system	Every year at AP26 and AP27; every other year at other locations	Measure directly using a contained flow-through cell with probe portals. Probe is factory calibrated	NA	0.02 µmhos/cm	Field

NA = not applicable

- AP23-MW67 BTEX, MTBE, and PAHs;
- AP17-MW40 BTEX, PAHs, vinyl chloride;
- AP16-MW39 BTEX and PAHs;
- AP15-MW37 BTEX, vinyl chloride;
- AP12-MW24 BTEX and PAHs;
- AP11-MW14 BTEX, PAHs, and TRPH; and
- AP10-MW9 BTEX and PAHs.

Analytical methods for these targeted parameters are identified in Table 10.1.

10.2.2 Sampling Frequency

Each of the groundwater sampling points at AP26 and AP27 will be sampled every year until all COPC concentrations decrease below SSTLs and Tier 1 TCLs. Attainment of both Tier 1 TCLs and SSTLs is estimated to occur in within approximately 3 years (i.e., by the year 2002, assuming that the source area excavation and pumping activities occur in late 1998). Therefore, three annual sampling events, beginning in 1999, would be performed. The groundwater sampling points at AP23, AP17, AP16, AP15, AP12, AP11, and AP10 will be sampled every other year because temporal changes in dissolved COPC concentrations are not anticipated to be rapid. Historical data should be reviewed to determine at what time of year maximum dissolved contaminant concentrations are typically detected at Site SS-15A (e.g., during high-water periods), and the annual and biennial sampling events should be timed to coincide with these periods. In the event of a hurricane, the groundwater and nearby surface water will be monitored within six months following the storm to assess the impact on this otherwise stable plume.

Sampling results will be evaluated after each event to document reduction of contaminant concentrations and plume stability. Monitoring of all seven wells in the

LTM network at AP26 and AP27 will continue until the site has uniformly attained the Tier 1 TCLs and SSTLs for groundwater. Two years of annual sampling will be performed following attainment of the Tier 1 TCLs to ensure continuing compliance with the approved target concentrations (assumed to occur in 2002 and 2003). Monitoring of the remaining seven LTM wells at other apron lines should continue at least until contaminant reductions below Tier 1 TCLs have been clearly documented.

10.3 CONTINGENCY PLAN

Should engineered remediation and natural chemical attenuation processes fail to achieve and maintain cleanup goals and retard plume migration, there should be no significant impact on the land use plans for the site. No nonindustrial land use has been proposed for Site SS-15A; for the foreseeable future, Site SS-15A will continue to be used as a flightline apron. If cleanup goals are not achieved at Site SS-15A, institutional controls may have to be maintained to ensure that intrusive workers are protected from prolonged contact with impacted media. Nonetheless, even if Tier 1 TCLs are not met at Site SS-15A in the predicted timeframe, the site will still be suitable for intrusive activities so long as OSHA requirements are enforced.

Groundwater extraction is not anticipated at the site as long as alternate potable water supplies exist. In the unlikely event that shallow groundwater from the site must be extracted for potable uses, and applicable Tier 1 TCLs for groundwater have not yet been achieved, the following contingency actions are available:

- The results of groundwater sampling will be evaluated to determine if there is a trend indicating that natural chemical attenuation is not proceeding at the rates predicted in Section 6.

- If onsite groundwater is to be used as a potable water source before natural attenuation processes can achieve Tier 1 TCLs, or if shortening of the remedial timeframe is required, more active methods of remediation will be evaluated.

These more active methods could include excavation of source area soils and localized groundwater pumping at other locations across the site, similar to what is proposed for apron lines AP26 and AP27.

Failure of the proposed soil remediation and ongoing natural chemical attenuation to achieve risk-based cleanup goals will not impact the current or proposed industrial uses of Site SS-15A, unless groundwater must be extracted for long-term potable use or the land use changes to residential. Both of these scenarios are highly unlikely. Because low groundwater velocity at the site, multidirectional flow, and natural chemical attenuation processes have been shown to be effective in minimizing migration, no detectable levels of COPCs are expected to migrate to the Flightline Canal, which represents the nearest current groundwater discharge point.

10.4 IMPLEMENTATION SCHEDULE

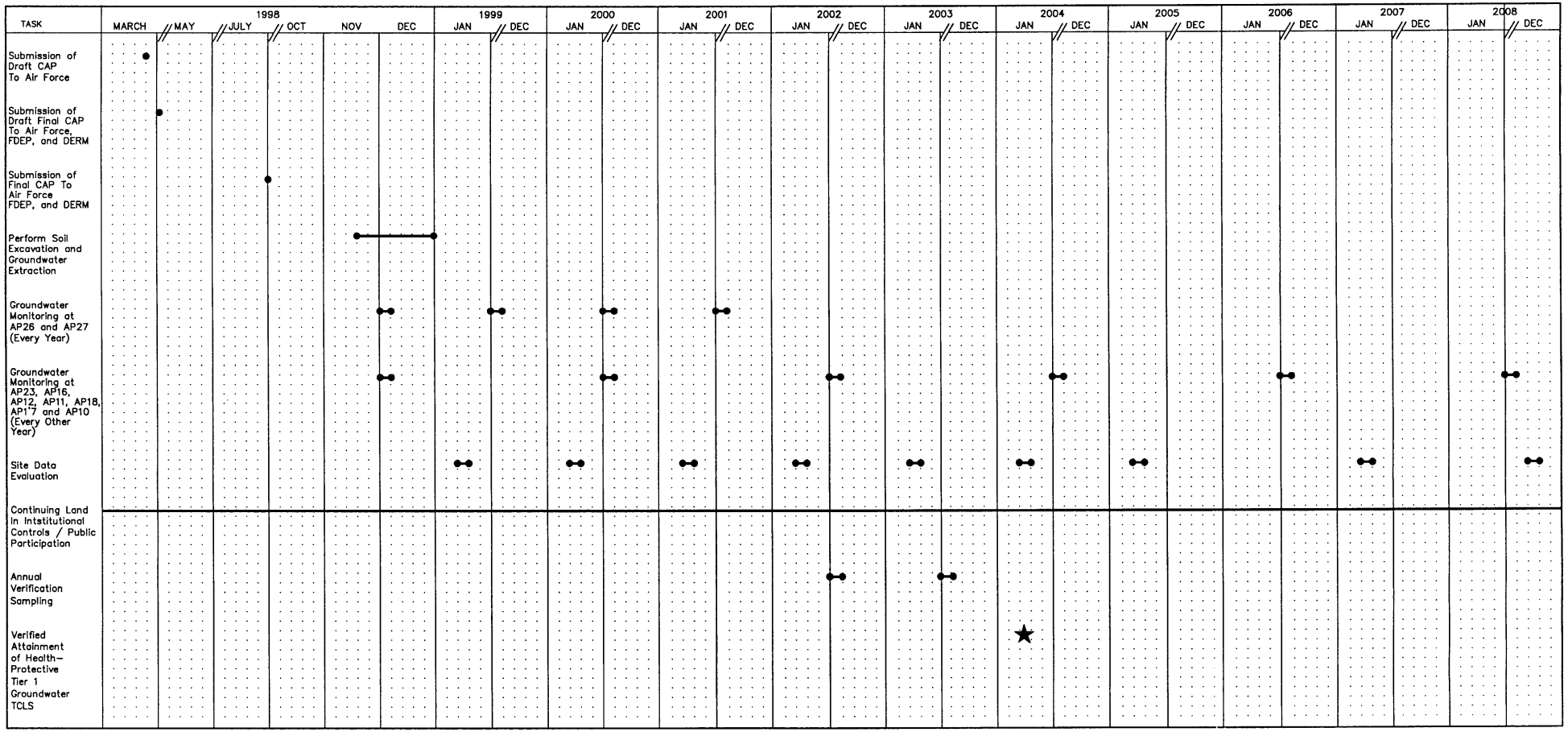
Figure 10.3 is a proposed schedule for implementation of the CAP at Site SS-15A. The schedule is provided for planning purposes only, and is subject to timely approval of the CAP by the Air Force and regulators.

10.5 COST OF IMPLEMENTATION

A summary of the estimated present-worth cost of implementing the recommended remedial alternative is provided in Section 9.3.3.3. Table 10.2 provides a cost estimate, based on estimated expenditures during the next 5 fiscal years, to assist the Air Force in budgeting for implementation of the recommended Site SS-15A corrective actions. The present worth of implementing Alternative 3 is $195,654. It is estimated that it will take about 3 years to attain Tier 1 TCLs and SSTLs in groundwater under Alternative 3. Verification of continuing compliance will require an additional 2 years, for a total projected compliance timeframe of 5 years (i.e., 1998 until 2003).

FIGURE 10.3

IMPLEMENTATION OF PROPOSED ACTIONS
SITE SS-15A, HOMESTEAD ARB, FLORIDA



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TABLE 10.2
ALTERNATIVE 3 IMPLEMENTATION
ESTIMATED COST BY FISCAL YEAR [a/]
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Task	FY99	FY2000	FY2001	FY2002	FY2003
Soil Excavation and Groundwater Pumping	$79,440				
Groundwater Sampling in Accordance with LTM Plan	$18,406[b/]	$12,011	$21,074	$13,752	$24,128
Site Management	$6,000	$6,420	$6,869	$7,350	$7,864
FISCAL YEAR TOTALS	**$103,846**	**$18,431**	**$27,943**	**$21,102**	**$31,992**

a/ Assumes a 7-percent annual inflation rate (USEPA, 1993).
b/ Currently funded under Parsons ES contract with AFCEE.

SECTION 11

REFERENCES

Abdul, S.A., Gibson, T.L., and Rai, D.N., 1987. Statistical correlations for predicting the partition coefficient for nonpolar organic contaminants between aquifer organic carbon and water, *Hazardous Waste and Hazardous Materials*, vol. 4, no. 3, p. 211-222.

Altenschmidt, U. and Fuchs, G., 1991. Anaerobic degradation of toluene in denitrifying *Pseudomonas* sp.: Indication for toluene methylhydroxylation and benzoyl-CoA as central aromatic intermediate, *Arch. Microbial.*, vol. 156, p. 152-158.

Alvarez, P.J.J., and Vogel, T.M., 1991. Substrate interactions of benzene, toluene, and para-xylene during microbial degradation by pure cultures and mixed culture aquifer slurries, *Applied and Environmental Microbiology*, vol. 57, p. 2981-2985.

Aronson and Howard. 1997. Anaerobic Biodegradation of Organic Chemicals in Groundwater: A summary of Field and Laboratory Studies. Prepared for American Petroleum Institute. August.

Arthur D. Little, Inc., 1987. *The Installation Restoration Program Toxicolgy Guide.* vol. 3. p. 64-7 - 64-14. June.

Atlas, R.M., 1981. Microbial degradation of petroleum hydrocarbons - an environmental perspective: *Microbiological Reviews*, vol. 45, no. 1, p. 180-209.

Atlas, R.M., 1984. *Petroleum Microbiology,* Macmillan Publishing Company, New York.

Atlas, R.M., 1988. *Microbiology - Fundamentals and Applications,* Macmillan Publishing Company, New York.

Baedecker, M.J., Siegel, D.I., Bennett, P.C., Cozzarelli, I.M., 1988. The fate and effects of crude oil in a shallow aquifer: I. The distribution of chemical species and geochemical facies, In: G.E. Mallard, and SE. Ragone, editors, U.S. Geological Survey Toxic Substances Hydrology Program, *Proceedings of the Technical Meeting,* Phoenix, Arizona, September 26-30, 1988: U.S. Geological Survey Water-Resources Investigations Report 88-42320, p. 29-22.

Baedecker, M.J., and Cozzarelli, I.M., 1991. Geochemical modeling of organic degradation reactions in an Aquifer contaminated with Crude Oil, U.S. Geological Survey Water-Resources Investigations Report 91-4034,Reston, VA., p 627-632.

Bartha, R., 1986. Biotechnology of petroleum pollutant biodegradation, *Microbial Ecology*, vol. 12, p. 155-172.

Bauman, B, 1991, Biodegradation research of the American Petroleum Institute, presented at *In Situ* Bioreclamation: Application and Investigation for Hydrocarbons and Contaminated Site Remediation, San Diego, CA., March 19-21, 1991.

Beller, H.R., Reinhard, M., and Grbic-Galic, D., 1992. Metabolic byproducts of anaerobic toluene degradation by sulfate-reducing enrichment cultures, *Appl. Environ. Microbiol.*, vol. 58, p. 3192-3195.

Berg et al. 1994

Billington, J.W., G.-L. Huang, F. Szeto, W.Y. Shiu, and D. Mackay. 1988. "Preparation of Aqueous Solutions of Sparingly Soluble Organic Substances: I. Single Component Systems," *Environmental Toxicology Chemistry*, 7:117-124.

Bohon, R.L., and Claussen, W.F., 1951. The solubility of aromatic hydrocarbons in water, *Journal of American Chemical Society*, vol. 73, no. 4, p.1571-1578.

Borden, R.C., 1991. Simulation of enhanced in situ biorestoration of petroleum hydrocarbons, *In Situ Bioreclamation: Application and Investigation for Hydrocarbons and Contaminated Site Remediation.* Eds., R.E. Hinchee and R. F. Olfenbuttel. Butterworth-Heinemann. p. 529-534.

Borden, R.C., 1994. Natural Bioremediation of Hydrocarbon-Contaminated Ground Water, *Handbook of Bioremediation,* Lewis Publishers, Boca Raton, FL.

Borden, Robert C., Gomez, Carlos A., and Becker, Mark T., 1995. Geochemical indicators of intrinsic bioremediation, *Ground Water*, vol. 33, no. 2, p. 180-189.

Bouwer, E.J., 1992. Bioremediation of Subsurface Contaminants, *Environmental Microbiology,* Mitchell, R., ed., Wiley-Liss, New York, New York.

Bouwer, E.J., 1994. Bioremediation of chlorinated solvents using alternate electron acceptors, *Handbook of Bioremediation,* Lewis Publishers, Boca Raton, FL.

Brown, R.A., Dey, J.C. and McFarland, W.E., 1991a. Integrated site remediation combining groundwater treatment, soil vapor extraction, and bioremediation, *In Situ Bioreclamation: Application and Investigation for Hydrocarbons and Contaminated Site Remediation,* Eds., R.E. Hinchee and R. F. Olfenbuttel, Butterworth-Heinemann. p. 444-449.

Buscheck, T.E., and Alcantar, C.M., 1995. Regressional techniques and analytical solutions to demonstrate intrinsic bioremediation, *In Situ* and On-Site

Bioreclamation, The Third International Symposium. Sponsored by Battelle, accepted for presentation April 1995.

Center for Environmental & Human Toxicology, University of Florida. 1997. *Final Technical Report: Development of Soil Cleanup Target Levels for Chapter 62-770, F.A.C.* June.

Chapelle, F.H., 1993. *Ground-water Microbiology and Geochemistry*. John Wiley and Sons, Inc., New York, NY.

Chapelle, F.H., 1994. Assessing the Efficiency of Intrinsic Bioremediation, *In Proceedings of the Symposium on Intrinsic Bioremediation of Ground Water*, August 30 - September 1, 1994: US Environmental Protection Agency, p. 171.

Chiang, C.Y., Salanitro, H.P., Chai, E.Y., Colthart, H.D., and Klein, C.L., 1989. Aerobic biodegradation of benzene, toluene, and xylene in a sandy aquifer - data analysis and computer modeling, *Ground Water*, vol. 27, no. 6, p. 823-834.

Daubert, T.E. and R.P Danner. 1989. Data Compilation Tables of Properties of Pure Compounds. Am Inst Chem Eng.

Davis, J.W., Klier, N.J., and Carpenter, 1994. Natural biological attenuation of benzene in ground water beneath a manufacturing facility, *Ground Water*, vol. 32, no. 2, p. 215-226.

Davis, W.W., M.E. Krahl, and G.H.A. Clowes. 1942. "Solubility of Carcinogenic and Related Hydrocarbons in Water," *Journal of American Chemical Society*, 64(1):108-110.

Davis, W.W., and T.V. Parke, Jr. 1942. "A Nephelometric Method for Determination of Solubilities of Extremely Low Order," *Journal of American Chemical Society*, 64(1):101-107.

Daubert and Danner. MTBE

Domenico, P.A. 1987. An Analytical Model for Multidimensional Transport of a Decaying Contaminant Species. Journal of Hydrology, 91 (1987) 49-58.

Downey, D.C., and Hall, J.F. 1994. *Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing - Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential.* Prepared for the Air Force Center for Environmental Excellence, Brooks Air Force Base, San Antonio, Texas.

Driscoll, F.G. *Groundwater and Wells.* Second Edition. Published by Johnson Filtration Systems Inc., St. Paul, Minnesota.

Eadie, B.J., N.R. Morehead, and P.F. Landrum. "Three-Phase Partitioning of Hydrophobic Organic Compounds in Great Lakes Waters," *Chemosphere*, 20(1/2):161-178 (1990).

Edwards, E.A., and Grbic-Galic, D., 1992. Complete mineralization of benzene by aquifer microorganisms under strictly anaerobic conditions, *Appl. Environ. Microbiol.*, vol. 58, p. 2663-2666.

Engineering-Science, Inc. 1983. *Installation Restoration Program, Phase I-Records Search, Charleston AFB, South Carolina.* Prepared for Charleston AFB, USAF AFESC/DEV (Tyndall AFB) and HQ MAC/DEEV (Scott AFB).

Florida Administrative Code, Chapter 62-770. 1977. *Petroleum Contamination Site Cleanup Criteria.* June 19.

Florida Department of Environmental Protection. 1997. *Petroleum Contamination Site Cleanup Criteria.* F.A.C. Chapter 62-770.

Geraghty & Miller, Inc. 1992. *Draft Contamination Assessment Report for Site SS-15, Flightline Fuel Ayatem (Former Site SP-9).* Prepared for U.S. Corps of Engineers, Missouri River Division.

Geraghty & Miller, Inc. 1993. *Final Contamination Assessment Report for Site SS-15, Flightline Fuel Ayatem (Former Site SP-9).* Prepared for U.S. Corps of Engineers, Missouri River Division.

Gibson, D.T., and Subramanian, V., 1984. Microbial degradation of aromatic hydrocarbons, *Microbial Degradation of Organic Compounds*, Ed., D.T. Gibson, Marcel Dekker, Inc., p. 181-252.

Godsy, E.M. *et al.*, 1992. Methanogenic biodegradation of creosote contaminants in natural and simulated ground-water ecosystems. Ground Water 30(2): 232-242.

Godsy, E.M., 1994. Microbiological and geochemical degradation processes, *Symposium on Intrinsic Bioremediation in Ground Water,* Denver, CO. August 30 - September 1, 1994, p.35-40.

Grbic-Galic, D., 1989. Microbial degradation of homocyclic and heterocyclic aromatic hydrocarbons under conditions, *Dev. Ind. Microbiol.*, vol. 30, p. 237-253.

Grbic-Galic, D., 1990. Anaerobic microbial transformation of nonoxygenated aromatic and alicyclic compounds in soil, subsurface, and freshwater sediments, *Soil Biochemistry,* Eds Bollag, J.M., and Stotzky, G. Marcel Dekker, Inc., New York, NY. p. 117-189.

Haag, F., Reinhard, M., and McCarty, P.L., 1991, Degradation of toluene and p-xylene in an anaerobic microcosms: Evidence for sulfate as a terminal electron acceptor, *Environ. Toxicol. Chem.*, vol. 10, p. 1379-1389.

Higgins, I.J., and Gilbert, P.D., 1978. The biodegradation of hydrocarbons, K.W.A. Chator and H.J. Somerville, The Oil Industry and Microbial Ecosystems: Heyden and Sons, London, p. 80-114.

Hinchee, R.E., Ong, S.K., Miller, R.N., Downey, D.C., and Frandt, R. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Prepared for the Air Force Center for Environmental Excellence, Brooks Air Force Base, San Antonio, Texas. January.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko. 1991. *Handbook of Environmental Degradation Rates.* Lewis Publishers. Chelsea, Michigan.

Hutchins, S.R., and Wilson, J.T., 1991. Laboratory and field studies on BTEX biodegradation in a fuel-contaminated aquifer under denitrifying conditions, *In Situ Bioreclamation, Applications and Investigations for Hydrocarbon and Contaminated Site Remediation,* Eds. R.E. Hinchee and R.F. Olfenbuttel. Butterworth-Heinemann. Boston, MA. p. 157-172.

Isnard, S., and Lambert, S., 1988. Estimating bioconcentration factors from octanol-water partition coefficient and aqueous solubility, *Chemosphere*, vol. 17, no. 1, p. 21-34.

Jobson, A.F., Cook, F.D., and Westlake, D.W., 1972. Microbial utilization of crude oil, *Applied and Environmental Microbiology*, vol. 23, p. 1082-1089.

Klevens, H.B. 1950. "Solubilization of Olycyclic Hydrocarbons. *Journal of Physical Colloid Chemistry*, 54(2):283-298.

Leahy, J.G., and Colwell, R.R., 1990. Microbial degradation of hydrocarbons in the environment, *Microbiolgical Reviews*, vol. 53, no. 3, p. 305-315.

Lee, M.D., 1988. *Biorestoration of Aquifers Contaminated with Organic Compounds: CRC Critical Reviews in Environmental Control.* vol. 18. p. 29-89.

Litchfield, J.H., and Clark, L.C., 1973. Bacterial activities in ground waters containing petroleum products, American Petroleum Institute, Pub. No. 4211.

Lovley, D.R., and Phillips, E.J.P., 1988. Novel mode of microbial energy metabolism: organic carbon oxidation coupled to dissimilatory reduction of iron or manganese, *Applied and Environmental Microbiology*, vol. 56, no. 6, p. 1472-1480.

Lovley, D.R., Phillips, E.J.P., and Lonergan, D.J., 1991. Enzymatic versus noenzymatic mechanisms for Fe(III) reduction in aquatic sediments, *Environmental Science and Technology*, vol. 26, no. 6, p. 1062-1067.

Lovley, Derek R., Chapelle, Francis H., and Woodward, Joan C., 1994. Use of dissolved H_2 concentrations to determine distribution of microbially catalyzed redox reactions in anoxic groundwater, *Environmental Science and Technology*, vol. 28, no. 7, p. 1205-1210.

Lyman, W.J., Reehl, W.F., and Rosenblatt, T.A., 1992,. *Handbook of Chemical Property Estimation Methods Environmental Behavior of Organic Compounds.* McGraw-Hill, Inc., New York, NY.

Mackay, D. and W.-Y. Shiu. 1977. "Aqueous Solubility of Polynuclear Aromatic Hydrocarbons," *Journal of Chemical Engineering Data*, 22(4):399-402.

Mackay, D., and Shiu, W.Y., 1981. A critical review of Henry's Law Constants for chemicals of environmental interest, *Journal of Physical Chemistry* Reference Data, vol. 10, no. 4, p. 1175-1199.

Malone, D.R., Kao, C.M., and Borden, R.C., 1993. Dissolution and biorestoration of nonaqueous phase hydrocarbons - models development and laboratory evaluation, *Water Resources Research*, vol. 29, no. 7, p. 2003-2213.

May, W.E., S.P. Wasik, and D.H. Freeman. 1978. "Determination of the Aqueous Solubility of Polynuclear Aromatic Hydrocarbons by a Coupled Column Liquid Chromatographic Technique," *Analytical Chemistry*, 50(1):175-179.

May, W.E., S.P. Wasik, and D.H. Freeman. 1978. "Determination of the Solubility Behavious of Some Polycyclic Aromatic Hydrocarbons in Water," *Analytical Chemistry*, 50(7):997-1000.

McAllister, Paul M., and Chiang, Chen Y., 1994. A practical approach to evaluating natural attenuation of contaminants in ground water, presented at the USEPA Symposium on Intrinsic Bioremediation of Ground Water, Denver, CO.

McLain, Captain. 1998. Tables containing construction worker exposure assumptions received from Eglin AFB, Florida. June 12.

Means, J.C., S.G. Wood, J.J. Hassett, and W.L. Banwart. "Sorption of Polynuclear Aromatic Hydrocarbons by Sediments and Soils," *Environmental Science Technology*, 14(2):1524-1528 (1980).

Michelson, K.D, D.L Kringel, G.L. Ginsberg, and W.H. Koch. 1993. Comparative analysis of two models to estimate vapor intrusion through a building foundation and associated cancer risks. Air & Waste Management Association, Denver, CO. June 13.

Micromedex, Inc., 1998. *Toxicology, Occupational Medicine and Environmental Series (TOMES) Plus Database*. Denver, Colorado.

Montgomery, J. H. and L. M. Welkom, 1990. *Groundwater Chemicals Desk Reference*. Lewis Publishers, Michigan.

Montgomery. 1996. Groundwater Chemicals. Desk Reference. Second Edition. Lewis Publishers.

Mueller, J.G., Chapman, P.J., Blattman, B.O., and Pritchard, P.H., 1994, Isolation and characterization of a fluoranthene-utilizing strain of Pseduomonas paucimobilis. *Applied and Environmental Microbiology*, vol. 56, p. 1079-1086.

National Oceanic and Atmospheric Administration (NOAA). 1977. To be completed in final draft review.

Newell, C.J., McLeod, R.K., and Gonzales, J.R. 1996. BIOSCREEN Natural Attenuation Decision Support System User's Manual, Version 1.3. June.

NIOSH. 1997. Pocket Guide to Chemical Hazards. U.S. Department of Health and Human Services.

OHM Remediation Services Corp. 1995a. *Contamination Assessment Report, Flightline Pumphouse and Apron Building No. 840 to Building No. 890, Homestead Air Reserve Base, Dade County, Florida.* Prepared for U.S. Army Corps of Engineers, Homestead Area Office.

OHM Remediation Services Corp. 1995b. *Site SS-15A, Flightline Apron, First Quarter (Annual) Monitoring Only Report, Homestead Air Reserve Base, Dade County, Florida.* Prepared for U.S. Air Force Center for Environmental Excellence, Base Closure Restoration Division (ERB).

OHM Remediation Services Corp. 1996a. *Site SS-15A, Flightline Apron, Second Quarter (Annual) Monitoring Only Report, Homestead Air Reserve Base, Dade County, Florida.* Prepared for U.S. Air Force Center for Environmental Excellence, Base Closure Restoration Division (ERB).

OHM Remediation Services Corp. 1996b. *Site SS-15A, Flightline Apron, Third Quarter (Annual) Monitoring Only Report, Homestead Air Reserve Base, Dade County, Florida.* Prepared for U.S. Air Force Center for Environmental Excellence, Base Closure Restoration Division (ERB).

OHM Remediation Services Corp. 1996c. *Site SS-15A, Flightline Apron, Fourth Quarter (Annual) Monitoring Only Report, Homestead Air Reserve Base, Dade County, Florida.* Prepared for U.S. Air Force Center for Environmental Excellence, Base Closure Restoration Division (ERB).

OHM Remediation Services Corp. 1996d. Technical Memorandum *Soil Disposal Profile Analytical Project Requirements.* Prepared for U.S. Air Force Center for Environmental Excellence, Base Closure Restoration Division (ERB).

OHM Remediation Services Corp. 1997a. *Site SS-15A, Flightline Apron, Year Two First Quarter Monitoring Only Report, Homestead Air Reserve Base, Dade County, Florida.* Prepared for U.S. Air Force Center for Environmental Excellence, Base Closure Restoration Division (ERB).

OHM Remediation Services Corp. 1997b. *Site SS-15A, Flightline Apron, Year Two Second Quarter Monitoring Only Report, Homestead Air Reserve Base, Dade County, Florida.* Prepared for U.S. Air Force Center for Environmental Excellence, Base Closure Restoration Division (ERB).

OHM Remediation Services Corp. 1997c. *Site SS-15A, Flightline Apron, Year Two Third Quarter Monitoring Only Report, Homestead Air Reserve Base, Dade County, Florida.* Prepared for U.S. Air Force Center for Environmental Excellence, Base Closure Restoration Division (ERB).

OHM Remediation Services Corp. 1997d. *Site SS-15A, Flightline Apron, Year Two Fourth Quarter Monitoring Only Report, Homestead Air Reserve Base, Dade*

County, Florida. Prepared for U.S. Air Force Center for Environmental Excellence, Base Closure Restoration Division (ERB).

Parker, K.S., R.C. Sims, and R.R. Dupont. 1990. Transformation of PAHs in soil systems, *Journal of Environmental Engineering*, vol. 116, No. 3, pp. 632-640.

Parsons ES. 1997a. Final Remedial Action Plan for Homestead Air Force Base, Site SS-15B.

Parsons ES. 1997b. Draft Work Plan for the Risk-Based Remediation of Site SS-15A.

Perry, J.J., 1977. Microbial metabolism of cyclic hydrocarbons and related compounds, *Critical Reviews in Microbiology*, vol., 5, p. 387-412.

Reinhard, M., 1994. In-Situ bioremediation technologies for petroleum-derived hydrocarbons based on alternate electron acceptors (other than molecular oxygen), *Handbook of Bioremediation,*. Lewis Publishers, Boca Raton, FL. 1994.

Salanitro, J.P.. 1993. The role of bioattenuation in the management of aromatic hydrocarbon plumes in aquifers, *Ground Water Monitoring and Remediation*, vol. 13, pp. 150-161.

Schwarz, F.P. and S.P. Wasik. 1977. "A Fluorescence Method for the Measurement of the Partition Coefficients of Naphthalene, 1-Methylnaphthalene, and 1-Ethylnaphthalene in Water," J. *Chemical Engineering Data*, 22(3):270-273.

Simpkin, T.J., and Gresbrecht, G., 1994. Bioremediation of polycyclic aromatic hydrocarbons in sediments from and industrial complex, *Bioremediation of Chlorinated and Polycyclic Aromatic Hydrocarbon Compounds,* Eds., .E. Hinchee, A. Leeson, L. Simprini, and S.K. Ong. Lewis Publishers, Ann Arbor.

Sims, R.C., W.C. Doucette, J.E. McLean, W.J. Grenney, and R.R. DuPont. 1988. *Treatment Potential for 56 EPA Listed Hazardous Chemicals in Soils.* USEPA Report-600/6-88-001, 105 p.

Smith, J.H., W.R. Mabey, N. Bohonos, B.R. Holt, and S.S. Lee. 1978. "Environmental Pathways of Selected Chemicals in Freshwater Systems. Part II. Laboratory Studies," Environmental Research Lab, Athens, Georgia. USEPA Report-600/7-78-074 432 p.

Stieber, M., K. Böckle, P. Werner, and F.H. Frimmel. 1990. Biodegradation of polycyclic aromatic hydrocarbons (PAH) in the subsurface., F. Arend, M. Hinseveld, and W. J. Van den Brink (Eds.), pp. 473-479. Kluwer Academic Publishers, Netherlands.

Stumm, W. and Morgan, J.J., 1981, *Aquatic Chemistry.* John Wiley & Sons, New York, NY.

Thierrin, J., Davis, G.B., Barber, C., Patterson, B.M., Pribac, F., Power, T.R., and Lambert, M., 1992. Natural degradation rates of BTEX compounds and napthalene in a sulfate reducing ground water environment, *In-Situ* Bioremediation Symposium "92", Niagara-on-the-Lake, Ontario, Canada. September 20-24, 1992: In Press.

Tonner-Navarro, L., S.M. Roberts. 1997. *Final Technical Report: Development of Soil Cleanup Target Levels for Chapter 62-770. F.A.C.* June 18.

U.S. Department of Helath and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. 1997. *NIOSH Pocket Guide to Chemical Hazards.* June.

USEPA. 1980. "Treatability Manual - Volume I: Treatability Data," Office of Research and Development Report-600/8-80-042a, 1035 p.

USEPA. 1982. "Aquatic Fate Process Data for Organic Priority Pollutants," Office of Water Regulations and Standards, Report-440/4-81-014, 407 p.

USEPA. 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies (RI/FS) Under CERCLA.* OSWER Directive 9355.3-01.

USEPA. 1989. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A),* Interim Final, Publication EPA 540/1-89/002.

USEPA. 1992, *Guidelines for Exposure Assessment*; Notice, Federal Register, Vol. 57, No. 104 (Friday, May 29, 1992).

USEPA. 1994a. *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review.* Publication EPA 540/R-94/012.

USEPA. 1994b. *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review.* Publication EPA 540/R-94/013.

Verschueren, K., 1983. *Handbook of Environmental Data on Organic Chemicals,* Van Nostrand Reinhold Co., New York, New York.

Walters and Luthy. 1984

Weidemeier, T.H., Downey, D.C., Wilson, J.T., Kampbell, D.H., Miller, R.N., and Hansen, J.E. 1995. *Technical Protocol for Implementing the Intrinsic Remediation (Natural Attenuation) with Long-term Monitoring Option for Dissolved-phase Fuel Contamination in Ground Water.* Prepared by the Air Force Center for Environmental Excellence, Brooks Air Force Base, San Antonio, Texas.

Wiedemeier, T.H., Swanson, M.A., Moutoux, D.E., Gordon, E.K., Wilson, J.T., Wilson, B.H., Kampbell, D.H., Hansen, J.E., Haas, P., and Chappelle, F.H. 1996. Technical protocol for evaluating natural attenuation of chlorinated

solvents in groundwater (Draft - revision 0): prepared for the Air Force Center for Environmental Excellence, San Antonio, TX.

Wilson, B.H., Smith, G.B., and Rees, J.F., 1986. Biotransformations of selected alkylbenzenes and halogenated aliphatic hydrocarbons in methanogenic aquifer material: a microcosm study, *Environmental Science and Technology*, 20(10):997-1002.

Wilson, B.H., Bledsoe, B., and Kampbell, D., 1987. Biological processes occurring at an aviation gasoline spill site, R.C. Averett and D.M. McKnight editors, *Chemical Quality of Water and the Hydrologic Cycle*. Lewis Publishers, Chelsea, Michigan, p.125-137.

Wilson, B.H., Wilson, J.T., Kampbell, D.H., Bledsoe, B.E., and Armstrong, J.M., 1990. Biotransformation of monoaromatic and chlorinated hydrocarbons at an aviation gasoline spill site, *Geomicrobiology Journal*, 8:225-240.

Woodward-Clyde Consultants. 1995.

Young, L.Y., 1984. Anaerobic degradation of aromatic compounds, *Microbial Degradation of Aromatic Compounds,* Ed. Gibson, D.R., ed.:. Marcel-Dekker, New York.

Zobell, C.E., 1946. Action of microorganisms on hydrocarbons, *Bacterial Review*. vol. 10, p. 1-49.

