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**Final Work Plan for an
Engineering Evaluation/Cost Analysis
in Support of the Risk-Based Approach
to Remediation at Area D**



**Ellsworth Air Force Base
Rapid City, South Dakota**

Prepared For

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

and

**Ellsworth Air Force Base
Rapid City, South Dakota**

August 1994

ENGINEERING-SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado 80290

AQM01-01-0293

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SECTION 1

INTRODUCTION

This work plan was prepared by Engineering-Science, Inc. (ES) and describes the scope of work required for the collection and analysis of data to complete an engineering evaluation/cost analysis (EE/CA) in support of a risk-based remediation decision for soil and ground water contaminated with fuel hydrocarbons at Area D Bulk Fuel Storage (Area D) at Ellsworth Air Force Base (AFB), Rapid City, South Dakota. Area D, a petroleum, oil, and lubricant (POL) tank farm, is part of the base-wide fuel distribution system. This work plan is the equivalent of a treatability study test design (TSTD) for the field test of the risk-based approach to the remediation of Area D. This innovative technology is sponsored by the Air Force Center for Environmental Excellence (AFCEE) at Brooks AFB, under contract F41624-93-C-8044, "Risk-Based Approach to Fuel Spill Remediation." The Area D demonstration is a component of a multisite initiative being sponsored by AFCEE to demonstrate how quantitative fate and transport calculations and risk information based on site-specific data can be integrated to quickly determine the type and magnitude of remedial action required at a site to minimize contaminant migration and receptor risks.

1.1 GOALS AND OBJECTIVES

The risk-based approach is designed to combine natural, or intrinsic, remediation with low-cost source removal technologies such as *in situ* bioventing to economically reduce risks posed by subsurface petroleum spills. There are three primary goals of this demonstration project. The first goal is to determine if remedial actions are necessary to minimize contaminant migration and potential receptor exposure to fuel-hydrocarbon-contaminated environmental media at Area D. The second goal is to implement any necessary and appropriate remedial technologies at Area D. It is possible that at some fuel-contaminated sites, intrinsic remediation alone will be sufficient to minimize or eliminate potential risks to human health and the environment. Implementation of the intrinsic remediation option under these circumstances would require only long-term monitoring to confirm the effectiveness of this remediation approach. At other sites, however, it may be necessary to supplement intrinsic remediation and long-term monitoring with some type of engineered solution, such as source removal, to minimize contaminant migration and receptor exposure. A combination of removal (e.g., free product recovery, bioventing), intrinsic remediation, and/or administrative commitments (e.g., long-term monitoring, land use restrictions) constitute a remedial alternative. The third goal is to collect data on how best to implement a risk-based remediation at a site, which will eventually be incorporated into a programmatic protocol on the risk based approach. This protocol document will standardize site characterization, modeling, and interpretive procedures. Lessons learned and case studies

developed as part of this demonstration program will be factored into the protocol document to illustrate how best to complete a risk-based remediation of a site.

The specific objective of the work described herein is to develop an EE/CA that identifies and evaluates an appropriate remedial alternative for contaminated environmental media at Area D at Ellsworth AFB, South Dakota, that will be protective of human health and the environment. This EE/CA will be prepared to satisfy the documentation requirements of a corrective action plan as specified by the South Dakota Department of Environment and Natural Resources in Section 74:03:28:21 of Chapter 74:03:28, Underground Storage Tanks (USTs). This work plan describes the specific site characterization activities and data analyses which will be performed in support of the EE/CA and the risk-based approach to remediation for Area D.

1.2 SCOPE OF WORK

The major milestones of this demonstration project are as follows: (1) gather site-specific data on the nature and extent of contamination in the soil and ground water at Area D; (2) determine whether an unacceptable risk to human health or the environment currently exists or may occur in the foreseeable future using quantitative contaminant transport models and risk estimates; and (3) evaluate, recommend, design, construct, and operate an innovative remedial alternative that both reduces the source of contamination and minimizes or eliminates potential risks to human health and the environment due to exposure to Area D contamination. These major milestones are briefly described in this section and illustrated in Figure 1.1.

1.2.1 Determining Contaminant Distribution

The risk-based approach to remediation for Area D is designed to provide risk reduction to levels that are protective of human health and the environment through the use of a remedial alternative that is permanent or has a high degree of long-term effectiveness. The EE/CA prepared as part of this field test of an innovative technology will evaluate and integrate site-specific data using streamlined risk assessment procedures to develop and determine final site-specific cleanup levels. It is the intent of the Air Force to demonstrate a risk-based remediation approach for Area D. Therefore, site characterization efforts will involve identifying the principal risks at the site which must be addressed by a combination of source removal, intrinsic remediation, and long-term monitoring.

Site characterization studies in support of the risk-based approach for Area D will consider the four primary contaminant phases associated with subsurface JP-4 fuel hydrocarbon contamination:

- Vapors in the soil gas of the vadose zone soils,
- Residual fuel in the vadose zone (unsaturated) soils,
- Free-phase product floating on the ground water, and
- Dissolved-phase fuel contaminants in the ground water.

Volatilization and upward molecular diffusion of fuel hydrocarbon contamination can result in measurable concentrations of hydrocarbons in the vadose zone soil gas and above-grade atmosphere. If present in sufficient quantities, fuel will spread downward and laterally through the vadose zone soils, leaving residual fuel in the vadose zone which can create a long-term

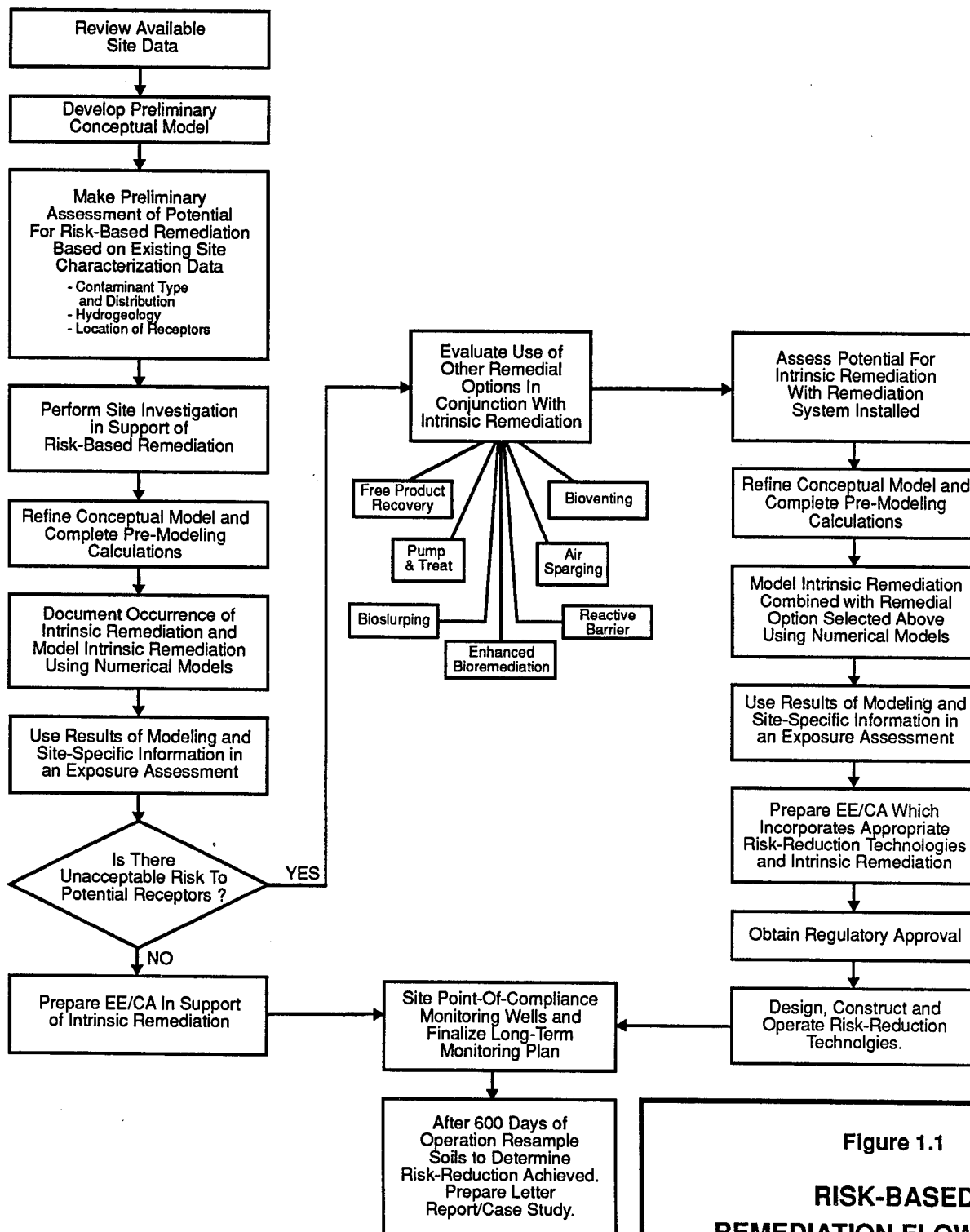


Figure 1.1
**RISK-BASED
REMEDATION FLOW CHART**

EE/CA Work Plan
Risk-Based Approach to Remediation
Area D, Ellsworth AFB, South Dakota

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ground water contaminant source (Abdul, 1988; American Petroleum Institute, 1980). Gradual partitioning of fuel contaminants from either the free-phase source or the residual fuel product in vadose zone soil into ground water results in a dissolved-phase contaminant plume that can migrate downgradient under the influence of mass transport processes (e.g., Domenico and Schwartz, 1990). If contaminated ground water discharges to a surface water body, dissolved-phase hydrocarbons may also contaminate the surface water. Available data indicate that transport of site-related contaminants to surface water via ground water is not possible at this site given the distance to any surface water (see Section 2 of this work plan for more details). Therefore, site characterization activities for Area D will include sampling of soil, soil gas, and ground water. Sufficient samples will be collected and analyzed to assess the risk to human health and the environment and to demonstrate attainment of site-specific risk-based cleanup levels. Section 4 of this work plan provides additional details on site characterization data needed to support a risk-based approach to remediation at Area D.

1.2.2 Estimating Potential Risks to Human Health and the Environment

The risk-based approach to remediation is dependent on conservatively estimating levels of residual fuel that can remain onsite and not pose an unacceptable risk to human health or the environment. The risk-based approach to remediation allows site-specific flexibility in determining which potential remedial alternatives afford the highest degree of long-term effectiveness appropriate for the current and future uses of the site. The US Environmental Protection Agency (EPA) recognizes that the mere presence of a contaminant does not necessarily warrant remediation, and that the goal of remediation investigations is to determine what remedial actions are necessary to eliminate or minimize risks to human health and the environment (EPA, 1987). Using site-specific data, a quantitative source-and-release analysis and an exposure pathway analysis will be completed to determine which if any of the four contaminant phases (i.e., soil gas, residual contamination in vadose zone soils, free-phase product, or dissolved-phase contamination) may pose a risk to human health and the environment. Quantitative contaminant fate and transport models such as Bioplume II (Rifai et al., 1988) will be used to determine whether fuel contaminants could migrate to a potential receptor exposure point. This is one of the key steps in the risk-based approach to remediation because it ensures that costly engineered solutions are not employed at a site which does not and will not pose a risk to human health or the environment.

However, in the event that site data indicate that contamination from Area D could migrate to a potential receptor exposure point, site-specific, risk-based cleanup goals will be developed using well-defined quantitative procedures to determine the cleanup levels necessary for each medium to eliminate or minimize current and potential future risks to human and ecological receptors. These quantitative risk-based cleanup goals will be used to assess whether it will be necessary to supplement intrinsic remediation with an engineered remediation technology to minimize or eliminate potential risks.