APPENDIX A

GEOLOGIC LOGS AND GROUNDWATER SAMPLING FORMS

GEOLOGIC BORING LOG

BORING NO. AP15-SB1 | CONTRACTOR: Precision Drilling | DATE SPUD: 10/24/97 17:30
CLIENT: AFCEE | RIG TYPE: CME-35 | DATE CMPL: 10/24/97 17:50
JOB NO.: 731298 | DRLG METHOD: split spoon | ELEVATION:
LOCATION: HARB AP15 | BORING DIA.: 2.5" | TEMP.: ~80°F
GEOLOGIST: J. Hall | DRLG FLUID: — | WEATHER: Sunny
COMMENTS: Adj to SB2

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			6" Asphalt - Auger to 2'					
				SAND md gray sl moist					
				Limestone lt-md gray sl. odor	LAB	2-4		18,16,11,9	0/14
				dk gr. stain					17:40
	5			SAA, some blk stain v.sl odor				4,6,11,14	0/26
	10								
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost

Water level drilled

GEOLOGIC BORING LOG

BORING NO. API8-MPB- | CONTRACTOR: Precision Drilling | DATE SPUD: 10/24/97 1450
CLIENT: AFCEE | RIG TYPE: CME 35 | DATE CMPL: 10/24/97
JOB NO.: 731298.03000 | DRLG METHOD: SSA | ELEVATION:
LOCATION: HARB API8 | BORING DIA.: 4" | TEMP.: ~85°F
GEOLOGIST: J. Hall | DRLG FLUID: — | WEATHER: Sunny
COMMENTS:

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			6" Asphalt					
				Sand & Crushed Limestone					
				Limestone, grey stain, fuel					
				odor		2-6	G		0.0/18
	5								
	10								
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost

Water level drilled

GEOLOGIC BORING LOG

BORING NO. AP18-UW1 CONTRACTOR: Precision Drilling DATE SPUD: 10/24/97 14:50
CLIENT: AFCEE RIG TYPE: CME 75 DATE CMPL: 10/24/97
JOB NO.: 731298.0300 DRLG METHOD: HSA ELEVATION:
LOCATION: HARB AP18 BORING DIA.: 8" OD TEMP.: 85°F
GEOLOGIST: J. Hall DRLG FLUID — WEATHER: Sunny
COMMENTS:

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			Auger to 3' SAND					
				md grey - md-stg. odor					0/32 ppmv
				Sand & Limestone lt-grey, dk	Lab	3-5		14/16	720
	5			grey stain stg odor				14/15	1500
				SAA, less stain, md-stg odor				8/13/10	0/3800
								13	6" recovery
				auger to 8'					
	10								
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost

Water level drilled

GEOLOGIC BORING LOG

BORING NO. AP18 - MPA - | CONTRACTOR: Precision Drilling | DATE SPUD: 10/24/97 1420
CLIENT: AFCEE | RIG TYPE: CME 35 | DATE CMPL: 10/24/97
JOB NO.: 731298.0300 | DRLG METHOD: SSA | ELEVATION:
LOCATION: HARB AP-18 | BORING DIA.: 4" | TEMP.: ~85°F
GEOLOGIST: J. Hall | DRLG FLUID — | WEATHER: Sunny
COMMENTS:

Elev. (ft.)	Depth (ft.)	Profile	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			6" Asphalt					
				SAND & Limestone, tan, moist					
				LIMESTONE, grey stain, fuel					00/78 ppmv
				odor		2-6	G		
	5								
	10								
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost

Water level drilled

GEOLOGIC BORING LOG

BORING NO. AP20 SB1 | CONTRACTOR: Precision Drilling | DATE SPUD: 10/24/97 1200
CLIENT: AFCEE | RIG TYPE: CME 35 | DATE CMPL: 10/24/97
OB NO.: 731298.03000 | DRLG METHOD: Split Spoon | ELEVATION:
LOCATION: HARB AP 20 | BORING DIA.: 2.5" | TEMP.: ~85°F
GEOLOGIST: J. Hall | DRLG FLUID — | WEATHER: Sunny
COMMENTS:

Elev. (ft.)	Depth (ft.)	Profile	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			6" Asphalt					0/0
				Auger to 3'					
				Sand ltgrey V. moist no odor					
				Limestone lt-md grey moist	Lab	3-5		26 30 24 20	0/2
	5			no odor Water @ 5'					17:20
				Limestone ltgrey wet no odor					0/0
	10								
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery

Core lost

Water level drilled

GEOLOGIC BORING LOG

BORING NO. AP26-SB1 | CONTRACTOR: Precision Drilling | DATE SPUD: 10/24/97 0944
CLIENT: AFCEE | RIG TYPE: CME 35 | DATE CMPL: 10/24/97 10:10
JOB NO.: 731298.03000 | DRLG METHOD: ~~HSA~~ split spoon | ELEVATION:
LOCATION: HARB AP-18 | BORING DIA.: 2.5" ~~ID~~ | TEMP.: ~80°F
GEOLOGIST: J. Hall | DRLG FLUID: — | WEATHER: Sunny
COMMENTS:

Elev. (ft.)	Depth (ft.)	Profile	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			6" Asphalt				33	
				crushed lime rock				19 19	~~2~~ 1/3 ppm
				Limestone				25 13 17	
								18 17	
	5			SAA				17 16	
				WL ~5.5'		5-7		17	1/5 ppm slight
				SAA Black stain ~6-7' fuel odor	SB (LAB)			14	0.05
				SAA ~no stain no odor					0/10 ppm
				TD=9'					
	10								
	15								
	20								
	25								
	30								

sl – slight; tr – trace; sm – some; & – and; @ – at; w – with
v – very; lt – light; dk – dark; bf – buff; brn – brown; blk – black
f – fine; m – medium; c – coarse; BH – Bore Hole; SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost
Water level drilled

GEOLOGIC BORING LOG

BORING NO. AP26-SB2 | CONTRACTOR: Precision Drilling | DATE SPUD: 10/24/97 10:15
CLIENT: AFCEE | RIG TYPE: CME 35 | DATE CMPL: 10/24/97 10:30
JOB NO.: 731298-03000 | DRLG METHOD: Split spoon | ELEVATION:
LOCATION: HARB AP-26 | BORING DIA.: 2.5" | TEMP.: ~85°F
GEOLOGIST: J. Hall | DRLG FLUID: — | WEATHER: Sunny
COMMENTS:

Elev. (ft.)	Depth (ft.)	Profile	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			6" ASPHACT					
				Crushed limerock to ~ 2'				24 19 26	0/0
				Limestone					
				Sand & Limestone sl gr-stain	Lab	3-5		15 27 25/7	0/0
	5			no odor					10:20
				Limerock - poor recovery, no stain				8 22 1/6	0/3
				no odor					
				SAA, v. sl. stain?			X	13 9 17 26	—
	10			SAA no stain					0/0
	15								
	20								
	25								
	30								

sl – slight | v – very | f – fine
tr – trace | lt – light | m – medium
sm – some | dk – dark | c – coarse
& – and | bf – buff | BH – Bore Hole
@ – at | brn – brown | SAA – Same As Above
w – with | blk – black

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost
Water level drilled

GEOLOGIC BORING LOG

BORING NO. AP26-SB3 CONTRACTOR: Precision Drilling DATE SPUD: 10/24/97 10:40
CLIENT: AFCEE RIG TYPE: CME 35 DATE CMPL: 10/24/97 11:00
JOB NO.: 731298.03000 DRLG METHOD: ~~HSA~~ / spoon ELEVATION:
LOCATION: HARB AP-26 BORING DIA.: 2.5" TEMP.: ~ 80 °F
GEOLOGIST: J. Hall DRLG FLUID ~ WEATHER: Sunny
COMMENTS:

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1								
				Sand, crushed limerock				16 .5 32 29	0/0 ppm
				Limestone @ ~ 2'					
				SAND, Limerock, md grey, moist no odor				23 27 38 23	0/0 ppm -St
	5								0/6
				SAA, blk stain sl. odor	Lab	5-7			0/13
				5-7 wi ~ 5.5'					10:55
				SAA, blk stain, md. fuel odor					
	10			SAA - no stain, no odor.					
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost

Water level drilled

GEOLOGIC BORING LOG

BORING NO. AP26-SB4 | CONTRACTOR: Precision Drilling | DATE SPUD: 10/24/97 1105
CLIENT: AFCEE | RIG TYPE: CME 4535 | DATE CMPL: 11
JOB NO.: 731298.03000 | DRLG METHOD: Drive-Split Spoon | ELEVATION:
LOCATION: HARB - AP-26 | BORING DIA.: 2.5" | TEMP.: ~85°F
GEOLOGIST: J. Hall | DRLG FLUID — | WEATHER: Sunny
COMMENTS:

Elev. (ft.)	Depth (ft.)	Profile	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			Asphalt ~6"					
				Sand, Limerock fragments, ltgrey no color					0/0 ppm
				Limerock grey/blk stain Stg odor ~5-6'	Lab	3.5			0/1100 ppm 11:15
	5								
				SAA, Stg odor	Lab	5-7			0/40 ppm BTEX, PAH only 1126
						7-9	X		No recovery
	10			Limerock, lt grey, no stain no odor					6" recovery
				TD=9'					64 ppm
	15								
	20								
	25								
	30								

sl – slight; tr – trace; sm – some; & – and; @ – at; w – with
v – very; lt – light; dk – dark; bf – buff; brn – brown; blk – black
f – fine; m – medium; c – coarse; BH – Bore Hole; SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost
Water level drilled

GEOLOGIC BORING LOG

BORING NO. AP26 SB5 — CONTRACTOR: Precision Drilling — DATE SPUD: 10/24/97 13:37
CLIENT: AFCEE — RIG TYPE: CME 35 — DATE CMPL: 10/24/97
JOB NO.: 731288.0300r — DRLG METHOD: ~~HSA~~ Split spoon — ELEVATION:
LOCATION: HARB - AP 26 — BORING DIA.: 2.5 ~~ID~~ — TEMP.: ~85°F
GEOLOGIST: J. Hall — DRLG FLUID: — — WEATHER: p. sunny
COMMENTS: Background TOC

Elev. (ft.)	Depth (ft.)	Profile	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			Auger to 6'					
	5								
				Limerock ltgrey, wet		6-8			0/0 ppm 14:00
	10			rec. odor SAA		8-10			0/0 ppm 14:05
	15								
	20								
	25								
	30								

sl – slight; tr – trace; sm – some; & – and; @ – at; w – with
v – very; lt – light; dk – dark; bf – buff; brn – brown; blk – black
f – fine; m – medium; c – coarse; BH – Bore Hole; SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost
Water level drilled

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 75 AP 26

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 13.60(ft)
Static Water Level (SWL) 5.46 (ft)
Water Column (TD-SWL) 8.14(ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.30 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.9 gal (~~casings~~)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1358	initial	31.3	6.81	0.843	1.2	-142.5	Strong Petro	Clear
1402	1	30.7	6.75	0.827	0.7	-165.9	"	"
1407	2	30.2	6.81	0.791	0.1	-180.9	"	"
1410	3.0	30.5	6.80	0.763	0.1	-196.1	"	"
1412	3.5	30.5	6.82	0.746	0.1	-197.6	"	"
1414	4.0	30.4	6.83	0.730	0.1	-208.2	"	"

Total Volume Removed (PV) 4.0 gal (casings)
(DV)(CV) _____(gallons)

Weather Ptly Sunny 85°F, wind W - 10-15 mph

Date Sampled 29 Oct 97
Time Sampled 1430

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW76 AP 26

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 12.16 (ft)
Static Water Level (SWL) 5.58 (ft)
Water Column (TD-SWL) 6.42 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.03 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.08 gal (~~casings~~)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond 0752	D.O (mg/L)	Redox mV	Odor	Visual Appearance
0915	initial	29.2	7.01		1.16	-104.0	mod Petro	Clear.
0922	1.0	28.8	6.96	0747	0.42	-129.8	" "	Clear
0927	2.0	29.4	6.97	0.728	0.2	-132.5	"	"
0930	2.5	29.4	6.97	0.712	0.2	-138.3	"	"
0935	3.0	29.5	6.96	0.705	0.2	-141.0	"	"

Total Volume Removed (PV) 3.25 gal (~~casings~~)
(DV)(CV) _____(gallons)

Weather Sunny, 75°F, Wind Light from N.

Date Sampled 29 OCT 97
Time Sampled 0945

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW77 AP 26

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____ (in)
Bailer Length (L) _____ (ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____ (gal/bailer)

Total Well Depth (TD) 11.85 (ft)
Static Water Level (SWL) 5.35 (ft)
Water Column (TD-SWL) 6.50 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.04 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____ (bails/casing volume)

Purge Volume (PV) 3.12 gal (~~casings~~)
(BCV)(PV) _____ (bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1004	initial	36.4	6.78	0.751	1.2	-6.97	mod petro	Clear
1008	1	36.0	6.81	0.744	0.4	-75.9	"	"
1011	2	36.2	6.84	0.741	0.2	-80.0	"	"
1013	2.5	36.4	6.80	0.738	0.1	-83.4	"	"
1015	3.0	36.3	6.83	0.730	0.1	-81.0	"	"

Total Volume Removed (PV) 3.25 gal (~~casings~~)
(DV)(CV) _____ (gallons)

Weather Sunny, Warm 75° F, Wind Light from W.

Date Sampled 29 OCT 97
Time Sampled 1030

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 104 AP2C

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 12.46 (ft)
Static Water Level (SWL) 5.29 (ft)
Water Column (TD-SWL) 7.11 (ft)
Casing Inside Diameter (CID) _____(in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.14 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.41 gal (~~casings~~)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1444	initial	30.7	6.89	0.684	0.8	-125.1	NONE	Clear
1447	1	30.7	6.87	0.687	0.2	-147.5	"	"
1452	2	30.5	6.89	0.682	0.2	-155.5	"	"
1454	2.5	30.5	6.89	0.684	0.2	-159.4	"	"
1457	3.0	30.2	6.91	0.681	0.2	-160.8	"	"
1459	3.5	30.4	6.90	0.684	0.2	-163.2	"	"

Total Volume Removed (PV) 3.50 gal (~~casings~~)
(DV)(CV) _____(gallons)

Weather Mostly Cloudy @ 80-85°F, Wind N @ 10-15 mph

Date Sampled 29OCT97
Time Sampled 1500

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 112 AP 26

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 13.00 (ft)
Static Water Level (SWL) 5.11 (ft)
Water Column (TD-SWL) 7.89 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.26 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.75 gal ~~(casings)~~
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1605	initial	28.9	6.78	0.916	1.26	-77.9	Slight Petro.	Cloudy
1611	1	28.9	6.81	0.842	0.2	-79.4	"	"
1615	2	28.8	6.81	0.836	0.2	-82.6	"	Clear
1618	2.5	29.3	6.82	0.849	0.2	-84.5	"	"
1626	3.0	29.4	6.81	0.847	0.2	-85.6	"	"
1623	3.5	29.2	6.85	0.797	0.2	-87.3	"	"

Total Volume Removed (PV) 3.75 gal ~~(casings)~~
(DV)(CV) _____(gallons)

Weather Mostly Cloudy, 75°F Wind W 10 mph.

Date Sampled 28 OCT 97
Time Sampled 1634

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW113 AP 26

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 13.00 (ft)
Static Water Level (SWL) 5.37 (ft)
Water Column (TD-SWL) 7.63 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.22 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.66 gal (~~casings~~)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
0934	initial	29.6	6.49	0.650	3.0	-122.4	Slight Petr	Clear
0938	1	28.9	6.75	0.688	0.4	-133.4	"	Clear
0944	2	28.6	6.82	0.678	0.3	-134.2	"	"
0947	2.5	29.1	6.77	0.687	0.2	-127.2	"	"
0949	3.0	29.4	6.79	0.684	0.2	-127.9	"	"
0952	3.5	28.7	6.80	0.679	0.2	-136.4	"	"

Total Volume Removed (PV) 3.75 gal (~~casings~~)
(DV)(CV) _____(gallons)

Weather Sunny 75°F Wind N at 20 mph, Gusty.

Date Sampled 28 OCT 97
Time Sampled ~~1444~~

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number

Sample Number MW 114 AP26

Type of Sample: grab composite depth interval other

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 13.00 (ft)
Static Water Level (SWL) 5.40 (ft)
Water Column (TD-SWL) 7.60 (ft)
Casing Inside Diameter (CID) _____(in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.20 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.50 (casings)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1614	initial	30.3	6.99	0.497	1.50	-134.5	Mod Petro	Clear
1617	1	30.1	6.99	0.496	0.4	-158.3	"	"
1620	2	30.4	6.99	0.495	0.2	-170.2	"	"
1622	2.5	30.3	7.00	0.491	0.2	-178.8	"	"
1624	3.0	30.2	7.02	0.488	0.1	-185.4	"	"
1626	3.5	30.2	7.03	0.486	0.1	-188.5	"	"

Total Volume Removed (PV) 3.50 (casings)
(DV)(CV) _____(gallons)

Weather Cloudy, 80°F, Wind 10 mph - North

Date Sampled 29 OCT 97
Time Sampled 1615

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW115 AP 26

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 13.85 (ft)
Static Water Level (SWL) 5.56 (ft)
Water Column (TD-SWL) 8.35 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.33 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 4.00 gal ~~(casings)~~
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1023	initial	27.8	6.82	0.798	1.96	-115.4	Slight Petro	Cloudy
1027	1	28.3	6.82	0.773	0.3	-133.2	"	"
1632	2	28.3	6.85	0.764	0.2	-141.2	"	"
1637	3	29.0	6.77	0.761	0.1	-147.8	"	clear
1646	3.5	28.6	6.84	0.751	0.1	-148.9	"	clear
1043	4.0	28.8	6.78	0.751	0.1	-150.5	"	"

Total Volume Removed (PV) 4.66 gal ~~(casings)~~
(DV)(CV) _____(gallons)

Weather Sunny, 75° F, Wind N at 20 mph Gusty.

Date Sampled 28 OCT 97
Time Sampled 1045

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 116 AP 26

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 12.90 (ft)
Static Water Level (SWL) 5.45 (ft)
Water Column (TD-SWL) 7.45 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.26 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.54 gal (~~casings~~)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1522	initial	30.3	6.96	0.568	0.9	-111.4	NONE	Clear
1526	1	30.9	6.98	0.578	0.4	-122.2	"	"
1530	2	30.9	6.98	0.594	0.2	-130.9	"	"
1534	2.5	30.3	6.96	0.590	0.2	-134.4	Slight	"
1533	3.0	30.1	6.97	0.596	0.2	-136.5	"	"
1538	3.5	30.2	6.95	0.598	0.2	-136.0	"	"

Total Volume Removed (PV) . 3.54 gal (~~casings~~)
(DV)(CV) _____(gallons)

Weather Mostly Cloudy 80°F, wind N 10 mph.

Date Sampled 29 OCT 97
Time Sampled 1545

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number ~~MW~~ DW-2 AP 26

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____ (in)
Bailer Length (L) _____ (ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____ (gal/bailer)

Total Well Depth (TD) 30.25 (ft)
Static Water Level (SWL) 5.34 (ft)
Water Column (TD-SWL) 24.91 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 3.98 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____ (bails/casing volume)

Purge Volume (PV) 11.95 gal (casings)
(BCV)(PV) _____ (bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1051	initial	28.4	7.17	0.683	1.4	44.5	NONE	Clear
1104	3	27.1	7.11	0.699	0.1	43.7	NONE	"
1114	6	27.0	7.08	0.702	0.0	44.6	"	"
1123	9	27.0	7.08	0.704	0.0	48.4	"	"
1131	12	26.9	7.07	0.705	0.0	49.3	"	"

Total Volume Removed (PV) 12.0 gal (casings)
(DV)(CV) _____ (gallons)

Weather Sunny 75°F, wind N 5-10 mph.

Date Sampled 29 OCT 97
Time Sampled 1145

Name of Sampler M. Rasberry.

GROUND WATER SAMPLE

Project Name Homestead ARB
Project Number _____

Sample Number MW 9 API ϕ

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 12.17 (ft)
Static Water Level (SWL) 5.35 (ft)
Water Column (TD-SWL) 6.82 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.09 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.25 Gal (~~casings~~)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1506	initial	30.3	6.83	ϕ.539	1.ϕ	-177.6	~~Strong~~ Moderate Petro	Clear
1510	1	29.6	6.91	ϕ.538	ϕ.3	-197.3	"	"
1514	2	29.5	6.97	ϕ.542	ϕ.2	-208.ϕ	"	"
1516	2.5	29.6	6.9ϕ	ϕ.549	ϕ.2	-211.8	"	"
1519	3.0	29.5	6.9ϕ	ϕ.556	ϕ.2	-215.6	"	"

Total Volume Removed (PV) _____(casings)
(DV)(CV) _____(gallons)

Weather ~~Sunny~~ Ptly Sunny Wem 85°F Wind SE 15-20 mph

Date Sampled 27 OCT 97
Time Sampled 1538

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 10 AP 10

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____ (in)
Bailer Length (L) _____ (ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____ (gal/bailer)

Total Well Depth (TD) 12.23 (ft)
Static Water Level (SWL) 5.71 (ft)
Water Column (TD-SWL) 6.52 (ft)
Casing Inside Diameter (CID) 2" (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.04 (gal/casing)

Bails/Casing Volume (BCV)

CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ ~~3.15~~ (bails/casing volume)

Purge Volume (PV) 3.0 gal
(BCV)(PV) ~~3.31~~ (casings) _____ (bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1024	initial	29.4	7.06	0.487	3.0	+126.9	none	clear
1027	1	29.1	7.08	0.461	2.2	+121.3	"	"
1030	2	28.9	7.18	0.451	2.2	+117.3	"	"
1033	2.5	28.8	7.17	0.448	2.2	+116.3	"	"
1035	3.0	28.8	7.18	0.446	2.1	+116.1	"	"

Total Volume Removed (PV) 3.0 (casings)
(DV)(CV) _____ (gallons)

Weather Sunny Warm 80°F Windy 15-20 mph. from E.

Date Sampled 27-OCT-97
Time Sampled 1040

Name of Sampler M. Rasbery

JHA 11/90

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 11 API8

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____ (in)
Bailer Length (L) _____ (ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____ (gal/bailer)

Total Well Depth (TD) 12.40 (ft)
Static Water Level (SWL) 1.02 (ft)
Water Column (TD-SWL) 6.38 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.02 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____ (bails/casing volume)

Purge Volume (PV) 3.0 Sel (~~casings~~)
(BCV)(PV) _____ (bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O. (mg/L)	Redox mV	Odor	Visual Appearance
1137	initial	29.7	6.83	Ø.662	3.2	+141.3	Slight Petro	Cloudy.
1140	1	29.4	6.79	Ø.659	1.1	+137.Ø	"	"
1143	2	29.3	6.82	Ø.643	Ø.7	+131.7	"	"
1145	2.5	29.1	6.88	Ø.637	Ø.5	+128.2	"	"
1147	3.0	29.Ø	6.89	Ø.623	Ø.5	+127.2		

Total Volume Removed (PV) 3.Ø Sel. (~~casings~~)
(DV)(CV) _____ (gallons)

Weather Sunny, Warm, 80°F wind E 15-20 mph

Date Sampled 27 OCT 97
Time Sampled 1155

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 110 AP 10

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 13.13 (ft)
Static Water Level (SWL) 5.07 (ft)
Water Column (TD-SWL) 8.06 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.29 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.86 gal (casings)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH 7.34	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1421	initial	29.8	~~8.79~~	0.454	2.7	+141.8	Slight Petrol	clear
1425	1	29.3	7.26	0.441	0.5	+131.6	"	"
1429	2	29.2	7.25	0.446	0.4	+128.3	"	"
1431	2.5	29.2	7.21	0.441	0.4	+127.1	"	"
1433	3.0	29.1	7.22	0.443	0.4	+125.6	"	"
1435	3.5	29.2	7.18	0.442	0.4	+124.4	"	"

Total Volume Removed (PV) 4.6 (casings)
(DV)(CV) _____(gallons)

Weather Ptly Cloudy Warm 85°F Windy E 20 mph

Date Sampled 27 OCT 97
Time Sampled 1436

Name of Sampler M. Rasberry.

GROUND WATER SAMPLE

1000 mgl

Project Name Homestead
Project Number _____

Sample Number MW-14 AP-11

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) ~~15.0~~ 12.0 (ft)
Static Water Level (SWL) _____(ft)
Water Column (TD-SWL) ~5' (ft) Product prevented water level from working.
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1 gal (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) ≈3.0 gal (~~casings~~)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox MV	Odor	Visual Appearance
1011	initial	29.6	6.69	0.638	7.37	-190.7	Strong Petro	Clear.
1019	1	29.1	7.10	0.595	~~7.44~~	-208.6	"	"
1028	2	29.1	7.13	0.593	~~7.44~~	-195.4	"	"
1029	2.5	29.1	7.14	0.590	~~7.44~~	-198.8	"	"
1037	3.0	28.9	7.17	0.591	~~7.41~~ 16.6	-204.7	"	"

Total Volume Removed (PV) _____(casings)
(DV)(CV) 3.0 (gallons)

Weather Sunny warm 85°F. Wind E at 10-15 mph.

Date Sampled 26 OCT 97
Time Sampled 1040

Name of Sampler M. Rasberry

Note - could not collect LNAPL sample - insufficient thickness

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 15 AP-11

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 12.85 (ft)
Static Water Level (SWL) 5.35 (ft)
Water Column (TD-SWL) 7.50 (ft)
Casing Inside Diameter (CID) 2" (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.20 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ Ø (bails/casing volume)

Purge Volume (PV) 3.6 gal (casings)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1353	initial	30.2	7.20	Ø.585	4.20	+99.Ø	Slight Hydro	Clear
1356	1	29.5	7.13	Ø.579	2.50	+141.4	"	"
1400	2	29.1	7.17	Ø.572	1.20	+104.7	"	"
1407	2.5	29.1	7.12	Ø.564	Ø.90	+105.4	"	"
1414	3	29.2	7.15	Ø.555	Ø.84	+105.4	"	"
1416	3.5	29.2	7.14	Ø.556	Ø.70	+105.2	"	"

Total Volume Removed (PV) 4.0 (casings)
(DV)(CV) _____(gallons)

Weather Sunny Warm 85°F Wind 15-20 mph. E.

Date Sampled 26 OCT 97
Time Sampled 1415

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 11e April

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 12.80 (ft)
Static Water Level (SWL) 5.38 (ft)
Water Column (TD-SWL) 7.42 (ft)
Casing Inside Diameter (CID) 2" (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.2 (gal/casing)

Bails/Casing Volume (BCV)

$$CV/BV \text{ or } \frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)} \quad \text{_____(bails/casing volume)}$$

Purge Volume (PV) 3.6 gal (casings)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1501	Initial	30.2	6.73	0.744	4.4	-88.2	None	Clear
1504	1	29.5	6.73	0.747	0.8	-102.9	"	"
1507	2	29.1	6.73	0.749	0.7	-115.7	"	"
1510	2.5	28.9	6.75	0.743	0.7	-117.3	"	"
1513	3.0	28.8	6.77	0.735	0.6	-118.6	"	"
1515	3.5	29.0	6.76	0.732	0.5	-119.8	"	"

Total Volume Removed (PV) _____(casings)
(DV)(CV) 4.0 (gallons)

Weather Sunny Warm 85°F Wind E at 10-15 mph

Date Sampled 4-OCT-97
Time Sampled 1520

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 95 API1

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 12.10 (ft)
Static Water Level (SWL) 5.19 (ft)
Water Column (TD-SWL) 6.91 (ft)
Casing Inside Diameter (CID) _____(in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.11 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.3 gal ~~(casings)~~
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
0939	Initial	29.3	6.53	0.535	2.8	+128.3	None	Clear
0942	1	28.8	7.10	0.506	1.2	+119.5	"	"
0945	2	28.7	7.17	0.495	0.7	+114.6	"	"
0947	2.5	28.7	7.19	0.495	0.7	+112.3	"	"
0949	3.0	28.7	7.20	0.493	0.7	+110.7	"	"
0951	3.5	28.7	7.17	0.494	0.6	+108.9	"	"

Total Volume Removed (PV) 4 gal ~~(casings)~~
(DV)(CV) _____(gallons)

Weather Sunny Windy 15-20 mph. 75-80°F.

Date Sampled 27-OCT 97
Time Sampled 0952

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 63 AP 22

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 12.10 (ft)
Static Water Level (SWL) 5.03 (ft)
Water Column (TD-SWL) 7.07 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.13 (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.39 gal (~~casings~~)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1712	initial	29.1	7.06	Ø.538	2.5Ø	-11Ø.6	mod petro	clear
1715	1	28.8	6.97	Ø.628	Ø.5	-93.7	"	"
1718	2	28.6	6.93	Ø.658	Ø.3	-96.Ø	"	"
1721	2.5	28.6	6.93	Ø.664	Ø.2	-1Ø3.7	"	"
1724	3.0	28.6	6.92	Ø.668	Ø.2	-1Ø7.8	"	"
1727	3.5	28.6	6.94	Ø.672	Ø.2	-149.5	"	"

Total Volume Removed (PV) 3.5 gal (~~casings~~)
(DV)(CV) _____(gallons)

Weather Mostly Cloudy 85°F E Wind 10-15 mph

Date Sampled 27 OCT 97
Time Sampled 1730

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 64 AP 22

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 12.05 (ft)
Static Water Level (SWL) 4.76 (ft)
Water Column (TD-SWL) 7.29 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.16 (gal/casing)

Bails/Casing Volume (BCV)

$$CV/BV \text{ or } \frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$$ _____(bails/casing volume)

Purge Volume (PV) 3.5Ø gal ~~casings~~
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox MV	Odor	Visual Appearance
1414	Initial	28.Ø	7.Ø4	Ø.713	2.2	+82.6	NONE	Clear
1419	1	27.7	7.ØØ	Ø.767	Ø.2	+66.6	NONE	Clear
1422	2	27.9	6.94	Ø.764	Ø.2	+61.5	NONE	"
1426	2.5	27.8	6.96	Ø.766	Ø.2	+61.3	"	"
1428	3.0	27.5	7.ØØ	Ø.76Ø	Ø.2	+62.Ø	"	"
1436	3.5	27.6	7.Ø3	Ø.694	Ø.2	+68.9	"	"

Total Volume Removed (PV) 3.5Ø gal ~~casings~~
(DV)(CV) _____(gallons)

Weather Mostly Cloudy, 75°F. Wind N at 15-20, gusty.

Date Sampled 28 OCT 97
Time Sampled 1445

Name of Sampler M. Rasberry

GROUND WATER SAMPLE

Project Name Homestead
Project Number _____

Sample Number MW 111 AP 22

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____(in)
Bailer Length (L) _____(ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____(gal/bailer)

Total Well Depth (TD) 13.45 (ft)
Static Water Level (SWL) 5.31 (ft)
Water Column (TD-SWL) 8.14 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.3 gal (gal/casing)

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ _____(bails/casing volume)

Purge Volume (PV) 3.9 gal (casings)
(BCV)(PV) _____(bails)

Time	Casing/ Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1628	initial	30.2	6.91	0.689	1.8	+60.9	Slight Petro	Clear
1631	1	29.8	6.86	0.685	0.3	+63.9	"	"
1635	2	29.5	6.92	0.687	0.2	+65.5	"	"
1637	2.5	29.5	6.93	0.685	0.2	+66.7	"	"
1639	3.0	29.5	6.89	0.685	0.2	+67.8	"	"
1641	3.5	29.5	6.91	0.681	0.2	+69.3	"	"

Total Volume Removed (PV) 4.0 gal ~~(casings)~~
(DV)(CV) _____(gallons)

Weather Mostly Cloudy, Warm 85°F Wind 10-15 mph.

Date Sampled 27 OCT 97
Time Sampled ~~1615~~ 1615

Name of Sampler M. Rasberry

AP-17

GROUND WATER SAMPLE

Project Name Homestead
Project Number 731298.03000

Sample Number MW-40 AP-17

Type of Sample: grab composite depth interval other _____

Bailer Volume (BV)
Bailer Inside Diameter (BID) _____ (in)
Bailer Length (L) _____ (ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____ (gal/bailer)

Total Well Depth (TD) 12.80 (ft)
Static Water Level (SWL) 5.20 (ft)
Water Column (TD-SWL) 7.60 (ft)
Casing Inside Diameter (CID) 2 (in)
Casing Volume (CV) 1.22 ~~1.22~~ (gal/casing)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$

Bails/Casing Volume (BCV)
CV/BV or $\frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)}$ ~~3.6~~ (bails/casing volume)

Purge Volume (PV) 3.6 (~~casings~~) gal
(BCV)(PV) _____ (bails)

Time	~~Casing~~/Bail No. (gal)	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1624	initial	29.6	7.76	6.788	8.54	+175.7	Mod Petro	Clear
1630	1	29.4	7.77	6.789	8.63	+195.6	"	"
1638	2	29.4	7.75	6.788	8.54	+225.8	"	"
1647	2.5	29.4	6.63	6.796	8.50	+231.4	"	"
1657	3	29.2	6.71	6.818	—	+240.4	"	"
	3.6							
					0.2			

meter not working /AA

Total Volume Removed (PV) 3. (casings)
(DV)(CV) 3.6 (gallons)

Weather _____

Date Sampled 10/23/97
Time Sampled 17:00

Name of Sampler _____

AP-17

GROUND WATER SAMPLE

Project Name Homestead
Project Number 731298.03000

Sample Number MW-99 AP-17

Type of Sample: grab composite depth interval other _____

Bailer Volume* (BV)
Bailer Inside Diameter (BID) _____ (in)
Bailer Length (L) _____ (ft)
$(BID/24)^2(L)(\pi)(7.48)$ _____ (gal/bailer)

Total Well Depth (TD) 12.26 (ft)
Static Water Level (SWL) 5.07 (ft)
Water Column (TD-SWL) 7.19 (ft)
Casing Inside Diameter (CID) 2.0 (in)
Casing Volume (CV)
$(CID/24)^2(TD-SWL)(\pi)(7.48)$ 1.17 (gal/casing)

Bails/Casing Volume (BCV)

$$CV/BV \text{ or } \frac{(CID/24)^2(TD-SWL)}{(BID/24)^2(L)} \quad \text{_____ (bails/casing volume)}$$

Purge Volume (PV) ~~3~~ (casings) (3.5 gal)
(BCV)(PV) _____ (bails)

Time	~~Casing~~ gal. Bail No.	Temp °C	pH	Elec Cond	D.O (mg/L)	Redox mV	Odor	Visual Appearance
1503	initial	30.0	6.34	.881	8.09	274.9	NONE	Clear
1512	1	29.6	6.62	0.854	8.46	279.0	NONE	Clear
1519	2	28.9	6.68	0.793	8.45	279.5	NONE	Clear
1524	2.5	29.4	6.63	0.770	8.53	279.7	NONE	Clear
1529	3.0	29.2	6.66	0.759	8.58	279.4	NONE	Clear
1533	3.5	29.4	6.68	0.744	8.55	280.0	NONE	Clear
	final				→ 0.2	+112.2		

meter not working JHA

Total Volume Removed (PV) _____ (casings)
(DV)(CV) 3.5 (gallons)

Weather _____

Date Sampled 23 OCT 97
Time Sampled 1536

Name of Sampler _____

OCTOBER 1997 GROUNDWATER LEVELS
RISK-BASED APPROACH TO REMEDIATION
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Location	Elevation of TOC (feet above NGVD)	Depth to Groundwater (feet below TOC)		Groundwater Elevation (feet above NGVD)	
		Parsons ES	OHM[a/]	Parsons ES	OHM
MW-5	5.79	-----[b/]	3.87	-----	1.92
MW-9	6.93	5.35	5	1.58	1.93
MW-10	7.32	5.71	-----	1.61	-----
MW-11	7.63	6.02	-----	1.61	-----
MW-14	6.93	-----	5.12	-----	1.81
MW-15	6.98	5.35	-----	1.63	-----
MW-16	6.99	5.38	-----	1.61	-----
MW-17	6.59	-----	4.65	-----	1.94
MW-21	6.80	-----	5.01	-----	1.79
MW-23	7.65	-----	5.9	-----	1.75
MW-24	7.72	-----	5.95	-----	1.77
MW-34	5.84	-----	4.07	-----	1.77
MW-35	6.99	-----	5.25	-----	1.74
MW-37	7.64	-----	5.88	-----	1.76
MW-38	7.77	-----	6	-----	1.77
MW-39	6.61	-----	4.85	-----	1.76
MW-40	6.90	5.2	5.15	1.70	1.75
MW-41	7.00	-----	-----	-----	-----
MW-44	6.97	-----	5.23	-----	1.74
MW-46	7.12	-----	5.39	-----	1.73
MW-50	7.93	-----	6.2	-----	1.73
MW-54	6.89	-----	5.22	-----	1.67
MW-56	7.05	-----	5.38	-----	1.67
MW-63	6.57	5.03	4.88	1.54	1.69
MW-64	6.29	4.76	-----	1.53	-----
MW-66	5.78	-----	4.07	-----	1.71
MW-67	6.87	-----	5.19	-----	1.68
MW-69	7.06	-----	-----	-----	-----
MW-75	6.98	5.46	5.25	1.52	1.73
MW-76	7.10	5.58	5.36	1.52	1.74
MW-77	6.90	5.35	-----	1.55	
MW-78	7.39	-----	5.65	-----	1.74
MW-82	5.81	-----	-----	-----	-----
MW-90	5.86	-----	-----	-----	-----
MW-93	6.87	-----	-----	-----	-----
MW-95	6.83	5.19	-----	1.64	-----
MW-96	6.84	-----	5.03	-----	1.81
MW-97	5.88	-----	4.11	-----	1.77
MW-98	6.66	-----	4.88	-----	1.78
MW-99	6.79	5.07	5.01	1.72	1.78
MW-100	6.85	-----	5.12	-----	1.73
MW-101	5.98	-----	4.23	-----	1.75
MW-102	6.79	-----	5.06	-----	1.73
MW-104	6.82	5.29	5.06	1.53	1.76
MW-105	7.06	-----	5.3	-----	1.76
MW-109	4.64	-----	2.89	-----	
MW-110	6.85	5.07	4.72	1.78	2.13
MW-111	6.86	5.31	-----	1.55	-----
MW-112	6.66	5.11	-----	1.55	-----
MW-113	6.90	5.37	-----	1.53	-----
MW-114	6.90	5.4	5.18	1.50	1.72
MW-115	-----	5.5	-----	-----	-----
MW-116	-----	5.45	-----	-----	-----
DW-2	6.92	5.34	-----	1.58	-----

[a/] Year Two Third Quarter MO results (OHM, 1997_).

[b/] ----- = Not measured.

APPENDIX B

DATA RELEVANT TO PREDICTIVE CHEMICAL FATE ASSESSMENT

Appendix B

Corrective Action Plan
Risk-Based Approach to Remediation
Site SS-15A, Homestead ARB, Florida

Electron Donor and Electron Acceptor Half Cell Reactions

HALF-CELL REACTIONS	$\Delta G°_r$ (kcal/ equiv)*	$\Delta G°_r$ (kJ/ equiv)*	E° (V)	Eh (V)	pe	Conditions for Eh and pe §
ELECTRON-ACCEPTOR (REDUCTION) HALF CELL REACTIONS						
$5e^- + 6H^+ + NO_3^- \Rightarrow 0.5N_2 + 3H_2O$ *Denitrification*	-28.7	-120.	+1.24	+0.708	+12.0	pH = 7 $\Sigma[N]=10^{-3}$
$4e^- + 4H^+ + O_2 \Rightarrow 2H_2O$ *Aerobic Respiration*	-28.3	-119.	+1.23	+0.805	+13.6	pH = 7 Po_2=0.21 atm
$2e^- + 4H^+ + \underline{MnO_2} \Rightarrow Mn^{2+} + 2H_2O$ *Pyrolusite Dissolution/Reduction*	-28.3	-119	+1.23	+0.550	+9.27	pH = 7 $\Sigma[Mn]=10^{-5}$
$CO_2 + e^- + H^+ + \underline{MnOOH} \Rightarrow MnCO_3 + H_2O$ *a Manganite Carbonation/Reduction*	-23.1	-96.8	+1.00	+0.408	+6.90	pH = 8 $Pco_2=10^{-2}$
$e^- + H^+ + MnO_2 \Rightarrow \underline{MnOOH}$ *Pyrolusite Hydrolysis/Reduction*	-22.1	-92.5	+0.959	+0.545	+9.21	pH = 7
$e^- + 3H^+ + \underline{Fe(OH)_{3,amph.}} \Rightarrow Fe^{2+} + 2H_2O$ *Amorphous "Goethite" Dissolution/Reduction*	-21.5	-89.9	+0.932	+0.163	+2.75	pH = 6 $\Sigma[Fe]=10^{-5}$
$8e^- + 10H^+ + NO_3^- \Rightarrow NH_4^+ + 3H_2O$ *Nitrate Reduction*	-20.3	-84.9	+0.879	+0.362	+6.12	pH = 7
$2e^- + 2H^+ + NO_3^- \Rightarrow NO_2^- + H_2O$ *Nitrate Reduction*	-18.9	-78.9	+0.819	+0.404	+6.82	pH = 7
$e^- + 3H^+ + \underline{FeOOH} \Rightarrow Fe^{2+} + 2H_2O$ *"Ferric oxyhydroxide" Dissolution/Reduction*	-15.0	-62.9	+0.652	-0.118	-1.99	pH = 6 Σ [Fe]=10^{-5}
$e^- + 3H^+ + \underline{Fe(OH)_{3,xline.}} \Rightarrow Fe^{2+} + 3H_2O$ *Crystallized "Goethite" Dissolution/Reduction*	-11.8	-49.2	+0.510	-0.259	-4.38	pH = 6 Σ [Fe]=10^{-5}
$e^- + H^+ + CO_{2,g} + \underline{Fe(OH)_{3,amph.}} \Rightarrow \underline{FeCO_3} + 2H_2O$ *Amorphous "Goethite" Carbonation/Reduction*	-11.0	-46.2	+0.479	-0.113	-1.90	pH = 8 $Pco_2=10^{-2}$ atm
$8e^- + 9H^+ + SO^{2-}_4 \Rightarrow HS^- + 4H_2O$ *Sulfate Reduction*	-5.74	-24.0	+0.249	-0.278	-4.70	pH = 8
$8e^- + 10H^+ + SO^{2-}_4 \Rightarrow H_2S^o + 4H_2O$ *Sulfate Reduction*	-6.93	-28.9	+0.301	-0.143	-2.42	pH = 6
$8e^- + 8H^+ + CO_{2,g} \Rightarrow CH_{4,g} + 2H_2O$ *Methanogenesis*	-3.91	-16.4	+0.169	-0.259	-4.39	pH = 7 $Pco_2=10^{-2}$ $P_{CH_4}=10^0$

HALF-CELL REACTIONS	$\Delta G°_r$ (kcal/ equiv)*	$\Delta G°_r$ (kJ/ equiv)*	$E°$ (V)	Eh (V)	pe	Conditions for Eh and pe §
ELECTRON-DONOR (OXIDATION) HALF CELL REACTIONS						
$12H_2O + C_6H_6 \Rightarrow 6CO_2 + 30H^+ + 30e^-$ *Benzene Oxidation*	+2.83	+11.8	-0.122	+0.316	+5.34	pH = 7 $P_{CO_2}=10^{-2}$
$14H_2O + C_6H_5CH_3 \Rightarrow 7CO_2 + 36H^+ + 36e^-$ *Toluene Oxidation*	+2.96	+12.4	-0.128	+0.309	+5.22	pH = 7 $P_{CO_2}=10^{-2}$
$16H_2O + C_6H_5C_2H_5 \Rightarrow 8CO_2 + 42H^+ + 42e^-$ *Ethylbenzene Oxidation*	+2.96	+12.4	-0.128	+0.309	+5.21	pH = 7 $P_{CO_2}=10^{-2}$
$16H_2O + C_6H_4(CH_3)_2 \Rightarrow 8CO_2 + 42H^+ + 42e^-$ *m-Xylene Oxidation*	+3.02	+12.7	+0.131	-0.305	-5.88	pH = 7 $P_{CO_2}=10^{-2}$
$20H_2O + C_{10}H_8 \Rightarrow 10CO_2 + 48H^+ + 48e^-$ *Naphthalene Oxidation*	+2.98	+12.5	-0.130[a]	+0.309	+5.22	pH = 7 $P_{CO_2}=10^{-2}$
$18H_2O + C_6H_3(CH_3)_3 \Rightarrow 9CO_2 + 48H^+ + 48e^-$ *1,3,5-Trimethylbenzene Oxidation*	+3.07	+12.8	-0.133[a]	+0.303	+5.12	pH = 7 $P_{CO_2}=10^{-2}$
$18H_2O + C_6H_3(CH_3)_3 \Rightarrow 9CO_2 + 48H^+ + 48e^-$ *1,2,4-Trimethylbenzene Oxidation*	+3.07	+12.9	-0.134[a]	+0.302	+5.11	pH = 7 $P_{CO_2}=10^{-2}$
$12H_2O + C_6H_5Cl \Rightarrow 6CO_2 + 29H^+ + 28e^- + Cl^-$ *Chlorobenzene Oxidation*	+2.21	+9.26	-0.096[a]	+0.358	+6.05	pH = 7 $P_{CO_2}=10^{-2}$

NOTES:

* = $\Delta G°_r$ for half cell reaction as shown divided by the number of electrons involved in reaction.