The risk-based approach to remediation is not intended to replace a traditional baseline risk assessment where the final decision is whether remediation actions are necessary (EPA, 1989b). However, a baseline risk assessment will not be necessary at sites to be addressed using the risk-based approach as it has already been determined that some action will be taken. The risk-based approach is more analogous to an evaluation of the long-term risks associated with implementing a specific remedial action at a site (EPA, 1991b). This innovative approach streamlines the

remedial decision process by focusing data collection and evaluation on identifying which remedial action most cost effectively reduces potential risks to human health and the environment. The risk-based approach compresses the traditional multistep remediation process into one project with the intent of quickly and cost effectively reducing any risks associated with chemical contamination at or migrating from Area D.

A quantitative, iterative process will be used to assess the potential effectiveness of various remedial alternatives (e.g., intrinsic remediation alone vs. various source removal options coupled with intrinsic remediation) in minimizing contaminant migration and receptor exposure. Chemical-specific, risk-based cleanup levels will be derived using site-specific data and quantitative human health-based risk assessment procedures whenever a chemical-specific standard or alternate concentration is not available or appropriate. These risk-based cleanup levels will incorporate data on technical limitations, effectiveness, practicability, and other relevant features of the various remedial alternatives considered appropriate for the site. Risk-based cleanup levels will be factored into the final design of an appropriate remedial action for Area D. Sections 2 and 5 of this work plan provide more detail on how human health and environmental risks associated with various remedial alternatives considered for Area D will be evaluated as part of this demonstration.

1.2.3 Developing an Appropriate Remedial Approach

The risk-based approach for the remediation of Area D is intended to quickly define a remedial alternative that will reduce or eliminate significant risks to human health and/or the environment. Identification and evaluation of any remedial technology, including intrinsic remediation, will be based on an evaluation of (1) long-term effectiveness; (2) permanence; (3) ability to reduce contaminant toxicity, mobility, and/or volume; (4) implementability; and (5) cost. The EE/CA must provide sufficient technical data on the recommended remedial alternative to show that it eliminates or abates present and future threats to human health and the environment, and that appropriate long-term commitments such as long-term monitoring are designed to supplement intrinsic remediation or any engineering controls.

A key objective of this evaluation will be to determine potential short- and long-term risks to the community and site workers. Determining how effective any one remedial technology may be at achieving desired protective remediation levels will require application of data from past treatability studies, an understanding of governing contaminant fate and transport processes, and engineering judgment. Both quantitative and qualitative analyses will be completed in support of the selection and design of an appropriate remedial action for the site. Long-term monitoring as part of this field test of innovative technology will likely involve the installation and sampling of confirmation, point-of-compliance wells, and other monitoring wells. Confirmation wells will be located immediately downgradient (i.e., within 1 or 2 years) of the existing plume and will provide for early confirmation of model and engineering predictions. The point-of-compliance (POC) wells will be located further downgradient (e.g., along the property boundary; at a location approximately 5 years downgradient of the current plume; 1 or 2 years upgradient of the nearest shallow ground water receptor) to verify that site-related contamination does not pose an unacceptable risk to potential receptors over time. The location of POC wells will be established in concert with regulatory authorities to be protective of any potential receptor. Other wells that can be used to monitor the effectiveness of a ground water remediation over time will at least include one well upgradient of the contaminant plume, one well within the anaerobic zone, and

one within the aerobic treatment zone. The final number and location of wells to be included in a long-term monitoring program will depend on hydrogeologic, risk reduction, and other regulatory considerations. Any requirements for institutional controls or long-term monitoring required to protect human health and the environment will be clearly described in the EE/CA. Requirements for long-term monitoring will be dependent upon the permanence or degree of long-term effectiveness afforded by the recommended remedial alternative.

Evaluation of remedial technologies as part of this field test will also focus on whether the technology can readily and economically achieve desired remediation levels and what uncertainties may be involved in this determination. Details on implementability with respect to expected time to achieve desired remediation levels will be factored into the evaluation. Identifying and assessing specific remedial technologies will also provide valuable information as to which technologies will be less effective in risk reduction at Area D.

The risk-based approach to remediation should streamline the remedial decision-making process by providing sufficient data to support the selection, design, and implementation of a low-cost, final remedial alternative for Area D that will minimize contaminant migration and potential receptor exposure. The streamlined process should also reduce the amount of time between identification of a potential risk to human health and the environment and remediation of that risk. Additionally, site data to be collected will assist in subsequent risk analysis and remedial design efforts for other contaminated areas at Ellsworth AFB by quantifying fate and transport mechanisms in local soils and ground water. This information will assist in the evaluation of the effectiveness of other remedial technologies.

1.3 WORK PLAN ORGANIZATION

This work plan is oriented toward the collection of site-specific data to be used to complete quantitative analyses of contaminant migration potential and the potential risks associated with contaminant migration. This work plan describes the need for additional data and how that data will be collected in the field and then analyzed using contaminant fate and transport models such as Bioplume II. Data from completed and ongoing treatability studies, such as the bioventing pilot test, will be used both to characterize the current nature and extent of potential source contamination and to estimate the effectiveness of additional source removal activities at Area D, should such measures be necessary to minimize future contaminant migration and receptor exposure. This work plan also describes the methods of risk analysis that will be used to identify and develop remedial actions for Area D. This work plan was prepared to coordinate the activities of all agencies involved in this risk-based demonstration including AFCEE, Ellsworth AFB, and ES.

This work plan is based on a review of existing site characterization data and the data needs of the risk-based approach to remediation. The work plan consists of seven sections, including this introduction. Section 2 summarizes existing data on the physical characteristics and nature and extent of contamination at Area D. Section 3 presents a conceptual site model that will aid in defining necessary site characterization activities and subsequent data analyses. Section 4 describes the data needs of the risk-based approach to remediation for Area D. The proposed sampling strategy for the collection of additional site characterization data is presented. Section 5 discusses the proposed risk analysis methods and the EE/CA report format. Section 6 includes a proposed schedule defining milestone dates for the demonstration project at Area D. Section 7

contains the references used in preparing this document. This work plan also contains two appendices. Appendix A is the detailed site-specific sampling and analysis plan (SAP). Appendix B is the site-specific health and safety plan, an addendum to the program health and safety plan (ES, 1994).

SECTION 2

REVIEW OF AVAILABLE SITE DATA

Existing site-specific data were used to describe the physical characteristics of environmental media and the nature and extent of contamination at Area D. Review of available site data will aid in defining the additional site characterization data necessary to fill current data gaps, support quantitative modeling efforts, develop long-term risk-based cleanup levels, and evaluate, select, and implement the most cost-effective remedial alternative for the site.

2.1 SITE BACKGROUND

Ellsworth AFB is located approximately 12 miles east of Rapid City, South Dakota (Figure 2.1). Area D, a POL tank farm, is located in the central portion of the base, to the east of the north hanger complex. Figure 2.2 shows the location of Area D on Ellsworth AFB.

Area D consists of two aboveground fuel storage tanks (ASTs) with a combined capacity of 90,000 barrels (bbl), two 25,000-gallon underground storage tanks (USTs), a 1,500-gallon UST, a 1,000-gallon UST, two JP-4 dispensers, and a railroad spur with fuel unloading headers (Figure 2.3). Currently the ASTs contain JP-4, the large USTs contain gasoline and diesel fuel, and the two smaller tanks are used as holdover and off-specification fuel tanks. This also appears to be the historical configuration for tank use at the site. Fuels can be unloaded by three different systems. Bulk fuels can be unloaded from rail tank cars, from conventional tanker trucks, or via an underground pipeline coming from Area C, another tank farm located on the southern edge of the base (ES, 1993).

On 11 September 1990, after a failed system pressure test at Area D, the South Dakota Department of Environment and Natural Resources (SD DENR) was notified of a possible release. Following this report, FMG, Inc. of Rapid City, South Dakota was contracted to perform a fuel spill contamination survey at Area D (FMG, 1992). During the two phases of this investigation, 18 monitoring wells were installed and six borings were drilled in the vicinity of Area D. Hydrocarbon contamination was found in soil and ground water within and downgradient of Area D. Fuel spills, overfilling, and leaking transfer lines are the suspected sources of subsurface contamination at this site. No remedial actions have been implemented to date at the site.

The entire base has been qualitatively characterized in preparation for a full-scale remedial investigation/feasibility study (RI/FS) (EA, 1994). Area D has been characterized under a fuel spill contamination survey (FMG, 1992) and as part of the bioventing pilot test program sponsored by AFCEE (ES, 1993). The results of these investigations indicate contamination that includes an isolated area of free product in the vicinity of permanent ground water monitoring

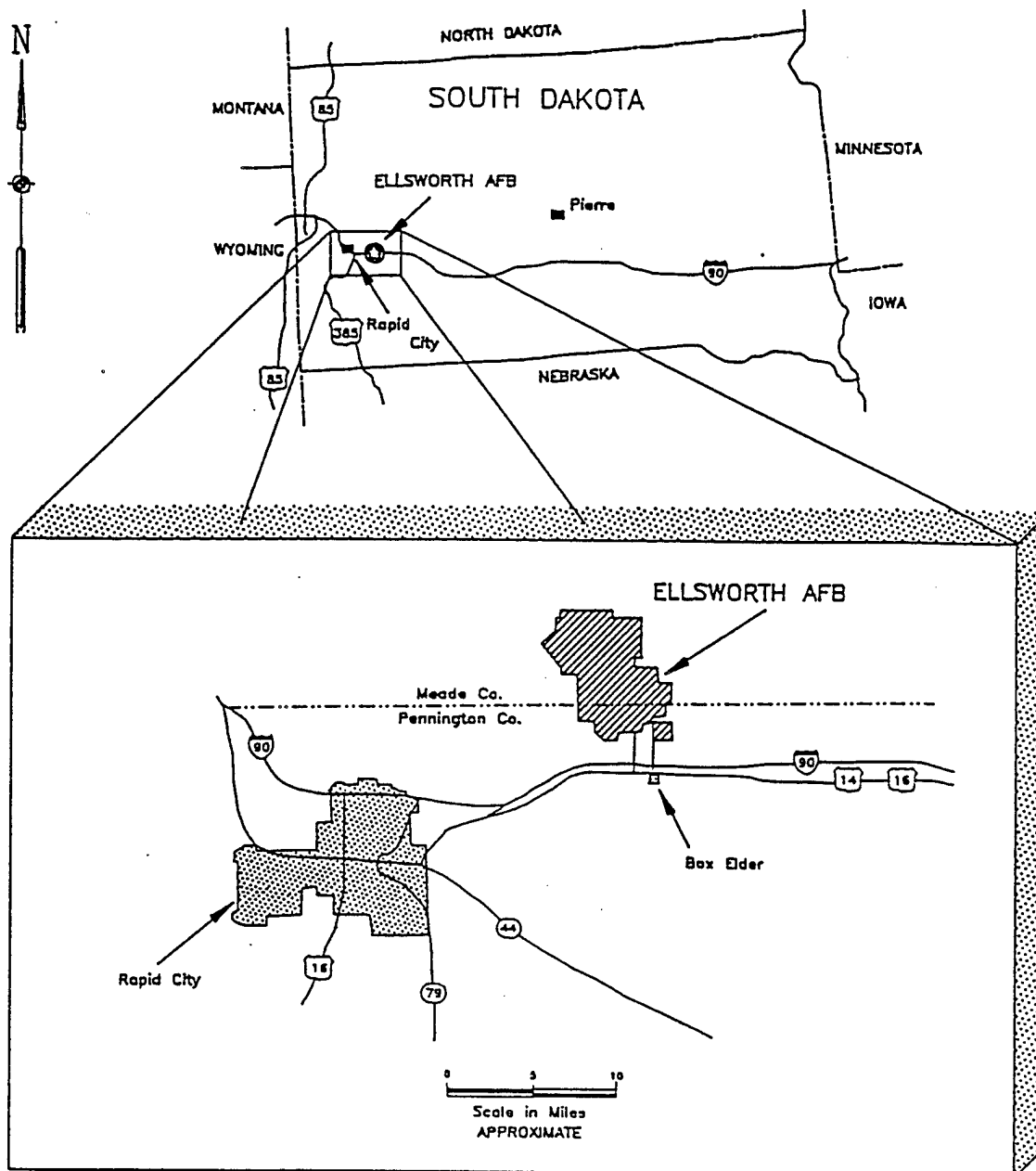


FIGURE 2.1

REGIONAL LOCATION OF ELLSWORTH AFB

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Area D, Ellsworth AFB, South Dakota