§ = Conditions assumed for the calculation of Eh and pe (pe = Eh/0.05916). Where two dissolved species are involved, other than those mentioned in this column, their activities are taken as equal. Note, this does not affect the free energy values listed.

[a] = $E°$ calculated using the following equation; $E° = \Delta G°_r (J/nF) * 1.0365 \times 10^{-5}$ (VF/J) from Stumm and Morgan, 1981

Coupled Oxidation Reactions

Coupled Benzene Oxidation Reactions	$\Delta G°_r$ (kcal/mole Benzene)	$\Delta G°_r$ (kJ/mole Benzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$7.5O_2 + C_6H_6 \Rightarrow 6CO_{2,g} + 3H_2O$ *Benzene oxidation /aerobic respiration*	-765.34	-3202	3.07:1
$6NO_3^- + 6H^+ + C_6H_6 \Rightarrow 6CO_{2,g} + 6H_2O + 3N_{2,g}$ *Benzene oxidation / denitrification*	-775.75	-3245	4.77:1
$30H^+ + 15MnO_2 + C_6H_6 \Rightarrow 6CO_{2,g} + 15Mn^{2+} + 18H_2O$ *Benzene oxidation / manganese reduction*	-765.45	-3202	10.56:1
$3.75\ NO_3^- + C_6H_6 + 7.5\ H^+ + 0.75\ H_2O \Rightarrow 6\ CO_2 + 3.75\ NH_4^+$ *Benzene oxidation / nitrate reduction*	-524.1	-2193	2.98:1
$60H^+ + 30Fe(OH)_{3,a} + C_6H_6 \Rightarrow 6CO_2 + 30Fe^{2+} + 78H_2O$ *Benzene oxidation / iron reduction*	-560.10	-2343	21.5:1
$7.5H^+ + 3.75SO_4^{2-} + C_6H_6 \Rightarrow 6CO_{2,g} + 3.75H_2S^o + 3H_2O$ *Benzene oxidation / sulfate reduction*	-122.93	-514.3	4.61:1
$4.5H_2O + C_6H_6 \Rightarrow 2.25CO_{2,g} + 3.75CH_4$ *Benzene oxidation / methanogenesis*	-32.40	-135.6	0.77:1

Coupled Ethylbenzene Oxidation reactions	$\Delta G°_r$ kcal/mole Ethylbenzene	$\Delta G°_r$ kJ/mole Ethylbenzene	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5O_2 + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 5H_2O$ *Ethylbenzene oxidation /aerobic respiration*	-1066.13	-4461	3.17:1
$8.4NO_3^- + 8.4H^+ + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 9.2H_2O + 4.2N_{2,g}$ *Ethylbenzene oxidation / denitrification*	-1080.76	-4522	4.92:1
$42H^+ + 21MnO_2 + C_6H_5C_2H_5 \Rightarrow 8CO_2 + 21Mn^{2+} + 26H_2O$ *Ethylbenzene oxidation / manganese reduction*	-1066.27	-4461	17.24:1
$84H^+ + 42Fe(OH)_{3,a} + C_6H_5C_2H_5 \Rightarrow 8CO_2 + 42Fe^{2+} + 110H_2O$ *Ethylbenzene oxidation / iron reduction*	-778.48	-3257	22.0:1
$10.5H^+ + 5.25SO_4^{2-} + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 5.25H_2S^o + 5H_2O$ *Ethylbenzene oxidation / sulfate reduction*	-166.75	-697.7	4.75:1
$5.5H_2O + C_6H_5C_2H_5 \Rightarrow 2.75CO_{2,g} + 5.25CH_4$ *Ethylbenzene oxidation / methanogenesis*	-39.83	-166.7	0.79:1

Coupled Naphthalene Oxidation Reactions	$\Delta G°_r$ (kcal/mole naphthalene)	$\Delta G°_r$ (kJ/mole naphthalene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$12O_2 + C_{10}H_8 \Rightarrow 10CO_2 + 4H_2O$ *Naphthalene oxidation /aerobic respiration*	-1217.40	-5094	3.00:1
$9.6NO_3^- + 9.6H^+ + C_{10}H_8 \Rightarrow 10CO_2 + 8.8H_2O + 4.8N_{2,g}$ *Naphthalene oxidation / denitrification*	-1234.04	-5163	4.65:1
$24MnO_2 + 48H^+ + C_{10}H_8 \Rightarrow 10CO_2 + 24Mn^{2+} + 28H_2O$ *Naphthalene oxidation / manganese reduction*	-1217.57	-5094	16.31:1
$48Fe(OH)_{3,a} + 96H^+ + C_{10}H_8 \Rightarrow 10CO_2 + 48Fe^{2+} + 124H_2O$ *Naphthalene oxidation / iron reduction*	-932.64	-3902	40.13:1
$6SO_4^{2-} + 12H^+ + C_{10}H_8 \Rightarrow 10CO_2 + 6H_2S^o + 4H_2O$ *Naphthalene oxidation / sulfate reduction*	-196.98	-824.2	4.50:1
$8H_2O + C_{10}H_8 \Rightarrow 4CO_2 + 6CH_4$ *Naphthalene oxidation / methanogenesis*	-44.49	-186.1	1.13:1

Coupled Benzo(k)fluoranthene Oxidation Reactions	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$18.4NO_3^- + 18.4\ H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 15.2H_2O + 9.2N_2$ Benzo(k)fluoranthene oxidation/denitrification	4.53:1
$46\ MnO_2 + 92H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 46\ Mn^{2+} + 52H_2O$ Benzo(k)fluoranthene oxidation/manganese reduction	15.88:1
$92Fe(OH)_3 + 184H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 92Fe^{2+} + 236H_2O$ Benzo(k)fluoranthene oxidation/iron reduction	39.06:1
$11.5\ SO_4^{2-} + 23H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 11.5\ H_2S + 6H_2O$ Benzo(k)fluoranthene oxidation/sulfate reduction	4.38:1
$17H_2O + C_{20}H_{12} \Rightarrow 8.5CO_2 + 11.5CH_4$ Benzo(k)fluoranthene oxidation/methanogenesis	0.73:1

Coupled Benzo(b)fluoranthene Oxidation Reactions	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$18.4NO_3^- + 18.4\ H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 15.2H_2O + 9.2N_2$ Benzo(b)fluoranthene oxidation/denitrification	4.53:1
$46\ MnO_2 + 92H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 46\ Mn^{2+} + 52H_2O$ Benzo(b)fluoranthene oxidation/manganese reduction	15.88:1
$92Fe(OH)_3 + 184H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 92Fe^{2+} + 236H_2O$ Benzo(b)fluoranthene oxidation/iron reduction	39.06:1
$11.5\ SO_4^{2-} + 23H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 11.5\ H_2S + 6H_2O$ Benzo(b)fluoranthene oxidation/sulfate reduction	4.38:1
$17H_2O + C_{20}H_{12} \Rightarrow 8.5CO_2 + 11.5CH_4$ Benzo(b)fluoranthene oxidation/methanogenesis	0.73:1

Coupled Benzo(a)pyrene Oxidation Reactions	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$18.4NO_3^- + 18.4\ H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 15.2H_2O + 9.2N_2$ Benzo(a)pyrene oxidation/denitrification	4.53:1
$46\ MnO_2 + 92H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 46\ Mn^{2+} + 52H_2O$ Benzo(a)pyrene oxidation/manganese reduction	15.88:1
$92Fe(OH)_3 + 184H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 92Fe^{2+} + 236H_2O$ Benzo(a)pyrene oxidation/iron reduction	39.06:1
$11.5\ SO_4^{2-} + 23H^+ + C_{20}H_{12} \Rightarrow 20CO_2 + 11.5\ H_2S + 6H_2O$ Benzo(a)pyrene oxidation/sulfate reduction	4.38:1
$17H_2O + C_{20}H_{12} \Rightarrow 8.5CO_2 + 11.5CH_4$ Benzo(a)pyrene oxidation/methanogenesis	0.73:1

Coupled Benzo(a)anthracene Oxidation Reactions	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$16.8\ NO_3^- + 16.8H^+ + C_{18}H_{12} \Rightarrow 18CO_2 + 14.4\ H_2O + 8.4N_2$ Benzo(a)anthracene oxidation/denitrification	4.57:1
$42MnO_2 + 84H^+ + C_{18}H_{12} \Rightarrow 18CO_2 + 42Mn^{2+} + 48H_2O$ Benzo(a)anthracene oxidation/manganese reduction	16.03:1
$84Fe(OH)_3 + 168H^+ + C_{18}H_{12} \Rightarrow 18CO_2 + 84Fe^{2+} + 216H_2O$ Benzo(a)anthracene oxidation/iron reduction	39.42:1
$10.5SO_4^{2-} + 21H^+ + C_{18}H_{12} \Rightarrow 18CO_2 + 10.5H_2S + 6\ H_2O$ Benzo(a)anthracene oxidation/sulfate reduction	4.42:1
$15H_2O + C_{18}H_{12} \Rightarrow 7.5CO_2 + 10.5CH_4$ Benzo(a)anthracene oxidation/methanogenesis	0.74:1

Coupled Acenaphthene Oxidation Reactions	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$11.6NO_3^- + 11.6H^+ + C_{12}H_{10} \Rightarrow 12CO_2 + 10.8H_2O + 5.8N_2$ Acenaphthene oxidation/denitrification	4.67:1
$29MnO_2 + 58H^+ + C_{12}H_{10} \Rightarrow 12CO_2 + 29\ Mn^{2+} + 34H_2O$ Acenaphthene oxidation/manganese reduction	16.38:1
$58Fe(OH)_3 + 116H^+ + C_{12}H_{10} \Rightarrow 12CO_2 + 58Fe^{2+} + 150H_2O$ Acenaphthene oxidation/iron reduction	40.30:1
$7.25SO_4^{2-} + 14.5H^+ + C_{12}H_{10} \Rightarrow 12CO_2 + 7.25\ H_2S + 5H_2O$ Acenaphthene oxidation/sulfate reduction	4.52:1
$9.5H_2O + C_{12}H_{10} \Rightarrow 4.75CO_2 + 7.25CH_4$ Acenaphthene oxidation/methanogenesis	0.75:1

Coupled Methyl tert butylether Oxidation Reactions	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$6NO_3^- + 6H^+ + C_5OH_{12} \Rightarrow 5CO_2 + 9H_2O + 3N_2$ Methyl tert butyl ether oxidation/denitrification	4.23:1
$15MnO_2 + 30H^+ + C_5OH_{12} \Rightarrow 5CO_2 + 15Mn^{2+} + 21H_2O$ Methyl tert butyl ether oxidation/manganese reduction	14.83:1
$30\ Fe(OH)_3 + 60H^+ + C_5OH_{12} \Rightarrow 5CO_2 + 30Fe^{2+} + 81H_2O$ Methyl tert butyl ether oxidation/iron reduction	36.48:1
$3.75SO_4^{2-} + 7.5H^+ + C_5OH_{12} \Rightarrow 5CO_2 + 3.75H_2S + 6H_2O$ Methyl tert butyl ether oxidation/sulfate reduction	4.09:1
$1.5H_2O + C_5H_{12}O \Rightarrow 1.25CO_2 + 3.75CH_4$ Methyl tert butyl ether oxidation/methanogenesis	0.68:1

Gibbs Free Energy of Formation for Species used in Half-Cell reactions and Coupled Oxidation-Reduction Reactions

Species	State	$\Delta G^{\circ}_{f,298.15}$ (kcal/mole)	Source
e^-	i	0	std
H^+	i	0	std
O_2	g	0	std
H_2O	l	-56.687	Dean (1972)
Carbon Species			
CO_2	g	-94.26	Dean (1972)
CH_2O, formalydehyde	aq	-31.02	Dean (1972)
C_6H_6, benzene	l	+29.72	Dean (1972)
CH_4, methane	g	-12.15	Dean (1972)
$C_6H_5CH_3$, toluene	l	+27.19	Dean (1972)
$C_6H_5C_2H_5$, ethylbenzene	l	+28.61	Dean (1972)
$C_6H_4(CH_3)_2$, o-xylene	l	+26.37	Dean (1972)
$C_6H_4(CH_3)_2$, m-xylene	l	+25.73	Dean (1972)
$C_6H_4(CH_3)_2$, p-xylene	l	+26.31	Dean (1972)
C_2Cl_4, PCE	l	+1.1	CRC Handbook (1990)
C_2HCl_3, TCE	l	+2.9	CRC Handbook (1990)
$C_2H_2Cl_2$, c-DCE	l	+5.27	CRC Handbook (1990)
C_2H_4, ethene	g	+16.28	CRC Handbook (1990)
$C_{10}H_8$, naphthalene	l	+48.05	Dean (1972)
$C_6H_3(CH_3)_3$, 1,3,5-TMB	l	+24.83	Dean (1972)
$C_6H_3(CH_3)_3$, 1,2,4-TMB	l	+24.46	Dean (1972)
C_2H_3Cl, vinyl chloride	g	+12.4	Dean (1972)
C_6H_5Cl, chlorobenzene	l	+21.32	Dean (1972)
$C_{14}H_{10}$, phenanthrene	l	+64.12	Dean (1972)
Nitrogen Species			
NO_3^-	i	-26.61	Dean (1972)
N_2	g	0	std
NO_2^-	i	-7.7	Dean (1972)
NH_4^+	aq	-18.97	Dean (1972)
Sulfur Species			
SO_4^{2-}	i	-177.97	Dean (1972)
H_2S	aq	-6.66	Dean (1972)
H_2S	g	-7.9	Dean (1972)
HS^-	i	+2.88	Dean (1972)
Iron Species			
Fe^{2+}	i	-18.85	Dean (1972)
Fe^{3+}	i	-1.1	Dean (1972)
Fe_2O_3, hematite	c	-177.4	Dean (1972)
FeOOH, ferric oxyhydroxide	c	-117.2	Naumov *et al.* (1974)
$Fe(OH)_3$, goethite	a	-167.416	Langmuir and Whittemore (1971)
$Fe(OH)_3$, goethite	c	-177.148	Langmuir and Whittemore (1971)
$FeCO_3$, siderite	c	-159.35	Dean (1972)
Manganese Species			
Mn^{2+}	i	-54.5	Dean (1972)
MnO_2, pyrolusite	c	-111.18	Stumm and Morgan (1981)
MnOOH, manganite	c	-133.29	Stumm and Morgan (1981)
$MnCO_3$, rhodochrosite	p	-194	Dean (1972)
Chloride Species			
Cl^-	aq	-31.37	Dean (1972)

NOTES:

c = crystallized solid
a = amorphous solid (may be partially crystallized - dependent on methods of preparation)
p = freshly precipitated solid
i = dissociated, aqueous ionic species (concentration = 1 m)
aq = undissociated aqueous species
g = gaseous
l = liquid
std = accepted by convention
Wherever possible multiple sources were consulted to eliminate the possibility of typographical error.

Additional BIOSCREEN Modeling Results

Benzene

Using groundwater monitoring data from 1995 through October 1997, calculated decay rates for benzene dissolved in groundwater ranged from 0.0011 day^{-1} (half-life of 1.7 years) to 0.0048 day^{-1} (half-life of 0.4 year), with an average value of 0.002 day^{-1} (half-life of 0.8 year). The minimum and average site-specific solute biodegradation rates for benzene were combined with the source decay rate attributable to physical flushing derived from the batch flushing model assuming 3 months of flushing per year (0.0003 day-1, equivalent to a half-life of 6.3 years) to derive minimum and average total source decay rates for use in the BIOSCREEN simulations. The simulation results using the average values are described in Section 6 of the CAP.

The following four simulations were run for benzene:

1. Using the average source and solute decay rates;

2. Using the average source decay rate and minimum solute decay rate;

3. Using the minimum source decay rate and the average solute decay rate; and

4. Using the minimum source and solute decay rates.

The first-order reaction model indicates that dissolved benzene concentrations will steadily decrease to below 1 µg/L within 6 to 11 years, depending on the values used for the solute and source decay rates. The predicted time frames for this decrease for simulations 1, 2, 3, and 4 (described above) were 6 years, 10.5 years, 6.5 years, and 11 years, respectively. The maximum predicted downgradient extent of the dissolved benzene plume exceeding 1 µg/L was 35 to 40 feet from the source area.

The instantaneous reaction model predicts that benzene will be "instantaneously" degraded and will not persist in the groundwater. Therefore, this model does not appear to be accurately simulating site conditions.

Benzo(a)pyrene

The following two simulations were performed for benzo(a)pyrene:

1. Source half-life equals 5.8 years and solute half-life equals 1000 years (no solute decay); and

2. Source half-life equals 5.8 years and solute half-life equals 0.92 year (the average value estimated in Section 6.6.3.4 of the CAP).

Results of both first-order reaction simulations indicate that dissolved benzo(a)pyrene concentrations will decrease to less than 0.2 μg/L after approximately 27 years. Similar to benzene, the instantaneous reaction model indicates that dissolved benzo(a)pyrene will not persist in groundwater because the theoretical assimilative capacity of the groundwater exceeds the concentration of benzo(a)pyrene leaching from the source areas soils.

ALTERNATIVE 1 **BENZENE**

B1a

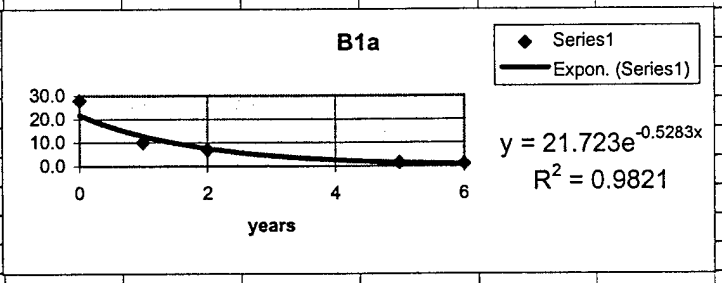
.Source (avg rate): Batch flush k = -.119/yr (3 mo.) + avg. solute biodeg k = -0.90/yr

k (total) = -1.02/yr; t1/2 = 0.68 yr; Koc = 79

Solute avg k = -0.90; t1/2 = 0.77yr

year	conc	distance
0	28.0	0
1	10.1	0
2	7.0	5
5	1.5	15
6	1.0	15

Time to 1.0 ug/L = 6 years



B1b

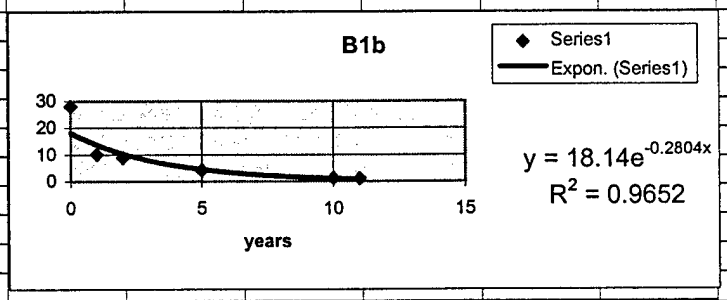
.Source (avg rate): Batch flush k = -.119/yr (3 mo.) + avg. solute biodeg k = -0.90/yr

k (total) = -1.02/yr; t1/2 = 0.68 yr; Koc = 79

Solute min. k = -0.40; t1/2 = 1.73

year	conc	distance
0	28	
1	10.1	5
2	8.9	5
5	4.2	20
10	1.1	35
11	0.9	40

Time to 1.0 ug/L = approx 10.5 years



B2a

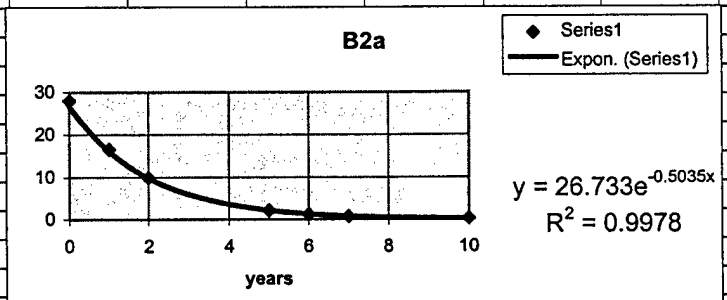
.Source (min rate): Batch flush k = -.119/yr (3 mo.) + solute biodeg k = -.0.40/yr

k (total) = -0.52/yr; t1/2 = 1.3yr; Koc = 79

Solute avg k = -0.90; t1/2 = 0.77yr

year	conc	distance
0	28	
1	16.6	0
2	9.9	0
5	2.1	0
6	1.2	0
7	0.7	0
10	0.2	0

Time to 1.0 ug/L = approx 6.5 years



B2b

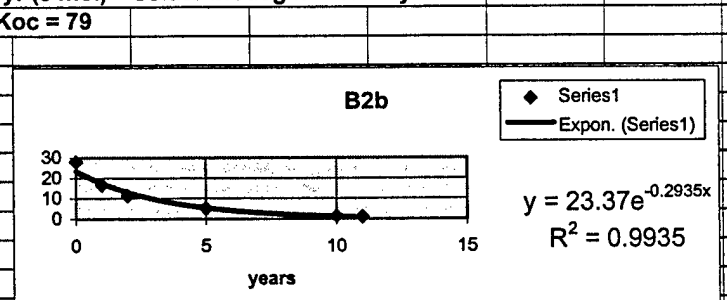
.Source (min rate): Batch flush k = -.119/yr (3 mo.) + solute biodeg k = -.0.40/yr

k (total) = -0.52/yr; t1/2 = 1.3yr; Koc = 79

Solute min. k = -0.40; t1/2 = 1.73

year	conc	distance
0	28	0
1	16.6	0
2	11.3	5
5	5.2	15
10	1.2	30
11	1	35

Time to 1.0 ug/L = approx 11 years



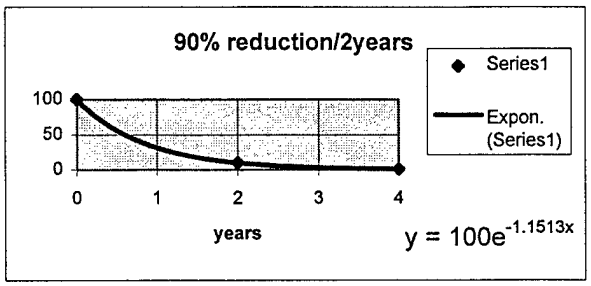
BENZENE
Alternative 2 - Bioventing

Common inputs:
Seepage velocity; 5.1 ft/yr
Dispersion; 4.1 ft
Adsorption; 1.5
Kd; 79 L/kg
Source (groundwater) concentration 28 µg/L
Note: Override Bioscreen source half-life calculation - input value directly

Assume 90% BTEX reduction in 2 years { typically 90% after one year but assume soil saturated 6 mo/yr (Bioventing Performance and cost Summary, AFCEE, 1994)

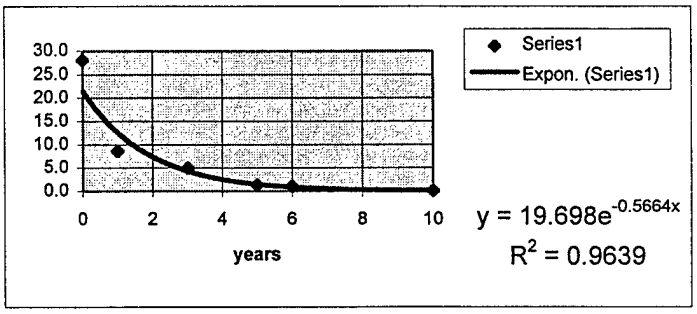
Determine source k

year	number
0	100
2	10
4	1
6	0.1



Source half-life = 0.42yr; k = -1.63yr (batch flush (-0.12/yr) + 90%/ 2yr w/bioventing (-1.51))
Solute half-life = 0.77yr (site avg k)

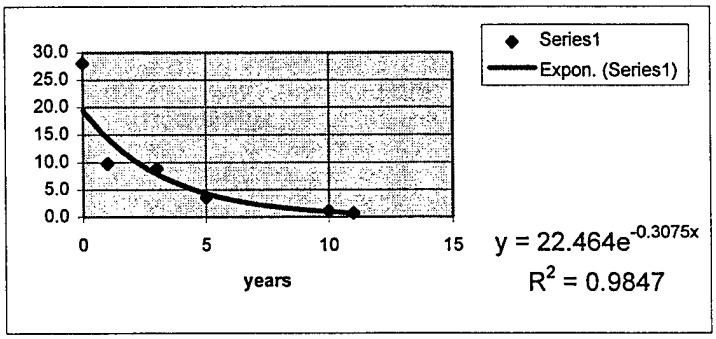
Year	Conc. (ug/L)	Distance
0	28.0	0
1	8.6	5
3	5.0	10
5	1.3	15
6	**1.0**	**20**
10	0.1	30



Time to 1.0 ug/L = approx. 6 years

Source half-life = 0.42yr; k = -1.63yr (batch flush (-0.12/yr) + 90%/ 2yr w/bioventing (-1.51))
Solute half-life = 1.73 yr (site low k)

Year	Conc. (ug/L)	Distance
0	28.0	0
1	9.8	5
3	8.9	10
5	3.6	20
10	1.1	35
11	0.7	35



Time to 1.0 ug/L = approx. 10 years

BENZENE

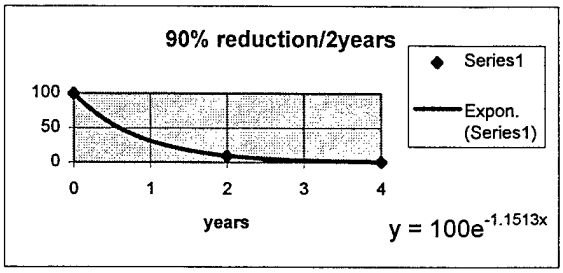
Alternative 2 - Bioventing Add 6 months of source degradation during times of saturation

Common inputs:
Seepage velocity; 5.1 ft/yr
Dispersion; 4.1 ft
Adsorption; 1.5
Kd; 79 L/kg
Source (groundwater) concentration 28 µg/L
Note: Override Bioscreen source half-life calculation - input value directly

Assume 90% BTEX reduction in 2 years { typically 90% after one year but assume soil saturated 6 mo/yr (Bioventing Performance and cost Summary, AFCEE, 1994)

Determine source k

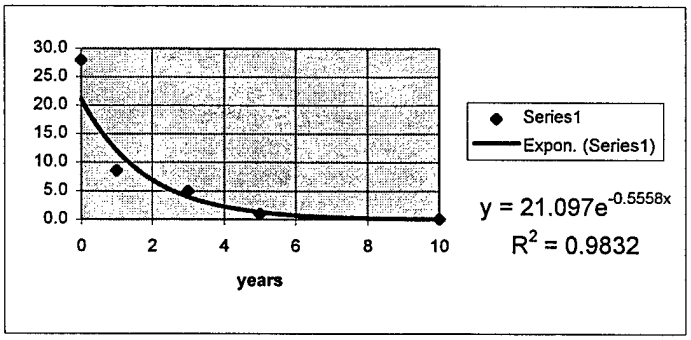
year	number
0	100
2	10
4	1
6	0.1



Source half-life = 0.33yr; k = -2.08yr (batch flush (-0.12/yr) + 90%/ 2yr w/bioventing (-1.51) + 1/2 avg solute biodegradation rate (-0.45/yr))
Solute half-life = 0.77yr (site avg k)

Year	Conc. (ug/L)	Distance
0	28.0	0
1	8.6	5
3	5.0	10
5	**1.0**	**15**
10	0.1	35

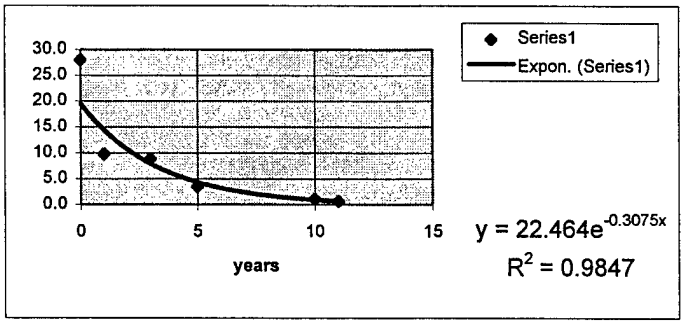
Time to 1.0 ug/L = approx. 5 years



Source half-life = 0.33yr; k = -2.08yr (batch flush (-0.12/yr) + 90%/ 2yr w/bioventing (-1.51) + 1/2 avg solute biodegradation rate (-0.45/yr))
Solute half-life = 1.73 yr (site low k)

Year	Conc. (ug/L)	Distance
0	28.0	0
1	9.8	5
3	8.9	10
5	3.6	20
10	1.1	35
11	0.7	35

Time to 1.0 ug/L = approx. 10 years



Benzo(a)pyrene results for aerobic (bioventing) and anerobic conditions
Alternative 1 and Alternative 2

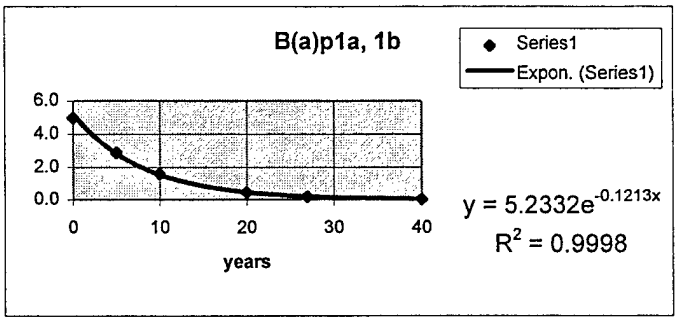
Common inputs:
Seepage velocity; 5.1 ft/yr
Dispersion; 4.1 ft
Adsorption; 17,000
Kd; 2000 L/kg
Source (groundwater) concentration 5 µg/L
Note: Override Bioscreen source half-life calculation - input source term directly

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B(a)p1a
Source half-life = 5.8 yr (anaerobic)
Biodegradation (solute) half-life = 1000 yr

Year	Conc. (µg/L)
0	5.0
5	2.9
10	1.6
20	0.5
27	0.2
40	0.0

Time to 0.2 mg/L = approx. 27 years



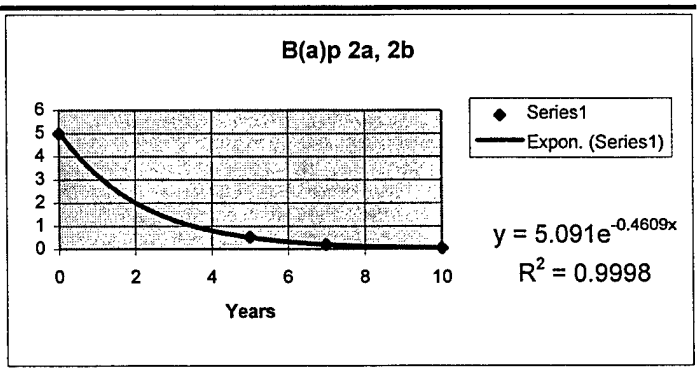
B(a)p1b
Source half-life = 5.8 yr (anaerobic)
Biodegradation (solute) half-life = 0.92 yr (naphthalene - site-average)

Year	Conc. (µg/L)
0	5.0
5	2.9
10	1.6
20	0.5
27	0.2
40	0.0

B(a)p2a
Source half-life = 1.45 yr (aerobic)
Biodegradation (solute) half-life = 1000 yr

Year	Conc. (µg/L)
0	5.0
5	0.5
7	0.2
10	0.1

Time to 0.2 mg/L = approx. 7 years



B(a)p2b
Source half-life = 1.45 yr (aerobic)
Biodegradation (solute) half-life = 0.92 yr (naphthalene - site-average)

Year	Conc. (µg/L)
0	5
5	0.53
7	0.2
10	0.05

Contaminant Flushing Calculations--Simulated Batch Flush Model (Saturated)

Homestead ARB Site SS-15A

Prepared by: JRH, 2/13/98

Calculations assume fuel residuals remain in soils at or below the water table and that groundwater is continuously moving through these soils. This results in the partitioning of contaminatns compounds from the soils into the groundwater. This aquifer is modeled as a batch reactor in which clean groundwater enters contaminated soil which releases contaminants into the water based on the partitioning coefficient (Kd). Each pore volume of groundwater is then replaced with clean groundwater and the desorption cycle is repeated.

Knowns:

1. Linear groundwater velocity = approx. 5.1 ft/yr
2. porosity = approx. 0.20
3. soil bulk density (estimated for weathered limestone) = 2 g/cubic cm.
4. starting benzene concentration in groundwater = 28 ug/L (max. detected in last 1 year)
5. Average soil TOC concentration = 721 mg/kg = 721 x 10^{-6} mg TOC/mg soil =0.000721 = foc
6. Koc for benzene = 79 L/kg (fuels protocol) or 38 L/kg (Bioscreen User's Manual) = Organic Carbon Partion Coefficient
7. Kd for benzene = (foc) (Koc) = 0.057 L/kg using Koc of 79, and 0.027 L/kg using Koc of 38
8. Kd for benzo(a)pyrene = approx. 2000 L/kg (Montgomery, 1996)

Assumptions:

1. 100% of equilibrium will be reached with each flush (reasonable due to low groundwater migration velocity)
2. Simulated reactor volume = volume of contaminated soil in the saturated zone at an average source area (assumed to approximate a circle with a diameter of 20 feet and a thickness of 4 feet).

Contaminated soil volume = $pi(r^2)h$ = 3.141 (100 ft^2)(4 ft) = 1256 ft^3 = 36 m^3

Mass of soil = (2 g/cm^3) (10^6 cm^3/m^3) (1kg/1000g) (36 m^3) = 72,000 kg = 2000 kg/m^3

Mass of water = (1 g/cm^3) (0.20 cm^3 water/cm^3 aquifer) (10^6 cm^3/m^3) (1kg/1000g) (36 m^3) = 7200 kg =200 kg/m^3

A new volume of water will pass through the seasonally-saturated soil mass approximately every 15.6 years:

20 feet fravel distance / 5.1 feet per year GW velocity = 3.9 years

Assuming that contaminated soil is saturated 3 months per year (1/4 year), the equivalent of one pore volume of flushing will occur every 15.6 years (4 x 3.9 = 15.6).

Equations:

Kd = soil concentration / water concentration = ug/kg / ug/L

Therefore, water concentration = soil concentration / Kd

M(s) = mass of contaminant in soil

M(w) = mass of contaminant in water

M(s, new) = m(s,old) - m(w)

ug/kg = ug/kg - ug/L

Need to correct for density: 200 kg/m^3 / 2000 kg/m^3 = 0.10 L/kg

Therefore, ug/kg remaining = ug/kg initial - [ug/L leached x 0.10 L/kg]

This equation is used to compute the decrease in soil benzene concentrations over time in the attached spreadsheet.

The Kd value is used in combination with each new soil concentration to compute the resulting groundwater concentration.

As described above, it is estimated that the equivalent of one pore volume of groundwater flushes through the seasonally saturated contaminated soil interval every 15.6 years. Therefore, 1/15.6 (or 0.064) flushes occurs each year.

According to this model, it would take approximately 28 years for physical flushing alone to reduce maximum groundwater benzene concentrations to less than 1 ug/L assuming a benzene Kd of 0.057 L/kg. It would take approximately 13 years for physical flushing alone to reduce maximum groundwater benzene concentrations to less than 1 ug/L assuming a benzene Kd of 0.027 L/kg.

However, this model does not take biodegradation into account. The biodegradation rate computed for benzene in the

saturated zone using the single-well (diminishing plume) method of Buscheck and Alcantar (1995) ranged from 0.0011 to 0.0048 day^{-1}. Therefore, during the estimated 3 months per year that the contaminated soils are saturated, they are being biodegraded. It is highly likely that contaminants are also being biodegraded during the other 9 months per year when the soils are not saturated given the presence of soil moisture in the vadose zone that can support microbial populations.

If the soil benzene leaching rates are graphed, they yield rates of 0.00033 to 0.0007 day-1, which are equivalent to half-lives of 5.7 years to 2.7 years. Adding the most conservative physical flushing rate (0.00033 day-1) to the biodegradation rate yields a combined benzene source weathering rate for use in the Bioscreen model.

APPENDIX C

CALCULATION OF TIER 2 SITE-SPECIFIC TARGET LEVELS (SSTLS)

APPENDIX C
CALCULATION OF SITE-SPECIFIC TARGET LEVELS (SSTLs) - GROUNDWATER
INDUSTRIAL LAND USE - CONSTRUCTION SCENARIO
RME SCENARIO
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Exposure Assumptions		
Body Weight (BW)	70	kg
Exposure Frequency (EF)	46	days/yr
Exposure Duration (ED)	1	yr
Ingestion Rate (IR)	0.005	L/hr
Conversion Factor (CF)	0.001	L/cm^3
Exposure Time Dermal(ET_D)	2	hr/day
Permeability Constant (PC)	chem-specific	cm/hr
Surface Area (SA)	5300	cm^2
Oral Absorption Factor (OABS)	chem-specific	unitless
Exposure Time Inhalation (ET_I)	8	hrs/day
Inhalation Rate (InhR)	2.5	m^3/hr
Area of Trench (A)	300000	cm^2
Length of Side Perpendicular to Wind (LS)	15	m
Average Wind Speed (V)	4.47	m/sec
Mixing Height Above Water (MH)	2	m
Molecular Weight (MW)	chem-specific	g/mol
Henry's Law Constant (HLC)	chem-specific	atm m^3/mol
Averaging Time (AT)		
Noncarcinogens	365	days
Carcinogens	25550	days
Target Risk Level (TR)	1.00E-06	unitless
Target Hazard Quotient (THQ)	1	unitless

Toxicity Value Definitions

RfDo = Reference Dose (Oral) mg/kg-day
RfDd = Reference Dose (Dermal) mg/kg-day
RfDi = Reference Dose (Inhalation) mg/kg-day
SFo = Oral Slope Factor kg-day/mg
SFd = Dermal Slope Factor kg-day/mg
SFi = Inhalation Slope Factor kg-day/mg
SSTL-non = Noncarcinogenic SSTL mg/L
SSTL-car = Carcinogenic SSTL mg/L

Mass Transfer Coefficient (K) (cm/s) chem-specific

$1/K = 1/K(l) + [(8.2E\text{-}5(atm\ m^3/mol\ °K)*298°K)/(HCL*K(g))]$

Liquid Mass Transfer Coefficient (K(l)) (cm/s) chem-specific

$K(l) = ([32(g/mol)/MW]^{0.5})*0.0061(cm/sec)$

Gas Mass Transfer Coefficient (K(g)) (cm/s) chem-specific

$K(g) = ([18(g/mol)/MW]^{0.335})*1.39(cm/sec)$

Noncarcinogens

SSTL (mg/L) = (THQ*BW*AT)/[ED*EF([1/RfDo*IR*ET]+[1/RfDd*SA*PC*ET*CF]+ [(ET*InhR*CF*K*A)/(RfDi*LS*V*MH)])]

Carcinogens

SSTL (mg/L) = (TR*BW*AT)/[ED*EF([SFo*IR*ET]+[SFd*SA*PC*ET*CF]+ [(SFi*ET*InhR*CF*K*A)/(LS*V*MH)])]

Chemical Name	MW	HLC [a]	PC [b]	OABS [c]	RfDo [d]	RfDd	RfDi	SFo	SFd	SFi	K(g)	K(l)	K	SSTL Carcinogen mg/L	SSTL Non-Carc. mg/L
Volatiles															
Benzene	78.11	5.60E-03	2.10E-02	9.00E-01	3.00E-03	2.70E-03	1.71E-03	2.90E-02	3.22E-02	2.90E-02	8.50E-01	3.90E-03	3.83E-03	3.13E+00	2.99E+00
Ethylbenzene	106.17	7.90E-03	7.40E-02	8.00E-01	1.00E-01	8.00E-02	2.90E-01	-- [e]	--	--	7.67E-01	3.35E-03	3.30E-03	--	5.33E+01
MTBE	88.15	5.87E-04	4.20E-03	8.00E-01	5.00E-03	4.00E-03	8.60E-01	--	--	--	8.16E-01	3.68E-03	3.10E-03	--	4.18E+01
PAHs															
Acenaphthene	154.21	1.60E-04	1.32E-01	5.00E-01	6.00E-02	3.00E-02	3.00E-02	--	--	--	6.77E-01	2.78E-03	1.71E-03		1.13E+01

APPENDIX C
CALCULATION OF SITE-SPECIFIC TARGET LEVELS (SSTLs) - GROUNDWATER
INDUSTRIAL LAND USE - CONSTRUCTION SCENARIO
RME SCENARIO
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Exposure Assumptions

Body Weight (BW)	70	kg
Exposure Frequency (EF)	46	days/yr
Exposure Duration (ED)	1	yr
Ingestion Rate (IR)	0.005	L/hr
Conversion Factor (CF)	0.001	L/cm^3
Exposure Time Dermal(ET_D)	2	hr/day
Permeability Constant (PC)	chem-specific	cm/hr
Surface Area (SA)	5300	cm^2
Oral Absorption Factor (OABS)	chem-specific	unitless
Exposure Time Inhalation (ET_I)	8	hrs/day
Inhalation Rate (InhR)	2.5	m^3/hr
Area of Trench (A)	300000	cm^2
Length of Side Perpendicular to Wind (LS)	15	m
Average Wind Speed (V)	4.47	m/sec
Mixing Height Above Water (MH)	2	m
Molecular Weight (MW)	chem-specific	g/mol
Henry's Law Constant (HLC)	chem-specific	atm m^3/mol
Averaging Time (AT)		
Noncarcinogens	365	days
Carcinogens	25550	days
Target Risk Level (TR)	1.00E-06	unitless
Target Hazard Quotient (THQ)	1	unitless

Toxicity Value Definitions

RfDo = Reference Dose (Oral)	mg/kg-day
RfDd = Reference Dose (Dermal)	mg/kg-day
RfDi = Reference Dose (Inhalation)	mg/kg-day
SFo = Oral Slope Factor	kg-day/mg
SFd = Dermal Slope Factor	kg-day/mg
SFi = Inhalation Slope Factor	kg-day/mg
SSTL-non = Noncarcinogenic SSTL	mg/L
SSTL-car = Carcinogenic SSTL	mg/L

Mass Transfer Coefficient (K) (cm/s) chem-specific

$$1/K = 1/K(l) + [(8.2E\text{-}5(atm\ m^3/mol\ °K)*298°K)/(HCL*K(g))]$$

Liquid Mass Transfer Coefficient (K(l)) (cm/s) chem-specific

$$K(l) = ([32(g/mol)/MW]^{0.5})*0.0061(cm/sec)$$

Gas Mass Transfer Coefficient (K(g)) (cm/s) chem-specific

$$K(g) = ([18(g/mol)/MW]^{0.335})*1.39(cm/sec)$$

Noncarcinogens

SSTL (mg/L) = (THQ*BW*AT)/[ED*EF([1/RfDo*IR*ET]+[1/RfDd*SA*PC*ET*CF]+ [(ET*InhR*CF*K*A)/(RfDi*LS*V*MH)])]

Carcinogens

SSTL (mg/L) = (TR*BW*AT)/[ED*EF([SFo*IR*ET]+[SFd*SA*PC*ET*CF]+ [(SFi*ET*InhR*CF*K*A)/(LS*V*MH)])]

Chemical Name	MW	HLC [a/]	PC [b/]	OABS [c/]	RfDo [d/]	RfDd	RfDi	SFo	SFd	SFi	K(g)	K(l)	K	SSTL Carcinogen mg/L	SSTL Non-Carc. mg/L
Benzo(a)anthracene	228.30	3.40E-06	8.10E-01	5.00E-01	--	--	--	7.30E-01	1.46E+00	3.10E-01	5.94E-01	2.28E-03	7.97E-05	3.10E-03	--
Benzo(a)pyrene	252.32	1.10E-06	1.20E+00	5.00E-01	--	--	--	7.30E+00	1.46E+01	3.10E+00	5.74E-01	2.17E-03	2.55E-05	2.09E-04	--
Benzo(b)fluoranthene	252.32	1.10E-04	1.20E+00	5.00E-01	--	--	--	7.30E-01	1.46E+00	3.10E-01	5.74E-01	2.17E-03	1.18E-03	2.09E-03	--
Benzo(k)fluoranthene	252.32	8.30E-07	1.20E+00	5.00E-01	--	--	--	7.30E-02	1.46E-01	3.10E-02	5.74E-01	2.17E-03	1.93E-05	2.09E-02	--
Naphthalene	128.18	4.80E-04	6.90E-02	1.00E+00	4.00E-02	4.00E-02	4.00E-02	--	--	--	7.20E-01	3.05E-03	2.51E-03	--	2.60E+01

TRPH cannot compute SSTLs due to lack of toxicity data

a/ Henry's Law Constants taken from Table 3a of Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C. (FDEP, 1997).
b/ Permeability constants taken from or calculated per Dermal Exposure Assessment: Principles and Application (USEPA, 1992).
c/ The oral absorption values were taken from Tables 4a and 4b of Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C. (FDEP, 1997).
d/ Toxicity values taken from Tables 4a and 4b of Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C. (FDEP, 1997).
e/ "--" indicates that no toxicity data is available.
Note: SSTLs include dermal contact, incidental ingestion, and inhalation pathways.

APPENDIX C

CALCULATION OF SITE-SPECIFIC TARGET LEVELS (SSTLs) - GROUNDWATER
INDUSTRIAL LAND USE - CONSTRUCTION SCENARIO
CT SCENARIO
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Exposure Assumptions		
Body Weight (BW)	70	kg
Exposure Frequency (EF)	15	days/yr
Exposure Duration (ED)	1	yr
Ingestion Rate (IR)	0.0025	L/hr
Conversion Factor (CF)	0.001	L/cm^3
Exposure Time Dermal(ET_D)	1	hr/day
Permeability Constant (PC)	chem-specific	cm/hr
Surface Area (SA)	2910	cm^2
Oral Absorption Factor (OABS)	chem-specific	unitless
Exposure Time Inhalation (ET_I)	4	hrs/day
Inhalation Rate (InhR)	0.8	m^3/hr
Area of Trench (A)	300000	cm^2
Length of Side Perpendicular to Wind (LS)	15	m
Average Wind Speed (V)	4.47	m/sec
Mixing Height Above Water (MH)	2	m
Molecular Weight (MW)	chem-specific	g/mol
Henry's Law Constant (HLC)	chem-specific	atm m^3/mol
Averaging Time (AT)		
Noncarcinogens	365	days
Carcinogens	25550	days
Target Risk Level (TR)	1.00E-06	unitless
Target Hazard Quotient (THQ)	1	unitless

Toxicity Value Definitions

RfDo = Reference Dose (Oral) mg/kg-day
RfDd = Reference Dose (Dermal) mg/kg-day
RfDi = Reference Dose (Inhalation) mg/kg-day
SFo = Oral Slope Factor kg-day/mg
SFd = Dermal Slope Factor kg-day/mg
SFi = Inhalation Slope Factor kg-day/mg
SSTL-non = Noncarcinogenic SSTL mg/L
SSTL-car = Carcinogenic SSTL mg/L

Mass Transfer Coefficient (K) (cm/s) chem-specific

$$1/K = 1/K(l) + [(8.2E\text{-}5(atm\ m^3/mol\ ^oK)*298^oK)/(HCL*K(g))]$$

Liquid Mass Transfer Coefficient (K(l)) (cm/s) chem-specific

$$K(l) = ([32(g/mol)/MW]^{\wedge}0.5)*0.0061(cm/sec)$$

Gas Mass Transfer Coefficient (K(g)) (cm/s) chem-specific

$$K(g) = ([18(g/mol)/MW]^{\wedge}0.335)*1.39(cm/sec)$$

Noncarcinogens

SSTL (mg/L) = (THQ*BW*AT)/[ED*EF([1/RfDo*IR*ET]+[1/RfDd*SA*PC*ET*CF]+ [(ET*InhR*CF*K*A)/(RfDi*LS*V*MH)])]

Carcinogens

SSTL (mg/L) = (TR*BW*AT)/[ED*EF([SFo*IR*ET]+[SFd*SA*PC*ET*CF]+ [(SFi*ET*InhR*CF*K*A)/(LS*V*MH)])]

Chemical Name	MW	HLC [a]	PC [b]	OABS [c]	RfDo [d]	RfDd	RfDi	SFo	SFd	SFi	K(g)	K(l)	K	SSTL Carcinogen mg/L	SSTL Non-Carc. mg/L
Volatiles															
Benzene	78.11	5.60E-03	2.10E-02	9.00E-01	3.00E-03	2.70E-03	1.71E-03	2.90E-02	3.22E-02	2.90E-02	8.50E-01	3.90E-03	3.83E-03	4.20E+01	4.31E+01
Ethylbenzene	106.17	7.90E-03	7.40E-02	8.00E-01	1.00E-01	8.00E-02	2.90E-01	-- [e]	--	--	7.67E-01	3.35E-03	3.30E-03	--	6.09E+02
MTBE	88.15	5.87E-04	4.20E-03	8.00E-01	5.00E-03	4.00E-03	8.60E-01	--	--	--	8.16E-01	3.68E-03	3.10E-03	--	4.76E+02
PAHs															
Acenaphthene	154.21	1.60E-04	1.32E-01	5.00E-01	6.00E-02	3.00E-02	3.00E-02	--	--	--	6.77E-01	2.78E-03	1.71E-03		1.29E+02

APPENDIX C

CALCULATION OF SITE-SPECIFIC TARGET LEVELS (SSTLs) - GROUNDWATER

INDUSTRIAL LAND USE - CONSTRUCTION SCENARIO

CT SCENARIO

SITE SS-15A

HOMESTEAD AFB, FLORIDA

Exposure Assumptions		
Body Weight (BW)	70	kg
Exposure Frequency (EF)	15	days/yr
Exposure Duration (ED)	1	yr
Ingestion Rate (IR)	0.0025	L/hr
Conversion Factor (CF)	0.001	L/cm^3
Exposure Time Dermal(ET_D)	1	hr/day
Permeability Constant (PC)	chem-specific	cm/hr
Surface Area (SA)	2910	cm^2
Oral Absorption Factor (OABS)	chem-specific	unitless
Exposure Time Inhalation (ET_I)	4	hrs/day
Inhalation Rate (InhR)	0.8	m^3/hr
Area of Trench (A)	300000	cm^2
Length of Side Perpendicular to Wind (LS)	15	m
Average Wind Speed (V)	4.47	m/sec
Mixing Height Above Water (MH)	2	m
Molecular Weight (MW)	chem-specific	g/mol
Henry's Law Constant (HLC)	chem-specific	atm m^3/mol
Averaging Time (AT)		
Noncarcinogens	365	days
Carcinogens	25550	days
Target Risk Level (TR)	1.00E-06	unitless
Target Hazard Quotient (THQ)	1	unitless

Toxicity Value Definitions

RfDo = Reference Dose (Oral) mg/kg-day
RfDd = Reference Dose (Dermal) mg/kg-day
RfDi = Reference Dose (Inhalation) mg/kg-day
SFo = Oral Slope Factor kg-day/mg
SFd = Dermal Slope Factor kg-day/mg
SFi = Inhalation Slope Factor kg-day/mg
SSTL-non = Noncarcinogenic SSTL mg/L
SSTL-car = Carcinogenic SSTL mg/L

Mass Transfer Coefficient (K) (cm/s) chem-specific

$$1/K = 1/K(l) + [(8.2E\text{-}5(atm\ m^3/mol\ ^oK)*298^oK)/(HCL*K(g))]$$

Liquid Mass Transfer Coefficient (K(l)) (cm/s) chem-specific

$$K(l) = ([32(g/mol)/MW]^{0.5})*0.0061(cm/sec)$$

Gas Mass Transfer Coefficient (K(g)) (cm/s) chem-specific

$$K(g) = ([18(g/mol)/MW]^{0.335})*1.39(cm/sec)$$

Noncarcinogens

SSTL (mg/L) = (THQ*BW*AT)/[ED*EF([1/RfDo*IR*ET]+[1/RfDd*SA*PC*ET*CF]+ [(ET*InhR*CF*K*A)/(RfDi*LS*V*MH)])]

Carcinogens

SSTL (mg/L) = (TR*BW*AT)/[ED*EF([SFo*IR*ET]+[SFd*SA*PC*ET*CF]+ [(SFi*ET*InhR*CF*K*A)/(LS*V*MH)])]

Chemical Name	MW	HLC [a]	PC [b]	OABS [c]	RfDo [d]	RfDd	RfDi	SFo	SFd	SFi	K(g)	K(l)	K	SSTL Carcinogen mg/L	SSTL Non-Carc. mg/L
Benzo(a)anthracene	228.30	3.40E-06	8.10E-01	5.00E-01	--	--	--	7.30E-01	1.46E+00	3.10E-01	5.94E-01	2.28E-03	7.97E-05	3.46E-02	--
Benzo(a)pyrene	252.32	1.10E-06	1.20E+00	5.00E-01	--	--	--	7.30E+00	1.46E+01	3.10E+00	5.74E-01	2.17E-03	2.55E-05	2.34E-03	--
Benzo(b)fluoranthene	252.32	1.10E-04	1.20E+00	5.00E-01	--	--	--	7.30E-01	1.46E+00	3.10E-01	5.74E-01	2.17E-03	1.18E-03	2.34E-02	--
Benzo(k)fluoranthene	252.32	8.30E-07	1.20E+00	5.00E-01	--	--	--	7.30E-02	1.46E-01	3.10E-02	5.74E-01	2.17E-03	1.93E-05	2.34E-01	--
Naphthalene	128.18	4.80E-04	6.90E-02	1.00E+00	4.00E-02	4.00E-02	4.00E-02	--	--	--	7.20E-01	3.05E-03	2.51E-03	--	3.08E+02

TRPH cannot compute SSTLs due to lack of toxicity data

a/ Henry's Law Constants taken from Table 3a of Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C. (FDEP, 1997).
b/ Permeability constants taken from or calculated per Dermal Exposure Assessment: Principles and Application (USEPA, 1992).
c/ The oral absorption values were taken from Tables 4a and 4b of Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C. (FDEP, 1997).
d/ Toxicity values taken from Tables 4a and 4b of Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C. (FDEP, 1997).
e/ "--" indicates that no toxicity data is available.
Note: SSTLs include dermal contact, incidental ingestion, and inhalation pathways.

APPENDIX C
CALCULATION OF SITE-SPECIFIC TARGET LEVELS (SSTLs) - SOIL
INDUSTRIAL LAND USE - CONSTRUCTION SCENARIO
RME SCENARIO
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Exposure Assumptions			Toxicity Value Definitions	
Body Weight(BW)	70	kg	RfDo = Reference Dose (Oral)	mg/kg-day
Exposure Frequency (EF)	180	days/yr	RfDd = Reference Dose (Dermal)	mg/kg-day
Exposure Duration (ED)	1	yr	RfDi = Reference Dose (Inhalation)	mg/kg-day
Fraction Ingested (FI)	1	unitless	SFo = Oral Slope Factor	kg-day/mg
Ingestion Rate (IR)	480	mg/day	SFd = Dermal Slope Factor	kg-day/mg
Surface Area (SA)	5300	cm^2	SFi = Inhalation Slope Factor	kg-day/mg
Adherence Factor (AF)	1	mg/cm^2-day	SSTL-non = Noncarcinogenic PRG	mg/kg
Dermal Absorption Factor (DABS)	0.01	unitless	SSTL-car = Carcinogenic PRG	mg/kg
Volatilization Factor (VF)	chem-specific	m^3/kg	OABS = Oral Absorption Factor	unitless
Particulate Emission Factor (PEF)	1.24E+09	m^3/kg	**SSTL Calculations**	
Conversion Factor (CF)	1.00E-06	kg/mg	Noncarcinogens	
Averaging Time (AT)			SSTL (mg/kg) = ((THQ*BW*AT)/((1/RfDo*CF*EF*ED*IR*FI)+	
Noncarcinogens	365	days	(1/RfDd*CF*SA*AF*DABS*EF*ED)+(1/RfDi*IRi*EF*ED*(1/VF+1/PEF)))	
Carcinogens	25550	days		
Inhalation Rate (IRi)	20	m^3/day	Carcinogens	
Target Risk Level (TR)	1.00E-06	unitless	SSTL (mg/kg) = ((TR*BW*AT)/((SFo*CF*EF*IR*FI*ED)+	
Target Hazard Quotient (THQ)	1	unitless	(SFd*CF*SA*AF*DABS*EF*ED)+(SFi*IRi*EF*ED*(1/VF+1/PEF)))	

Chemical of Potential Concern	Carcinogen Classification [a]	VF [b]	RfDo [c]	OABS [c]	RfDd [c]	RfDi [c]	SFo [c]	SFd [c]	SFi [c]	SSTL-non (mg/kg)	SSTL-car (mg/kg)
Volatiles											
Benzo(a)anthracene	B2	9.96E+06	--	5.00E-01	--	--	7.30E-01	1.46E+00	3.10E-01	--	2.32E+01
Benzo(a)pyrene	B2	2.70E+07	--	5.00E-01	--	--	7.30E+00	1.46E+01	3.10E+00	--	2.32E+00
Benzo(b)fluoranthene	B2	5.22E+06	--	5.00E-01	--	--	7.30E-01	1.46E+00	3.10E-01	--	2.32E+01
Dibenz(a,h)anthracene	B2	8.03E+07	--	5.00E-01	--	--	7.30E+00	1.46E+01	3.10E+00	--	2.32E+00
Indeno(1,2,3-cd)pyrene	B2	6.40E+07	--	5.00E-01	--	--	7.30E-01	1.46E+00	3.10E-01	--	2.32E+01
TRPH	--	8.68E+03	4.00E-02	5.00E-01	2.00E-02	6.00E-02	--	--	--	2.68E+03	--

[a] USEPA classification system for carcinogens: B2 = probable human carcinogen

[b] Volatilization factors taken from Table 3a and Appendix C (TRPH only) of *Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C.* (FDEP, 1997)

[c] Toxicity values taken from Tables 4a and 4b and Appendix C (TRPH only) of *Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C.* (FDEP, 1997)

Note: SSTLs include dermal contact, incidental ingestion, and inhalation exposure pathways.

APPENDIX C
CALCULATION OF SITE-SPECIFIC TARGET LEVELS (SSTLs) - SOIL
INDUSTRIAL LAND USE - CONSTRUCTION SCENARIO
CT SCENARIO
SITE SS-15A
HOMESTEAD AFB, FLORIDA

Exposure Assumptions		
Body Weight(BW)	70	kg
Exposure Frequency (EF)	60	days/yr
Exposure Duration (ED)	1	yr
Fraction Ingested (FI)	1	unitless
Ingestion Rate (IR)	200	mg/day
Surface Area (SA)	3160	cm^2
Adherence Factor (AF)	0.2	mg/cm^2-day
Dermal Absorption Factor (DABS)	0.01	unitless
Volatilization Factor (VF)	chem-specific	m^3/kg
Particulate Emission Factor (PEF)	1.24E+09	m^3/kg
Conversion Factor (CF)	1.00E-06	kg/mg
Averaging Time (AT)		
Noncarcinogens	365	days
Carcinogens	25550	days
Inhalation Rate (IRi)	6.4	m^3/day
Target Risk Level (TR)	1.00E-06	unitless
Target Hazard Quotient (THQ)	1	unitless

Toxicity Value Definitions

RfDo = Reference Dose (Oral)	mg/kg-day
RfDd = Reference Dose (Dermal)	mg/kg-day
RfDi = Reference Dose (Inhalation)	mg/kg-day
SFo = Oral Slope Factor	kg-day/mg
SFd = Dermal Slope Factor	kg-day/mg
SFi = Inhalation Slope Factor	kg-day/mg
SSTL-non = Noncarcinogenic PRG	mg/kg
SSTL-car = Carcinogenic PRG	mg/kg
OABS = Oral Absorption Factor	unitless

SSTL Calculations

Noncarcinogens

SSTL (mg/kg) = ((THQ*BW*AT)/((1/RfDo*CF*EF*ED*IR*FI)+ (1/RfDd*CF*SA*AF*DABS*EF*ED)+(1/RfDi*IRi*EF*ED*(1/VF+1/PEF)))

Carcinogens

SSTL (mg/kg) = ((TR*BW*AT)/((SFo*CF*EF*IR*FI*ED)+ (SFd*CF*SA*AF*DABS*EF*ED)+(SFi*IRi*EF*ED*(1/VF+1/PEF)))

Chemical of Potential Concern	Carcinogen Classification [a/]	VF [b/]	RfDo [c/]	OABS [c/]	RfDd [c/]	RfDi [c/]	SFo [c/]	SFd [c/]	SFi [c/]	SSTL-non (mg/kg)	SSTL-car (mg/kg)
Volatiles											
Benzo(a)anthracene	B2	9.96E+06	--	5.00E-01	--	--	7.30E-01	1.46E+00	3.10E-01	--	1.92E+02
Benzo(a)pyrene	B2	2.70E+07	--	5.00E-01	--	--	7.30E+00	1.46E+01	3.10E+00	--	1.92E+01
Benzo(b)fluoranthene	B2	5.22E+06	--	5.00E-01	--	--	7.30E-01	1.46E+00	3.10E-01	--	1.92E+02
Dibenz(a,h)anthracene	B2	8.03E+07	--	5.00E-01	--	--	7.30E+00	1.46E+01	3.10E+00	--	1.92E+01
Indeno(1,2,3-cd)pyrene	B2	6.40E+07	--	5.00E-01	--	--	7.30E-01	1.46E+00	3.10E-01	--	1.92E+02
TRPH	--	8.68E+03	4.00E-02	5.00E-01	2.00E-02	6.00E-02	--	--	--	2.42E+04	--

[a/] USEPA classification system for carcinogens: B2 = probable human carcinogen

[b/] Volatilization factors taken from Table 3a and Appendix C (TRPH only) of *Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C.* (FDEP, 1997)

[c/] Toxicity values taken from Tables 4a and 4b and Appendix C (TRPH only) of *Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, F.A.C.* (FDEP, 1997)

Note: SSTLs include dermal contact, incidental ingestion, and inhalation exposure pathways.

BENZENE

CAS NUMBER

71-43-2

COMMON SYNONYMS

None noted.

ANALYTICAL CLASSIFICATION

Volatile organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: 1,791 mg/L [1]
Vapor Pressure: 95.19 mm Hg at 25°C [1]
Henry's Law Constant: 5.43 x 10^{-3} atm-m^3/mole [1]
Specific Gravity: 0.879 at 15/5°C [2]
Organic Carbon Partition Coefficient: 31 - 143 [1]

FATE DATA: HALF-LIVES

Soil: 5 - 16 days [3]
Air: 2.09 - 20.9 days [3]
Surface Water: 5 - 16 days [3]
Groundwater: 10 days to 2 years [3]

NATURAL SOURCES

Crude oil, volcanoes, forest fires, and plants [1].

ARTIFICIAL SOURCES

Gasoline, fuel oils, chemical industry, coke ovens, mining, manufacturing, and cigarette smoke [1].

FATE AND TRANSPORT

Benzene will rapidly volatilize from surface soil and water. That which does not volatilize from permeable surface and subsurface soils will be highly to very highly mobile, and can be expected to leach to nearby groundwater which is not protected by a confining layer. It is fairly soluble, and will be carried with the groundwater to discharge points. It may be subject to biodegradation in soils, shallow groundwater, and surface water. Benzene will not be expected to significantly adsorb to sediment, bioconcentrate in aquatic organisms, or hydrolyze. Photodegradation may be a significant removal mechanism in surface water which is not conducive to microbial degradation. Benzene will undergo significant photodegradation in air, but may be washed out with rain [1].

HUMAN TOXICITY

General. Benzene is absorbed into the body following ingestion, inhalation, and dermal contact, and must undergo metabolic transformation to exert its toxic effects. Metabolism occurs primarily in the liver, and to a lesser extent, in the bone marrow [4]. The primary targets of benzene toxicity are the CNS and the blood [4,5]. Benzene is genotoxic to humans and the USEPA has placed it in weight-of-evidence cancer group A, indicating that it is a human carcinogen [6].

Oral Exposure. A chronic oral RfD for benzene is currently under review by the USEPA [6]. Benzene is readily absorbed following oral exposure. The lowest reported fatal dose in humans is 50 mg/kg [5]. Acute oral LD_{50} values in animals include 930 to 5600 mg/kg in rats, 2000 mg/kg in dogs, and 4700 mg/kg in mice [4,5]. Data regarding the ingestion of benzene in humans are limited to acute overexposure. Ingestion of 2 mL (29 mg/kg) has resulted in depression of the CNS, while ingestion of 10 mL (143 mg/kg) has been fatal [5]. The cause of death was usually respiratory arrest, CNS depression, or cardiac collapse [4]. In animals, longer-term oral exposure has resulted in toxic effects on the blood (cytopenia: decrease in various cellular elements of the blood) and the immunological system (decreased white blood cells) [4]. There is no evidence that oral exposure to benzene causes effects on reproduction and development, but studies in animals suggest that benzene may affect fetal development [4]. There is no information regarding carcinogenic effects in humans following oral exposure to benzene, but studies in animals indicate that benzene ingestion causes cancer in various regions of the body [4]. An oral slope factor of 0.029 $(mg/kg\text{-}day)^{-1}$ is based on an increase in the incidence of leukemia in occupationally-exposed workers [6]. The oral slope factor was extrapolated from the inhalation data.

Inhalation Exposure. A chronic inhalation RfC for benzene is currently under review by the USEPA [6]. Benzene is readily absorbed following inhalation exposure. The lowest reported fatal concentration in humans is 6380 mg/m^3 for a 5 minute exposure [5]. Acute inhalation LC_{50} values in rats ranged from 10,000 ppm for 7 hours to 13,700 ppm for 4 hours [4,5]. Most of the available data regarding benzene exposure involve workers exposed in the workplace. The acute effects of benzene exposure involve the CNS. Brief exposure to concentrations of 700 to 3000 ppm can cause drowsiness, dizziness, headaches, and unconsciousness, and exposure to concentrations of 10,000 to 20,000 ppm can result in death [4]. In most cases, the effects will end when exposure ceases. The hematopoietic system is the primary target of toxicity following long-term exposure: exposure for several months to years results in pancytopenia (reduction in red blood cells, platelets, and white blood cells), while continued exposure for many years results in anemia or leukemia. The lowest concentration resulting in the hematological effects is approximately 10 to 50 ppm [5]. Benzene has been shown to cause chromosomal aberrations in bone marrow and lymphocytes in workers exposed to concentrations >100 ppm [5]. Chromosomal damage has been found in animals at concentrations as low as 1 ppm [5]. Benzene is not known to be teratogenic (cause birth defects) in humans, but has been found to cause various problems in the developing fetus of animals (low birth weight and delayed bone formation) [4,5]. Occupational exposure to benzene has resulted in leukemia in exposed workers [4,5]. An inhalation unit risk of 8.3×10^{-6} $(ug/m^3)^{-1}$ is based on the incidence of leukemia in occupationally-exposed workers [6].

Dermal Exposure. Dermal exposure to benzene may cause redness and dermatitis [4,5]. Systemic effects have not been reported following dermal exposure to benzene.

REFERENCES

1. Howard, P.H., 1990. Handbook of Environmental Fate and Exposure Data For Organic Chemicals, Vol. II: Solvents. Lewis Publishers, Inc. Chelsea, Michigan. 546 pp.

2. Merck, 1989. The Merck Index. Eleventh Edition. Merck & Company, Inc. Rahway, NJ.

3. Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko, 1991. Handbook of Environmental Degradation Rates. Lewis Publishers. Chelsea, Michigan.

4. ATSDR, 1991. Toxicological Profile for Benzene (Draft). Agency for Toxic Substances and Disease Registry. USPHS/USEPA. October 1991.

5. Arthur D. Little, Inc., 1989. The Installation Restoration Program Toxicology Guide. Volume 2. Cambridge, MA. July 1989.

6. USEPA, 1995. Integrated Risk Information System (IRIS). Database. Online.

ETHYLBENZENE

CAS NUMBER

100-41-4

COMMON SYNONYMS

None noted.

ANALYTICAL CLASSIFICATION

Volatile organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: 161 mg/L at 25°C [1]
Vapor Pressure: 9.53 mm Hg at 25°C [1]
Henry's Law Constant: 8.44 x 10^{-3} atm-m^3/mole [1]
Specific Gravity: 0.87 at 25/25°C [2]
Organic Carbon Partition Coefficient: 871 [1]

FATE DATA: HALF-LIVES

Soil: 3 to 10 days [3]
Air: 8.56 hours to 3.57 days [3]
Surface Water: 3 to 10 days [3]
Groundwater: 6 to 228 days [3]

NATURAL SOURCES

Coal tar and petroleum [4].

ARTIFICIAL SOURCES

Manufacture of styrene, solvent, petroleum refining, vaporization/spills of gasoline and diesel fuel, auto emissions, paints, inks, insecticides, and cigarette smoke [1,2,4].

FATE AND TRANSPORT

Ethylbenzene released to surface soils will probably undergo partial volatilization and, given its limited ability to sorb to soils (K_{oc} = 871), leach to groundwater. Evidence suggests that this material undergoes biodegradation in groundwater, and may also do so in soils if the initial loading doesn't prove toxic to soil-based microorganisms. If released to surface waters, ethylbenzene is expected to volatilize fairly readily. As with groundwater, rapid biodegradation can be predicted after an initial acclimation period. Ethylbenzene shows only a slight to moderate tendency to adsorb to soils and sediments in water. Bioconcentration in aquatic organisms is not expected to be significant (BCF = 145). Ethylbenzene is expected to exist in the atmosphere primarily as a vapor, based upon its vapor pressure value (9.53 mm Hg). Principally, ethylbenzene will be

removed from the atmosphere via reaction with hydroxyl radicals; some washout via rainfall may be expected [1].

HUMAN TOXICITY

General. Humans exposed to ethylbenzene may experience eye and throat irritation, decreased movement, and dizziness. Studies in animals have shown liver and kidney damage, nervous system changes, and blood changes [4]. The USEPA has placed ethylbenzene in weight-of-evidence group D, indicating that it is not classifiable as to human carcinogenicity [5].

Oral Exposure. A chronic RfD of 0.1 mg/kg-day is based on a NOEL of 97.1 mg/kg-day and a LOAEL of 291 mg/kg-day determined for liver and kidney toxicity in a rat subchronic to chronic oral bioassay [5]. Studies in animals revealed that ethylbenzene is quickly and effectively absorbed following oral exposure. The oral (gavage) LD_{50} in rats is reported to be 4,728 mg/kg. No information was located regarding death or health effects in humans following oral exposure [4].

Inhalation Exposure. The RfC of 1 mg/m^3 is based on a NOAEL of 434 mg/m^3 determined for developmental toxicity in rats and rabbits exposed via inhalation [5]. Ethylbenzene is rapidly and efficiently absorbed via inhalation in humans and animals. A 4-hour LC_{50} of 4,000 ppm was reported for rats. Exposure-related adverse effects in animals included those to the liver and kidneys, eye irritation, profuse lacrimation, CNS depression, and ataxia. No deaths were reported for humans following inhalation of ethylbenzene. The effects observed in humans included pulmonary and ocular irritation, profuse lacrimation, chest constriction, dizziness, vertigo, and possible hematological alterations. Exposure of pregnant rats to levels above 138 ppm for 24 hours/day for 9 days had adverse developmental effects [4].

Dermal Exposure. Liquid ethylbenzene is rapidly absorbed through the skin; however, absorption of vapors through the skin is minimal. The dermal LD_{50} in rabbits for liquid ethylbenzene was reportedly 15,415 mg/kg. Ethylbenzene appears to be a slight eye irritant in rabbits [4].

REFERENCES

1. Howard, P.H., 1989. Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume I: Large Production and Priority Pollutants. Lewis Publishers, Inc. Chelsea, MI. 574 pp.

2. Merck, 1989. The Merck Index, Eleventh Edition. Merck & Company, Inc. Rahway, NJ.

3. Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, E.M. Michalenko, 1991. Handbook of Environmental Degradation Rates. Lewis Publishers, Inc. Chelsea, MI. 725 pp.

4. ATSDR, 1990. Toxicological Profile for Ethylbenzene. Agency for Toxic Substances and Disease Registry. USPHS/USEPA. December 1990.

5. USEPA, 1995. Integrated Risk Information System (IRIS). Online Database.

POLYCYCLIC AROMATIC HYDROCARBONS

GENERAL

Polycyclic aromatic hydrocarbons (PAHs) are a large group of chemicals formed during the incomplete combustion of organic materials. There are over one hundred PAHs, and they are found throughout the environment in air, water, and soil. Seven of the 15 PAHs addressed in this profile are classified as probable human carcinogens [1,2].

CAS NUMBERS

Acenaphthene	83-32-9	Chrysene	218-01-9
Acenaphthylene	208-96-8	Dibenzo(a,h)anthracene	53-70-3
Anthracene	120-12-7	Fluoranthene	206-44-0
Benzo(a)anthracene	56-55-3	Fluorene	86-73-7
Benzo(a)pyrene	50-32-8	Indeno(1,2,3-cd)pyrene	193-39-5
Benzo(b)fluoranthene	205-99-2	Phenanthrene	85-01-8
Benzo(g,h,i)perylene	191-24-2	Pyrene	129-00-00
Benzo(k)fluoranthene	207-08-9		

COMMON SYNONYMS

Polynuclear aromatic hydrocarbons, PNAs, PAHs.

ANALYTICAL CLASSIFICATION

Semivolatile organic.

PHYSICAL AND CHEMICAL DATA

Water Solubility: insoluble to 3.93 mg/L [1]
Vapor Pressure: negligible to very low at 25°C [1]
Henry's Law Constant: 6.95×10^{-8} to 1.45×10^{-3} atm-m^3/mole [1]
Specific Gravity: approximately 0.9 to 1.4 at 0 to 27°C [1]
Organic Carbon Partition Coefficient (K_{oc}): 2.5×10^3 to 5.5×10^6 [1]

FATE DATA: HALF-LIVES

Soil: 12.3 days to 5.86 years [3]
Air: 0.191 hours to 2.8 days [3]
Surface Water: 0.37 hours to 1.78 years [3]
Groundwater: 24.6 days to 10.4 years [3]

NATURAL SOURCES

Volcanoes, forest fires, crude oil, and oil shale [1].

ARTIFICIAL SOURCES

Motor vehicles and other petroleum fuel engines, wood-burning stoves and fireplaces, furnaces, cigarette smoke, industrial smoke or soot, and charcoal-broiled foods [1].

FATE AND TRANSPORT

Because the physical and chemical properties of PAHs vary substantially depending on the specific compounds in question, the fate and transport characteristics vary. Thus, the following discussion is presented in very general terms. Some fate characteristics are roughly correlated with molecular weight; so the compounds are grouped as follows [1]:

- Low molecular weight: acenaphthene, acenaphthylene, anthracene, fluorene, and phenanthrene;
- Medium molecular weight: fluoranthene and pyrene; and
- High molecular weight: benzo(a)anthracene, benzo(b)fluoranthene, benzo-(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, dibenzo-(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

PAHs are present in the atmosphere in the gaseous phase and sorbed to particulates. They may be transported great distances, and are subject to photodegradation as well as wet or dry deposition [1].

PAHs in surface water are removed by volatilization, binding to particulates and sediments, bioaccumulation, and sorption onto aquatic biota. The low molecular weight PAHs have Henry's Law constants in the range of 10^{-3} to 10^{-5} atm-m^3/mole, and would therefore be expected to undergo significant volatilization; medium molecular weight PAHs have constants in the 10^{-6} range; and high molecular weight PAHs have constants in the range of 10^{-5} to 10^{-8}. Half-lives for volatilization of benzo(a)anthracene and benzo(a)pyrene from water have been estimated to be greater than 100 hours. It has been reported that lower molecular weight PAHs could be substantially removed by volatilization under conditions of high temperature, shallow depth, and high wind. For example, anthracene was found to have a half-life for volatilization of 18 hours in a stream with moderate current and wind. In an estuary, volatilization and adsorption are the primary removal mechanisms for medium and high molecular weight PAHs, whereas volatilization and biodegradation are the major mechanisms for low molecular weight compounds. PAHs can bioaccumulate in plants and animals, but are subject to extensive metabolism by high-trophic-level consumers, indicating that biomagnification is not significant [1].

Potential mobility in soil is related to the organic carbon partition coefficient (K_{oc}). The low molecular weight PAHs have K_{oc} values in the range of 10^3 to 10^4, which indicates a moderate potential to be adsorbed to organic material. Medium molecular weight compounds have values on the order of 10^4, while high molecular weight compounds have values in the 10^5 to 10^6 range. The latter compounds, then, have a much greater tendency to adsorb and resist movement through soil. Volatilization of the lower molecular weight compounds from soil may be substantial. However, some

portion of PAHs in soil may be transported to groundwater, and then move laterally in the aquifer, depending on soil/water conditions [1].