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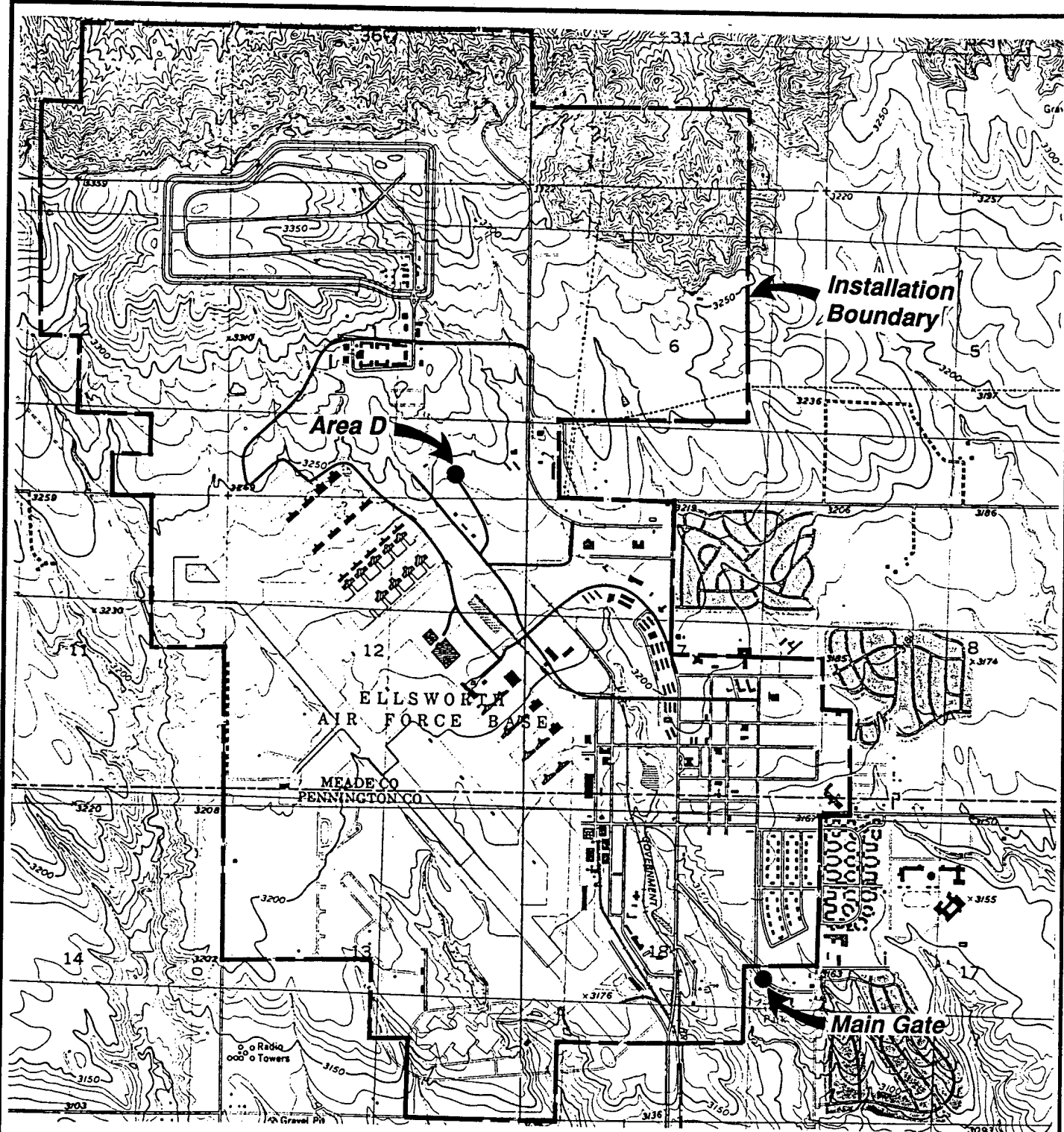


FIGURE 2.2

LOCATION OF AREA D

EE/CA Work Plan
Risk-Based Approach to Remediation
Area D, Ellsworth AFB, South Dakota

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LEGEND

- MONITORING WELL
- ◆ BOREHOLE
- - - JET FUEL LINES
- +++++ RAILROAD TRACKS

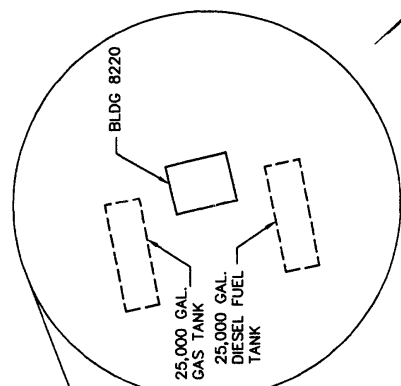
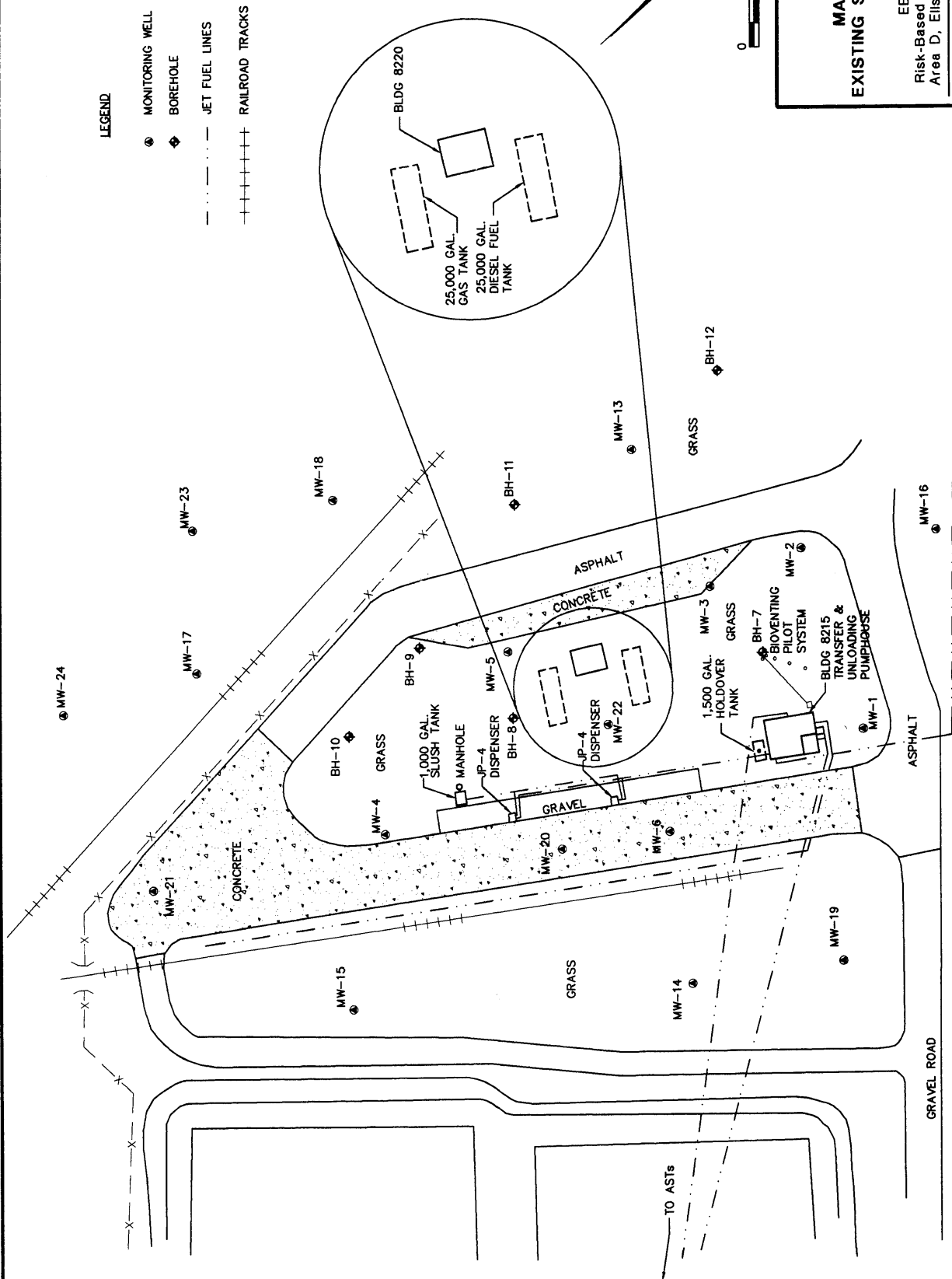


FIGURE 2.3

MAP OF AREA D
EXISTING SAMPLING LOCATIONS

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well MW-6, located in the center of the fuel loading and unloading area (refer to Figure 2.3). Benzene, toluene, ethylbenzene, and total xylenes (BTEX) have been detected in the ground water at Area D. Of these contaminants, total xylenes and toluene were detected most frequently. However, benzene was the only volatile organic compound (VOC) detected at a concentration above its federal maximum contaminant level (MCL) of 5 micrograms per liter ($\mu\text{g/L}$). The MCL was exceeded in three ground water wells, MW-1, MW-4, and MW-20, at concentrations of 10 $\mu\text{g/L}$, 440 $\mu\text{g/L}$, and 2,675 $\mu\text{g/L}$ respectively. The highest concentrations of toluene and total xylenes were recorded at well MW-4. The highest concentration of ethylbenzene was recorded at well MW-20 (FMG, 1991 and 1992). More than 3 feet of free product was encountered in well MW-6 on 12 April 1994, during a preliminary investigation performed by ES. FMG reported that free product was also evident in MW-4 and BH-10 during drilling and well installation activities that took place in October 1991. However, after well development, product was not evident in MW-4. BH-10 was not completed as a well (FMG, 1991). It should also be noted that at the time of installation (10 October 1991) MW-6 was dry and produced no ground water, even during a sampling event 2 weeks later. No explanation is given as to why the well now contains free product and over 6 feet of ground water. Further details on the physical characteristics of Area D and the probable nature and extent of subsurface fuel hydrocarbon contamination are presented in subsequent sections of this work plan.

2.2 PHYSICAL SETTING

Data from previous site characterization efforts were reviewed. Relevant portions of these data are summarized in the following sections.

2.2.1 Site Topography and Surface Hydrology

Figure 2.2 shows the location of the Area D on Ellsworth AFB and the surrounding environs. The base has relatively flat topography which slopes gently southeastward. No abrupt elevation changes occur within the boundaries of the base except close to the northern border where there is a steep northward escarpment.

The Soils Conservation Service (SCS) has identified one primary soil association at Area D, clay loam soils of the Nunn clay association. The permeability of these soils can range from less than 4.2×10^{-5} to 4.2×10^{-3} centimeters per second (cm/sec) (EA, 1994).

The main surface water bodies located on the base are Bandit, Heritage, Gateway, and Golf Course Lakes. Two unnamed bodies of surface water are located immediately upstream of Bandit Lake. All of these water bodies are in the same drainage and are connected by an unnamed ephemeral stream. Area D is in the watershed for this drainage, although it is located approximately 1 mile upgradient from the nearest surface water body. The drainage and other ditches and storm sewers on base eventually discharge into Box Elder Creek, an ephemeral stream 1 mile to the south of the base boundary. Water uses designated for the creek include irrigation, wildlife propagation, and livestock (EA, 1994).

Based on initial site investigation data, the ground water gradient at Area D is toward the north and northeast. This flow is perpendicular to surface drainage in the area. Additionally, ground water at Area D is an average of approximately 14 feet below ground surface (bgs). These two factors make it unlikely that ground water at Area D is in hydraulic communication with any surface waters in the area.

Surface elevation at Area D is approximately 3,250 feet above mean sea level (MSL). Surface drainage is primarily toward the southeast paralleling the concrete and asphalt roads in the fuel yard. A storm water drain is located just to the west of Building 8215 along the concrete roadway. The nearest surface water drainage feature, a drainage ditch, is located approximately 450 feet east of the site along Scott Drive.