HUMAN TOXICITY

General. Ingestion of, inhalation of, or dermal contact with PAHs by laboratory animals has been shown to produce tumors. Reports in humans show that individuals exposed by inhalation or dermal contact for long periods of time to mixtures of PAHs and other compounds can also develop cancer. However, the relationship of exposure to any individual PAH with the onset of cancer in humans is not clear [1]. The available RfDs and weight-of-evidence groups for the PAHs addressed in this profile are presented in Table 1. The available slope factors are presented below. No other toxicity values were available [2,4].

Oral Exposure. Indirect evidence suggests that benzo(a)pyrene may not be readily absorbed following oral exposure in humans. On the other hand, absorption in rats appears to be rapid and efficient. Whether or not there is actually a significant difference between humans and rats in the capacity to absorb benzo(a)pyrene is questionable. It should be noted that the degree of uptake is highly dependent on the vehicle of administration. A NOAEL of 150 mg/kg-day was determined for gastrointestinal, hepatic, and renal effects in rats following acute oral exposure to benzo(a)pyrene or benzo(a)anthracene. LOAELs in the range of 40 to 160 mg/kg-day were determined for developmental and reproductive effects in mice following acute oral exposure to benzo(a)pyrene [1]. An oral slope factor of 7.3 $(mg/kg\text{-}day)^{-1}$ for benzo(a)pyrene is based on tumors detected in the forestomachs of rats and mice in various diet studies [2].

Inhalation Exposure. The USEPA does not currently provide inhalation RfCs for any of the PAHs [2,4]. Pure PAH aerosols appear to be well absorbed from the lungs of animals. However, PAHs adsorbed to various particles appear to be poorly absorbed, if at all. The latter are most likely to be removed from the lungs by mucociliary clearance and subsequent ingestion. Lung cancer in humans has been strongly associated with long-term inhalation of coke-oven emissions, roofing-tar emissions, and cigarette smoke, all of which contain mixtures of carcinogenic PAHs. It has been estimated that the 8-hour time-weighted average exposure to PAHs in older coke plants was approximately 22 to 33 $\mu g/m^3$ [1]. An inhalation slope factor of 6.1 $(mg/kg\text{-}day)^{-1}$ for benzo(a)pyrene is based on tumors detected in the respiratory tracts of hamsters in a chronic intermittent inhalation study [4].

Dermal Exposure. Limited *in-vivo* evidence exists that PAHs are at least partially absorbed by human skin. An *in-vitro* study with human skin indicated that 3% of an applied dose of benzo(a)pyrene was absorbed after 24 hours. Studies in mice indicated that at least 40% of an applied dose of benzo(a)pyrene was absorbed after 24 hours. The carcinogenic PAHs as a group cause various noncancerous skin disorders in humans and animals. Substances containing mixtures of PAHs have been linked to skin cancers in humans. Studies in laboratory animals have demonstrated the ability of benz(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene to induce skin tumors [1].

REFERENCES

1. ATSDR, 1990. Toxicological Profile for Polycyclic Aromatic Hydrocarbons. Agency for Toxic Substances and Disease Registry. USPHS/USEPA. NTIS No. PB91-181537. December 1990.

2. USEPA, 1995. Integrated Risk Information System (IRIS). Online. Database.

3. Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko, 1991. Handbook of Environmental Degradation Rates. Lewis Publishers. Chelsea, Michigan.

4. USEPA, 1994. Health Effects Assessment Summary Tables (HEAST). Office of Emergency and Remedial Response. OHEA ECAO-CIN-821. March 1994.

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T-BUTYL METHYL ETHER

HSDB - Hazardous Substances Data Bank

7.0 ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Document Outline

SUMMARY
POLLUTION SOURCES
ENVIRONMENTAL FATE
ENVIRONMENTAL TRANSFORMATIONS
ENVIRONMENTAL TRANSPORT
ENVIRONMENTAL CONCENTRATIONS
HUMAN EXPOSURE

SUMMARY

Environmental Fate/Exposure Summary:

t-Butyl methyl ether may be released as a result of its use as an octane booster for unleaded gasoline and its use in the manufacture of isobutene. If t-butyl methyl ether is released to soil, it will be subject to volatilization. It will be expected to exhibit very high mobility in soil and, therefore, it may leach to groundwater. It will not be expected to hydrolyze in soil. If t-butyl methyl ether is released to water, it will not be expected to significantly adsorb to sediment or suspended particulate matter, bioconcentrate in aquatic organisms, hydrolyze, directlyphotolyze, or photooxidize via reaction with photochemically produced hydroxyl radicals in the water, based upon estimated physical-chemical properties or analogies to other structurally related aliphatic ethers. t-Butyl methyl ether in surface water willbe subject to rapid volatilization with estimated half-lives of4.1 hr and 2.0 days for volatilization from a river one meter deep flowing 1 m/sec with a wind velocity of 3 m/sec and a model pond, respectively. It may be resistent to biodegradation in environmental media based upon screening test data from a study using activated sludge inocula. Many ethers are known to be resistant to biodegradation. If t-butyl methyl ether is released to theatmosphere, it will be expected to exist almost entirely in thevapor phase based on its vapor pressure. It will be susceptibleto photoxidation via vapor phase reaction with photochemically produced hydroxyl radicals with an estimated half-life of 5.6 days for this process. Direct photolysis will not be an important removal process since aliphatic ethers do not adsorb light at wavelenghts >290 nm. The most probable route of general populationexposure to t-butyl methyl ether is probably via inhalation of contaminated air. Exposures through dermal contact may occur in occupational settings. (SRC).

POLLUTION SOURCES

Artificial Sources:

t-Butyl methyl ether may be released as a result of its use as an octane booster for unleaded gasoline (up to 7% by volume) and its use in the manufacture of isobutene(1,2).

ENVIRONMENTAL FATE

1TERRESTRIAL FATE: If t-butyl methyl ether is released to soil, it will be subject to

1 TERRESTRIAL FATE: If t-butyl methyl ether is released to soil, it will be subject to volatilization based upon a reported Henry's Law constant of 5.87X10-4 atm-cu m/mole(1) and vapor pressure of 249 mm Hg at 25 deg C(2). It will be expected to exhibit very high mobility(5,SRC) in soil and, therefore, it may leach to groundwater, based upon an estimated Koc of 11.2(3,4,SRC). It will not be expected to hydrolyze in soil(4). Butyl methyl ether may be resistent to biodegradation in soil based upon screening test data from a study using activated sludge inocula(6,SRC). Many ethers are known to be resistant to biodegradation(7).

2 AQUATIC FATE: If t-butyl methyl ether is released to water, it will not be expected to significantly adsorb to sediment or suspended particulate matter(1,2,SRC), bioconcentrate in aquatic organisms(1,2,SRC), hydrolyze(2), directly photolyze(3), or photooxidize via reaction with photochemically produced hydroxyl radicals in the water(4), based upon estimated physical-chemical properties or analogies to other structurally related aliphatic ethers(1-3,SRC). t-Butyl methyl ether in surface water will be subject to rapid volatilization(2,5,SRC). Using a reported Henry's Law constant of 5.87X10-4 atm-cu m/mole(5), a half-life for volatilization of t-butyl methyl ether from a river one meter deep flowing 1 m/sec with a wind velocity of 3 m/sec has been estimated to be 4.1 hr at 25 deg C(2,SRC). The volatilization half-life from a model pond, which considers the effect of adsorption, has been estimated to be 2.0 days(6). t-Butyl methyl ether may be resistent to biodegradation in environmental media based upon screening test data from a study using activated sludge inocula(7,SRC). Many ethers are known to be resistant to biodegradation(8).

3 ATMOSPHERIC FATE: If t-butyl methyl ether is released to the atmosphere, it will be expected to exist almost entirely in the vapor phase(2) based upon a reported vapor pressure of 249 mm Hg at 25 deg C(3). It will be susceptible to photooxidation via vapor phase reaction with photochemically produced hydroxyl radicals. An atmospheric half-life of 5.6 days at an atmospheric concentration of 5X10+5 hydroxyl radicals per cu cm has been calculated for this process based upon a measured rate constant(1,SRC). Direct photolysis will not be an important removal process since aliphatic ethers do not absorb light at wavelengths >290 nm(4).

ENVIRONMENTAL TRANSFORMATIONS

Biodegradation:

No data concerning the biodegradation of t-butyl methyl ether in environmental media were located. An activated sludge aqueous screening study found that the compound was biodegraded very slowly with a 1% theoretical biological oxygen demand being measured after 21 days incubation(1). These screening test results suggest that t-butyl methyl ether may be resistent to biodegradation in the environment(SRC). Studies of three biological treatment processes indicated that most of the compound could be removed from wastewater by treatment, but it was not determined whether the removal was due to biological activity or to some other processes such as volatilization or adsorption(2). The percentages of the compound removed by a conventional activated sludge process, an activated sludge process supported by powder activated carbon treatment (PACT), and the PACT-process in combination with wet-air regeneration of activated carbon containing surplus sludge were: 85%, 94%, and 95%, respectively(2). Many ethers are known to be resistant to biodegradation(3).

Abiotic Degradation:

The rate constant for the vapor phase reaction of t-butyl methyl ether with photochemically produced hydroxyl radicals has been measured to be 2.84X10-12 cu cm/molecule-sec at 25 deg C(1) which corresponds to an atmospheric half-life of 5.6 days at an atmospheric concentration of 5X10+5 hydroxyl radicals per cu cm(SRC). Addition of t-butyl methyl ether to a simulaneously mixture increased the amount of ozone formed and NO consumed(4). Hydrolysis is not expected to be significant under normal environmental conditions (pH 5-9)(2). Direct photolysis will not be an important removal process since aliphatic ethers do not absorb light at wavelengths >290 nm(3).

ENVIRONMENTAL TRANSPORT

Bioconcentration:

BCF: 1.5 in Japanese carp(1). Based upon this experimental BCF, t-butyl methyl ether will not be expected to bioconcentrate in aquatic organisms(SRC).

Soil Adsorption/Mobility:

Based upon a reported water solubility of 51,000 mg/L at 25 deg C(1), a Koc of 11.2 has been estimated using a recommended regression equation(2). Based upon this estimated Koc, t-butyl methyl ether will be expected to exhibit very high mobility in soil(3). t-Butyl methyl ether, therefore, may leach through soil to groundwater if it does not volatilize or biodegrade first(SRC).

Volatilization from Soil/Water:

The half-life for volatilization of t-butyl methyl ether from a river one meter deep flowing 1 m/sec with a wind velocity of 3 m/sec is estimated to be 4.1 hr at 25 deg C(1,SRC) based on a reported Henry's Law constant of 5.87X10-4 atm-cu m/mole(2). The volatilization half-life from a model pond, which considers the effect of adsorption, has been estimated to be 2.0 days(3,SRC). Based upon the Henry's Law constant and a reported vapor pressure of 249 mmHg at 25 deg C(4), t-butyl methyl ether will be subject to volatilization from surfaces and near-surface soil(SRC).

ENVIRONMENTAL CONCENTRATIONS

Water Concentrations:

GROUNDWATER: t-Butyl methyl ether has been detected at concn up to 50 ppb in the Old Bridge aquifer under an industrial plant in South Brunswick Township, NJ (no sampling dates specified)(1). A contamination abatement system installed at this aquifer, including 7 extraction wells and a water treatment facility, reduced the t-butyl methyl ether concn by an estimated 26%(1).

HUMAN EXPOSURE

Probable Routes of Human Exposure:

1 General population exposure to t-butyl methyl ether is probablyvia inhalation of contaminated air and dermal exposure. Exposure through inhalation and dermal contact may occur in occupational settings. (SRC)

2 NIOSH (NOES Survey 1981-1983) has statistically estimated that 3,522 workers are exposed to t-butyl methyl ether in the USA(1).

APPENDIX D

BIOVENTING PILOT TEST DATA

HOMESTEAD ARB - APRON LINE AP-18 - INITIAL PILOT TESTING, OCTOBER 199'

Biodegradation Rate Calculations | enter data | calculated data

Formula: $K_b = K_o \times 1/100\% \times A \times D_o \times C$ Where:

K_b = fuel biodegradation rate

K_o = O_2 utilization rate (%/min.)

A = volume of air/kg soil

D_o = O_2 density = 1340 mg/L

C = Carbon/O_2 ratio for hexane mineralization = 1/3.5

Solving for 1 L of soil:

Monitoring Point:		VW1		MPA	MPB	
Oxygen util. rate	K_o =	0.00720	%/min.	0.00480	0.00510	
Moisture Content [a/]	w =	15	%	15	15	
Soil Type [b/]		limestone		limestone	limestone	
Porosity:	n =	0.35		0.35	0.35	
Unit weight (dry):	${}^{g}d = G*{}^{g}w*(1-n)$ =	1.72	g/cm^3	1.72	1.72	
Void ratio:	$e = n/1-n$ =	0.54		0.54	0.54	
Specific gravity:	G =	2.65		2.65	2.65	
Void volume:	$V_v = n * 1$ L =	0.35	liters	0.35	0.35	
Deg. of saturation:	$S_r = Gw/e$ =	0.74		0.74	0.74	
Volume of water:	$V_w = S_r * V_v$ =	0.26	liters	0.26	0.26	
Volume of air:	$V_a = V_v - V_w$ =	0.09	liters	0.09	0.09	
Bulk density:	${}^{g}d + (V_w * {}^{g}w)$ =	2	kg/L soil	2	2	
Air filled volume:	$A = V_a$/Bulk Density	0.045	L air/kg soil	0.045	0.045	
	K_b =	652	mg TPH/ kg soil/ year	435	462	

$K_b = K_o * 1/100\% * A * D_o * C *$ 525,600 min/yr

[a/] Moisture is taken from

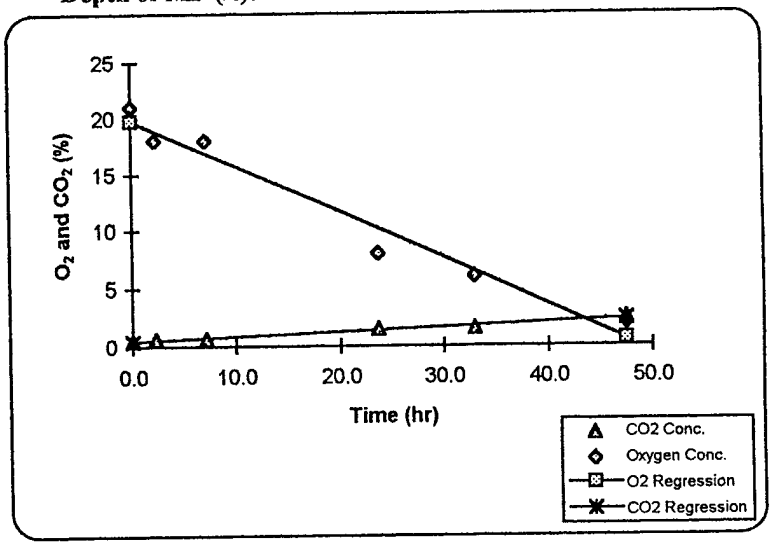
[b/] Assume: Soil properties are specified from Table 1.4. (Ref. Foundation Engineering, Peck, Hanson, and Thornburn, John Wiley Press, 1974)

Periodic In Situ Respiration Test

Date: 10/26/97 **Site Name:** Homestead, AP-18

Monitoring Point: VW1 **Depth of MP (ft):** 2.5-7.5

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)
10/26/97 09:05	0.0	21.00	0.50
10/26/97 11:20	2.3	18.00	0.60
10/26/97 16:13	7.1	18.00	0.70
10/27/97 08:45	23.7	8.00	1.50
10/27/97 18:00	32.9	6.00	1.60
10/28/97 08:35	47.5	2.00	2.50



Biodegradation Rate (mg/kg/day)

O_2 Utilization Rate

Ko	0.007 %/min
	0.403 %/hr
	9.676 %/day

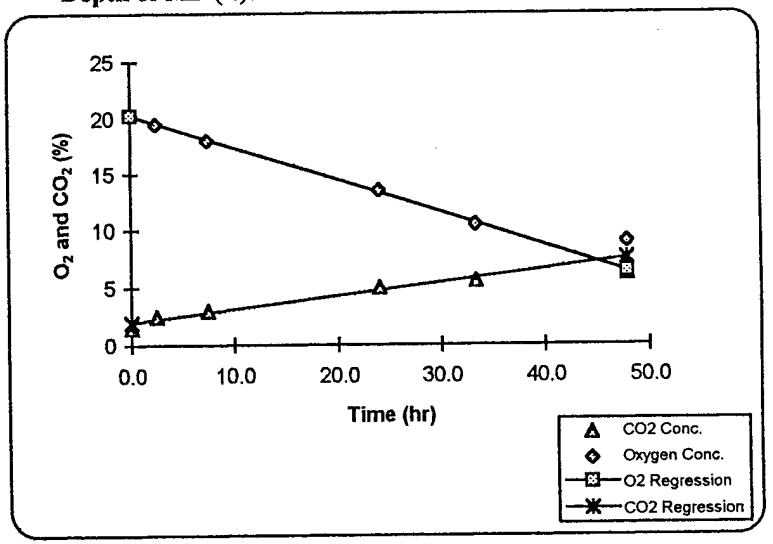
Regression Lines	O_2	CO_2
Slope	-0.4032	0.0405
Intercept	0.9824	0.0760
Determination Coef.	0.9652	0.9791
No. of Data Points.	6	6

Periodic In Situ Respiration Test

Date: 10/26/97 **Site Name:** Homestead, AP-18

Monitoring Point: MPA **Depth of MP (ft):** 4

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)
10/26/97 08:49	0.0	20.30	1.50
10/26/97 11:16	2.5	19.50	2.50
10/26/97 16:14	7.4	18.00	3.00
10/27/97 08:47	24.0	13.50	5.00
10/27/97 18:05	33.3	10.50	5.60
10/28/97 08:40	47.9	9.00	6.20



Regression Lines	O_2	CO_2
Slope	-0.2895	0.1168
Intercept	0.0942	0.2419
Determination Coef.	0.9991	0.9644
No. of Data Points.	5	5

Biodegradation Rate (mg/kg/day)

O_2 Utilization Rate

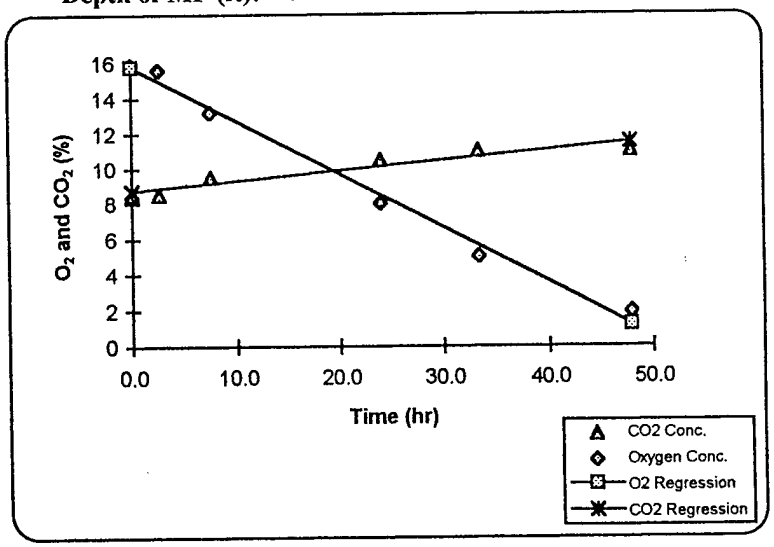
Ko	0.005 %/min
	0.289 %/hr
	6.948 %/day

Periodic In Situ Respiration Test

Date: 10/26/97 **Site Name:** Homestead, AP-18

Monitoring Point: MPB **Depth of MP (ft):** 4

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)
10/26/97 08:51	0.0	15.90	8.50
10/26/97 11:24	2.5	15.60	8.50
10/26/97 16:20	7.5	13.20	9.50
10/27/97 08:50	24.0	8.00	10.50
10/27/97 18:07	33.3	5.00	11.00
10/28/97 08:42	47.9	1.90	11.00



Biodegradation Rate (mg/kg/day)

O_2 Utilization Rate

Ko	0.005 %/min
	0.305 %/hr
	7.313 %/day

Regression Lines	O_2	CO_2
Slope	-0.3047	0.0574
Intercept	0.3824	0.2752
Determination Coef.	0.9907	0.8797
No. of Data Points.	6	6

VW1

RECORD SHEET FOR IN SITU RESPIRATION TEST

SITE HARB 5S15A
DATE 10/26/97
LOCATION AP18
SAMPLER(S) J. Hall

MONITORING POINTS H VW1
O2 METER NO. ~~DT038~~ 93010057
HYDROCARBON METER NO. DT038
SHUT DOWN DATE 10/26/97

CO2 METER NO.
HE METER NO.
TIME 09:00

	Date/ Time	CO2 (%)	O2 (%)	Total Hydrocarbon	Helium	Comments	Date/ Time	CO2 (%)	O2 (%)	Total Hydrocarbon	Helium	Comments
0	10/26/97 0905	0.5	21.0	250x2								
2	1120	0.6	18.0	620x2								
7	1613	0.7	18.0	1300x2								
24	10/27 0845	1.5	8.0	2000x2								
33	1800	1.6	6.0	2200x2								
48	10/28 0835	2.5	2.0	2200x2								

MPA

MPB

RECORD SHEET FOR IN SITU RESPIRATION TEST

SITE HARB SS15A
DATE
LOCATION API8
SAMPLER(S) J. Hall

MONITORING POINTS
O2 METER NO. 93010057
HYDROCARBON METER NO. DT038
SHUT DOWN DATE 10/26/97

CO2 METER NO.
HE METER NO.
TIME 09:00

16.8 0.0 >10,000 x2

16.0 0.0 950x2

	Date/ Time	CO2 (%)	O2 (%)	Total Hydrocarbon	Helium	Comments	Date/ Time	CO2 (%)	O2 (%)	Total Hydrocarbon	Helium	Comments
0	10/26/97 0849	1.5	20.3	7200x2			10/26/97 0851	8.5	15.9	3500x2		
2	1116	2.5	19.5	5000 x2			1124	8.5	15.6	3000x2		
7	1614	3.0	18.0	5200x2			1620	9.5	13.2	3000x2		
24	10/27 0847	5.0	13.5	5200x2			10/27 0850	10.5	8.0	2900x2		
33	1805	5.6	10.5	4800x2			1807	11.0	5.0	2900x2		
48	10/28 0840	6.2	9.0	4900x2			10/28 0842	11.0	1.9	2000x2		

front moved three days night

Record Sheet for Air Permeability Test.

SITE AP-18 HARB
DATE 10/25/97
SAMPLER(S) M. Kaberry

TYPE OF TEST
TEST DATE 10/25/97
TIME ~~15:05~~ Start. 15:10

Pressure/Vacuum ("H_2O)

Distance from Vent Well (ft)		15.0'	30.0'		
elapsed Time	ln(t)	MPB	MW43		
0:0		ϕ.ϕ4	ϕ.5ϕ		
ϕ:30		ϕ.4	ϕ.26		
~~1:00~~		ϕ.52	ϕ.32		
1:36		ϕ.64	ϕ.41		
2:00		ϕ.71	ϕ.46		
2:30		ϕ.77	>.5		
3:00		ϕ.83	>.5		
3:30		ϕ.86	>5		
4:00		ϕ.88	>.5		
4:30		ϕ.92	"		
5:00		ϕ.94	"		26 OCT 97 845 →

Distance from Vent Well					
Time	ln(t)	MPB	MP43		
7:00		1.ϕϕ	ϕ.75		
8:00		1.4ϕ	~~ϕ.88~~ .81		
9:00		1.1ϕ	ϕ.84		
10:00		1.1ϕ	ϕ.86		
15:00		1.7ϕ	ϕ.92		
20:00		1.25	ϕ.95		
30:00		~~1.35~~	>1.ϕϕ		
40:00		1.4ϕ	~~1.1ϕ~~		
50:00		1.35	~~1.15~~		
1:00:00		1.4ϕ	1.15		
		1.6ϕ	1.2ϕ		

09:45 - time change

Record Sheet for Air Permeability Test.

SITE AP18 HARB
DATE 10/25/97
SAMPLER(S) J. Hall

TYPE OF TEST 10/25/97
TEST DATE 10/25/97
TIME Start 15:10

Pressure/Vacuum ("H_2O)

Screen 2.5-7.5

Distance from Vent Well (ft)		10.0	23.5		
Time (min)	ln(t)	MPA	MW42	VW1	
0.0		0	0.1	0	
0.5		2.1	0.25	66	
1.0		2.8	0.40	64	
1.5		3.2	0.55		
2.0		3.4	.65	63	
2.5		3.5	.75		
3.0		3.6	.80	62	
3.5					
4.0		3.8	.95	62	
4.5					
5.0		4.0	1.05	61	
10/26/97		4.7		42	

(09:45) 08:45 - (time change)

Distance from Vent Well					
Time	ln(t)	MPA	MW42	VW1	
6		4.1	1.10	60	
7		4.2	1.15		
8		4.2	1.25	59	
9		4.~~15~~ 30	1.25		
10		4.~~15~~ 30	1.30	59	
15		4.~~25~~ 50	1.40	58	
20		4.60	1.45	57	
30		4.8	1.5	56	
40		4.8	1.6	54	
50		4.9	1.6	54	
60		4.9	1.7	53	
		4.7	1.65	42	

APPENDIX E

SCREENING AND DEVELOPMENT OF REMEDIAL ALTERNATIVES

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SCREENING AND DEVELOPMENT OF REMEDIAL ALTERNATIVES

1.1 OVERVIEW

This appendix identifies a variety of remedial approaches and technologies that were considered in developing remedial alternatives for Site SS-15A. This initial screening was based on three primary evaluation criteria: effectiveness in meeting established SSTLS and eventually Tier 1 TCLs, technical and administrative implementability, and relative cost. The purpose of this screening was to quickly focus the CAP on the most promising and cost-effective methods for remediating Site SS-15A. This appendix focuses on how selected active remedial technologies could be combined with natural chemical attenuation to achieve an effective site cleanup.

2.1 SCREENING OF REMEDIAL TECHNOLOGIES

Table 1 provides a summary of the remedial approaches and technologies considered for Site SS-15A. All of these technologies are appropriate for the remediation of fuel-contaminated soils or groundwater. Technologies which are used for non-fuel contaminants have been purposely deleted from this focused initial screening. Several of the most promising technologies considered during screening have been retained as candidates for the development of remedial alternatives and evaluated in Section 9 of the CAP. The following paragraphs provide a brief description of each approach or technology group and its site-specific applicability for this site.

2.1.1 Long-Term Monitoring

Long-term monitoring of groundwater is essential in evaluating the progress of intrinsic and engineered remediation and for ensuring that cleanup criteria are achieved over a specified time interval.

2.1.1.1 Soil and Soil Gas Monitoring

Soil and soil gas monitoring provides information for assessing the effectiveness of an implemented soil remedial technology. Extensive soil sampling at Site SS-15A has revealed low to moderate contamination in unsaturated and saturated soils in the source areas. All detected soil contaminants are below target risk-based remedial goals that are protective of human health given current and future proposed land uses. However, soil contaminant concentrations is localized areas exceed levels that are protective of groundwater at Site SS-15A. Soil gas is used as an indicator of VOC reduction, and oxygen and carbon dioxide concentrations can indicate the level of hydrocarbon biodegradation occurring in the soil. Long-term soil and soil gas monitoring was retained for further evaluation.

TABLE E.1
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL AND GROUNDWATER REMEDIATION SITE SS-15A, HOMESTEAD ARB, FLORIDA

General Response Action	Technology Type	Process Option	Technical Implementability	Effectiveness in Attaining Target Remedial Goals	Relative Cost	Retain
Long-Term Monitoring	Periodic Groundwater Monitoring	Long-term Monitoring Wells	Existing wells are available to confirm the progress of remediation.	Necessary component of all remediation strategies	Low	Yes
		Point-of-Action Wells	Sufficient distance exists between the plume and the nearest potential receptor to locate several additional wells if needed.	Necessary component of all remediation strategies	Low	Yes
	Periodic Soil/Soil Gas Monitoring	Installation of Additional Soil Borings and Vapor Monitoring	Extensive soil sampling indicates no soil contamination above 30-day SSTLs. Soil gas sampling indicates that inhalation risks are insignificant. However, monitoring of these media could indicate progress in meeting Tier 1 TCLs and in evaluating effectiveness of soil remediation activities.	Available data indicate that additional soil and soil gas sampling not required.	Low	Yes
Institutional Controls	Land and Ground Water Use Control	Land Use Control/Regulate Well Permits	Contaminated area is currently within the Base boundary. Land-use and groundwater use are under Base jurisdiction. Institutional controls can be implemented when the site is leased.	Necessary component of risk-based cleanup	Low	Yes
		Seal/Abandon Existing Wells	No drinking water wells located within 1,000 feet of plume.	Not required at this site.	Low	No
		Point-of-Use Treatment	No groundwater is extracted from the plume area for use. Other sources of drinking water are available at the site.	Not required at this site.	Moderate	No
	Public Education	Meetings/ Newsletters	Important to convey a clear understanding of acceptable land and groundwater use.	Necessary to obtain risk-based closure	Low	Yes
Containment of Plume	Hydraulic Controls	Interceptor Trench Collection	Fate and transport modeling indicate that future migration of dissolved contaminants will be minimal, negating the need for plume interception.	High	High	No

TABLE E.1 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL AND GROUNDWATER REMEDIATION
SITE SS-15A, HOMESTEAD ARB, FLORIDA

General Response Action	Technology Type	Process Option	Technical Implementability	Effectiveness in Attaining Target Remedial Goals	Relative Cost	Retain
Containment of Plume (cont.)	Hydraulic Controls (cont.)	Minimum Pumping/Gradient Control	Source area groundwater could be extracted from existing monitoring wells or newly installed wells or from backhoe pits in combination with soil excavation. Would entail short-term disturbance of flightline apron.	High	Low to moderate	Yes
	Physical Controls	Slurry Walls/Grout Curtains	Requires significant disruption. Limited effectiveness. Plume containment not needed.	Moderate	High	No
		Sheet Piling	Requires significant disruption. Limited effectiveness. Plume containment not needed.	Moderate	High	No
	Reactive/Semi-Permeable Barriers	Biologically Active Zones	Natural biodegradation of groundwater contaminants can be stimulated by allowing contaminated groundwater to flow through an aquifer zone which has enhanced oxygen and nutrient conditions. Plume is naturally biodegrading and future migration predicted to be minimal.	Moderate	High	No
In Situ Groundwater Treatment	Biological	Oxygen and/or Nutrient Enhanced Biodegradation (Biosparging)	Differs from biologically active zone in that oxygen (air) is injected upgradient from plume and allowed to migrate downgradient. In theory, this method can more rapidly reduce higher fuel hydrocarbon concentrations in and immediately downgradient of the source. Plume is naturally biodegrading and future migration predicted to be minimal.	Moderate	High	No

TABLE E.1 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL AND GROUNDWATER REMEDIATION
SITE SS-15A, HOMESTEAD ARB, FLORIDA

General Response Action	Technology Type	Process Option	Technical Implementability	Effectiveness in Attaining Target Remedial Goals	Relative Cost	Retain
In Situ Groundwater Treatment (cont.)	Chemical/Physical (cont.)	Intrinsic Remediation	A combination of natural biological, chemical, and physical removal mechanisms which occur to varying degrees on every site. Groundwater sampling at Site SS-15A indicates that this is a major, ongoing remediation process.	High	Low	Yes
		Air Sparging (Volatilization)	Injection of air into contaminated aquifer creating a mass transfer of BTEX and highly sorptive PAHs into air bubbles and into vadose zone. Limited radius of influence and short-circuiting are common problems. Anisotropic subsurface (limestone) may limit effectiveness.	Low to High, depending on degree of heterogeneity and anisotropy	High	No
Aboveground Groundwater Treatment	Biological	Bioreactors	High flow rates require excessive retention times and large reactors. BTEX is often volatilized in these systems.	Moderate	High	No
	Chemical/Physical	Air Stripping	Cost-effective technology for removing varying concentrations of BTEX at higher flow rates and longer durations. Potential permitting for air emissions.	High	High	No
		Activated Carbon	Cost effective for more dilute concentrations of BTEX/PAHs and short-term pumping. Creates a carbon disposal problem.	High	High due to carbon cost	No
		UV/Ozone Reactors	High flow rates require excessive retention times and large, expensive reactors.	Moderate	High	No

TABLE E.1 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL AND GROUNDWATER REMEDIATION SITE SS-15A, HOMESTEAD ARB, FLORIDA

General Response Action	Technology Type	Process Option	Technical Implementability	Effectiveness in Attaining Target Remedial Goals	Relative Cost	Retain
Aboveground Groundwater Treatment (cont.)	Chemical/Physical (cont.)	Direct Discharge to Industrial Waste Water Treatment Plant (IWWTP)	Viable option when an IWWTP is available and capable of handling BTEX/PAHs and hydraulic loading. IWWTP not available for this site.	High	High	No
Treated Groundwater Disposal	Discharge to IWWTP or Sanitary Sewer	IWWTP	Viable option when an IWWTP is available and capable of handling BTEX/PAHs and hydraulic loading. IWWTP not available for this site.	High	High	No
		Sanitary Sewer	Viable option when access to sanitary sewer exists and hydraulic loading is acceptable. Sewer line near this site.	High	Low when sewer available	Yes
	Treated Groundwater Reinjection	Vertical Injection Wells	Not recommended due to clogging and high maintenance.	Moderate	High	No
		Injection Trenches	Require large trenches and can be subject to injection well permitting.	Moderate	High	No
	Discharge to Surface Waters	Storm Drains	Viable option but generally requires NPDES or other discharge permit.	High	Moderate Permitting Costs	Yes
Source Reduction/Soil Remediation	Free Product Recovery	Dual-Pump Systems	Best suited for sites with >1 foot free product where aboveground groundwater treatment exists. Free product at site is minimal to nonexistent.	Low	High	No

TABLE E.1 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL AND GROUNDWATER REMEDIATION SITE SS-15A, HOMESTEAD ARB, FLORIDA

General Response Action	Technology Type	Process Option	Technical Implementability	Effectiveness in Attaining Target Remedial Goals	Relative Cost	Retain
Source Reduction/Soil Remediation (cont.)	Free Product Recovery (cont.)	Skimmer Pumps/Bailers/ Wicks	Best suited for sites with <1 foot free product where groundwater pumping is undesirable. Low horizontal gradient will limit effectiveness. Free product is minimal to nonexistent at the site.	Moderate	Low	No
		Total Fluids Pumping	Best suited for sites with thin saturated zones where excessive groundwater will not be pumped. Free product is minimal to nonexistent at the site.	Moderate	High	No
		Bioslurping	Combined vapor extraction, bioventing, and free product recovery system has been operated at some sites with success. Free product is minimal to nonexistent at the site.	Moderate	Intermediate	No
	Excavation/ Treatment of Soils	Excavation	May disrupt flightline apron operations, but contaminant source areas are localized and amenable to "hotspot" excavation.	High	Low to Moderate	Yes
		Biological Landfarming	Could potentially be performed, but existence of off-Base thermal treatment facilities make this option less desirable.	Moderate	Moderate	No
		Thermal Desorption	Off-Base thermal treatment facilities exist and could be used.	Moderate	High	Yes
	In Situ	Bioventing	Bioventing would be successful at Site SS-15A based on pilot test results.	High	Low	Yes
		Soil Vapor Extraction	Vapor extraction may be feasible at this site, but would not rapidly remediate non-volatile PAHs which are of primary concern. Off-gas treatment may be required.	High	High due to off-gas treatment	No

TABLE E.1 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR SOIL AND GROUNDWATER REMEDIATION
SITE SS-15A, HOMESTEAD ARB, FLORIDA

General Response Action	Technology Type	Process Option	Technical Implementability	Effectiveness in Attaining Target Remedial Goals	Relative Cost	Retain
Source Reduction/Soil Remediation (cont.)	*In Situ* (cont.)	Soil Washing	Additional pore volumes of water and/or surfactant solution are forced through aquifer material to enhance the partitioning of hydrocarbons into the groundwater. Creates special above ground treatment problems.	Moderate	High	No

2.1.1.2 Groundwater Monitoring

Groundwater monitoring approaches are essential for evaluating the effectiveness of implemented groundwater remediation approaches or technologies, particularly natural attenuation processes. LTM wells can be utilized to monitor contaminants and their attenuation within and near the existing plume. The predictions of fate and transport models are often verified using LTM wells within the plume. Point of action (POA) wells can be established at downgradient locations to ensure that contaminants do not advance at concentrations that may present an unacceptable risk beyond an area under reliable exposure controls. Sufficient LTM wells are now available at this site to assess both vertical and horizontal contaminant transport and attenuation. The suitability of existing wells for LTM is addressed in Section 10 of the CAP. Long-term groundwater monitoring was retained as a key component of the remedial alternatives for this site.

2.1.2 Land and Groundwater Use Control

Some degree of land and groundwater use control will be required if contaminant concentrations in groundwater at Site SS-15A exceed the 30-day groundwater SSTLs. Land and groundwater use controls also can be enacted to minimize the potential for direct receptor contact with site contamination and to maintain the exposure assumptions used to derive the SSTLs.

2.1.2.1 Land Use Control

Physical barriers and deed restriction/easements can be used to control land use. Access to this site is currently limited by fencing around the Base perimeter, controlled access to the site, and complete pavement coverage of all impacted media. Physical barriers and deed restrictions on land and resource uses were retained for further evaluation.

2.1.2.2 Groundwater Use Control

Groundwater use controls can eliminate the possibility of direct exposure of site workers to contaminated groundwater. Groundwater use can be controlled by regulating well permits, minimizing excavations below the water table, and when no other source of drinking water is available, installing point-of-use treatment systems. Contaminated groundwater at this site remains within an area under Base control, and no active drinking water wells exist on or near the site. The regulation of future well permits in the vicinity of Site SS-15A was retained for further evaluation.

2.1.3 Public Education

At many hazardous waste sites, public education is required to inform the public of the risks associated with site contamination and to provide the necessary warnings to prevent unintentional contact with site soils or groundwater. Although no unacceptable human health risk is currently associated with this site, any future release of this property to private citizens or business should be accompanied with a clear understanding of where unacceptable contamination may still exist and the appropriate land uses that will prevent exposure. Public education was retained as a remedial approach.

2.1.4 Containment of the Groundwater Plume

Plume containment uses either hydraulic controls, such as limited groundwater pumping, or physical barriers such as slurry walls, to minimize downgradient plume migration. This strategy is most often used to halt the advance of highly contaminated groundwater before it impacts downgradient drinking waters or surface waters. Groundwater quality data and fate and transport modeling indicate that migration of dissolved contaminants will be minimal.