Surface features at the site include grassy areas; concrete, asphalt and gravel driveways and parking areas; and two buildings. Building 8215 is the transfer and unloading pumphouse which controls flow of JP-4 jet fuel in the POL yard. Building 8220 is a smaller building which houses pumps for the gasoline and diesel fuel USTs located at the site. Underground fuel pipelines, which may have leaked previously, are the suspected source of contamination at this site.

2.2.2 Site Geology and Hydrogeology

The geology of Area D consists of a veneer of unconsolidated alluvial and colluvial material overlying the Pierre Shale. The unconsolidated material consists of Quaternary and Recent alluvial deposits of sand, gravel, silt, and clay, and can extend to a depth of approximately 30 feet bgs. Generally, the stratigraphy of the deposits can be described as 10 to 24 feet of lean clay overlying 2 to 5 feet of coarse-grained sand and approximately 5 feet of gravel. The underlying Pierre Shale is estimated to be 860 feet thick in the vicinity of Ellsworth AFB. No borings have been completed as part of previous investigations at Area D that penetrate through the Pierre Shale.

Figure 2.4 depicts the location of the hydrogeologic cross section developed from information from previous site investigation efforts. Figures 2.5 and 2.6 show the north-south and east-west hydrogeologic cross sections for Area D.

The shallowest water-bearing zone underlying Area D is generally thought to contain ground water under unconfined conditions. Ground water at Area D is encountered at depths ranging from approximately 8 to 27 feet below bgs, corresponding to a ground water surface elevation ranging from approximately 3,226 to 3,231 feet above MSL. Ground water beneath the site occurs in the deeper gravel unit.

Figure 2.7 is a map of the approximate ground water surface at Area D created with data from the April 1994 preliminary investigation performed by ES in support of risk-based remediation of the site. Ground water flow is generally northward with a change in direction toward the northeast along the northern edge of the site. The direction of ground water flow is apparently controlled by the elevation of the upper surface of the Pierre Shale. The average hydraulic gradient for the site has been calculated to be about 0.025 foot per foot (ft/ft) (FMG, 1992). Although no pump or slug tests have been performed at Area D, monitoring wells installed at the site were observed to recharge very slowly (FMG 1992). Given these characteristics and the lack of data on hydrogeologic conditions at the site, slug tests are recommended for the shallow aquifer as part of this demonstration project. This requirement for additional field testing is described further in Section 4 of this work plan.

2.3 NATURE AND EXTENT OF CONTAMINATION

The following sections summarize existing analytical data on the nature and extent of contamination at or migrating from Area D. Data from previous sampling events and a limited

LEGEND

- ① MONITORING WELL
- ◆ BOREHOLE
- - - - - JET FUEL LINES
- +++++ RAILROAD TRACKS
- A ——— A' HYDROGEOLOGIC CROSS SECTION

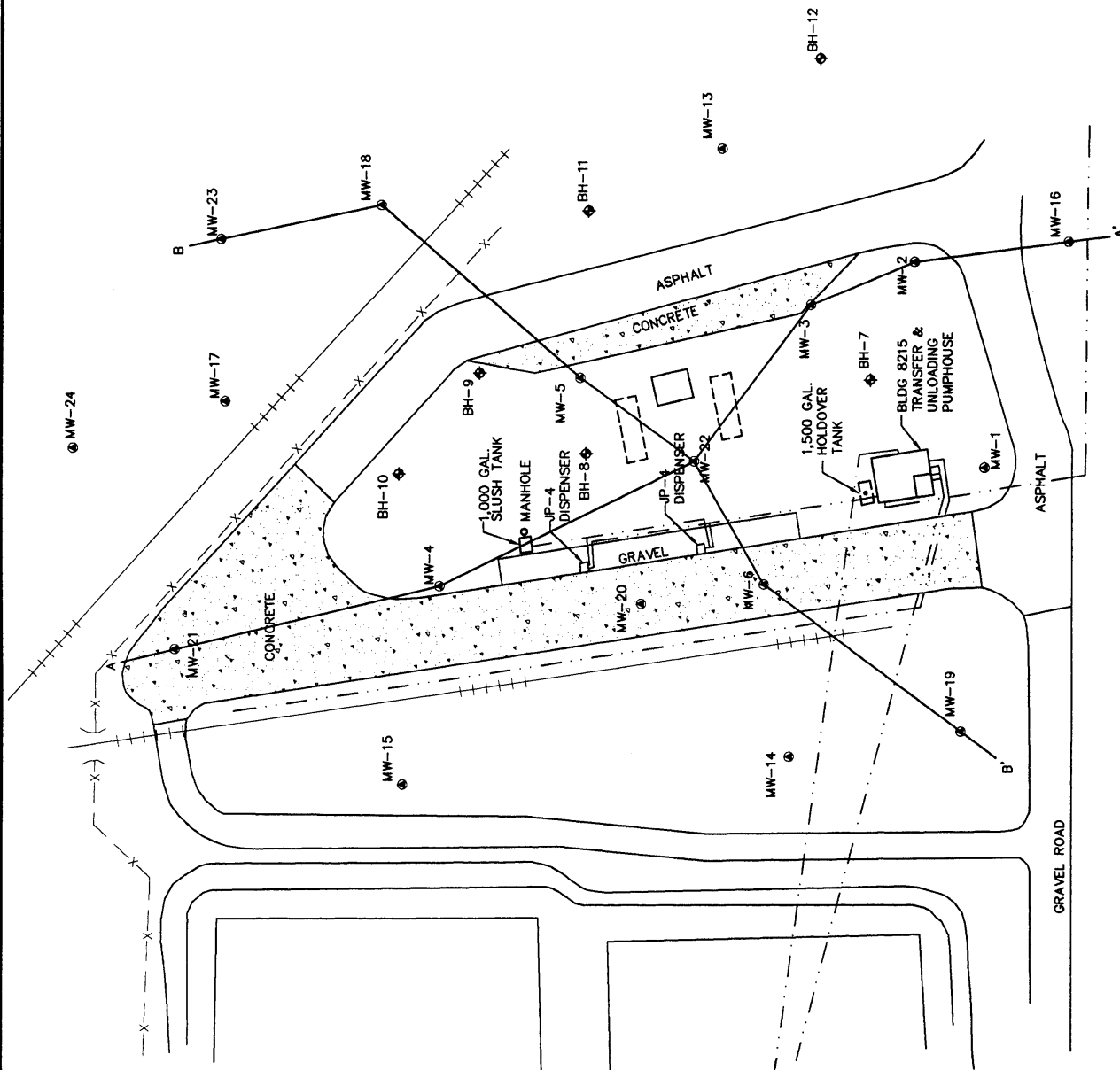


FIGURE 2.4

LOCATION OF HYDROGEOLOGIC CROSS SECTIONS

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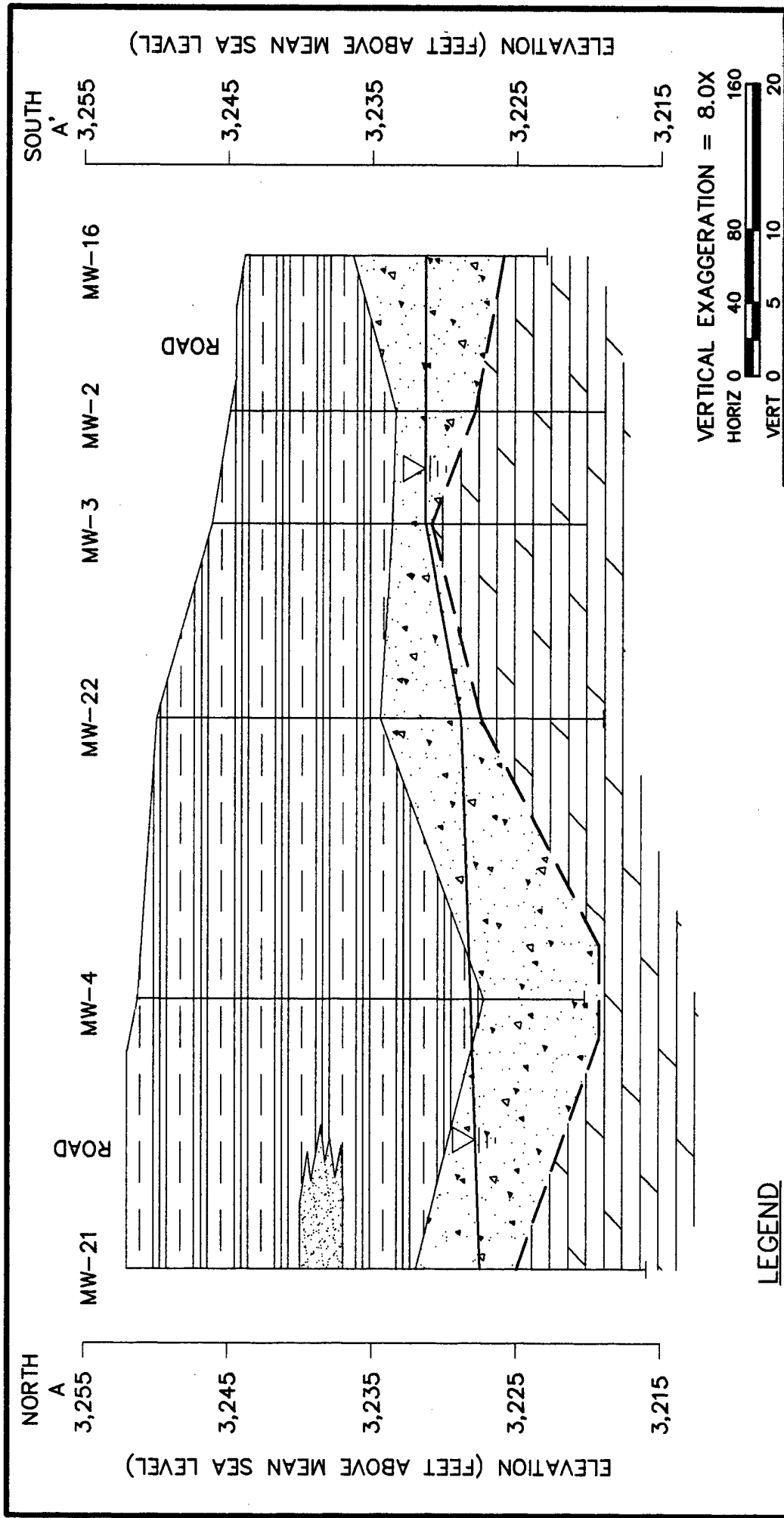


FIGURE 2.5

**NORTH-SOUTH HYDROGEOLOGIC
CROSS SECTION A-A'**

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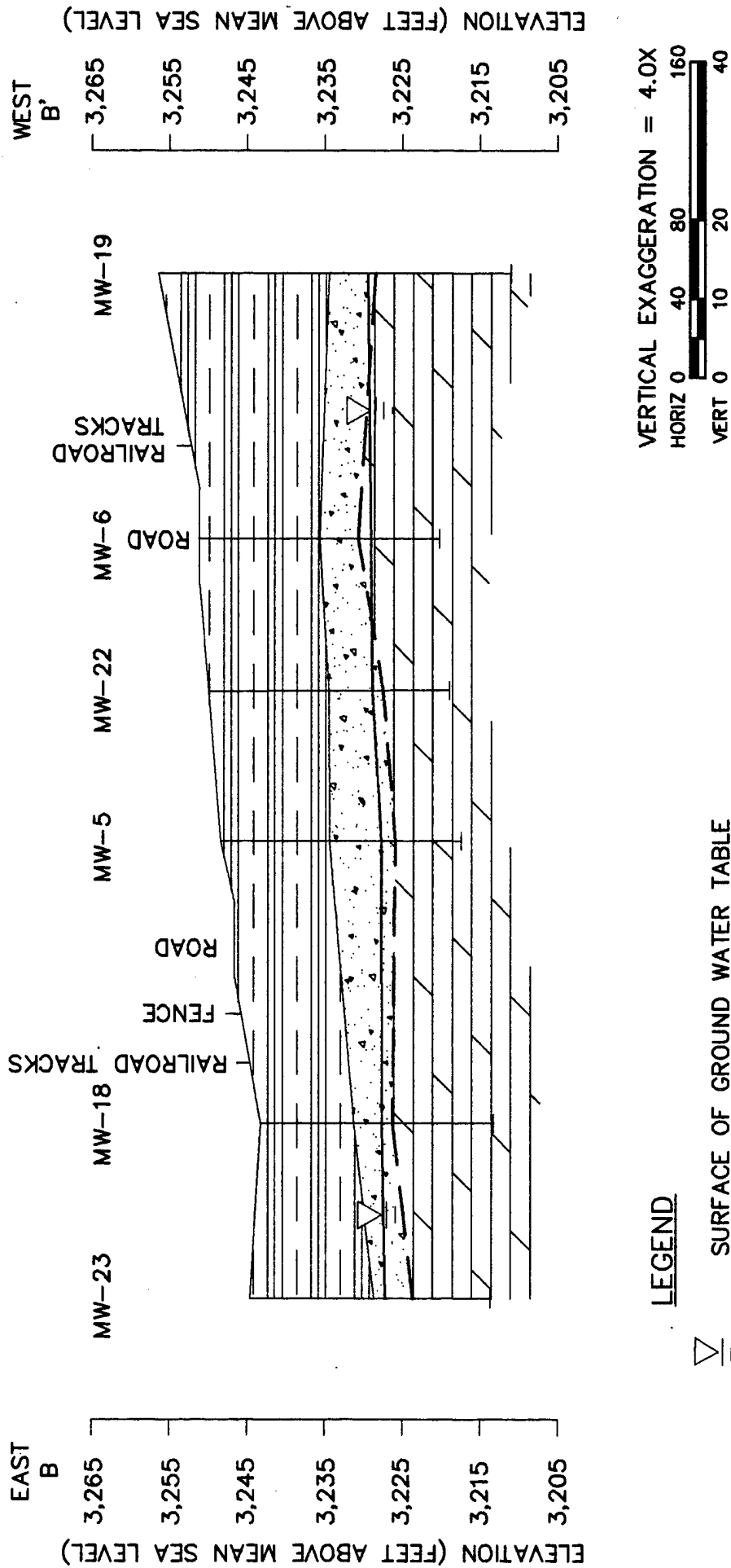


FIGURE 2.6

EAST-WEST HYDROGEOLOGIC CROSS SECTION B-B'

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LEGEND

- MONITORING WELL
- ◆ BOREHOLE
- - - JET FUEL LINES
- + + + RAILROAD TRACKS
- 3228.00 WATER ELEVATION CONTOUR (FEET ABOVE MEAN SEA LEVEL)

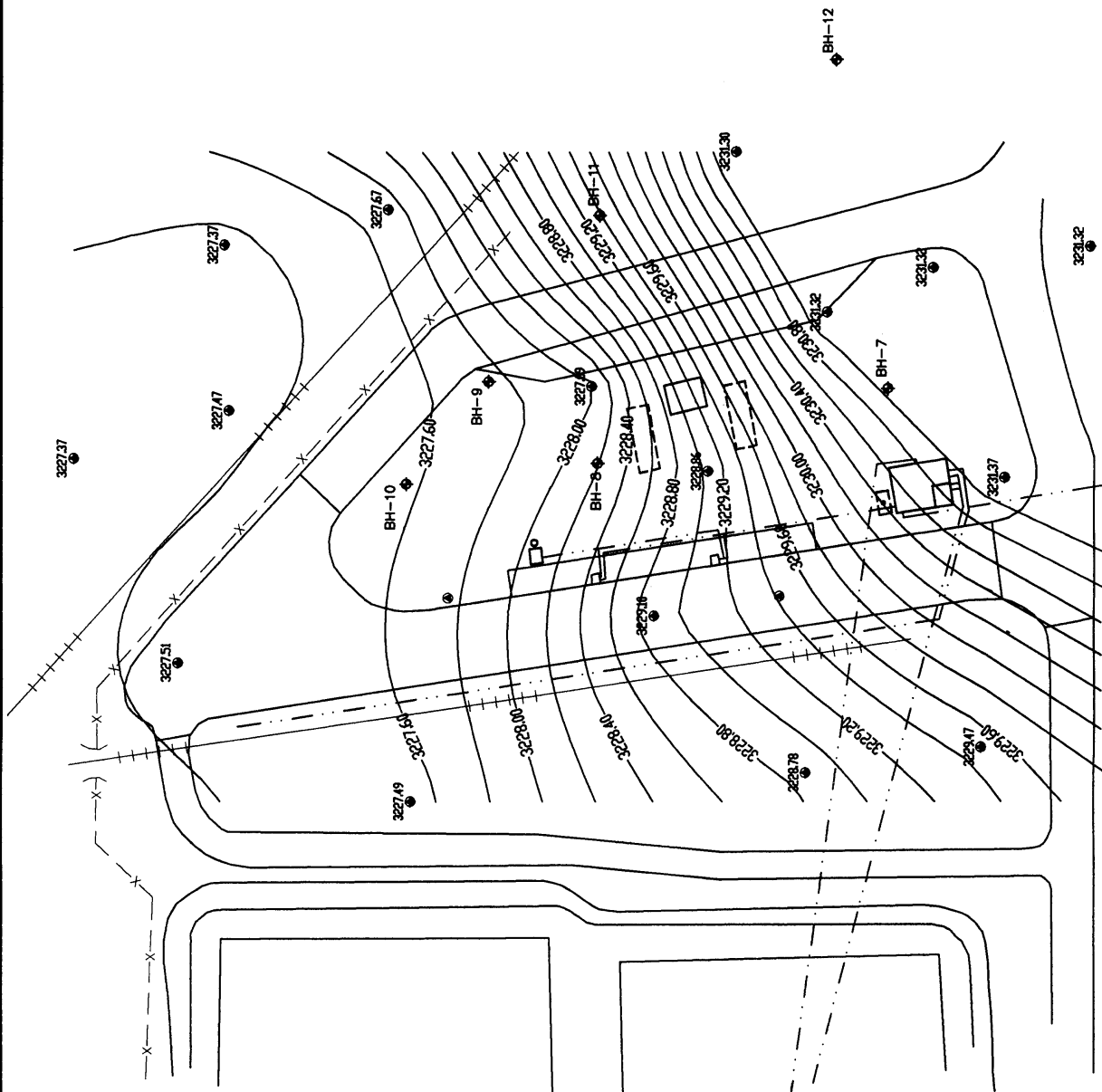


FIGURE 2.7

GROUND WATER SURFACE MAP

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soil gas survey have been reviewed to estimate the probable nature and extent of contamination at the site.

2.3.1 Soil Gas Data

The results of a limited soil gas survey conducted in 1993 at Area D indicate a soil gas plume located to the east of Building 8215 (ES, 1993). The focus of this soil gas survey was to identify target areas for the bioventing pilot-scale system. The survey was not designed to determine the total extent of soil contamination at the site. Soil gas analytical results indicated high concentrations of total volatile hydrocarbons (TVH) and BTEX compounds. Laboratory TVH concentrations ranged between 68,000 and 650 parts per million, volume per volume (ppmv). Maximum BTEX concentrations ranged from 9 to 388 ppmv, respectively.

Several of the soil gas samples collected as part of the survey showed depleted oxygen concentrations. Samples collected from 0 to 10 feet bgs had oxygen concentrations near ambient conditions (i.e., 20 percent), whereas samples collected at depths greater than 10 feet bgs (into the coarse-sand layer) had oxygen concentrations ranging from 0 to 1.5 percent. Carbon dioxide concentrations varied from 0.6 to 11.2 percent. Data on depleted oxygen levels with depth suggests that significant biological fuel degradation may be occurring in the deeper fuel-contaminated soils at the site (ES, 1993). However, because these soil gas samples were taken from a significantly contaminated portion of the site, additional soil gas samples are needed in other areas to adequately delineate the extent of soil gas and soil contamination at Area D and to better assess the potential risk of VOCs emanating from contaminated soil. Section 4 of this work plan describes these additional requirements.

2.3.2 Soil Data

Soil data collected during two discrete sampling events conducted under the fuel spill contamination survey report (FMG, 1992) indicate that soil contamination exists throughout the grassy area at Area D (Figure 2.8). Soil samples obtained during the bioventing demonstration project (ES, 1993) focused on the contaminated area where the pilot-scale system was installed. Drilling in the unsaturated portion of the unconsolidated deposits yielded materials with visible contamination in localized intervals anywhere from ground surface to 20 feet bgs.

Total recoverable petroleum hydrocarbon (TRPH) and BTEX soil contamination is widespread at Area D. The lateral extent of significant [i.e., more than 100 milligrams per kilogram (mg/kg) TRPH] soil contamination appears to be bounded by MW-17 and 21 on the north, MW-16 and 19 on the south, BH-12 and BH-9 on the east, and MW-14 and 15 on the west.

Fuel contamination extends from the surface, or near surface, to a depth of approximately 26.5 feet bgs (FMG, 1991). The depth of contamination varies throughout the area, suggesting that contamination potentially came from multiple sources, including surface spills. Laboratory results for TRPH in soil samples ranged from less than 1 mg/kg at several outlying monitoring well borings to 4,340 mg/kg at bioventing monitoring point MPB at a depth of 10 feet bgs (refer to Figure 2.8). The distribution of BTEX is similar to that of TRPH, with the exception that no BTEX compounds were detected in samples from MW-20 and -22 (FMG, 1992). All BTEX compounds were detected in soil samples, with total xylenes being the most prevalent. Benzene concentrations ranged from less than 0.2 to 15 mg/kg at bioventing monitoring point MPA at a

LEGEND

- MONITORING WELL
 - ◆ BOREHOLE
 - - - JET FUEL LINES
 - ++++ RAILROAD TRACKS
 - 800— SOIL TRPH CONCENTRATION (mg/kg)
- CONTOUR INTERVAL IS 200 mg/kg