2.1.4.1 Hydraulic Controls

Hydraulic controls extract contaminated groundwater to prevent further migration of the plume. Hydraulic controls considered for this site include a limited, short-term pumping of contaminant source area groundwater to facilitate rapid reductions in dissolved contaminant concentrations. Site SS-15A is entirely covered by concrete or asphalt. In order to install groundwater extraction wells or backhoe pits, cutting of concrete or asphalt, making this option more costly. However, the contaminated areas appear to be very localized, and groundwater contaminant concentrations that exceed SSTLs could be relatively rapidly reduced by short-term, aggressive pumping. Therefore, groundwater pumping to reduce dissolved contaminant concentrations at Site SS-15A was retained as a remedial alternative.

Contaminated areas are too localized, and plume migration is predicted to be too minimal to justify installation of groundwater interceptor trenches or french drains. Therefore, groundwater interception trenches were not retained as a remedial alternative.

2.1.4.2 Physical Groundwater Barriers

Slurry walls, grout curtains, and sheet pilings are physical structures capable of limiting downgradient contaminant migration. However, contaminants are not removed by such physical barriers, they are only contained. When compared to an interceptor trench where contaminants are contained and removed, containment alone is a less effective option. Available data indicate that plume migration is and will be minimal, negating the need for interception. Additionally, the pavement covering the site would make it more costly to install any physical subsurface barriers at Site SS-15A. Physical groundwater barriers were not retained for further consideration.

2.1.4.3 Reactive/Semipermeable Barriers

Reactive, semipermeable barriers are an emerging technology which uses a downgradient chemically reactive wall or biologically active treatment zone to intercept and treat groundwater contaminants as they pass through the treatment zone. This technology has the advantage over simple physical barriers in that contaminants are actually destroyed and groundwater flow is uninterrupted. Installation of barrier wall(s) are not necessary due to the current and predicted future lack of dissolved contaminant migration, and the long-term maintenance cost would be very large. Reactive walls and biological active zones were not retained for further evaluation.

2.1.5 *In situ* Groundwater Treatment

In situ treatment includes both engineered and natural processes which are capable of destroying or immobilizing dissolved contamination in place. *In situ* treatment is generally less expensive than aboveground treatment because there is no need to extract, treat, and then dispose of groundwater.

2.1.5.1 Natural Attenuation

As thoroughly discussed in Section 6 of the CAP, natural attenuation takes advantage of destructive and nondestructive attenuation mechanisms to bring about a net reduction in groundwater contaminant concentrations. Destructive attenuation mechanisms include biodegradation, abiotic oxidation, and hydrolysis. Nondestructive attenuation mechanisms include sorption, dilution, and volatilization (Wiedemeier *et al.*, 1995). At this site, the historical decrease in average dissolved contaminant concentrations and geochemical evidence both confirm that natural attenuation is a fairly significant and ongoing cleanup process at this site. Therefore, this remedial approach was retained from the screening process.

2.1.5.2 Enhanced/Active Biological Groundwater Treatment via Biosparging

Enhanced *in situ* biodegradation takes advantage of natural biological processes by providing enhanced electron acceptor conditions and, when required, enhanced nitrogen/phosphorus (i.e., nutrient) conditions to stimulate microbial growth and more rapid biodegradation. Section 6 of the CAP provides geochemical evidence that a low oxygen concentrations in source area groundwater at Site ST-27 may be limiting the biodegradation of dissolved contaminants in the plume. Low flow-rate air injection into groundwater, known as biosparging, can be used to increase dissolved oxygen concentrations in groundwater and promote biodegradation. However, the potential anisotropy of subsurface materials may limit the effectiveness of this approach. Biosparging was not retained for evaluation as a method of enhancing natural biodegradation in the source area.

2.1.6 Aboveground Groundwater Treatment

Groundwater extraction and aboveground groundwater treatment offers the flexibility of more engineering controls than *in situ* remediation, and can usually treat a wider range of contaminants than *in situ* treatment. Groundwater extraction also provides greater control over plume migration and can be focused in areas of greatest contamination. As discussed in Section 2.1.4.1 of this appendix, active groundwater extraction techniques were retained for further evaluation.

2.1.6.1 Air Stripping

Air stripping technologies contact contaminated groundwater with clean air to volatilize (strip) dissolved contaminants from the aqueous phase. Air stripping is most effective for compounds with Henry's Law constants greater than 0.001 atm-m^3/mol, including BTEX compounds, which have Henry's Law constants of 0.0049 atm-m^3/mol to 0.0079 atm-m^3/mol. Air stripping was not retained as a treatment process option because it is most effective and cost-efficient for long-term treatment operations and

high contaminant concentrations. In addition, it does not effectively treat less volatile PAHs.

2.1.6.2 Activated Carbon Treatment

Activated carbon is a commonly used method of removing organic contaminants from groundwater as it passes through a packed-bed canister of granular activated carbon (GAC). Use of GAC as a treatment process option was retained because it is cost effective for short-term pumping and low contaminant concentrations, similar to the conditions at Site SS-15A. In addition, GAC will remove both volatile and non-volatile petroleum hydrocarbons from groundwater.

2.1.7 Source Removal/Soil Remediation Technologies

The removal or reduction of concentrated contaminants in the source area is normally an important element of a comprehensive site remediation. Two primary sources of contamination can potentially exist at fuel contaminated sites: LNAPL and residual fuels which are sorbed or occluded within the soil matrix. Residual fuels comprise the primary contaminant source at Site SS-15A; mobile LNAPL appears to be minimal to nonexistent.

Residual fuel contamination in the source areas at this site appears to be present in the vadose zone, capillary fringe, and the uppermost portion of the saturated zone. Residual fuel contamination appears to be limited to a thin layer of soil in the capillary fringe and saturated soils downgradient from the source area. Analysis of soil samples indicate that remaining soil COPCs are present at concentrations above Tier 1 TCLs that are protective of groundwater. Soil leaching modeling results (Section 6) indicate that contaminated soils are a significant source of groundwater in localized portions of Site SS-15A. Common soil remediation technologies such as soil vapor extraction and *in situ* bioventing, which depend on soil gas movement, will be effective based on the results of the bioventing pilot test performed at Apron Line AP-18. Soil flushing using surfactants is another option for reducing fuel residuals that is evaluated in this section.

2.1.7.1 Bioslurping

Bioslurping is a vacuum-mediated free product recovery and bioremediation technique that is applicable for the remediation and removal of measurable layers of LNAPL on groundwater. Bioslurping was not retained for further evaluation because mobile LNAPL appears to be minimal to nonexistent at Site SS-15A.

2.1.7.2 Product Skimmer Pumps and Wicks

Product skimmer pumps and wicks were not evaluated for use at Site SS-15A because mobile LNAPL appears to be minimal to nonexistent at the site.

2.1.7.3 Soil Vapor Extraction

SVE mechanically withdraws soil gas from the vadose zone to the surface using vent wells. If necessary, offgas can be treated prior to discharge into the atmosphere. By extracting soil gas from the vadose zone, the desorption of VOCs from soils into soil

gas is enhanced. Because SVE also results in an influx of oxygenated soil gas from clean soils, it also enhances the biodegradation of less volatile hydrocarbons. SVE was not retained for further evaluation because biodegradation of both VOCs and less volatile hydrocarbons (e.g., PAHs) could be accomplished via *in situ* bioventing without the need for expensive off-gas treatment.

2.1.7.4 Bioventing

Bioventing is mechanically similar to soil vapor extraction except that this technology uses much lower rates of air injection to provide the necessary oxygen to sustain biological degradation. Bioventing rates of air injection are typically one-tenth of vapor extraction rates for the same site. The effectiveness of this technology has been demonstrated in a major pilot testing program conducted at over 140 Air Force sites (Downey, 1994). A bioventing pilot test conducted at Site SS-15A is described in Section 8 of this CAP. The pilot test results indicate that bioventing could be implemented as a low-cost remedial technique for treatment of residual soil contamination. *In situ* bioventing was retained for further analysis.

2.1.7.5 Surfactant Soils Washing

Soil washing is used to enhance the natural partitioning of contaminants from the soil into the groundwater, and is generally associated with a groundwater extraction system. The more strongly sorbed compounds may require surfactant soil washing to facilitate the dissolution process. *In situ* soil washing is most effective in more permeable aquifer materials than those present at Site SS-15A. Soil washing usually involves the addition of a surfactant compound that has a nonpolar "tail" to dissolve the contaminant, and a polar end so that the formed miscelle is soluble in water. Biodegradable surfactants are desirable to ensure that new, recalcitrant chemicals are not introduced into the aquifer.

Two significant disadvantages are associated with this technology. Because surfactants are added in relatively high concentrations, they will exert a significant biological oxygen demand on the aquifer. This additional organic loading may exceed the natural assimilative capacity of the aquifer and promote the migration of both surfactant and fuel hydrocarbons. The second problem is that when the surfactant solution is recovered, it is difficult to separate contaminants from the surfactants so that surfactants can be recycled. Treatment of surfactant-laden groundwater can be achieved with activated carbon, but the surfactant will rapidly load the carbon, resulting in unacceptable treatment costs. Due to these technical difficulties, surfactant soils washing was not retained for further evaluation.

2.1.9 Soil Excavation and Treatment

Excavation and off-Base thermal treatment of contaminated site soils may be appropriate at this site given the very localized, isolated nature of the contaminant "hotspots". Therefore, these options were retained for further evaluation.

3.1 SUMMARY OF RETAINED REMEDIAL TECHNOLOGIES

Based on the initial technology screening discussed in Section 2 of this appendix and summarized in Table 1, several remedial approaches and technologies have been retained for the development of remedial alternatives and more detailed analysis. These technologies were selected to provide a range of passive to more active response actions, all of which can meet both the SSTLs (and eventually Tier 1 TCLs) at a reasonable cost or within a reasonable timeframe. The following remedial approaches and technologies have been retained :

- Long-term soil gas and groundwater monitoring;
- Limited land use controls;
- Groundwater use controls;
- Public education;
- Natural attenuation of soil and groundwater contamination;
- Bioventing for the treatment of residual soil contamination;
- Short term pumping of source area groundwater; and
- Excavation of source area soils.

Because natural attenuation, and specifically biodegradation, has been effectively removing compounds from the groundwater and limiting downgradient migration, this ongoing remediation process can only be enhanced through a reduction of residual soil contamination that is acting as a source of contamination to groundwater and more concentrated dissolved contamination in the vicinities of the source areas at AP26 and AP27. Two candidate source-reduction technologies, *in situ* bioventing and soil excavation, and one groundwater treatment technology, short-term groundwater pumping, have been retained for additional analysis. Each of these remediation approaches is described in greater detail, and their effectiveness is evaluated in Section 9 of this CAP.

4.1 REFERENCES

Downey, D.C. 1994. Bioventing Performance and Cost Summary. Proposal for Air Force Center for Environmental Excellence, Brooks Air Force Base, San Antonio, Texas. July.

Wiedemeier, T.H., Downey, D.C. Wilson, J.T., Kampbell, D.H., Miller, R.N., and Hansen, J.E. 1995. Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater. Prepared for the Air Force Center for Environmental Excellence, Brooks Air Force Base, San Antonio, Texas.

LTM 1 Cost Estimate (Alternative 1)
Offutt AFB B301
722450.2405

Author: JRH
Date: 5/23/97
Checked by:
Date:

Summary of Capital and Present Worth Costs

Monitoring Costs

Biennial Monitoring of 7 wells, 1998-2024, AP26-AP27
plus annual monitoring for 2 additional years (2025-2026)

Cost per Event	$12,455		
P/A i=7%, n=1	1998	$11,640	
P/A i=7%, n=3	2000	$10,167	
P/A i=7%, n=5	2002	$8,880	
P/A i=7%, n=7	2004	$7,756	
P/A i=7%, n=9	2006	$6,775	
P/A i=7%, n=11	2008	$5,917	
P/A i=7%, n=13	2010	$5,168	
P/A i=7%, n=15	2012	$4,514	
P/A i=7%, n=17	2014	$3,943	
P/A i=7%, n=19	2016	$3,444	
P/A i=7%, n=21	2018	$3,008	
P/A i=7%, n=23	2020	$2,627	
P/A i=7%, n=25	2022	$2,295	
P/A i=7%, n=27	2024	$2,004	
P/A i=7%, n=28	2025	$1,873	
P/A i=7%, n=29	2026	$1,751	
Total Present Worth Cost			$81,764

Biennial Monitoring of 5 wells, 1998-2008, Other Apron Lines

Cost per Event	$7,181		
P/A i=7%, n=1	1998	$6,711	
P/A i=7%, n=3	2000	$5,862	
P/A i=7%, n=5	2002	$5,120	
P/A i=7%, n=7	2004	$4,472	
P/A i=7%, n=9	2006	$3,906	
P/A i=7%, n=11	2008	$3,412	
Total Present Worth Cost			$29,483

Site Management every year (29 years)

Annual Cost	$6,000	
P/A i=7% n=29	PWF = 12.2776741	
	Present Worth Cost	$73,666

Total Capital and Present Worth Costs of LTM Program $184,912

ALTERNATIVE 1 Cost Estimate
Homestead ARB Site SS-15A
731298.04000

Author: JRH
Date: 3/17/1998
Checked by:
Date:

Groundwater Sampling - Years 1998--2024--7 wells sampled biennially
Apron lines AP26 and AP27

Sampling Labor	30 hours x		$60	/hour	$1,800
7 Long-Term Monitoring Wells					
5 QA/QC (1 dupl, 1 field blank, 1 trip blank, 1 MS, 1 MSD)					
12 Total Samples					
Analytical Subcontractor					
	12 BTEX		$70	/each	$840
	10 Methane		$75	/each	$750
	10 Nitrate		$20	/each	$200
	10 PAHs		$127	/each	$1,270
	7 field analysis		$10	/each	$70
Supplies			$300	lump sum	$300
Travel			$100	lump sum	$100
Data Management (20 hr x $60hr)			$1,200		$1,200
Data Validation (15 hr x $60/hr)			$900		$900
Reporting/Project Management Labor					
Word Processing	5	hours x	$25	/hour	$125
CADD	8	hours x	$50	/hour	$400
Reproduction	8	hours x	$20	/hour	$160
Staff Level	50	hours x	$60	/hour	$3,000
Proj. Manager	8	hours x	$80	/hour	$640
Editor	5	hours x	$60	/hour	$300
Reporting/Project Management ODCs			$400	lump sum	$400

Total for 1 Sampling Event $12,455

ALTERNATIVE 1 Cost Estimate
Homestead ARB Site SS-15A
731298.04000

Author: JRH
Date: 3/17/1998
Checked by:
Date:

Groundwater Sampling - Years 1998--2008--5 wells sampled biennially
Apron lines other than AP26 and AP27

Sampling Labor	24 hours x		$60	/hour	$1,440
5 Long-Term Monitoring Wells					
2 QA/QC (1 dupl, 1 trip blank)					
7 Total Samples					
Analytical Subcontractor					
	7 BTEX		$70	/each	$490
	6 Methane		$75	/each	$450
	6 Nitrate		$20	/each	$120
	6 naphthalene		$101	/each	$606
	2 TRPH		$75	/each	$150
	5 field analyses		$10	/each	$50
Supplies			$200	lump sum	$200
Travel			$100	lump sum	$100
Data Management (12 hr x $60hr)			$720		$720
Data Validation (10 hr x $60/hr)			$600		$600
Reporting/Project Management Labor (in addition to costs on cost1.xls)					
Word Processing	3	hours x	$25	/hour	$75
CADD	4	hours x	$50	/hour	$200
Reproduction	4	hours x	$20	/hour	$80
Staff Level	20	hours x	$60	/hour	$1,200
Proj. Manager	4	hours x	$80	/hour	$320
Editor	3	hours x	$60	/hour	$180
Reporting/Project Management ODCs			$200	lump sum	$200

Total for 1 Sampling Event $7,181

LTM Cost Estimate--Alternative 2
Homestead ARB Site SS-15A
731298.04

Author: JRH
Date: 3/17/98
Checked by:
Date:

Summary of Capital and Present Worth Costs

Monitoring Costs

Annual Monitoring of 7 wells, 1998-2004, apron lines AP26 and AP27 plus annual monitoring for 2 additional years to confirm

Cost per Event	$11,225		
P/A i=7%, n=1	1998	$10,491	
P/A i=7%, n=2	1999	$9,804	
P/A i=7%, n=3	2000	$9,163	
P/A i=7%, n=4	2001	$8,563	
P/A i=7%, n=5	2002	$8,003	
P/A i=7%, n=6	2003	$7,480	
P/A i=7%, n=7	2004	$6,990	
P/A i=7%, n=8	2005	$6,533	
P/A i=7%, n=9	2006	$6,106	
	Total Present Worth Cost		$73,133

Biennial Monitoring of 5 wells, 1998-2008, other apron lines

Cost per Event	$7,181		
P/A i=7%, n=1	1998	$6,711	
P/A i=7%, n=3	2000	$5,862	
P/A i=7%, n=5	2002	$5,120	
P/A i=7%, n=7	2004	$4,472	
P/A i=7%, n=9	2006	$3,906	
P/A i=7%, n=11	2008	$3,412	
	Total Present Worth Cost		$29,483

Site Management every year (9 years)

Annual Cost	$6,000	
P/A i=7% n=9	PWF = 6.51523225	
	Present Worth Cost	$39,091

Bioventing System Installation in 1998 (separate spreadsheet) $60,148

O&M of bioventing system plus respiration testing (7 years)

Annual Cost	$10,691	
P/A i=7% n=7	PWF = 5.3892894	
	Present Worth Cost	$57,617

LTM Cost Estimate--Alternative 2
Homestead ARB Site SS-15A
731298.04

Author: JRH
Date: 3/17/98
Checked by:
Date:

Confirmation Soil Sampling and Final Reporting	$12,455
Total Capital and Present Worth Costs of LTM Program	$271,927

Item AP26 and AP27 areas only	Unit	Unit cost	Quantity	Cost
Design/Procure/Construct/Optimize	hour	$70	250	$17,500
Per diem	day	$90	14	$1,260
Travel	l.s.	$2,000	1	$2,000
Equipment rental	l.s.	$1,000	1	$1,000
Materials and Equipment				
2 hp blower/gages/controls/etc.	lump sum	$1,500	1	$1,500
Pipe and fittings	l.f.	$1	800	$800
Blower enclosure	each	$500	1	$500
Construction Subcontractor				
Mob/demob	l.s	$800	1	$800
Asphalt cutting/trenching/backfill/compaction				
concrete patch	l.f.	$25	800	$20,000
Remove/replace well boxes	each	$250		$0
Soil disposal (clean)	c.y.	$16	20	$320
Soil disposal (contaminated, NOT hazardous)	c.y.	$100	10	$1,000
Electrical subcontractor	l.s.	$8,000	1	$8,000
Contingency	l.s.	10%	1	$5,468
SUBTOTAL OPTION 1 - SYSTEM INSTALLATION				$60,148
O&M cost per year	year			
System monitoring (2hr/mo)	hour	70	24	$1,680
annual testing/monitoring	hour	70	24	$1,680
Blower power (2hp x 0.746 kw/hp)	kw-hr	0.1	8760	$876
Subtotal O&M per year				$4,236
Present Worth of O&M (7 years)				$22,832
7 years $(P/A)^{7\%} = 5.39$				
Confirmation Soil Sampling and Reporting				
Cost per Event	$20,000			
P/A i=7%, n=7	2005	$12,455		$12,455

Total Alternative 2 ; Installation and O&M				**$95,435**
and final sampling/reporting				

LTM Cost Estimate--Alternative 3
Homestead ARB Site SS-15A
731298.04

Author: JRH
Date: 3/17/98
Checked by:
Date:

Summary of Capital and Present Worth Costs

Monitoring Costs

Annual Monitoring of 7 wells, 1998-2001, Apron Lines AP26 and AP27
plus annual monitoring for 2 additional years to confirm

Cost per Event	$11,225		
P/A i=7%, n=1	1998	$10,491	
P/A i=7%, n=2	1999	$9,804	
P/A i=7%, n=3	2000	$9,163	
P/A i=7%, n=4	2001	$8,563	
P/A i=7%, n=5	2002	$8,003	
P/A i=7%, n=6	2003	$7,480	
Total Present Worth Cost			$53,504

Biennial Monitoring of 5 wells, 1998-2002, Other Apron Lines

Cost per Event	$7,181		
P/A i=7%, n=1	1998	$6,711	
P/A i=7%, n=3	2000	$5,862	
P/A i=7%, n=5	2002	$5,120	
Total Present Worth Cost			$17,693

Biennial Monitoring of 5 wells, 2004-2008, Other Apron Lines

Cost per Event	$10,000		
P/A i=7%, n=7	2004	$6,227	
P/A i=7%, n=9	2006	$5,439	
P/A i=7%, n=11	2008	$4,751	
Total Present Worth Cost			$16,418

Site Management every year (6 years)

Annual Cost	$6,000	
P/A i=7% n=6	PWF = 4.76653966	
Present Worth Cost		$28,599

Soil Excavation and Treatment (separate spreadsheet)	$46,790
Groundwater Extraction and Treatment	$32,650
Total Capital and Present Worth Costs of LTM Program	$195,654

COST ESTIMATE FOR ALTERNATIVE 3 - HOT SPOT EXCAVATION/DEWATERING					
ITEM	**UNIT**	**# UNITS**	**UNIT COST**		**TOTAL**
Procurement	HR	50	$ 60.00		$ 3,000.00
Saw Cut Asphalt	LF	240	$ 2.25		$ 540.00
Remove/Dispose Asphalt/Concrete	SF	1800	$ 4.00		$ 7,200.00
Soil Excavation	CY	500	$ 2.50		$ 1,250.00
Soil Transport/Thermal Treatment	CY	500	$35		$ 17,500.00
Soil Sampling	EA	6	$ 300.00		$ 1,800.00
Compacted Backfill	CY	500	$ 6.00		$ 3,000.00
Install 4" Monitoring Well	EA	2	$ 750.00		$ 1,500.00
Asphalt Replacement (6")	SY	200	$ 40.00		$ 8,000.00
Engineering Oversight	HR	60	$ 50.00		$ 3,000.00
Total Soil Removal/Treatment					$ 46,790.00
					$ -
					$ -
Groundwater Dewatering Pumps	EA	1	$ 950.00		$ 950.00
Pretreatment Unit Lease	MONTH	1	$ 5,000.00		$ 5,000.00
Carbon Canisters (500lb)	EA	2	$ 3,000.00		$ 6,000.00
Freight	lump	1	$1,000		$ 1,000.00
Temporary Electrical	lump	1	$2,000		$ 2,000.00
Controls for GW Treatment	lump	1	$ 3,000.00		$ 3,000.00
Temporary 4" PVC Piping	LF	500	$ 3.00		$ 1,500.00
Water Samples	EA	8	$ 250.00		$ 2,000.00
System Setup/Demob	HR	80	$ 50.00		$ 4,000.00
Four Weeks Operation	HR	160	$ 45.00		$ 7,200.00
Total GW Dewatering					$ 32,650.00
					$ -
					$ -
TOTAL ALTERNATIVE CAPITAL COSTS					$ 79,440.00
					$ -
					$ -
					$ -
					$ -
					$ -
					$ -
					$ -
					$ -
					$ -
					$ -

APPENDIX F

SITE SAMPLING AND ANALYSIS PLAN

SITE SAMPLING AND ANALYSIS PLAN

FOR

THE CORRECTIVE ACTION AND LONG-TERM MONITORING PLAN FOR THE RISK-BASED REMEDIATION OF SITE SS-15A

HOMESTEAD AIR RESERVE BASE, FLORIDA

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
TECHNOLOGY TRANSFER DIVISION

BROOKS AIR FORCE BASE, TEXAS 78235-5000

AND

HOMESTEAD AIR RESERVE BASE, FLORIDA

March 1998

Prepared by:

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SECTION 1

INTRODUCTION AND DATA QUALITY OBJECTIVES

1.1 INTRODUCTION

The purpose of this site-specific sampling and analysis plan (SAP) is to describe the procedures to be followed when collecting data in support of implementing the selected remedial alternative, including the long-term monitoring plan (LTMP), which will be completed as a part of the Corrective Action Plan (CAP) for the risk-based remediation of Site SS-15A at Homestead Air Reserve Base (ARB), Florida. Details on analytical requirements, desired quantitation and detection limits, and sampling locations are identified within Section 10 of the CAP. Specific quality assurance (QA) sampling requirements for the SS-15A site are summarized herein as part of the site-specific sampling procedures. These additional samples will be used to determine the precision, accuracy, completeness, and representativeness of the final data set.

The remainder of Section 1 discusses data quality objectives. Soil sampling procedures are described in Section 2 and groundwater sampling procedures are described in Section 3. Field quality assurance/quality control (QA/QC) samples are described in Section 4. Section 5 describes field data reduction, validation, and reporting; Section 6 presents analytical procedures for groundwater sampling. References used in this SAP are listed in Section 7.

1.2 DATA QUALITY OBJECTIVES

The objectives of collecting and analyzing environmental samples are 1) to obtain the data needed to evaluate the effectiveness of the implemented remedial approach, excavation of excessively contaminated soil and the natural attenuation of groundwater; and 2) to establish when site-specific remediation goals that minimize or eliminate risk potential to receptors and limit offsite migration of site-related contamination are achieved. This section has been developed for use in conjunction with sampling activities to be undertaken at Site SS-15A and describes the QA/QC procedures and protocols that will be used during sample analysis. This section will serve as a controlling mechanism during implementation of the preferred remedial alternative to ensure that a sufficient quantity of data is collected and that all data collected are valid, reliable, and defensible.

1.3 ANALYTICAL DATA QUALITY LEVELS

Data quality objectives (DQOs) for the analyses described herein are defined in the interim final guidance, *Data Quality Objectives Process for Superfund* (USEPA, 1993). The analytical levels for this project's DQOs will conform to the two USEPA-defined categories of data. These data categories are defined below (USEPA, 1993):

Screening Data with Definitive Confirmation - Screening data are generated by rapid, less precise methods of analysis with less rigorous sample preparation. Sample preparation steps may be restricted to simple procedures such as dilution with a solvent, instead of elaborate extraction/digestion and cleanup. Screening data provide analyte identification and quantification, although the quantification may be relatively imprecise. At least 10 percent of the screening data are confirmed using analytical methods, QA/QC procedures, and QC criteria associated with definitive data. Screening data without associated confirmation data are not considered to be data of known quality. Results of field laboratory analyses conducted at the site will be considered screening-category data.

Definitive Data - Definitive data are generated using rigorous analytical methods, such as approved USEPA reference methods. Data are analyte-specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data (e.g., chromatograms, spectra, digital values) in the form of hard-copy printouts or computer-generated electronic files. Data may be generated at the site or at an off-site location, as long as the QA/QC requirements are satisfied. For the data to be definitive, either analytical or total measurement error must be determined. Results of fixed-based laboratory analyses of samples collected at the site will be considered definitive data.

During the AFCEE risk-based remediation program, the following data quality levels will be used as indicated:

- Screening analyses with definitive confirmation will be used for the air screening in worker breathing zones for health and safety purposes. This category may also be used to screen samples to select portions for further analysis. For example, soil gas or sample headspace may be screened to determine if laboratory analyses are required.

- Definitive analyses will be used to satisfy the requirements for long-term groundwater monitoring, soil excavation, and decision document preparation. USEPA Level III data from previous site investigations will be combined with newly acquired definitive data to evaluate the effectiveness of the selected remedial alternative and to determine when the cleanup goals have been achieved.

An effective QA program addresses DQOs for both field sampling and laboratory methodologies. The contractor's field QA efforts will focus on assuring that samples are representative of the conditions in the various environmental media at the time of sampling. Fixed-based laboratory QA efforts will be aimed primarily at assuring that analytical procedures provide sufficient accuracy and precision to reliably quantify contaminant levels in environmental samples. The contract laboratory also will ensure

that analyzed portions are representative of each sample, and that the results obtained from analysis of each sample are comparable to those obtained from analysis of other similar samples.

1.4 DATA QUALITY ASSESSMENT CRITERIA

Data assessment criteria will be used to evaluate the quality of both the field sampling and screening methods and laboratory performance for the project, and are expressed in terms of analytical precision, accuracy, representativeness, completeness, and comparability. Procedures used to assess data accuracy and precision are in accordance with *Guidelines Establishing Test Procedures for the Analyses of Pollutants,* Appendix III, "Example Quality Assurance and Quality Control Procedures for Organic Priority Pollutants" (40 CFR 136), and the respective analytical methods from the USEPA (1995) *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW-846.*

1.4.1 Precision

Precision is the measure of variability among individual sample measurements under prescribed conditions. The results of laboratory control samples (LCS) demonstrate the precision of the methods. When the LCS results meet the accuracy criteria, (USEPA, 1995) results are believed to be precise. This is based on the LCS being within control limits in comparison to LCS results from previous analytical batches of similar methods and matrices. The relative percent difference (RPD) of field duplicate, laboratory sample duplicate, and matrix spike/matrix spike duplicates (MS/MSD) results demonstrate the precision of the sample matrix. Precision will be expressed in terms of RPD between the values resulting from duplicate analyses. RPD is calculated as follows:

$$RPD = [(x1 - x2)/X][100]$$

where:

x1	=	analyte concentration in the primary sample
x2	=	analyte concentration in the duplicate sample
X	=	average analyte concentration in the primary and the duplicate sample.

Acceptable levels of precision will vary according to the sample matrix, the specific analytical method, and the analytical concentration relative to the method detection limit (MDL). For field duplicate samples, the target RPDs are $\leq$ 35 percent for soil and water samples. Precision criteria for the laboratory QC samples are defined by limits listed in Table 1.1. An RPD within the control limit indicates satisfactory precision in a measurement system.

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TABLE 1.1
QC[a/] ACCEPTANCE CRITERIA
RISK-BASED APPROACH TO REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R) [b/]	Precision Water (RPD) [c/]	Accuracy Soil (% R)	Precision Soil (RPD)
Aromatic Volatile Organic Compounds SW5030A/SW8021B (W[d/], S[e/])	1,2-Dichlorobenzene	61–134	≤ 20	51–134	≤ 30
	1,3-Dichlorobenzene	63–137	≤ 20	53–137	≤ 30
	1,4-Dichlorobenzene	66–135	≤ 20	56–135	≤ 30
	Benzene	75–125	≤ 20	65–125	≤ 30
	Chlorobenzene	75–129	≤ 20	65–129	≤ 30
	Ethylbenzene	71–129	≤ 20	61–129	≤ 30
	Toluene	70–125	≤ 20	60–125	≤ 30
	Vinyl Chloride	47-142	≤ 20	37-142	≤ 30
	Xylenes, total	71–133	≤ 20	61–133	≤ 30
	Surrogates:				
	1,4-Dichlorobutane	35-135	NA[f/]	35-135	NA
	Bromochlorobenzene	46–136	NA	36–146	NA
Volatile Organic Compounds SW5030A/SW8260B (W[d/], S[e/])	1,2-Dichlorobenzene	75-125	≤ 20	65–135	≤ 30
	1,3-Dichlorobenzene	75–125	≤ 20	65–135	≤ 30
	1,4-Dichlorobenzene	75–125	≤ 20	65–135	≤ 30
	Benzene	75–125	≤ 20	65–135	≤ 30
	Chlorobenzene	75–125	≤ 20	65–135	≤ 30
	Ethylbenzene	75–125	≤ 20	65–135	≤ 30
	Toluene	74–125	≤ 20	64–135	≤ 30
	Vinyl Chloride	46-134	≤ 20	36-144	≤ 30
	p/m xylenes	75–125	≤ 20	65–135	≤ 30
	o-xylenes	75–125	≤ 20	65–135	≤ 30
	Surrogates:				
	Dibromofluoromethane	75-125	NA	65-135	NA
	Toluene-D8	75-125	NA	65-135	NA
	4-Bromofluorobenzene	75-125	NA	65-135	NA
	1,2-DCA-D4	62-139	NA	52-149	NA
Methane RSK-175 (W)	Methane	70-130	≤ 20	NA	NA
	Ethane	70–130	≤ 20	NA	NA
	Ethene	70–130	≤ 20	NA	NA
Polynuclear Aromatic Hydrocarbons SW3510B/SW8310 (W) SW2550A/SW8310 (S)	1-Methylnaphthalene	25–150	≤ 30	25–160	≤ 50
	2-Methylnaphthalene	25–150	≤ 30	25–160	≤ 50
	Acenaphthalene	49–125	≤ 30	39–135	≤ 50
	Acenaphthene	43–130	≤ 30	33–140	≤ 50
	Anthracene	54–125	≤ 30	44–135	≤ 50

Parameter/Method	Analyte	Accuracy Water (% R) [b/]	Precision Water (RPD) [c/]	Accuracy Soil (% R)	Precision Soil (RPD)
Polynuclear Aromatic Hydrocarbons (Cont)	Benzo (a) Anthracene	39–135	≤ 30	29–145	≤ 50
	Benzo (a) Pyrene	52–125	≤ 30	42–135	≤ 50
	Benzo (b) Fluoranthene	31–137	≤ 30	25–147	≤ 50
	Benzo (g,h,i) Perylene	53–125	≤ 30	43–135	≤ 50
	Benzo (k) Fluoranthene	60–129	≤ 30	50–139	≤ 50
	Chrysene	59–134	≤ 30	49–144	≤ 50
	Dibenzo (a,h) Anthracene	51–125	≤ 30	41–135	≤ 50
	Fluoranthene	42–125	≤ 30	32–135	≤ 50
	Fluorene	53–125	≤ 30	43–135	≤ 50
	Indeno (1,2,3-c,d) Pyrene	55–125	≤ 30	45–135	≤ 50
	Naphthalene	43–125	≤ 30	33–135	≤ 50
	Phenanthrene	52–129	≤ 30	42–139	≤ 50
	Pyrene	55–125	≤ 30	45–135	≤ 50
	Surrogates:				
	Terphenyl-D14	25–157	NA	22–167	NA
Common Anions SW9060	Bromide	86–112	≤ 20	86–112	≤ 30
	Chloride	91–111	≤ 20	91–111	≤ 30
	Fluoride	86–114	≤ 20	86–114	≤ 30
	Nitrate	90–110	≤ 20	90–110	≤ 30
	Nitrite	88–116	≤ 20	88–116	≤ 30
	Phosphate	87–110	≤ 20	87–110	≤ 30
	Sulfate	88–115	≤ 20	88–115	≤ 30
E353.1	Nitrogen, nitrate/nitrite	80-120	≤ 20	80-120	NA
EPA Method TO-13 for Soil Gas Volatile Organics	Benzene			70-130	±30
	Toluene			70-130	±30
	Ethylbenzene			70-130	±30
	m,p-Xylene			70-130	±30
	0-Xylene			70-130	±30
	Total Volatile Hydrocarbons			NA	NA

Criteria: Sample, QC sample and blank I.S. area must be within ±40% of the calibration checks I.S. area. Retention Time (R.T.) must be within ±0.5 minutes of the calibration check's R.T.

SOURCE: AFCEE QAPP, Version 2.0, January 1997

[a/] QC = Quality Control
[b/] %R = Percent Recovery
[c/] RPD = Relative percent difference
[d/] W = Water
[e/] S = Soil
[f/] NA = Not Applicable

1.4.2 Accuracy

Accuracy is a measure of the closeness of a reported concentration to the true value. Accuracy is expressed as a bias (high or low) and is determined by calculating percent recovery (%R) from MS/MSDs, LCSs, and surrogate spikes. MS/MSD and surrogate spike %Rs indicate accuracy relevant to a unique sample matrix. LCS %Rs indicate accuracy relevant to an analytical batch lot, and are strictly a measure of analytical accuracy conditions independent of samples and matrices. The %R of an analyte, and the resulting degree of accuracy expected for the analysis of QC spiked samples, are dependent upon the sample matrix, method of analysis, and the compound or element being measured. The concentration of the analyte relative to the detection limit of the method also is a major factor in determining the accuracy of the measurement.

Accuracy is expressed as %R and is calculated as follows:

$$\%R = [(A-B)/C] \times 100$$

where:

A = spiked sample concentration

B = measured sample concentration (without spike)

C = concentration of spike added.

Accuracy criteria for the laboratory are defined by control limits listed in Table 1.1.

1.4.3 Completeness

Completeness is defined as the percentage of laboratory measurements judged to be valid on a method-by-method basis. Valid data are defined as all data and/or qualified data considered to meet the DQOs for this project. Data completeness is expressed as percent complete (PC) and should be $\geq$ 90 percent. The goal for meeting analytical holding times is 100 percent. At the end of each sampling event, the completeness of the data will be assessed. If any data omissions are apparent, the parameter in question will be resampled and/or reanalyzed, if feasible. The laboratory results will be monitored as they become available to assess laboratory performance and its effect on data completeness requirements. When appropriate, additional samples will be collected to ensure that laboratory performance meets PC requirements.

PC is calculated as follows:

$$PC = \frac{N_A}{N_I} X100$$

Where:

N_A = Actual number of valid analytical results obtained

N_I = Theoretical number of results obtainable under ideal conditions.

1.4.4 Comparability

Comparability expresses the confidence with which data from one sample, sampling round, site, laboratory, or project can be compared to those from another. Comparability during sampling is dependent upon sampling program design and time periods. Comparability during analysis is dependent upon analytical methods, detection limits, laboratories, units of measure, and sample preparation procedures.

Comparability is determined on a qualitative rather than quantitative basis. For this project, comparability of all data collected will be ensured by adherence to standard sample collection procedures, standard field measurement procedures, and standard reporting methods, including consistent units. For example, concentrations will be reported in a manner consistent with general industry practice (e.g., soil data will be reported on a dry-weight basis).

In addition, to support the comparability of fixed-base laboratory analytical results with those obtained in previous or future testing, all samples will be analyzed by USEPA-approved methods, where available. The USEPA-recommended maximum permissible holding times for organic and inorganic parameters will not be exceeded. All analytical standards will be traceable to standard reference materials. Instrument calibrations will be performed in accordance with USEPA method specifications, and will be checked at the frequency specified for the methods. The results of these analyses can then be compared with analyses by other laboratories and/or with analyses for other sites addressed by this site investigation.

1.4.5 Representativeness

Representativeness expresses the extent to which collected data define site contamination. Where appropriate, sample results will be statistically characterized to determine the degree to which the data accurately and precisely represent a characteristic of a population, parameter variation at a sampling point, a process, or an environmental condition.

Sample collection, handling, and analytical procedures will strive to obtain the most representative sample possible. Representative samples will be achieved by the following:

- Collection of samples from locations fully representing site conditions;
- Use of appropriate sampling procedures, including equipment and equipment decontamination;
- Use of appropriate analytical methods for the required parameters and project reporting limits; and
- Analysis of samples within the required holding times.

Sample representativeness also is affected by the portion of each collected sample that is chosen for analysis. The laboratory will adequately homogenize all samples prior to taking aliquots for analysis to ensure that the reported results are representative of the sample received. Because many homogenization techniques may cause loss of contaminants through volatilization, homogenization for all volatile organic compound (VOC) method analyses will be performed with extreme care to minimize these risks.

SECTION 2

SOIL SAMPLING

2.1 INTRODUCTION

Soil sampling will be performed during soil excavation to confirm that all excessively contaminated soil has been removed. The following sections describe soil sample collection, procedures for equipment decontamination, and surveying procedures to be used as part of the soil sampling field effort.