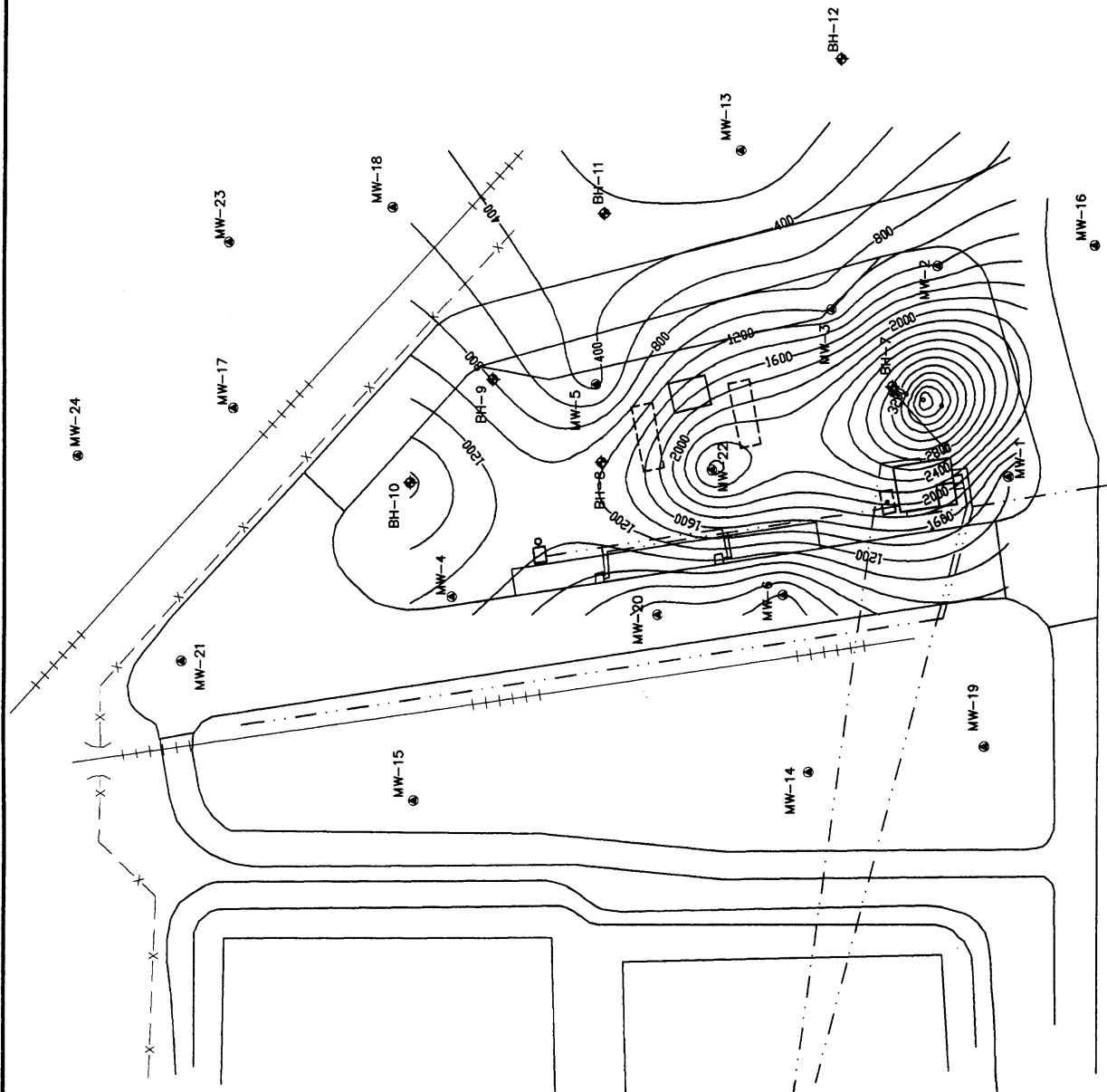


FIGURE 2.8

AREAL EXTENT OF SOIL CONTAMINATION

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depth of 10 feet bgs (ES, 1993). Laboratory results for TRPH and BTEX for all available soil boring locations completed at Area D are shown on Table 2.1. Additional soil borings are required within the grassy area to further delineate potential contaminant source areas and remediation requirements.

2.3.3 Ground Water Data

The distribution of hydrocarbon contamination at Area D suggested by the soil gas surveys and soil data differs from the distribution indicated by ground water quality data collected during the fuel spill contamination survey. TRPH were detected in ground water in several wells where TRPH was not detected in the soil during drilling activities. It appears that contaminated ground water may be migrating beyond the area of soil contamination to the eastern and northern edges of the site. Ground water data from 16 ground water monitoring wells located within or downgradient of the site have been compiled in Table 2.2 to indicate the probable nature and extent of ground water contamination at Area D. Samples were analyzed for TPH and BTEX. The samples were not analyzed for other organic compounds, including polynuclear aromatic hydrocarbons (PAHs) or chlorinated solvents.

Figure 2.9 depicts the probable extent of benzene, the only contaminant to exceed its federal MCL, in the shallow aquifer at Area D. The maximum concentration of benzene detected in ground water at Area D during previous site investigations by FMG, Inc. (1991) was 2,675 $\mu\text{g/L}$ (MW-20), which greatly exceeds its MCL of 5 $\mu\text{g/L}$. High concentrations of total BTEX compounds were also reported, with a maximum of 4,163 $\mu\text{g/L}$ measured at ground water monitoring well MW-20. Ethylbenzene was the only other BTEX compound detected at a concentration that approached its MCL. At well MW-20 ethylbenzene was detected at 659 $\mu\text{g/L}$ which is just below its MCL of 700 $\mu\text{g/L}$ (FMG, 1991).

Total xylenes were the BTEX compounds most frequently detected in the ground water at Area D during the field investigations. However, the maximum reported concentration of total xylenes of 1,680 $\mu\text{g/L}$ in ground water monitoring well MW-4 was significantly less than the federal MCL of 10,000 $\mu\text{g/L}$ (FMG, 1991). Ethylbenzene and toluene were also detected at Area D during field activities. Ethylbenzene was detected in five wells, MW-1, 2, 4, 17, and 20. Toluene was also detected in five wells (i.e., MW-1, 2, 4, 5, and 20). Toluene was detected at a maximum concentration of 15 $\mu\text{g/L}$ (at MW-4), which is significantly below its federal MCL of 1,000 $\mu\text{g/L}$ (FMG, 1991). Table 2.2 summarizes the analytical data for BTEX compounds at Area D collected during the spill contamination survey.

ES performed a preliminary investigation at Area D in April 1994 to support evaluation of the potential effectiveness of the intrinsic remediation option at the site. Data collected included concentrations of dissolved oxygen, temperature, and water levels. All sample analysis was performed using field instruments and methods approved under the AFCEE intrinsic remediation protocol document (Wiedemeier et al., in progress). Table 2.3 presents dissolved oxygen concentrations by sample location.

Available electron acceptors for *in situ* biodegradation, such as dissolved oxygen are present in the shallow aquifer, but appear to be depleted in the Area D source area and plume. Additional sampling is required to better define the geochemistry of the shallow aquifer, and the

TABLE 2.1

ANALYTICAL RESULTS FROM PREVIOUS SOIL SAMPLING EFFORTS
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Sample Location	MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	BH-7	BH-8
Sample Depth (feet bgs)	9-11	15-17	8-10	25-27	20-22	24-26	4-6	20.5-22.5
Parameter:								
Benzene (mg/kg)	<0.2	0.2	<0.4	0.3	<0.2	<0.2	0.4	<0.2
Toluene (mg/kg)	<0.2	0.3	6.3	17	0.3	<0.2	2.0	6.1
Ethylbenzene (mg/kg)	0.2	1.3	5.4	9.3	<0.2	0.3	15	5.7
Xylenes (mg/kg)	1.1	3.9	27	43	3.0	1.6	81	34
BTEX (mg/kg)	1.3	5.7	38.7	69.6	3.3	1.9	98.4	45.8
TRPH (mg/kg)	1,215	1,200	964	2,020	324	130	3,010	1,170

Sample Location	BH-9	BH-10	BH-11	BH-12	MW-13	MW-14	MW-15	MW-16
Sample Depth (feet bgs)	14-16	25-27	4-6	20-22	9-10.5	50-51.5	24-25.5	14-15.5
Parameter:								
Benzene (mg/kg)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene (mg/kg)	<0.2	1.7	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene (mg/kg)	<0.2	8.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Xylenes (mg/kg)	<0.2	24	<0.21	<0.2	<0.2	<0.2	<0.2	<0.2
BTEX (mg/kg)	0	33.8	0	0	0	0	0	0
TRPH (mg/kg)	<10	1,660	<10	<10	2.5	<1.0	<1.0	<1.0

TABLE 2.1 (Continued)

ANALYTICAL RESULTS FROM PREVIOUS SOIL SAMPLING EFFORTS
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Sample Location	MW-17	MW-18	MW-19	MW-20	MW-21	MW-22	MW-23	MW-24
Sample Depth (feet bgs)	19-20.5	14-15.5	9-10.5	14-15.5	19-20.5	9-10.5	19-20.5	19-20.5
Parameter:								
Benzene (mg/kg)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene (mg/kg)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene (mg/kg)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Xylenes (mg/kg)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
BTEX (mg/kg)	0	0	0	0	0	0	0	0
TRPH (mg/kg)	<1.0	<1.0	<1.0	242	<1.0	2724	<1.0	<1.0

Sample Location	VW-1	MPA	MPB
Sample Depth (feet bgs)	4-6	10	10
Parameter:			
Benzene (mg/kg)	6.4	15	3.2
Toluene (mg/kg)	13	10	3.7
Ethylbenzene (mg/kg)	53	40	17
Xylenes (mg/kg)	310	190	57
BTEX (mg/kg)	382.4	225	80.9
TRPH (mg/kg)	840	3,310	4,340

Sources: FMG, 1991 and 1992; ES, 1993.

TABLE 2.2

ANALYTICAL RESULTS FROM 1991-1992 GROUND WATER SAMPLING
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Sample Location	MW-1	MW-2	MW-3	MW-4	MW-5	MW-13	MW-14	MW-15
Parameter:								
Benzene (mg/L)	0.010	0.0008	<0.0005	0.440	<0.0005	<0.0005	<0.0005	<0.0005
Toluene (mg/L)	0.012	0.001	<0.005	0.015	0.0026	<0.0005	<0.0005	<0.0005
Ethylbenzene (mg/L)	0.036	0.0006	<0.0005	0.280	<0.0005	<0.0005	<0.0005	<0.0005
Xylenes (mg/L)	0.059	0.027	<0.001	1.680	0.020	<0.001	<0.001	<0.001
BTEX (mg/L)	0.117	0.027	0	2.415	0.0226	0	0	0
TPH (mg/L)	0.049	13.400	14.400	85.307	1.580	0.054	<0.010	<0.010

Sample Location	MW-16	MW-17	MW-18	MW-19	MW-20	MW-21	MW-23	MW-24
Parameter:								
Benzene (mg/L)	<0.0005	<0.005	<0.0005	<0.0005	2.675	<0.0005	<0.0005	<0.0005
Toluene (mg/L)	<0.0005	<0.005	<0.0005	<0.0005	0.012	<0.0005	<0.0005	<0.0005
Ethylbenzene (mg/L)	<0.0005	0.014	<0.0005	<0.0005	0.659	<0.0005	<0.0005	<0.0005
Xylenes (mg/L)	<0.001	0.187	<0.001	<0.001	0.817	<0.001	<0.001	<0.001
BTEX (mg/L)	0	0.201	0	0	4.163	0	0	0
TPH (mg/L)	<0.010	4.862	<0.010	<0.010	10.440	0.031	0.026	<0.010

Sources: FMG, 1991 and 1992.

LEGEND

- MONITORING WELL
- ◆ BOREHOLE
- - - JET FUEL LINES
- ++++ RAILROAD TRACKS
- - - PROBABLE EXTENT OF GROUND WATER BENZENE PLUME EXCEEDING 5 µg/L

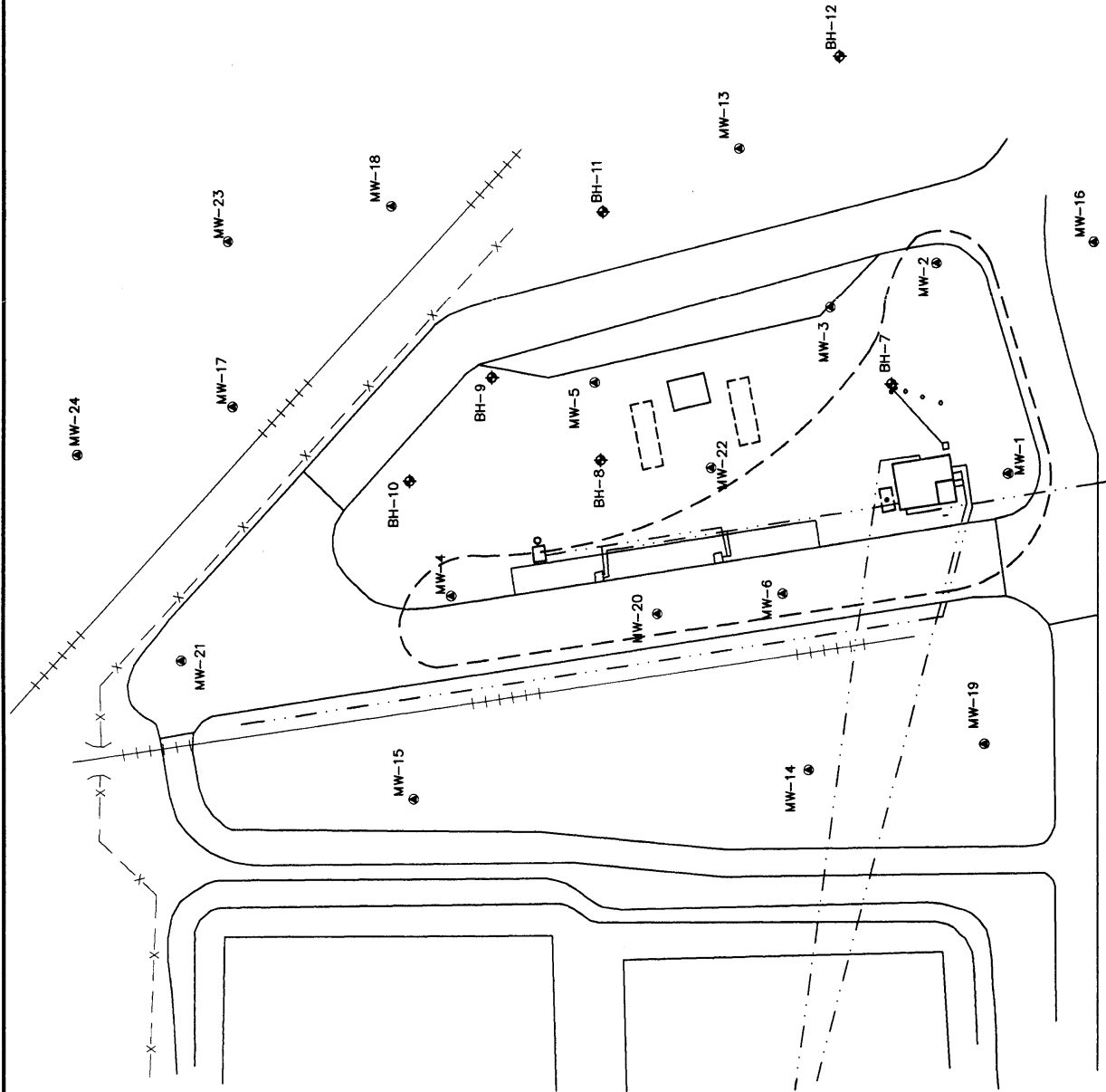


FIGURE 2.9

PROBABLE AREAL EXTENT OF
BENZENE IN GROUND WATER
(BASED ON AVAILABLE DATA)

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Area D, Ellsworth AFB, South Dakota
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TABLE 2.3
DISSOLVED OXYGEN CONCENTRATIONS MEASURED
DURING APRIL 1994 FIELD TESTING
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Well	Dissolved O ₂ at 1 Foot Below Ground Water Surface (ppm)	Dissolved O ₂ at 6 Feet Below Ground Water Surface (ppm)
MW-1	2.65	4.10
MW-2	0.00	0.00
MW-3	0.16	0.07
MW-4	well silted in	
MW-5	0.23	0.04
MW-6	product in well, no measurement taken	
MW-13	6.6	6.75
MW-14	1.22	0.94
MW-15	2.55	0.12
MW-16	4.50	4.74
MW-17	0.31	0.00
MW-18	5.40	5.6
MW-19	0.13	3.15
MW-20	0.00	0.00
MW-21	0.78	0.15
MW-22	0.12	0.07
MW-23	0.10	0.00
MW-24	3.17	0.40

mass-transport characteristics of the aquifer. Section 4 summarizes the additional hydrogeologic characterization activities that will be necessary to support the risk-based remediation of Area D.

2.3.4 Surface Water Data

Because of the lack of surface water in the vicinity of Area D, no surface water samples have been collected as part of previous investigations. Surface water from the drainage that encompasses Area D is sampled in accordance with the Ellsworth AFB National Pollution Discharge Elimination System (NPDES) permit. However, the discharge point that is the sampling point for this drainage is over 2 miles away and may not accurately reflect any contamination that may be emanating from Area D. Given the apparent lack of a potential contaminant migration pathway to surface water bodies, no sampling of surface water at Area D is planned. However, Section 4 of this work plan describes the additional data that will be collected to confirm that there is no potential for cross-media contamination involving surface water.

2.3.5 Frequency of Free Product

Free-phase JP-4 jet fuel product has been observed in one ground water monitoring well at Area D. Although product was also observed in two other borings during well installation and drilling, no product was observed after well development. As noted previously, more than 3 feet of free product was observed in ground water monitoring well MW-6 during the 1994 preliminary investigation performed by ES. FMG also reported free product in the well during its 1991-1992 sampling event (FMG, 1992). Section 4 of this work plan describes methods to be employed to quantify the existing extent of free product contamination at Area D using ground water monitoring well MW-6 or any other wells that may have free product. If a free product sample can be collected, it will be analyzed for its total BTEX content to determine how the remaining free product is partitioning into the underlying ground water and contributing to the dissolved-phase BTEX plume at Area D.

SECTION 3

IDENTIFICATION OF SITE MODELS

It will be necessary to collect sufficient data to comparatively evaluate the long-term effectiveness of various remedial alternatives in eliminating or minimizing current or potential future risks to human health and the environment. Section 3.1 describes a conceptual site model for Area D, which includes possible source and release mechanisms, governing fate and transport processes, potential exposure points and routes, and potential human and environmental receptors. Section 3.2 describes the Bioplume II model which will be used to quantitatively evaluate whether dissolved-phase ground water contamination can migrate to a receptor exposure point. Section 3.3 describes other quantitative contaminant fate and transport models that may be used to evaluate exposure potential from contamination in environmental media other than ground water.

3.1 CONCEPTUAL SITE MODEL

The purpose of developing a conceptual site model (CSM) is to evaluate existing information about the physical characteristics of the site, including potential contaminant sources, chemicals of concern, release mechanisms (e.g., leaching and volatilization), governing fate and transport processes (e.g., molecular diffusion, ground water migration), potential human and ecological receptors (e.g., current on-base workers, potential future on-base residents, current/future off-base residents, terrestrial vegetation and wildlife), exposure points (i.e., locations where receptors could come into contact with site-related contamination), and routes of exposure (e.g., inhalation, incidental ingestion, dermal contact), to identify the types of data necessary to quantify receptor exposure. The CSM will be used to define the nature of additional site characterization activities required at Area D to support identification, selection, and implementation of a final remedial alternative that minimizes contaminant migration and receptor exposure. The CSM constructed for Area D is shown schematically in Figure 3.1.

3.1.1 Definitions

It is appropriate at this point to define some of the key terms used in the risk-based approach to remediation. A *risk assessment* is the quantitative estimation of a hazard. A *baseline risk assessment* estimates the hazards that might exist if no remediation or institutional controls were applied at a site. A *conceptual site model* (CSM) qualitatively identifies how potential human and ecological receptors could come into contact with site-related contamination. A CSM is then used to assess data needs and guide data collection and analysis efforts. An *exposure assessment* involves estimating the type and magnitude of receptor exposures to contaminants of concern (COCs) that are present at or migrating from a site. COCs are chemicals that are potentially site-

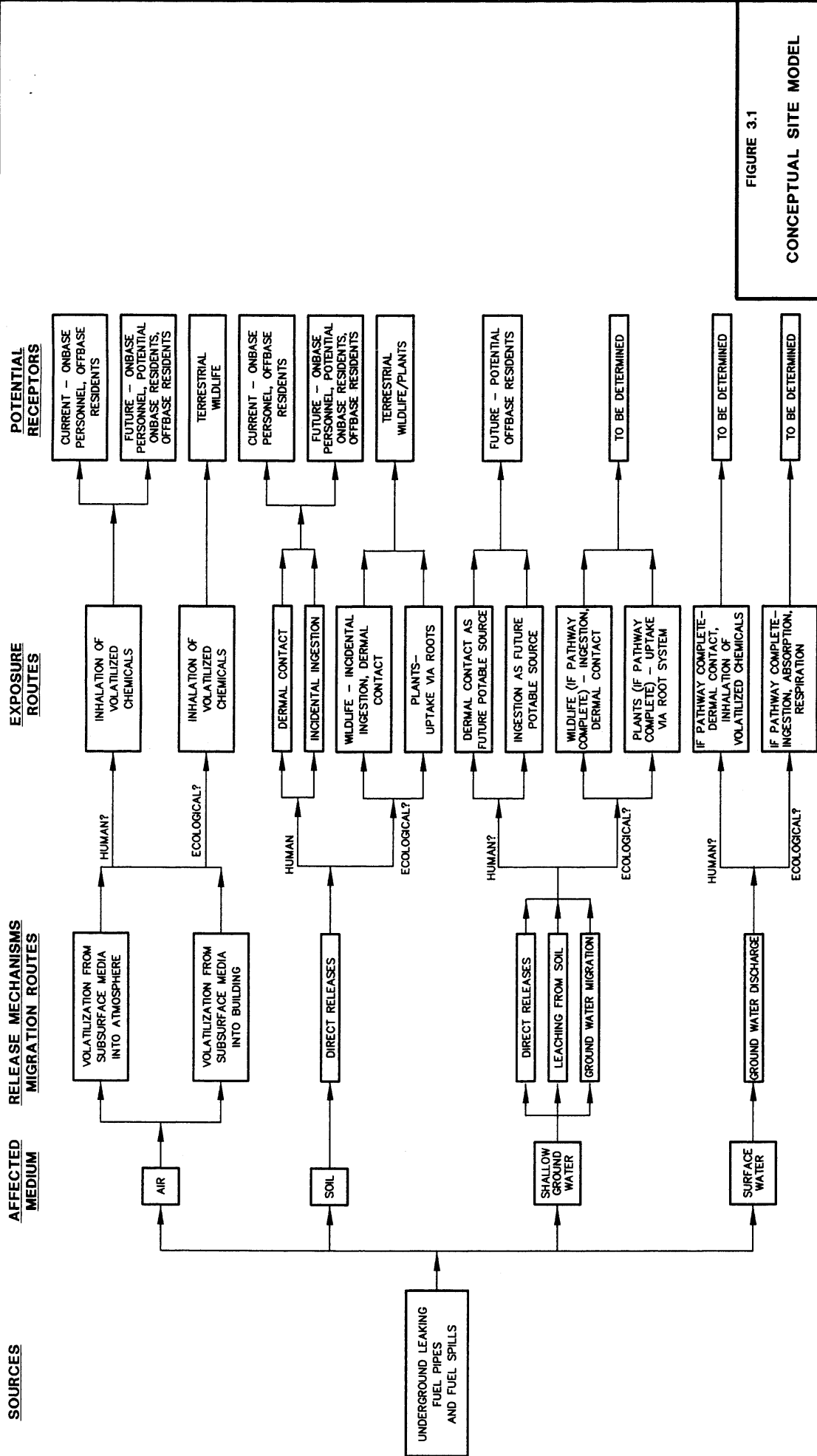


FIGURE 3.1

CONCEPTUAL SITE MODEL

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Risk-Based Approach to Remediation
Area D, Ellsworth AFB, South Dakota
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Denver, Colorado

related and whose data are of sufficient quality for use in a quantitative risk assessment. A *risk assessment concentration* or *exposure-point concentration* is the highest concentration a potential receptor would reasonably be expected to contact. The risk-based approach to remediation uses conservative quantitative models that account for the effects of fate and transport processes to estimate exposure point concentrations. The probable effectiveness of intrinsic remediation and other innovative source removal technologies such as bioventing to reduce exposure-point concentrations will be determined using conservative quantitative models.

Contaminant screening levels are conservative risk-based or promulgated criteria used to identify and screen out areas or environmental media that do not warrant further study. *Chemical-specific remediation goals* define the "acceptable" concentration of chemicals that can remain onsite following remediation and still meet remedial action objectives. These cleanup goals can either be risk-based or based on promulgated criteria. *Risk-based remediation goals* (remediation goals) are long-term target concentrations for environmental media based on target risk levels, toxicity information, and exposure equations rather than on promulgated cleanup standards. Remediation goals will be used to identify, select, and design an appropriate remedial alternative that will minimize or eliminate risks due to exposure to site-related contaminants. Remediation goals will be developed using site-specific land use assumptions, the procedures outlined in the EPA (1991a) Office of Solid Waste and Emergency Response (OSWER) Directive 9285.7-01B entitled *Human Health Evaluation Manual, Part B: Development of Risk-based Remediation Goals*. These remediation goals may be modified to address technical limitations, effectiveness, practicability, or other relevant considerations, including reasonable expected future exposure conditions at the site not already incorporated into the cleanup levels. These final cleanup goals are then compared to the exposure-point concentrations developed using the quantitative fate and transport models to estimate the type and magnitude of remediation required to protect human health and the environment. More details on the proposed risk analysis methods are presented in Section 5 of this work plan.