2.2 SOIL SAMPLING PROCEDURES

2.2.1 Soil Sampling

Soil sampling from excavation sidewalls will be accomplished using hand tools. A minimum of four soil samples, one from each of the four sidewalls, will be collected from each excavation. The exact location for each sample will be determined based on observations of possible contamination (i.e. staining, odor, or field screening), or in the absence of indicators of contamination, from the mid-point of the sidewall at a depth immediately above the groundwater surface. Samples for field screening and laboratory analysis will be collected from the excavation sidewalls using a decontaminated stainless-steel trowel or other appropriate tools. Samples will be immediately placed into laboratory-supplied jars for laboratory submittal. Another portion of each sample will be placed into a self-sealing plastic bag or clean glass jar covered with aluminum foil and a screw-on cap for field headspace screening. Samples for headspace screening will be allowed to equilibrate for approximately 10 minutes, then screened for organic vapors using a PID. Field screening results will be used to select samples for laboratory analysis and to determine the vertical and horizontal extent of contamination. All samples will be examined for evidence of contamination, and soil types will be described and classified according to the Unified Soil Classification System.

All sampling equipment will be decontaminated prior to use and between uses, as described in Section 2.6. If subsurface conditions are such that the planned sampling technique does not produce acceptable results another technique deemed more appropriate to the type of soils or limestone present will be used. Any alternate soil sampling procedure used must be approved by the Parsons ES site manager and will be appropriate for the subsurface lithologies present at the site.

The Parsons ES field hydrogeologist will be responsible for observing all sampling activities, maintaining a detailed log of the target sample location and depth, and properly labeling and storing samples.

All sampling activity will be recorded in a bound, sequentially numbered, field book. The sampling description will include:

- Sample location and depth;
- Presence or absence of contamination (e.g., staining, odor or elevated headspace screening readings);
- Soil or rock description of the target sampling interval, including color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- The depth of lithologic contacts and/or significant textural changes, measured and recorded to the nearest 0.1 foot (1 inch) if present within the target interval.

2.3 SAMPLE HANDLING

This section describes the handling of soil samples from the time of sampling until the samples arrive at the laboratory.

2.3.1 Sample Containers and Labels

New, laboratory-cleaned glass jars will be provided by the laboratory. The sample label will be firmly attached to the sample jar immediately after sample collection, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample depth;
- Sample location;
- Sampling date;
- Sampling time; and
- Sample collector's initials.

2.3.2 Sample Preservation

Samples will be properly prepared for transportation to the laboratory by placing the samples in an adequately padded cooler containing ice to maintain an approximate shipping temperature of 4 degrees centigrade (°C).

2.3.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the analytical laboratory. Samples will be shipped priority overnight via Federal Express®. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Label shipping container with:
  - Sample collector's name, address, and telephone number;
  - Laboratory's name, address, and telephone number;
  - Description of sample;
  - Quantity of sample; and
  - Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition, and in accordance with analytical method-specific holding times.

2.3.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sampling team and the other two copies will be sent to the laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;
- Place and address of collection;
- Sample matrix;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

2.3.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the Parsons ES field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance,
  - Sample odor;
- Weather conditions;
- Sampler's identification;
- Any other relevant information.

2.4 LABORATORY ANALYSES

Laboratory analyses will be performed by the designated laboratory on all soil samples and the required QA/QC samples (see Section 3.5 and Section 5). Soil samples will by analyzed by USEPA analytical method 8021B for aromatic volatile organic compounds (including MTBE), and selected samples will be analyzed by USEPA analytical method 8310 for polynuclear aromatic hydrocarbons (PAHs), and total recoverable petroleum hydrocarbons (TRPH) using Method FL-PRO. All containers, preservatives, and shipping requirements will be consistent with the laboratory protocol. Laboratory personnel will specify any additional QC samples required. Shipping containers, ice chests with adequate padding, and cooling media will be sent by the laboratory to the site.

2.5 QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

As a check on the quality of field sampling activities (sampling, containerization, shipment, and handling) QA/QC trip blanks, field blanks, equipment rinseate samples,

and field replicates will be sent to the laboratory. QA/QC sampling will include replicates for soil samples (frequency of 10 percent), rinseate samples (frequency of 10 percent), and a trip blank for each individual shipping cooler sent to the analytical laboratory containing samples for volatile organic compound (VOC) analysis. The procedures for the collection of field QA/QC samples are discussed in Section 5 of this SAP. Laboratory QA/QC procedures will include one matrix spike analysis, one laboratory control sample, and one laboratory blank sample test for each specific analysis requested.

2.6 EQUIPMENT DECONTAMINATION PROCEDURES

Only potable and distilled water will be used for decontamination. If the quality of the water source is questionable, then a decontamination water field blank will be collected for laboratory analysis. The procedures for the collection of the decontamination water blank are described in Section 5. The Parsons ES field scientist will make the final determination as to the suitability of site water for these activities.

Prior to sample collection, and between each sampling location, the sampling tools will be decontaminated. The decontamination fluids will be stored in 55-gallon DOT-approved drums for proper treatment and disposal. The following decontamination protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent (Liquinox® or equivalent);
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with reagent-grade isopropanol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

All decontamination activities will be conducted in a manner so that the excess water will be controlled and not allowed to flow into any open excavation.

2.8 SURVEY OF SAMPLING LOCATIONS

The vertical and horizontal locations of each sample will be located by Parsons ES field personnel after during sampling activities. Horizontal locations will be measured relative to the excavation outline. The excavations will be measured relative to existing groundwater wells that have established coordinates (i.e., previously surveyed by a register surveyor). Horizontal distances will be recorded to the nearest 0.1 foot by measuring the distance from each borehole to three established locations [monitoring wells or other previously surveyed locations (e.g., building corners) deemed more appropriate by field personnel]. These distances will be used to locate each excavation

and sample location on any additional maps generated as part of the risk-based investigation.

SECTION 3

GROUNDWATER SAMPLING

3.1 INTRODUCTION

This section describes the scope of work required for collecting groundwater samples from existing wells. Wells will be sampled using a peristaltic pump for collection of all samples. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Groundwater sampling will be conducted by qualified scientists and technicians trained in the conduct of well sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed the work plan and this site-specific sampling and analysis plan prior to sample acquisition and will have a copy of both available onsite for reference.

Activities that will occur during groundwater/ surface water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of existing wells, including:
  - Protective cover, cap and lock,
  - External surface seal and pad,
  - Well stick-up, cap, and datum reference,
  - Internal surface seal,
  - Condition of any dedicated equipment, if present;
- Groundwater sampling, including:
  - Water level measurements,
  - Visual inspection of borehole water,
  - Well purging,
  - Sampling;

- Sample preservation and shipment, including:
  - Sample preparation and preservation, as appropriate,
  - Onsite measurement of physical parameters,
  - Sample labeling,
  - Sample packaging in appropriate shipping containers;
- Completion of sampling records;
- Completion of chain-of-custody records; and
- Sample shipment via overnight courier.

Detailed groundwater/ surface water sampling and sample handling procedures are presented in following sections.

3.2 GROUNDWATER SAMPLING LOCATIONS

Groundwater samples will be collected from 12 existing wells at Site SS-15A. The location of some of these wells is shown in Figure 10.2 of the CAP.

3.3 EQUIPMENT DECONTAMINATION

All portions of sampling and test equipment that will contact the sample will be thoroughly cleaned before each use. This equipment may include water-level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the chemical constituents present at the SS-15A site, the following decontamination protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent (Liquinox® or equivalent);
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with reagent-grade isopropanol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

All decontamination fluids will be temporarily placed in 55-gallon DOT approved containers for proper disposal.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling form. If pre-cleaned dedicated

sampling equipment is used, the decontamination protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory and therefore will not need to be cleaned in the field. Equipment field blanks and equipment rinseate samples will be collected to assure that all containers and field equipment are free of contamination.

3.4 EQUIPMENT CALIBRATION

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite chemical measurements such as dissolved oxygen, pH, electrical conductivity, and temperature. Additional details on the calibration of field equipment are presented in Section 6 of this SAP.

3.5 SAMPLING PROCEDURES

Special care will be taken to prevent contamination of the groundwater and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient decontamination of equipment between wells. To prevent such contamination, the peristaltic pump and water level probe and cable used to determine static water levels and total well depth will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile gloves will be worn each time a different well or station is sampled. New, clean tubing will be used for the peristaltic pump for each of the wells sampled. Plastic will be placed around each of the wells to be sampled and sampling equipment will not be allowed to come in contact with the ground surface at any time during the sampling event.

The following paragraphs present the procedures for groundwater/ surface water sample acquisition from all groundwater/ surface water sampling locations. These activities will be performed in the same order as presented below. Exceptions to this procedure will be noted in the field scientist's field notebook.

3.5.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well or sampling location will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well. New, clean plastic we be placed around the well to prevent the contamination of both the ground surface and any equipment that may come into contact with the ground surface.

3.5.2 Water Level and Total Depth Measurements

Prior to removing any water from new monitoring points or existing wells, the static water level will be measured. An electrical water level probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. If the total depth of

the well is not known or is suspected to be inaccurate, total well depth will be measured by slowly lowering the water level probe to the bottom of the well. Total well depth will be measured to the nearest 0.01 foot. Total depth will only be measured when absolutely necessary to minimize the amount of sediment disturbance in the well. Based on water level and total depth information, the volume of water to be purged from the well can be calculated.

3.5.3 Well Purging

The static groundwater inside each well will be purged using a peristaltic pump. The well will be purged at a very low flow rate [10 milliliters per minute (ml/min) to 1,000 ml/min]. The objective of micropurging is to remove a small volume of water at a low flow rate from a discrete portion of the screened interval of the well without disturbing stagnant water within the casing. Therefore, the well purge rate must never be greater than the recharge rate of the well. During purging, the water level in the well will be monitored to ensure that no drawdown in the well occurs. The water level monitoring will allow the sampling technician to control pumping rates to minimize drawdown. As long as no drawdown is observed during pumping, it may be assumed that the low pumping rate within the discrete, screened portion of the well has not pulled stagnant casing water into the sample.

The pH, temperature, dissolved oxygen, and specific conductivity will be continuously monitored during well purging using a flow-through cell. The flow-through cell will be attached directly to the discharge tubing of the peristaltic pump using Teflon®-lined polyethylene tubing. New tubing will be used at each well. Purging will continue until the parameters have stabilized (less than 0.2 standard pH units or a 10-percent change for the other parameters over a 5-minute period) and the water is clear and free of fines. Research conducted on low-flow micropurging has found that dissolved oxygen and specific conductance readings are the most useful field indicator parameters for stabilization of background water chemistry during purging (Barcelona, *et. al.*, 1994). The research also concluded that stabilization of dissolved oxygen and specific conductance shows some correlation to stabilization of VOC concentrations in "formation" waters.

All purge water will be placed in DOT approved 55-gallon containers and disposed of properly. The contractor will be responsible for sampling, laboratory analysis, and arranging for the disposal of any contaminated or potentially contaminated purge water. Drums will be staged and temporarily stored at a location designated by Homestead ARB personnel onsite until analytical results are received.

3.5.4 Sample Extraction

A peristaltic pump with new tubing for each well will be used to extract groundwater samples for all analysis. Extraction equipment will be gently lowered into the water to prevent splashing. The sample will be transferred directly to the appropriate sample container. The water should be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. Sample containers for VOC analysis will be filled at approximately 200 ml/min and all other sample collection rates will not exceed

400 ml/min. Samples will be collected after the well has been purged using the peristaltic pump and after all field sampling parameters have been recorded at the well.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon containers used for well purge waters and disposed of at a licensed, off-Base disposal facility.

3.6 ONSITE CHEMICAL PARAMETER MEASUREMENT

Because many chemical parameters of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field using Hach® or CHEMetrics® test kits. The following discussion describes the field procedures for obtaining the onsite chemical parameter measurements. For information on individual instrument calibration procedures, please refer to the manufacturer's calibration procedure for the instrument.

Groundwater quality measurements such as temperature, pH, specific conductivity, dissolved oxygen, and reduction/oxidation (redox) potential will be continuously monitored during well purging using a flow-through cell. The flow-through cell will be attached directly to the discharge tubing of the peristaltic pump using Teflon®-lined polyethylene tubing. A new piece of tubing will be used for each well. All groundwater quality measuring equipment will be decontaminated following the procedures described in Section 3.4. The groundwater quality measuring equipment will be calibrated between each well following the manufacturer's recommended calibration procedures. The measurements observed immediately before groundwater sampling begins will be considered the final measurements for the sample, and will be recorded in the field notebook and on the point-specific sampling form.

Groundwater quality measurements such as ferrous iron, sulfate, sulfide, and alkalinity will be measured in the field using HACH® or CHEMetrics® field analysis methods. All appropriate equipment and glassware associated with the field analysis of groundwater samples will be decontaminated following the procedures described in Section 3.4. Groundwater samples for these measurements will be collected after all sample containers for laboratory analyses have been collected. Two 250-ml bottles of groundwater will be collected and capped for field analysis. The field analysis of groundwater samples should begin immediately after collection. Direct sunlight, contact with air, and high temperatures may greatly affect the concentrations of the analytes in question. If possible, analyses will be run indoors, and groundwater samples will be capped and stored in a cooler with a temperature maintained at 4°C when not in use. Duplicate analyses will be run at a frequency of 25 percent, or one duplicate sample for every four field analyses. One blank (distilled water) analysis will be performed for each sampling round.

3.7 LABORATORY SAMPLE HANDLING

This section describes the handling of samples to be analyzed by the fixed-based laboratory from the time of sampling until the samples arrive at the laboratory.

3.7.1 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the laboratory. The sample containers will be filled as described in Section 3.5.4, and the container lids will be tightly closed. Container lids will not be removed at any time prior to sample collection. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (groundwater, surface water, etc.);
- Sampling date;
- Sampling time;
- Preservatives added; and
- Sample collector's initials.

3.7.2 Sample Preservation

The laboratory will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4°C.

3.7.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to a preapproved laboratory. Samples will be shipped priority overnight via Federal Express®. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Label shipping container with:
  - Sample collector's name, address, and telephone number;
  - Laboratory's name, address, and telephone number;
  - Description of sample;
  - Quantity of sample; and
  - Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition, and within method-specific holding times.

3.7.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed as described in Section 3.4.4.

3.7.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field hydrogeologist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance,
  - Sample odor;
- Weather conditions;
- Water level prior to purging;
- Total well depth;
- Approximate Purge volume;
- Water level after purging;
- Well condition;
- Sampler's identification;
- Field measurements of pH, temperature, and specific conductivity; and
- Any other relevant information.

Groundwater sampling activities will be recorded on a groundwater sampling form or in the field scientist's field notebook. Figure 3.1 shows an example of the groundwater sampling record.

3.8 LABORATORY ANALYSES

Laboratory analyses will be performed on all groundwater samples and the required QA/QC samples (see Section 3.9). The analytical methods and detection limit requirements for this sampling event are listed in the CAP. Prior to sampling, arrangements will be made with the laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with laboratory protocol.

Laboratory personnel will specify any additional QC samples and prepare bottles for all samples. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to shipping. Shipping containers with adequate padding and cooling media will be sent by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratory.

3.9 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES AND SAMPLING

Field QA/QC samples for groundwater/ surface water sampling will include collection of field duplicates; equipment rinseate samples, field blanks, and trip blanks; decontamination of the water level probe; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater/ surface water), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain an approximate temperature of 4°C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature.

Groundwater QA/QC sampling frequency will be 10 percent or one sample for every ten wells/locations sampled. In the event that less than ten wells will be sampled in an event, a minimum of one sample will be collected. This ten percent frequency also applies to equipment rinseate samples and field duplicates. One decontamination water sample and one field blank will be collected per sampling event. One trip blank will be sent with each sample shipment. The procedures for the collection of field QA/QC samples are described in Section 5. The laboratory should plan to conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested.

FIGURE 3.1

GROUNDWATER SAMPLING RECORD

Sampling Location Homestead ARB
Sampling Dates _____

GROUND WATER SAMPLING RECORD - MONITORING WELL _____
(Identification)

REASON FOR SAMPLING: [X] Regular Sampling; [ ] Special Sampling;
DATE AND TIME OF SAMPLING: _____ at _____ a.m./p.m.
SAMPLE COLLECTED BY: _____ of Parsons ES
WEATHER: _____
DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____
_____
_____

MONITORING WELL CONDITION:
[ ] LOCKED: [ ] UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS: _____
INNER PVC CASING CONDITION IS: _____
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
[ ] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
[ ] MONITORING WELL REQUIRED REPAIR (describe): _____
_____
_____

Check-off
1 [ ] EQUIPMENT CLEANED BEFORE USE WITH _____
Items Cleaned (List): _____
_____
_____

2 [ ] PRODUCT DEPTH _____ FT. BELOW DATUM
Measured with: _____

WATER DEPTH _____ FT. BELOW DATUM
Measured with: _____

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: _____
Odor: _____
Other Comments: _____

4 [ ] WELL EVACUATION:
Method: _____
Volume Removed: _____
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

FIGURE 3.1 (cont.)
Groundwater Sampling Record

Monitoring Well No. _____ (Continued)

5 [ ] SAMPLE EXTRACTION METHOD:

[ ] Bailer made of:_____
[ ] Pump, type:_____
[ ] Other, describe:_____
_____

Sample obtained is [X] GRAB; [ ] COMPOSITE SAMPLE

6 [ ] ON-SITE MEASUREMENTS:

Time							Measured with
Temp (°C)							
pH							
Cond (µS/cm)							
DO (mg/L)							
Redox (mV)							
gallons purged							

7 [ ] SAMPLE CONTAINERS (material, number, size):_____
_____
_____
_____

8 [ ] ON-SITE SAMPLE TREATMENT:

[ ] Filtration: Method_____ Containers:_____
Method_____ Containers:_____
Method_____ Containers:_____

[ ] Preservatives added:

Method_____ Containers:_____
Method_____ Containers:_____
Method_____ Containers:_____
Method_____ Containers:_____

9 [ ] CONTAINER HANDLING:

[ ] Container Sides Labeled
[ ] Container Lids Taped
[ ] Containers Placed in Ice Chest

10 [ ] OTHER COMMENTS:_____
_____
_____
_____
_____

SECTION 4

FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

As a check on field sampling, QA/QC samples will be collected during each sampling event. Definitions for field QA/QC samples are presented below.

4.1 FIELD DUPLICATES

A field duplicate is defined as two or more samples collected independently at the same sampling location during a single act of sampling. Soil and sediment samples are divided into two equal parts (replicates) for analysis. Field duplicates will be indistinguishable from other samples by the laboratory. Each of the field duplicates will be uniquely identified with a coded identifier, which will be in the same format as other sample identifiers. Duplicate sample results are used to assess the precision of the sample collection process. Groundwater QA/QC sampling frequency for field duplicate samples will be 10 percent or one sample for every ten wells/locations sampled.

4.2 TRIP BLANKS

The trip blank is used to indicate potential contamination by VOCs or SVOCs during sample shipping and handling. A trip blank consists of analyte-free laboratory reagent water in a 40-milliliter (ml) glass vial sealed with a Teflon® septum. The blank accompanies the empty sample bottles to the field and is placed in each cooler containing water or soil matrix VOC/SVOC samples returning to the laboratory for analysis. The trip blank is not opened until analysis in the laboratory with the corresponding site samples.

4.3 EQUIPMENT RINSEATE BLANKS

Equipment rinseate blanks consist of distilled water poured into or pumped through the sampling device following decontamination. The rinseate is transferred to an appropriate sample bottle for the analysis and transported to the laboratory. The equipment rinseate samples are analyzed for the same laboratory parameters as the site samples. Equipment blanks are used to measure to contamination introduced to a sample set from improperly decontaminated sampling equipment. Groundwater QA/QC sampling frequency for equipment rinseate samples will be 10 percent or one sample for every ten wells/locations sampled.

4.4 DECONTAMINATION WATER BLANK

A decontamination water blank is designed to check the purity of potable water used for equipment decontamination during the field operation. Decontamination water blanks will be collected at the discretion of the field scientist. If the decontamination water is of questionable purity, then a blank sample will be collected. Decontamination water blanks are collected by filling the appropriate sample container directly from the potable water source. Decontamination water blanks are labeled, preserved, handled, and shipped in the same manner as an environmental water sample. The blank will be analyzed for the same analytes and parameters as the environmental samples.

4.5 FIELD BLANKS

A field blank is designed to assess the effects of ambient field conditions on sample results. One field blank will be collected during each sampling event. A field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for the same analytes and parameters as the environmental samples.

SECTION 5

FIELD DATA REDUCTION, VALIDATION, AND REPORTING

The following sections describe field analytical instrumentation calibration, and field data reporting, validation, reduction, and review.

5.1 CALIBRATION PROCEDURES AND FREQUENCY FOR FIELD TEST EQUIPMENT

Instruments and equipment used to gather, generate, or measure environmental data in the field will be calibrated with sufficient frequency and in such a manner that accuracy and reproducibility of results are consistent with the manufacturer's specifications. Field instruments may include a soil gas Gas Tech multi-gas meter, pH meter, digital thermometer, O_2/CO_2 meter, TVH meter, specific conductivity meter, dissolved oxygen meter, oxidation reduction potential meter, and Hach® spectrophotometer. A summary of calibration frequency and acceptance criteria is presented in Table 5.1.

5.2 FIELD DATA REDUCTION

During processing of field data, validation checks will be performed by individuals designated by the project manager. The purpose of these checks is to identify outliers; that is, data which do not conform within two standard deviations to the pattern established by other observations. The Students "t" test will be used to identify outliers when the total number of samples is less than 31, and the normal distribution will be used to identify others when the total number of samples is greater than 31. Although outliers may be the result of transcription errors or instrument breakdowns, they may also be manifestations of a greater degree of spatial or temporal variability than expected. Therefore, after an outlier has been identified, a decision must be made concerning its further use. Obvious mistakes in data will be corrected when possible, and the corrected values will be inserted. If the correct value cannot be obtained, the datum may be excluded. An attempt will be made to explain the existence of the outlier. If no plausible explanation can be found for the outlier, it may be excluded, and a note to that effect will be included in the report. Also, an attempt will be made to determine the effect of the outlier both when included in and when excluded from the data set, and the results will be discussed in the report. In addition, the data will be compared against those obtained in previous investigations (where available) and against applicable standards and guidelines.

5.3 REVIEW OF FIELD RECORDS

All field records are evaluated for the following:

TABLE 5.1
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC[a/] PROCEDURES
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]	Reporting Limit
SW9050	Conductance	Calibration with potassium chloride standard	Once per day at beginning of testing	± 5%	If calibration is not achieved, check meter, standards, and probe; recalibrate	0.02 µmhos/cm
		Field duplicate	10% of field samples	± 5%	Correct problem, repeat measurement	
SW9040	pH (water)	2-point calibration with pH buffers	Once per day at beginning of testing	± 0.05 pH units for every buffer	If calibration is not achieved, check meter, buffer solutions, and probe; replace if necessary; repeat calibration	pH units
		pH 7 buffer	At each sample location	± 0.1 pH units	Correct problem, recalibrate	
		Field duplicate	10% of field samples	± 0.1 pH units	Correct problem, repeat measurement	
E170.1	Temperature	Field duplicate	10% of field samples	± 1.0°C[c/]	Correct problem, repeat measurement	°C
ASTM[d/] D1498	Oxidation-reduction potential	Calibration with one standard	Once per day at beginning of testing	Two successive readings ± 10 millivolts	Correct problem, recalibrate	pe[e/] units
		Field duplicate	10% of field samples	± 10 millivolts	Correct problem, repeat measurement	
Hach™ 8221	Alkalinity	Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by standard solutions, and optical cell; replace if necessary; repeat calibration check	20.0 mg/L[f/]
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

TABLE 5.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
STREAMLINED RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
E360.1	Dissolved oxygen	Calibration check with one standard, and zero meter with sodium sulfate solution	Once per day at beginning of testing	± 5 %	Correct problem by checking meter, standard solutions, replace if necessary; repeat calibration check	0.5 mg/L
		Field duplicate	10% of field samples	RPD[g/] < 20%	Correct problem, repeat measurement	
HACH™ 8039	Nitrate (NO_3)	Calibration check with one standard, and zero meter w/sodium sulfate solution	Once per day at beginning of testing	± 5 %	Correct problem by checking meter, standard solutions, replace if necessary; repeat calibration check	0.07 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
HACH™ 8040	Nitrite (NO_2)	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.01 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

TABLE 5.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
STREAMLINED RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
Hach™ 8146	Ferrous Iron (Fe^{2+})	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.024 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
Hach™ 8034	Manganese	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.024 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
Hach™ 8131	Hydrogen Sulfide (H_2S)	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.024 mg/L

TABLE 5.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
STREAMLINED RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
HACH™ 8051	Sulfate (SO_4^{-2})	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.01 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
HACH™ 8131	Sulfide (S^{-2})	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	NA[h/]
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

TABLE 5.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
STREAMLINED RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
Gas Tech Multi-gas Meter	TVH and Methane	Accuracy check, (2 concentration points)	Once per day	± 20 %	Correct problem by checking meter, chech gas standards, correlate with lab analysis	20 ppmv
		Field duplicate	10% of field samples	± 20 %	Correct problem, repeat measurement	
Gas Tech Multi-gas Meter	Oxygen, Carbon Dioxide	Calibration check with ambient air and one standard	Once per day at beginning of testing	± 10 %	Correct problem by checking meter, gas standards, and reaction cell; replace if necessary; repeat calibration check	0.5 %
		Accuracy check, (2 concentration points)	Once per day	± 10 %	Correct problem by checking meter, gas standard , and reaction cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

[a/] QC = quality control.
[b/] All corrective actions will be documented, and the records will be maintained by the prime contractor.
[c/] °C = degrees Celsius.
[d/] ASTM = American Society for Testing and Materials.
[e/] pe = potential platinum electrode.
[f/] mg/L = milligrams per liter.
[g/] RPD = relative percent difference.
[h/] NA = not applicable.

Completeness of field records. The check of field record completeness will ensure that all requirements for field activities have been fulfilled, complete records exist for each field activity, and that the procedures specified in the SAP (or approved as field change requests) were implemented. Field documentation will ensure sample integrity and provide sufficient technical information to recreate each field event. The results of the completeness check will be documented, and environmental data affected by incomplete records will be identified in the technical report.

Identification of valid samples. The identification of valid samples involves interpretation and evaluation of the field records to detect problems affecting the representativeness of environmental samples. For example, field records can indicate whether a well is properly constructed or if unanticipated environmental conditions were encountered during construction. The lithologic and geophysical logs may be consulted to determine if a well is screened only in the water-bearing zone of concern. Records also should note sample properties such as clarity, color, odor, etc. Photographs may show the presence or absence of obvious sources of potential contamination, such as operating combustion engines near a well during sampling. Judgments of sample validity will be documented in the technical report, and environmental data associated with poor or incorrect field work will be identified.

Correlation of data. The results of field tests obtained from similar areas will be correlated. For example, soil gas TVH readings and VOC analysis results may be correlated. The findings of these correlations will be documented, and the significance of anomalous data will be discussed in the technical report.

Identification of anomalous field test data. Anomalous field data will be identified and explained to the extent possible. For example, a water temperature for one well that is significantly higher than any other well temperature in the same aquifer will be explained in the technical report.

Accuracy and precision of field data and measurements. The assessment of the quality of field measurements will be based on instrument calibration records and a review of any field corrective actions. The accuracy and precision of field measurements will be discussed.

Field record review is an ongoing process. Field team leaders will be responsible for ensuring that proper documentation is recorded during each site's sampling activities.

5.4 FIELD DATA VALIDATION AND REPORTING

The contractor analyst will review 100 percent of all screening data prior to reporting. Screening data will constitute all analytical method results from analyses performed in the field laboratory environment. The contractor will determine if their data quality objectives (DQOs) for field data have been met, and also will calculate the percent complete (PC) for field data results.

At a minimum, the review of screening data will focus on the following topics:

- Holding times;
- Method blanks;
- Field instrumentation detection limits;
- Analytical batch control records including calibrations, and spike recoveries;
- Completeness of data; and
- Flag all results with an "S" to denote sample results from field screening versus fixed laboratory results.

Field data will be validated using four different procedures, as described below:

- Routine checks (e.g., looking for errors in identification codes) will be made during the processing of data.
- Internal consistency of a data set will be evaluated. This step will involve plotting the data and testing for outliers.
- Checks for consistency of the data set over time will be performed. This can be accomplished by comparing data sets against gross upper limits obtained from historical data sets, or by testing for historical consistency. Anomalous data will be identified.
- Checks may be made for consistency with parallel data sets. An example of such a check would be comparing data from the same region of the aquifer or volume of soil.

SECTION 6

FIXED-BASE LABORATORY ANALYTICAL PROCEDURES

Application of a specific analytical method depends on the sample matrix and the analytes to be identified. Methods for each of the parameters likely to be included in the analytical program, as well as detection limits, are discussed in the following subsections. All analytical methods are USEPA approved.

6.1 ANALYTICAL METHODS

Analytical procedures will follow the established USEPA and/or American Society for Testing and Materials (ASTM) methods as recommended by AFCEE wherever such methods exist for a specified analyte. All approved methods are presented in Table 6.1. The referenced methods are defined in the following documents:

- USEPA (1983) *Methods for Chemical Analysis of Water and Wastes*, EPA 600/4-79-020.
- USEPA (1995) *Test Methods for Evaluating Solid Waste, Physical and Chemical Methods*, SW846, 3rd Edition , Update IIB.
- *American Society for Testing and Materials Methods* (ASTM, 1995).

6.1.2 Detection and Quantitation Limits

This section describes the terms, definitions, and formulas that will be used for detection and quantitation limits.

6.1.3 Instrument Detection Limit

The instrument detection limit (IDL) reflects the instrument operating efficiency, not sample preparation or concentration/dilution factors. The IDL is operationally defined as three times the standard deviation of seven replicate analyses of the lowest concentration that is statistically different from a blank. This represents 99-percent confidence that the signal identified is the result of the presence of the analyte, and not random noise.

6.1.4 Method Detection Limit

The method detection limit (MDL) is the lowest concentration at which a specific analyte in a matrix can be measured and reported with 99-percent confidence that the analyte concentration is greater than zero. MDLs are experimentally determined and

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TABLE 6.1
PRACTICAL QUANTITATION LIMITS
RISK-BASED APPROACH TO REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a/]	Unit	PQL	Unit
Aromatic Volatile Organics Compounds SW5030A/SW5025/ SW8021B (W[d/], S[e/])	Benzene	0.10	µg/L	0.01	mg/kg
	Chlorobenzene	0.10	µg/L	0.01	mg/kg
	Ethylbenzene	0.50	µg/L	0.01	mg/kg
	Toluene	0.10	µg/L	0.01	mg/kg
	Vinyl Chloride	0.40	µg/L	0.01	mg/kg
	Xylenes, Total	0.50	µg/L	0.01	mg/kg
Volatile Organics Compounds SW5030A/SW5025/ SW8260B (W[d/], S[e/])	Benzene	0.40	µg/L	0.002	mg/kg
	Chlorobenzene	0.40	µg/L	0.002	mg/kg
	Ethylbenzene	0.60	µg/L	0.003	mg/kg
	Toluene	1.10	µg/L	0.005	mg/kg
	Vinyl Chloride	1.10	µg/L	0.009	mg/kg
	p/m xylene	1.30	µg/L	0.007	mg/kg
	o-xylene	1.10	µg/L	0.005	mg/kg
Methane RSK-175 (W)	Methane	2.0	µg/L	NA[f/]	NA
	Ethane	4.0	µg/L	NA	NA
	Ethene	2.0	µg/L	NA	NA
Polynuclear Aromatic Hydrocarbons SW3510B/SW8310 (W) SW3550A/SW8310 (S)	Acenaphthene	18.0	µg/L	1.2	mg/kg
	Acenaphthylene	23.0	µg/L	1.54	mg/kg
	Anthracene	6.6	µg/L	0.44	mg/kg
	Benz (a) Anthracene	0.13	µg/L	0.009	mg/kg
	Benzo (a) Pyrene	0.23	µg/L	0.015	mg/kg
	Benzo (b) Fluoranthene	0.18	µg/L	0.012	mg/kg
	Benzo (g,h,i) Perylene	0.76	µg/L	0.05	mg/kg
	Benzo (k) Fluoranthene	0.17	µg/L	0.011	mg/kg
	Chrysene	1.5	µg/L	0.1	mg/kg
	Dibenzo (a,h) Anthracene	0.3	µg/L	0.02	mg/kg
	Fluoranthrene	2.1	µg/L	0.14	mg/kg
	Fluorene	2.1	µg/L	0.14	mg/kg
	Indeno (1,2,3-c,d) Pyrene	0.43	µg/L	0.03	mg/kg
	Naphthalene	18.0	µg/L	1.2	mg/kg
	Phenanthrene	6.4	µg/L	0.42	mg/kg
	Pyrene	2.7	µg/L	0.18	mg/kg
Common Anions SW9056	Bromide	0.1	mg/L	0.1	mg/kg
	Chloride	0.2	mg/L	0.2	mg/kg
	Fluoride	0.2	mg/L	0.2	mg/kg
	Nitrate	0.1	mg/L	0.1	mg/kg
	Nitrite	0.4	mg/L	0.1	mg/kg
	Phosphate	0.1	mg/L	0.1	mg/kg
	Sulfate	0.2	mg/L	0.2	mg/kg

TABLE 6.1
PRACTICAL QUANTITATION LIMITS
RISK-BASED APPROACH TO REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a/]	Unit	PQL	Unit
E160.1	Total Dissolved Solids	10.0	Mg/L	NA	NA
E160.2	Total Suspended Solids	5.0	mg/L	NA	NA
E310.1	Alkalinity	10.0	mg/L	NA	NA
E353.1	Nitrogen, Nitrate/Nitrite	0.1	mg/L	NA	NA
SW9050	Conductance	NA	NA	NA	NA
SW9040	pH	NA	NA	NA	NA

SOURCE: AFCEE QAPP, Version 1.1, February 1996

[a/] PQLs = practical quantitation limits. PQLs are equal to the project reporting limits.
[b/] µg/L = micrograms per liter.
[c/] mg/kg = milligrams per kilogram.
[d/] W = water.
[e/] S = soil.
[f/] NA = not applicable.
[g/] mg/L = milligrams per liter.

verified for each target analyte of the methods in the sampling program. The laboratory will determine MDLs for each analyte and matrix type prior to analysis of project samples. MDLs are based on the results of seven matrix spikes at the estimated MDL, and are statistically calculated in accordance with the Title 40, Code of Federal Regulations Part 136 (40 CFR 136). The standard deviation of the seven replicates is determined and multiplied by 3.14 (i.e., the 99-percent confidence interval from the one-sided Students T-test). MDLs must be determined annually as a minimum. The MDLs to be used are intended to allow that both nondetects and detects will be usable to the fullest extent possible for the project.

6.1.5 Project Reporting Limit

To define analytical data reporting limits that meet project DQOs, potential risk-based screening criteria were identified. State-specified "clean closure" concentrations, risk-based preliminary remediation goals (PRGs), regulatory concentrations, or other relevant soil, groundwater, and surface water action levels will be reviewed to identify the most stringent comparison criteria for each matrix likely to be applicable. The project reporting limits (PRLs), listed as the practical quantitation limits (PQL) in Table 6.1, will be reviewed in comparison to the risk-based screening criteria. Project reporting limits are those published in the current AFCEE QAPP Version 2.0 (1997) and by the FDEP (for Florida TRPH method FL-PRO), or as established historically by the laboratory when not available in the AFCEE QAPP. If state regulatory guidance standards for analytical method reporting limits are lower than the PQLs listed in Table 6.1, then the state-required limits will supersede the PQLs in Table 6.1.

The PRL is equivalent to the current PQL guidance listed in the AFCEE (1996) QAPP. Because the project remediation goals are developed for risk-based site closure, all sample results will be the reported at or above the MDL for each analyte. All results above the MDL but below the PQL will be qualified in the data deliverable from the laboratory with a "FJ" flag. The "FJ" flag will denote the sample result as below the PQL (see Section 6.6.2). Where practical, MDLs must be lower than the risk-based criterion determined for the project. Laboratories must verify the PRLs by analyzing a standard at or below the PRL within the calibration curve.

All analytical results for soils (both nondetected and detected) will be reported on a dry-weight basis (i.e., corrected for moisture content). The moisture content for each soil sample will be reported. The equation for moisture content given for the SW-846 Method SW3550 is as follows:

$$\frac{\text{Initial Weight - Dried Weight}}{\text{Initial Weight}} \times 100 = \%\ \text{moisture}$$

The result of the sample on a dry-weight basis is as follows:

$$\text{Result of analysis on wet weight basis} \times \frac{100}{100 - \%\ \text{Moisture}} = \text{Result of analysis on a dry-weight basis}$$

6.1.6 Sample Quantitation Limit

Sample quantitation limits (SQLs) are defined as the MDL multiplied by the dilution factor (DF) required to analyze the sample, and corrected for moisture or sample size. These adjustments may be due to matrix effects or to the high concentrations of some analytes. For example, if an analyte is present at a concentration that is greater than the linear range of the analytical method, the sample must be diluted for accurate quantitation. The DF raises the reporting limit, which then becomes the SQL. Because the reported SQLs take into account sample characteristics and analytical adjustments, they are the most relevant quantitation limits for evaluating nondetected chemicals.

6.1.7 Reporting Units

The following are the prescribed reporting units for all analytical methods:

Soil samples - organics: micrograms per kilogram (μg/kg), dry-weight basis;

Soil samples - inorganics/metals: milligrams per kilogram (mg/kg), dry-weight basis;

Water samples - inorganics/metals: milligrams per liter (mg/L); and

Water samples - organics: micrograms per liter (μg/L).

6.2 LABORATORY QUALITY CONTROL DATA

Laboratory QC data are necessary to determine the precision and accuracy of the analyses, confirm matrix interferences, and demonstrate target compound contamination of sample results. QC samples will be analyzed routinely by the analytical laboratory as part of the laboratory QC procedures. Contract laboratories performing definitive data quality analyses require a more stringent QC program than those performing screening-level data quality analyses. Definitions for QC samples are presented below. Frequency and acceptance requirements are defined in Table 6.2. All precision and accuracy control limit criteria are defined in Table 1.1.

6.2.1 Holding Time

Holding times for sample extraction and/or analysis as required by the methods will be met for all samples. The holding time is calculated from the date and time of sample collection to the time of sample preparation and/or analysis. All sample analyses to include dilutions and second-column confirmation will meet the required holding times. Results for samples exceeding holding time will be qualified as unusable (flagged "R"). Table 6.3 defines applicable method-specific analytical holding times.

6.2.2 Method Blanks

Method blanks are designed to detect contamination of the field samples in the laboratory environment. Method blanks verify that interferences caused by contaminants in solvents, reagents, glassware, or in other sample processing hardware

TABLE 6.2
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Aromatic Volatile Organic Compounds SW8021B and Alcohol SW8015B	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c/] < 20% for CFs[d/] or Rfs[e/] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verification	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL [f/]	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS[g/] for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
Aromatic Volatile Organic Compounds SW8021B SW8021B and Alcohol SW8015B (Cont)	MDL[h/] study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD[i/]	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Results reported between MDL and PRL	None	None	None
Volatile Organics SW8260B	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	SPCCs[j/] average RF ≥ 0.30[k/]; and RSD for all calibration analytes ≤ 30%	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±25% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Calibration verification	Daily, before sample analysis, every 12 hours of analysis time, and at end of analysis sequence	SPCCs average RF ≥ 0.30, and CCCs[l/] < 20% drift; and all calibration analytes within ±25% of expected value	Correct problem then repeat initial calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
Volatile Organics SW8260B (cont)	Check of mass spectral ion intensities using BFB[m/]	Prior to initial calibration and calibration verification	Refer to criteria listed in the method description	Retune instrument and verify
	IS[n/]	Every sample, spiked sample, standard, and method blank	Retention time ±30 seconds: EICP[o/] area within -50% to +100% of last calibration verification (12 hours) for each	Inspect mass spectrometer or GC[p/] for malfunctions; mandatory reanalysis of samples analyzed while system was malfunctioning
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then reextract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Semi-volatile Organics SW8270B	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	SPCCs average RF ≥ 0.05; and RSD for all calibration analytes ≤ 30%	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±25% of expected value	Correct problem then repeat initial calibration

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
Semi-volatile Organics SW8270B (cont)	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Calibration verification	Daily, before sample analysis, every 12 hours of analysis time, and at end of analysis sequence	SPCCs average RF ≥ 0.05; and CCCs < 20% drift; and all calibration analytes within ±25% of expected value	Correct problem then repeat initial calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Check of mass spectral ion intensities using DFTPP	Prior to initial calibration and calibration verification	Refer to criteria listed in the method description	Retune instrument and verify
	IS	Every sample, spiked sample, standard, and method blank	Retention time ±30 seconds: EICP area within -50% to +100% of last calibration verification (12 hours) for each	Inspect mass spectrometry or GC for malfunctions; mandatory reanalysis of samples analyzed while system was malfunctioning
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b]
Semi-volatile Organics SW8270B (cont)	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Polynuclear Aromatic Hydrocarbons SW8310, Formaldehyde SW8315, Ethylene Glycol SW8315 modified, and Methyl Carbamate Pesticides SW8318	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b]
Polynuclear Aromatic Hydrocarbons SW8310, Formaldehyde SW8315, Ethylene Glycol SW8315 modified, and Methyl Carbamate Pesticides SW8318 (cont)	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Confirmation [k/]	100% for all positive results	Same as for initial or primary analysis	Same as for initial or primary analysis
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
ICP Metals SW6010A and SW6010 Trace analyses	Initial multipoint calibration (minimum 3 standards and a blank)	Daily initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration check standard	Once per initial daily multipoint calibration	Analyte within ±10% of expected value	Correct problem then repeat initial calibration
	Highest calibration standard	Before beginning a sample run	All analytes within ±5% of expected value	Correct problem then repeat initial calibration
	Calibration blank	After every 10 samples and at end of the analysis sequence	No analyte detected >PQL.	Repeat twice, and average results; if average is not within ±3 standard deviations of background mean, terminate analysis; locate and correct problem; reanalyze previous 10 samples
	Continuing calibration verification (Instrument Check Standard)	After every 10 samples and at the end of the analysis sequence	All analyte(s) within ±10% of expected value	Repeat calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]
ICP Metals SW6010A and SW6010 Trace analyses (cont)	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	Interference check solution (ICS)	At the beginning and end of an analytical run or twice during an 8 hour period, whichever is more frequent	Within ±20% of expected value	Terminate analysis; correct problem; reanalyze ICS, reanalyze all affected samples
	LCS for the analyte	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Dilution test	Each new sample matrix	1:4 dilution must agree within ±10% of the original determination	Perform post-digestion spike addition
	Post-digestion spike addition	When dilution test fails	Recovery within 75-125% of expected results	Correct problem then reanalyze post-digestion spike addition
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b]
Lead and Lead-Based Paint SW7421, Selenium SW7740, Arsenic SW7060A, and Cadmium SW7131A	Initial multipoint calibration (minimum 3 standards and a blank)	Daily initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration check standard	Once per initial daily multipoint calibration	Analyte within ±10% of expected value	Correct problem then repeat initial calibration
	Calibration blank	Once per initial daily multipoint calibration	No analyte detected > PRL	Correct problem then reanalyze calibration blank and all samples associated with blank
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	The analyte within ±20% of expected value	Correct problem then repeat calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for the analyte	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b]
Lead and Lead-Based Paint SW7421, Selenium SW7740, Arsenic SW7060A, and Cadmium SW7131A (cont)	New matrix check; five-fold dilution test	Each new sample matrix	Five times dilution sample result must be ±10% of the undiluted sample result	Perform recovery test
	Recovery test	When new matrix check fails	Recovery within 85-115% of expected results	Run all samples by the method of standard addition
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Organo-phosphorus Pesticides SW8141A	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b]
Organo-phosphorus Pesticides SW8141A (cont)	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Chlorinated Herbicides SW8151	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Chlorinated Herbicides SW8151 (cont)	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Organo-chlorine Pesticides and PCBs SW8081	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Organo-chlorine Pesticides and PCBs SW8081 (cont)	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Breakdown check (Endrin and DDT)	Daily prior to analysis of samples	Degradation ≤20%	Repeat breakdown check
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Volatile and Extractable Total Petroleum Hydrocarbons SW8015 modified	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	%RSD < 20% or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Initial calibration verification	Daily, before sample analysis	All concentration levels of gasoline-range organics within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All concentration levels within ±15% of initial calibration	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No TPH detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria,	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Volatile and Extractable Total Petroleum Hydrocarbons SW8015 modified (cont)	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Mercury SW7470 and SW7471	Initial multipoint calibration (minimum 5 standards and a blank)	Daily initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration check standard	Once per initial daily multipoint calibration	Analyte within ±10% of expected value	Correct problem then repeat initial calibration
	Calibration blank	Once per initial daily multipoint calibration, every 10 samples, and ending	No analyte detected > PRL	Correct problem then reanalyze calibration blank and all samples associated with blank
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	The analyte within ±20% of expected value	Correct problem then repeat calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for the analyte	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Mercury SW7470 and SW7471 (cont)	New matrix check; five-fold dilution test	Each new sample matrix	Five times dilution sample result must be ±10% of the undiluted sample result	Perform recovery test
	Recovery test	When new matrix check fails	Recovery within 85-115% of expected results	Run all samples by the method of standard addition
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Common Anions E300.0	Multipoint calibration for all analytes (minimum 3 standards and one calibration blank)	Initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per multipoint calibration	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis or when elutent is changed	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	Instrument response within ±10% of expected response	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
		After every analytical batch	All analytes within ±10% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Common Anions E300.0 (cont)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Hexavalent Chromium SW7196	Multipoint calibration curve (minimum three standards and a blank)	Initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration verification	After each new stock standard preparation	Chromium within ±10% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 15 samples and at the end of the analysis sequence	Chromium within ±20% of expected value	Correct problem then repeat initial calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration
	Verification check to ensure lack of reducing condition and/or interference	Once for every sample matrix analyzed	Spike recovery between 85-115%	If check indicates interference, dilute and reanalyze sample persistent interference indicates the need to use and alternate method

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Hexavalent Chromium SW7196 (Cont)	MDL study	Once per year	Detection limits established shall be < the PQLs	None
	Method blank	One per analytical batch	No analyte detected > PQL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PQL	None	None	None
Total Petroleum Hydrocarbons E418.1	Multipoint calibration for all analytes (minimum 3 standards and one calibration blank)	Initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per multipoint calibration	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis or when elutent is changed	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	Instrument response within ±5% of expected response	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification

TABLE 6.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
Risk-Based Approach to Remediation

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Total Petroleum Hydrocarbons E418.1 (Cont)		After every analytical batch	All analytes within ±10% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None

a/ QC = quality control.
b/ All corrective actions associated with project work will be documented, and all records will be maintained by the laboratory.
c/ RSD = relative standard deviation.
d/ CF = control factor.
e/ RF = response factor.
f/ PRL = project reporting limit.
n/ IS = internal standard.
o/ EICP = extracted ion current profile.
p/ GC = gas chromatograph.
g/ LCS = laboratory control sample.
h/ MDL = method detection limit.
i/ MS/MSD = matrix spike/matrix spike duplicate.
j/ SPCC = system performance check compound.
k/ ≤30% = except for >0.10 for bromoform and >0.01 for chloromethane and 1,1-dichloroethane.
l/ CCC = continuing calibration check.
m/ BFB = 4-bromofluorobenzene.

TABLE 6.3
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES, SAMPLE VOLUMES, AND HOLDING TIMES
RISK-BASED APPROACH TO REMEDIATION

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Alkalinity	E310.2	P, G	4°C	50 ml	14 days
Common Anions	E300.0	P, G	4°C	50 ml	28 days for Br^-, F^-, Cl^-, and SO_4^{-2}; 48 hours for NO_3^-, NO_2^- and PO_4^{-3}
Filterable Residue	E160.1	P, G	4°C	100 ml	7 days
Nonfilterable Residue	E160.2	P, G	4°C	100 ml	7 days
Hydrogen Ion (pH)	SW9040/ SW9045	P, G	4°C	50 ml or 4 ounces	Analyze immediately
Ammonia, Nitrogen	E350.1	P, G	4°C, H_2SO_4 to pH < 2	500 ml	28 days
Nitrogen, Nitrate/Nitrite	E353.2	P, G	4°C, H_2SO_4 to pH < 2	500 ml	28 days
Cadmium	SW7131A	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	180 days (water and soil)
Mercury	SW7470/ SW7471	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	28 days (water and soil)
Metals[d/] (except Cadmium and Mercury)	SW6010A and SW7XXX[e/]	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	180 days (water and soil)
Total Petroleum Hydrocarbons (TVH)-Gasoline	SW8015 (modified)	G, Teflon®-lined septum, T	4°C, HCl to pH < 2	3 x 40 ml or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid

TABLE 6.3
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES, SAMPLE VOLUMES, AND HOLDING TIMES
RISK-BASED APPROACH TO REMEDIATION

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Alkalinity	E310.2	P, G	4°C	50 ml	14 days
Common Anions	E300.0	P, G	4°C	50 ml	28 days for Br^-, F^-, Cl^-, and SO_4^{-2}; 48 hours for NO_3^-, NO_2^- and PO_4^{-3}
Filterable Residue	E160.1	P, G	4°C	100 ml	7 days
Nonfilterable Residue	E160.2	P, G	4°C	100 ml	7 days
Hydrogen Ion (pH)	SW9040/ SW9045	P, G	4°C	50 ml or 4 ounces	Analyze immediately
Ammonia, Nitrogen	E350.1	P, G	4°C, H_2SO_4 to pH < 2	500 ml	28 days
Nitrogen, Nitrate/Nitrite	E353.2	P, G	4°C, H_2SO_4 to pH < 2	500 ml	28 days
Cadmium	SW7131A	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	180 days (water and soil)
Mercury	SW7470/ SW7471	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	28 days (water and soil)
Metals[d/] (except Cadmium and Mercury)	SW6010A and SW7XXX[e/]	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	180 days (water and soil)
Total Petroleum Hydrocarbons (TVH)-Gasoline	SW8015 (modified)	G, Teflon®-lined septum, T	4°C, HCl to pH < 2	3 x 40 ml or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid

TABLE 6.3
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES,
SAMPLE VOLUMES, AND HOLDING TIMES
RISK-BASED APPROACH TO REMEDIATION

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Total Petroleum Hydrocarbons (TEH)-Diesel	SW8015 (modified)	G, amber, T	4°C	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Volatile Aromatics	SW8021B	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	3 x 40 ml or 4 ounces	14 days (water and soil)
Volatile Organics	SW8260B	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	2 x 40 ml or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid
Volatile Halocarbons	SW8010A	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	3 x 40 ml or 4 ounces	14 days (water and soil)
Formaldehyde	SW8315	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Ethylene Glycol	SW8315 modified	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Alcohol Scan	SW8015B	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	3 x 40 ml or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid

TABLE 6.3 (Continued)
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES,
SAMPLE VOLUMES, AND HOLDING TIMES
RISK-BASED APPROACH TO REMEDIATION

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Total Petroleum Hydrocarbons (TPH)	E418.1	G, amber, T	4°C	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Chlorinated Herbicides	SW8151	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Organochlorine Pesticides and Polychlorinated Biphenyls (PCBs)	SW8081	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Organophosphorus Pesticides	SW8141A	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Semivolatile Organics	SW8270B	G, Teflon®-lined cap, T	4°C, 0.008% $Na_2S_2O_3$	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)

TABLE 6.3 (Continued)
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES,
SAMPLE VOLUMES, AND HOLDING TIMES
RISK-BASED APPROACH TO REMEDIATION

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Volatile organics	SW8260A/8240	G, Teflon®-lined septum, T	4°C, 0.008% $Na_2S_2O_3$ (HCl to pH < 2 for volatile aromatics by SW8240 and SW8260)[b]	3 x 40 ml or 4 ounces	14 days (water and soil)
Polynuclear Aromatic Hydrocarbons (PAHs)	SW8310	G, Teflon®-lined cap, T	4°C, store in dark, 0.008% $Na_2S_2O_3$	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Methyl Carbamate Herbicides	SW8318	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Lead (paint)	SW7421	P, G	4°C	2 ounces	180 days
Asbestos	NIOSH 7400	P, G	4°C	2 ounces	NA[f/]

a/ Polyethylene (P); glass (G); brass sleeves in the sample barrel (T).
b/ No pH adjustment for soil.
c/ Preservation with 0.008 percent $Na_2S_2O_3$ is only required when residual chlorine is present.
d/ All metals collected for a dissolved portion analysis will be filtered in the field prior to preservation.
e/ SW7XXX is all graphite furnace atomic absorption methods, SW7421, 7060, 7131, and 7740.
f/ Not applicable.

are known and minimized. The method blank will be ASTM Type II water (or equivalent) for water samples, and a purified solid matrix (Ottawa sand or equivalent) for soil samples. The concentration of target compounds in the blanks must be less than or equal to the PRL (Table 6.1). Exceptions are not made for common laboratory contaminants. If the blank contaminant concentration is not less than the specified limit, then the source of contamination will be identified, and corrective action will be taken. SQLs and detection limits will not be raised because of blank contamination. Analytical data will not be corrected for presence of analytes in blanks.

6.2.3 Laboratory Control Samples

Laboratory control samples (LCSs) are blank spikes made from clean laboratory-simulated matrices (reference method blank matrices) spiked with known concentrations of all target analytes of interest at levels approximately 10 times the MDLs. The LCS is carried through the complete sample preparation and analysis procedures. LCSs are designed to check the instrument and method accuracy. An LCS will be analyzed with every analytical batch. Failure of the LCS to meet %R criteria listed in Table 1.1 requires corrective action before any further analyses can continue. All sample results associated with the out-of-control LCS must be reanalyzed after control has been reestablished.

6.2.4 Surrogate Spike Analyses

Surrogate spike analyses are used to determine the efficiency of analyte recovery in sample preparation and analysis in relation to sample matrix. Calculated %R of the spike is used to measure the accuracy of the analytical method for an individual sample. A surrogate spike is prepared by adding to an environmental sample (before extraction) a known concentration of a compound similar in type to the target analytes (i.e., a surrogate compound) to be analyzed for organic target compounds. Surrogate compounds as specified in the methods will be added to all samples analyzed, including method blanks, MS/MSDs, LCSs, field samples, and duplicate samples.

6.2.5 Matrix Spike/Matrix Spike Duplicate

Matrix spike (MS) samples are designed to check the accuracy of the analytical procedures for the sample matrix by analyzing a field sample spiked in the laboratory with a known standard solution containing all the target analytes. A matrix spike duplicate (MSD) is the second of a pair of laboratory MS samples. The MSDs are designed to check the precision and accuracy of analytical procedures by sample matrix.

One MS/MSD pair will be collected for every group of 20 project samples of similar matrix. Field blanks or duplicates are not to be used as MS/MSDs. If surrogate and target analyte compounds concentrations are out of control in the MS/MSD, but the associated accuracy and precision are in control in the LCS, then the out-of-control situation will be attributed to a matrix interference. If the laboratory system is shown to be out-of-control (i.e., if the LCS is out-of-control), then re-extraction and reanalysis will be required. The laboratory will report the data from any reanalysis that is performed.

6.2.6 Analytical Batches

Analytical batches will be designated in the laboratory at a minimum of one batch per sample delivery group (SDG). Each SDG will be comprised of a maximum of 20 project samples of similar matrix collected within a 7-day period. Included in each SDG of 20 (or fewer) samples per analytical method will be an analytical batch identification number. This identification number will clearly allow a reviewer to determine the association between field samples and QC samples. Analytical batches also will be inclusive of preparation lots and calibration periods.

6.2.7 Retention Times

Retention time (RT) is the amount of time required for a target compound to elute from the chromatographic column, and the instrument detector to record a signal response. The RT window is the allowable deviation from the true expected RT for any one compound. A peak response within this RT window will constitute a positive detection for that compound. RT windows are QC criteria for all gas chromatograph (GC) and high-performance liquid chromatography (HPLC) methods. RT windows are determined through replicate analyses of a standard over multiple days. The calculation of RT windows is described in USEPA (1995) Method SW8000A. Corrective action is required when the RT windows are out of control.

6.2.8 Internal Standards

Internal standards (ISs) are compounds of known concentrations used to quantitate the concentrations of target detections in field and QC samples. ISs are added to all samples after sample extraction or preparation. Because of this, ISs provide for the accurate quantitation of target detections by allowing for the effects of sample loss through extraction, purging, and/or matrix effects. ISs are used for any method requiring an IS calibration. Corrective action is required when ISs are out of control.

6.2.9 Interference Check Standard

The interference check standard (ICS) is used to verify the background and interelement correction factors for metals in method SW6010A. The ICS is analyzed at the beginning and end of each analytical sequence. Method-specific acceptance limits listed in Table 1.1 will apply.

6.2.10 Second Column Confirmation

Quantitative confirmation of results at or above the PQL for samples analyzed by GC or HPLC will be required and will be completed within the method-required holding times. For GC methods, a second column is used for confirmation. For HPLC methods, a second column or a different detector is used. The result of the first column/detector will be the result reported.

6.2.11 Control Limits

The control limits associated with all method QC will follow guidance established in the AFCEE (1996) QAPP. For methods not defined in the AFCEE (1996) QAPP (e.g., SW3810 modified for methane), the acceptance criterion in Table 1.1 is listed as suggested guidance.

6.2.12 Calibration Requirements

Analytical instruments will be calibrated in accordance with the analytical methods. All analytes reported will be present in the initial and continuing calibrations, and these calibrations must meet the acceptance criteria specified in Table 1.1. Records of standard preparation and instrument calibration will be maintained by the contract laboratory. Records will unambiguously trace the preparation of standards and their use in calibration and quantitation of sample results. Calibration standards will be traceable to standard materials.

Analyte concentrations are determined with either calibration curves or response factors (RFs). For GC and GC/mass spectroscopy (MS) methods, when using RFs to determine analyte concentrations, the average RF from the initial five-point calibration will be used. The continuing calibration will not be used to update the RFs from the initial five-point calibration.

6.2.13 Standard Materials

Standard materials used in calibration and to prepare samples will be traceable to National Institute of Standards and Technology (NIST), USEPA, American Association of Laboratory Accreditation (A2LA) or other equivalent approved source, if available. The standard materials will be current, in accordance with the following expiration policy: The expiration dates for ampulated solutions will not exceed the manufacturer's expiration date or one year from the date of receipt, whichever occurs first. Expiration dates for laboratory-prepared stock and diluted standards will be no later than the expiration date of the stock solution or material, or the date calculated from the holding time allowed by the applicable analytical method, whichever occurs first. The laboratory will label standard and QC materials with expiration dates.

6.3 SAMPLE CUSTODY REQUIREMENTS

Sample custody begins in the field at the time of collection and continues throughout the laboratory analytical process. COC forms will be prepared at the time sample collection and will accompany the samples through the laboratory sample processing. To facilitate the documentation of sample custody, the laboratory will track the progress of sample preparation, analysis, and report preparation. Samples received by the laboratory will be checked carefully for label identification, COC forms, and any discrepancies. The laboratory will also note physical damage, incomplete sample labels, incomplete paperwork, discrepancies between sample labels and paperwork, broken or leaking containers, and inappropriate caps or bottles. On the day of receipt of samples from the contractor, the laboratory will send signed facsimile copies of all COCs and sample log-in receipt forms to the contractor. All discrepancies and/or

potential problems (e.g., lack of sample volume) will be discussed immediately with the contractor's project task manager.

The laboratory sample custodian will be required to provide a report to the contractor of any problems observed with any of the samples received. This report will also document the condition of samples, sample numbers received, corresponding laboratory numbers, and the estimated date for completion of analysis. The laboratory must receive written permission from the contractor before sending any samples (originally scheduled to be analyzed at their facility) to another laboratory. Analyses will not be performed on samples whose integrity has been compromised or is suspect.

6.4 SAMPLE HANDLING

Laboratory sample custody will be maintained by the following procedures:

1. The laboratory will designate a sample custodian responsible for maintaining custody of the samples and all associated paperwork documenting that custody.
2. Upon receipt of the samples, the sample custodian will sign the original COC form and compare the analyses requested thereon with the label on each sample container.
3. A qualitative assessment of each sample container will be performed to note any anomalies such as broken or leaking bottles or lack of preservation (e.g., ice melted enroute). This assessment will be recorded as part of the incoming COC procedure.
4. If the COC and samples correlate, and there has been no tampering with the custody seals, the "received by laboratory" box on the COC form will be signed and dated.
5. Care will be exercised to document any labeling or descriptive errors. In the event of discrepancies, breakage, or conditions that could compromise the validity of analyses, the laboratory project coordinator will immediately contact the task manager as part of the corrective action process.
6. Samples will be logged into the laboratory management computer system, which includes a tracking system for extraction and analysis dates. The laboratory will assign a laboratory work number to each sample for identification purposes. The sample custodian will log the laboratory work number and the field sample identification into a laboratory sample custody log. The laboratory sample custody log may either be hard copy or computerized, depending on the laboratory's system.
6. The samples will be stored in a secured area at a temperature of approximately 4 ± 2 degrees Celsius (°C) or cooler (as applicable) until analyses commence. The laboratory log should also contain the laboratory storage cooler number (if applicable) that the sample will be stored in while on the laboratory's premises. Samples will be logged when they are removed and returned from storage for

analysis. Samples must be stored in separate coolers from those used to store analytical standards, reagents, and/or QC samples.

8. The samples will be distributed to the appropriate analysts, with names of individuals who receive samples recorded in internal laboratory records.
9. The original COC form will accompany the laboratory report submittal and will become a permanent part of the project records.
10. Data generated from the analysis of samples also must be kept under proper custody by the laboratory.

Upon analysis, a laboratory lot control number will be assigned to the sample. All samples within a given laboratory analysis group (e.g., samples sharing the same laboratory QC measurement samples) will have identical laboratory lot control numbers.

Disposal of sample containers and remaining sample material will be the responsibility of the laboratory. Samples should be disposed of appropriately when all analyses and related QA/QC work are completed.

6.5 SAMPLE IDENTIFICATION AND SAMPLE CUSTODY RECORDS

The laboratory conducting the analysis of the samples will provide the data user with information on the laboratory sample identification system. With knowledge of this laboratory sample identification system, data generated at the laboratory can be tracked by both the laboratory and field sample identification systems.

Each sample will be logged into the laboratory system by assigning it a unique sample number. This laboratory number and the field sample identification number will be recorded on the laboratory report.

6.6 LABORATORY DATA REDUCTION, VALIDATION, AND REPORTING

6.6.1 Review Procedures for Definitive Data

The fixed-base laboratory will review 100 percent of all definitive data prior to reporting. The establishment of detection and control limits will be verified. Any control limits outside of the acceptable ranges specified in the analytical methods will be identified. Any trends or problems with the data will be evaluated. Any laboratory-established detection limits that exceed the established method-specified limits will be identified. The absence of records supporting the establishment of control criteria or detection limits will be noted. Analytical batch QC, calibration check samples, method calibrations, continuing calibration verifications, corrective action reports, the results of reanalysis, sample holding times, sample preservations, and any resampling and analysis all will be evaluated.

Samples associated with out-of-control QC data will be identified in the data package case narrative, and an assessment of the utility of such analytical results will be made. The check of laboratory data completeness will ensure that:

- All samples and analyses specified in the SAP have been processed;
- Complete records exist for each analysis and the associated QC samples; and
- Procedures specified in this SAP have been implemented.

The results of the completeness check will be documented.

An analyst other than the original data processor, will be responsible for reviewing all steps of the data processing. All input parameters, calibrations, and transcriptions will be checked. All manually input, computer-processed data will be checked. Each page of checked data will be signed and dated by the verifier.

QC sample results (LCSs, MS/MSDs, surrogates, initial calibration standards, and continuing calibration standards) are compared against stated criteria for accuracy and precision (Table 6.2). QC data must meet acceptance levels prior to processing the analytical data. If QC standards are not met, the cause will be determined. If the cause can be corrected without affecting the integrity of the analytical data, processing of the data will proceed. If the resolution jeopardizes the integrity of the data, reanalysis will occur. Decisions to repeat sample collection and analyses may be made by the contractor project manager based on the extent of the deficiencies and their importance in the overall context of the project.

6.6.2 Laboratory Data Reporting Flags

The following qualifiers must be used by the laboratory when reporting sample results.

Qualifier	Description
J	The analyte was positively identified, the quantitation is an estimation.
U	The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.
F	The analyte was positively identified but the associated numerical value is below the PQL.
R	The data are unusable due to deficiencies in the ability to analyze the sample and meet QC criteria.
B	The analyte was found in an associated blank, as well as in the sample.
M	A matrix effect was present.
T	Tentatively identified compound (using GC/MS)

6.6.3 Contractor Data Reporting Flags

The following define the contractor organic and inorganic data validation qualifiers:

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is the PRL (e.g., the nondetect level).

J - The associated value is an estimated quantity.

R - The data are unusable (Note: analyte may or may not be present).

UJ - The material was analyzed for but was not detected. The associated value is an estimate and may be inaccurate or imprecise.

6.6.4 Data Validation and Assessment of Usability

Data from QC samples will be assessed by the contractor using the procedures and criteria presented earlier in this section. This assessment will be a continuous process in which QA problems are identified immediately, and the appropriate corrective action is implemented. Additionally, the contractor will assess the usability of analytical data. Any limitations on data use will be expressed quantitatively to the extent practicable and will be documented in any reporting of the data.

This data usability review will include a review of the analytical methods, quantitation limits, and other factors important in determining the precision, accuracy, completeness, and representativeness of the final data set. The outcome of this data review will be a data set appropriate to support quantitative fate and transport analyses and risk analysis. The data evaluation methods defined in *Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual* (USEPA, 1989) and the *Guidance for Data Usability in Risk Assessment* (USEPA, 1992) will be used as appropriate.

6.6.5 Hard-Copy Data Deliverables

Data deliverables required for the analytical results include both a hard copy and an electronic copy. Hard-copy reporting of analytical results will include analytical results summaries for all field samples, and their associated QA/QC samples. The laboratory will be required to provide two copies of each hard copy data reporting package. Data reporting requirements for hard-copy analytical reports are in Table 6.4 as those items listed with an asterisk.

6.6.6 Electronic Data Deliverables

To facilitate data handling and management, both field and laboratory data will be entered into a computerized format. All data will be delivered to the contractor from the laboratory in the database format specified in the *Installation Restoration Program Information Management System (IRPIMS) Data Loading Handbook*, Version 2.2, AFCEE, 1991. The laboratory will be responsible for running QC Tools on the analytical data files prior to delivery to the contractor.

TABLE 6.4
REQUIRED LABORATORY DELIVERABLES

Method Requirements	Laboratory Deliverables (Definitive Data)
Requirements for all methods:	
- Case narrative	Project identification Analytical method description and reference citation. Discussion of unusual circumstances, problems, and nonconformances.
Monthly QA report	Any format to discuss issues which may affect data quality *
- Chain of Custody (COC)	Signed and dated when samples were* received at laboratory
- Dates of sample preparation and analysis (including first run and subsequent runs).	Specific deliverable depends upon* type of analysis
- Quantitation limits achieved.	Specific deliverable depends upon type* of analysis
- Dilution or concentration factors.	Specific deliverable depends upon* type of analysis
- Summary analytical batch report including analytical batch samples, method of analysis, matrix description, date of sample collection and receipt, laboratory identification number of each environmental sample plus identification number of each batch quality control (QC) sample (including Matrix Spike/Matrix Spike Duplicate (MS/MSD), calibration check, etc.).	Any format*
- Method reporting limits.	QC summary report*
- QC limits.	QC summary report*
- Practical Quantitation Limit (PQL) verification standard (weekly).	Any format
- Corrective action reports.	Any format *
- A copy of all raw laboratory analytical data.	Any format (chromatograms, mass spectra and data system printouts)
- Example sample calculation	Any format
- A copy of the sample preparation data form for each method indicating sample identification number, batch identification number, and date of preparation.	Any format (preparation, extraction, or digestion data)
Percent moisture for all soil samples	Any format *

TABLE 6.4 (Continued)
REQUIRED LABORATORY DELIVERABLES

Method Requirements	Laboratory Deliverables (Definitive Data)
Requirements for organic analytical methods:	
- Sample data sheets.	Summary information only a/*
- Surrogate recoveries.	Summary information only *
- MS/MSD.	Summary information only *
- Method blank analysis.	Summary information only *
- Laboratory control spike (LCS)	Summary information only*
- Instrument performance check (Tuning).	Summary information only
- Degradation/breakdown (SW8080).	Summary information only
- Initial calibration data	Summary information only
- Continuing calibration data.	Summary information only
- Calibration blank data	Summary information only
- Internal standard area and retention time summary data.	Summary information only
- Retention time windows	Summary information only*
- Second-column confirmation. To be done for all compounds that are detected above reporting limit	Summary information only*
- Analysis run log.	No format
Requirements for inorganic analytical methods	
Metals:	
- Sample data sheets.	Summary information only *
- Initial and continuing calibration.	Summary information only
- Method blank, taken through sample preparation.	Summary information only *
- Calibration blank data.	Summary information only
- Interference check sample.	Summary information only
- Laboratory control spike/laboratory control spike duplicate.	Summary information only*
- Matrix spike/matrix spike duplicate.	Summary information only *
- Post-digestion spike sample recovery	Summary information only
- Method of standard additions	Summary information only
- Serial dilutions	Summary information only
- Analysis run logs	No format

* Indicates hard-copy deliverables required for QC summary package of Option 3 and 4.

a\ Summarized results can be in any format that provides the necessary data to completely validate that QC parameter. Example formats are the form equivalents to those defined for the USEPA Contract Laboratory Program (CLP) or SW-846 programs.

The laboratory reporting system will be implemented and tested prior to beginning the sampling. Any problems detected in format will be corrected by laboratory prior to providing any electronic deliverables to the contractor. All data entered into the electronic data files will correspond to the data contained in the original laboratory reports and other documents associated with sampling and the laboratory hard copy data deliverable packages.

6.6.7 Quality Assurance Reports

At monthly intervals beginning with the initiation of sampling activities, the laboratory will submit to the contractor's project task manager an internal QA report that documents laboratory-related QA/QC issues. These reports will include discussions of any conditions adverse or potentially adverse to quality, such as:

- Responses to the findings of any internal or external systems or performance laboratory audits;
- Any laboratory or sample conditions which necessitate a departure from the methods or procedures specified in this SAP;
- Any missed holding times or problems with laboratory QC acceptance criteria; and
- The associated corrective actions taken.

Submittal of QA reports will not preclude earlier contractor notification of such problems when timely notice can reduce the loss or potential loss of quality, time, effort, or expense. Appropriate steps will be taken to correct any QA/QC concerns as they are identified. The QA reports and a summary of the laboratory QA/QC program and results will be included in the final project report.

6.7 CORRECTIVE ACTION

The following procedures have been established to assure that conditions adverse to data quality are promptly investigated, evaluated, and corrected. Adverse conditions may include malfunctions, deficiencies, deviations, and errors.

When a significant condition adverse to data quality is noted at the laboratory, the cause of the condition will be determined, and corrective action will be taken to prevent repetition. Condition identification, cause, reference documents, and corrective action planned will be documented and reported to the contractor QA officer by the laboratory QC coordinator. Following implementation of corrective action, the laboratory QC coordinator will report the actions taken and their results to the contractor project manager and QA officer. A record of the action taken and results will be attached to the data report package. If samples are reanalyzed, the assessment procedures will be repeated, and the control limits will be reevaluated to ascertain if corrective actions have been successful.

Implementation of corrective action is verified by documented follow-up action. All project personnel have the responsibility, as part of the normal work duties, to identify, report, and solicit approval of corrective actions for conditions adverse to data quality.

Corrective actions will be initiated in the following instances:

- When predetermined acceptance criteria are not attained (Tables 6.1, 6.2, and 6.3) (objectives for precision, accuracy, and completeness);
- When the prescribed procedure or any data compiled are faulty;
- When equipment or instrumentation is determined to be faulty;
- When the traceability of samples, standards, or analysis results is questionable;
- When QA requirements have been violated;
- When designated approvals have been circumvented;
- As a result of systems or performance audits;
- As a result of regular management assessments;
- As a result of intralaboratory or interlaboratory comparison studies; and
- At any other instance of conditions significantly adverse to quality.

Laboratory project management and staff, such as QA auditors, document and sample control personnel, and laboratory groups, will monitor work performance in the normal course of daily responsibilities.

The laboratory QC coordinator or designated alternate will audit work at the laboratory. Items, activities, or documents ascertained to be compliant with QA requirements will be documented, and corrective actions will be mandated in the audit report. The contractor QA officer and laboratory QC coordinator will log, maintain, and control the audit findings.

The contractor QA officer and laboratory QC coordinators are responsible for documenting all out-of-control events or non-conformance with QA protocols. The QC checks, their frequency, acceptance criteria, and corrective actions for out-of-control data are summarized in Table 1.1 for each analytical method. A nonconformance report will summarize each nonconformance condition. The laboratory will notify the contractor project manager or QA officer of any laboratory QA/QC nonconformances upon their discovery. Copies of all field change requests and corrective action forms will be maintained in the project files. A stop-work order may be initiated by the contractor if corrective actions are insufficient.

6.7 AUDITS

This section describes participation in external and internal systems audits for AFCEE contractors and laboratories.

6.7.1 System Audits

System audits review laboratory operations and the resulting documentation. An onsite audit ensures that the laboratory has all the personnel, equipment, and internal standard operating procedures (SOPs) needed for performance of contract requirements in place and operating. The system audits ensure that proper analysis documentation procedures are followed, that routine laboratory QC samples are analyzed, and that any nonconformances are identified and resolved.

6.7.2 Internal Audits

The laboratory must conduct internal system audits on a periodic basis. The results of these audits will be documented by the laboratory QC coordinator, and the laboratory will provide the contractor with the results of these internal audits.

6.7.3 External Audits

The contractor project QA officer or designee may conduct an external system audit of the laboratory during the performance project samples. This audit would evaluate the capabilities and performance of laboratory personnel, items, and activities. It also documents the measurement systems and identifies and corrects any deficiencies. The contractor QA manager acts on audit results by documenting deficiencies and informing the contractor project manager of the need for corrective action. The contractor project manager may suspend operations until problems are resolved. If conditions adverse to quality are detected, or if the contractor project manager requests additional audits, additional unscheduled audits may be performed.

In addition to the contractor audit of the laboratory, various state and/or federal agencies may conduct an audit prior to the commencement of the project, and may conduct additional audits as deemed necessary. The frequency and schedule of any such audits will be established by the auditing agency and coordinated directly with the laboratory.

6.7.4 Performance Audits

Laboratory performance audits may be conducted to determine the accuracy and implementation of the SAP by the contractor QA manager or designee prior to initiation of field sampling. Unplanned audits may be implemented if requested by the contractor project manager. In addition to in-house performance audits, the laboratory may also participate in interlaboratory performance evaluation studies for different state or federal agencies. The contractor project QA manager will act to correct any laboratory performance problems.

6.8 PREVENTIVE MAINTENANCE

6.8.1 Procedures

Equipment, instruments, tools, gauges, and other items requiring preventive maintenance will be serviced in accordance with the manufacturers' specified recommendations or written procedures developed by the operators.

6.8.2 Schedules

Manufacturers' procedures identify the schedule for servicing critical items in order to minimize the downtime of the measurement system. It will be the responsibility of the individual operator assigned to a specific instrument to adhere to the instrument maintenance schedule and to promptly arrange any necessary service. Servicing of the equipment, instruments, tools, gauges, and other items will be performed by qualified personnel.

The laboratory will establish logs to record maintenance and service procedures and schedules. All maintenance records will be documented and will be traceable to the specific equipment, instruments, tools, and gauges. Records produced for laboratory instruments will be reviewed, maintained, and filed by the operators at the laboratories.

6.8.3 Spare Parts

A list of critical spare parts will be requested from manufacturers and identified by the operator. These spare parts will be stored for availability and use in order to reduce downtime due to equipment failure and repair.

6.9 SUBCONTRACT LABORATORY SERVICES

The laboratory will assume responsibility for providing all analytical services specified in the laboratory agreement. Should it be agreed in writing that the laboratory may use an additional subcontract laboratory facility, the primary laboratory will supply to the contractor the SOPs, MDL studies, and QA plans for the other laboratories that are used. The laboratory will be responsible for communicating all analytical guidelines and QC requirements of the project to these laboratories. The QA officers from both the primary laboratory and the contractor will monitor the data from subcontract laboratories and correct any QC nonconformances.

SECTION 7

REFERENCES

Air Force Center For Environmental Excellence (AFCEE) 1991, *Installation Restoration Program Information Management System (IRPIMS) Data Loading Handbook,* Version 2.2.

AFCEE 1996, *Quality Assurance Project Plan, Version 1.1.* February.

American Society for Testing and Materials (ASTM) 1987, *American Society for Testing and Materials Methods.*

Barcelona, *et. al.*, 1994. *Reproducible Well-Purging Procedures and VOC Stabilization Criteria for Ground-Water Sampling.* January.

Downey, D.C., and Hall, J. F. 1994. *Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing - Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential.* Prepared for the Air Force Center for Environmental Excellence, Brooks Air Force Base, San Antonio, Texas.

Parsons Engineering Science, Inc. 1996. *Draft Corrective Action Plan for the Risk-Based Remediation of the MOGAS site.* Prepared for the Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas and Myrtle Beach Air Force Base, South Carolina, June.

United States Environmental Protection Agency (USEPA), 40 CFR 136, (Section 7.0, "Internal Quality Control Checks,"). *Guidelines Establishing Test Procedures for the Analyses of Pollutants,* Appendix III, "Example Quality Assurance and Quality Control Procedures for Organic Priority Pollutants".

USEPA, 1983, *Methods for Chemical Analysis of Water and Wastes*, EPA 600/4-79-020 .

USEPA, 1989, *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (*Part A).

USEPA, 1992. *Guidance for Data Useability in Risk Assessment.*

USEPA, 1993. *Data Quality Objectives Process for Superfund.*

USEPA, 1997. *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW-846,* (3rd Edition, Update III).