3.1.2 Previous Risk Estimates

A baseline human health risk assessment has not yet been completed for Area D at Ellsworth AFB. However, several work plans for baseline human health risk assessments for areas adjacent to and downgradient of Area D are in preparation. For example, the baseline human health risk assessment for OU-11 will address the current and future risks, both on-base and off-base, associated with shallow ground water. Eventually the findings of OU-specific investigations and other data regarding possible exposure of ecological receptors will be grouped into a baseline ecological risk assessment. The risk-based approach to remediation for Area D will be consistent with the approach outlined in these risk assessment work plans to the maximum extent practicable given the likely use of affected media at and downgradient of Area D.

3.1.3 Contaminants of Concern

This risk-based demonstration project will address the specific chemical constituents that may drive potential risks and impact the final remedial design for Area D. The COCs depend upon the nature of the source (i.e., a JP-4 jet fuel), the affected media (i.e., soil gas, vadose soil, saturated soil, and ground water), and the fate, transport, toxicity, and regulatory status of various JP-4 jet fuel constituents. Details on the chemical composition of JP-4 and the physiochemical properties

of these compounds are important factors that may influence fate and transport, and therefore desired remediation goals at the site.

The major component categories (and their represented percentage by weight) in JP-4 are n-alkanes (32 percent), branched alkanes (31 percent), cycloalkanes (16 percent), benzenes and alkylbenzenes (18 percent), and naphthalenes (3 percent). Other nonhydrocarbons are not important components in JP-4 by weight.

The environmental behavior of each group of specific hydrocarbons must be considered when identifying COCs for Area D. For example, some compounds may be relatively mobile and non-persistent in soil. These compounds may leach effectively from contaminated soil into underlying ground water and migrate as a dissolved-phase plume. Conversely, other compounds may be immobile under unsaturated conditions and therefore may not contribute to ground water contamination. Thus, based on the physiochemical properties of each JP-4 constituent, the relative concentration of each will vary with time and distance from the source of contamination. This effect is commonly called weathering.

Partitioning of chemical constituents from free-phase and residual contamination is an important mechanism of weathering that should be evaluated when identifying those compounds most likely to pose a risk to potential receptors and to require remediation. In general, migration of JP-4 through soils may be retarded to some extent. Once the JP-4 reaches ground water, however, the water solubility of each chemical constituent governs how it partitions into ground water. A fuel/water partition coefficient (K_{FW}) can be used to estimate the maximum concentration in ground water as a result of free-phase JP-4 contamination. Available K_{FW} data support the observation that light aromatics such as the BTEX compounds represent the greatest fraction of JP-4 that could impact ground water quality (see Table 3.1) by dissolving in and being transported by ground water.

Because JP-4 is composed of C_{14} and lighter hydrocarbons, it is likely to be significantly weathered where encountered at this site. Naphthalene is the only PAH that could be present at the site. Previous characterization efforts did not analyze for this specific compound. No chlorinated organic compounds have been detected at this site (see Section 2).

When establishing potential COCs for a site, it is also important to consider the availability and magnitude of toxicity values for each of the JP-4 constituents. Table 3.1 also identifies those compounds of a typical JP-4 sample for which accepted human health toxicity values are available (e.g., from the Integrated Risk Information System, IRIS). No toxicity data or promulgated standards are available for most of the specific chemical compounds that could be present in JP-4. Toxicity values are available for the BTEX compounds and naphthalene.

Thus, the COCs for soil gas, soil, and ground water at or migrating from Area D which will be addressed as part of this demonstration project include the BTEX compounds and naphthalene. Any free-phase fuel product samples collected during the field work phase of this project will be screened for naphthalene. This approach is consistent with SD DENR guidance on remediating soil and ground water contaminated with volatile compounds (Chapter 74:03:15, Ground Water Quality Standards, and 74:03:28, Remediation Criteria for Petroleum-Contaminated Soils).

TABLE 3.1
SUMMARY OF FUEL/WATER PARTITIONING COEFFICIENTS
AND AVAILABILITY OF TOXICITY DATA
FOR THE MAJOR COMPONENTS OF JP-4
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Fuel Component	% by Weight	Fuel/Water Partition Coefficient	Available Tox. Data?
Benzene	0.5	231	YES
Toluene	1.33	895	YES
Ethylbenzene	0.37	3410	YES
o-xylene	1.01	3160	YES
m-xylene	0.96	3530	YES
p-xylene	0.35	2960	YES
Napthalene	0.5	24000	YES
1,1,3-trimethylcyclohexane	0.48	651000	NO
1,2,3,4-tetramethylbenzene	0.75	45800	NO
1,2,3-trimethylcyclopentane	0.25	276000	NO
1,2,4-trimethylbenzene	1.01	12270	NO
1,2,4-trimethylcyclopentane	0.25	276000	NO
1,2-dimethyl-4-ethylbenzene	0.77	45800	NO
1,3,5-trimethylbenzene	0.42	6490	NO
1,3,5-trimethylcyclohexane	0.99	651000	NO
1,3-diethylbenzene	0.46	45800	YES
1,3-dimethyl-5-ethylbenzene	0.61	45800	NO
1,4-dimethyl-2-ethylbenzene	0.7	45820	NO
1-methylnapthalene	0.78	27000	NO
1-methyl-2-ethylbenzene	0.23	7710	NO
1-methyl-2-ethylcyclohexane	0.39	9360	NO
1-methyl-2-isopropylbenzene	0.29	35100	NO
1-methyl-3-ethylbenzene	0.49	12200	NO
1-methyl-3-ethylcyclohexane	0.17	9366	NO
1-methyl-4-ethylbenzene	0.43	6690	NO
1-methyl-4-ethylcyclohexane	0.48	9360	NO
1-methyl-4-propylbenzene	0.4	45800	NO
2,2,3,3-tetramethylbutane	0.24	509000	NO
2,2-dimethylbutane	0.1	37800	NO
2,2-dimethylhexane	0.71	509000	NO
2,2-dimethylpentane	0.25	37000	NO
2,4-dimethylhexane	0.58	509000	NO
2,5-dimethylheptane	0.52	1860000	NO
2,5-dimethylhexane	0.37	509000	NO
2,6-dimethylnapthalene	0.25	593000	NO
2,6-dimethylundecane	0.71	333000000	NO
2-methylheptane	2.7	1330000	NO
2-methylhexane	2.35	430000	NO

TABLE 3.1 (Continued)
SUMMARY OF FUEL/WATER PARTITIONING COEFFICIENTS
AND AVAILABILITY OF TOXICITY DATA
FOR THE MAJOR COMPONENTS OF JP-4
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Fuel Component	% by Weight	Fuel/Water Partition Coefficient	Available Tox. Data?
2-methylnaphthalene	0.56	31000	NO
2-methyloctane	0.88	2460000	NO
2-methylpentane	1.28	61900	NO
2-methylundecane	0.64	127000000	NO
3,3-dimethylhexane	0.26	509000	NO
3,4-dimethylheptane	0.43	1860000	NO
3-methylheptane	3.04	1650000	NO
3-methylhexane	1.97	270000	NO
3-methyloctane	0.79	2450000	NO
3-methylpentane	0.89	66350	NO
4-ethylheptane	0.18	2450000	NO
4-methylheptane	0.92	647000	NO
4-methyloctane	0.86	15100000	NO
cis-1,2-dimethylcyclopentane	0.34	16600	NO
cis-1,3-dimethylcyclohexane	0.42	160000	NO
cis-1,3-dimethylcyclopentane	0.54	16600	NO
Cyclohexane	1.24	11700	NO
Dimethylcyclohexane	0.43	160000	NO
Ethylcyclopentane	0.26	16600	NO
Isobutane	0.66	14300	NO
Isopropylbenzene	0.3	9040	YES
Methylcyclohexane	2.27	55300	NO
Methylcyclopentane	1.16	16600	NO
n-butane	0.12	11000	NO
n-butylcyclohexane	0.7	35200	NO
n-decane	2.32	644000000	NO
n-dodecane	2	786000000	NO
n-heptane	3.67	365000	NO
n-hexane	2.21	91000	YES
n-nonane	2.25	7160000	NO
n-octane	3.8	2020000	NO
n-pentane	1.06	18800	NO
n-propylbenzene	0.71	7090	NO
n-tetradecane	0.73	1.80E+09	NO
n-tridecane	1.52	488000000	NO
n-undecane	2.32	644000000	NO
trans-2,3-dimethylcyclopentane	0.36	16600	NO

3.1.4 Potential Source Areas and Release Mechanisms

As noted in Section 2, existing analytical data suggest that there may be more than one the contaminant source within Area D. Underground fuel transfer lines and incidental surface spills may have contributed to subsurface contamination at the site. Additional site characterization efforts are recommended as part of this demonstration project to more fully delineate discrete source areas within Area D. This detail is necessary to facilitate quantitative analyses of fate and transport processes and evaluation and design of an appropriate remedial action for the site.

The contaminant release mechanisms incorporated into this CSM are volatilization into the atmosphere and partitioning from soil or free product into ground water. This approach is consistent with the nature of contamination suspected at the site, the physical characteristics of the surrounding area, and the physiochemical properties of the COCs.

3.1.5 Fate and Transport Processes

Transport processes included in the CSM for Area D include (1) molecular diffusion through unsaturated soil, (2) air dispersion, and (3) ground water migration. Ground water discharge to and transport in surface water is not considered a complete exposure pathway at the site given the depth to ground water and the distance to the nearest downgradient drainage culvert or surface water body. Plant uptake of contamination from soil and subsequent transport through food chain pathways is also not considered a significant fate process for volatile compounds. Because the BTEX compounds and naphthalene are not considered persistent in biota, there is limited risk to wildlife due to food chain dynamics. Further, there are no data on the toxicity of these compounds for plants, suggesting again that these compounds do not bioaccumulate or bioconcentrate.

All the COCs to be considered for Area D readily volatilize from water into air. However, the presence of clays in the shallow soil at Area D may effectively limit upward diffusion of contamination as soil gas. The actual rate of emission from source soils at the site will be investigated as described in Section 4 of this work plan, and possibly modeled using the methods described in Sections 3.3 and 5.

The COCs for Area D are also expected to partition from contaminated unsaturated soil, which contains fuel residuals, or from free-phase fuel floating on the ground water surface into the underlying ground water, and migrate downgradient as a dissolved-phase plume. In addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, adsorption), these dissolved-phase contaminants will be slowly removed from the ground water system by other naturally-occurring destructive mechanisms, such as biodegradation, abiotic oxidation, and hydrolysis. The effects of these processes on the dissolved-phase ground water plume will be investigated using a quantitative ground water and solute-transport model such as Bioplume II. Data collection and analysis requirements are discussed in Sections 4 and 5 of this work plan, respectively.

3.1.6 Potential Human and Ecological Receptors

Assumptions about land use form the basis for identifying potential receptors and potential exposure pathways. EPA (1991c) advises that the land use associated with the highest (most conservative) potential level of exposure and risk that can reasonably be expected to occur should be addressed in risk-based remedial decisions. Although hypothetical future residential land use

provides the most conservative risk estimates, EPA risk assessment guidance materials state that this conservative approach may not be justifiable if the site is surrounded by an operating industrial facility that can be reasonably assumed to remain as an industrialized area. In these cases, the EPA recommends using other exposure scenarios, such as agricultural or light commercial/industrial, including a qualitative assessment of the likelihood that the assumed reasonable future land use will occur (55 *Federal Register* 710).

Ellsworth AFB is home to the 28th Bombardment Wing, which flies B-1B bombers, the 44th Strategic Missile Wing, which handles the Minuteman II Weapon System, and the 99th Tactics and Training Wing, which develops tactics and trains all bomber aircrews. The 44th Missile Wing will be deactivated by 1995, but the two aviation wings will be expanded. Ellsworth AFB is an active military installation with an airfield, hangars, maintenance and office facilities, and residential and recreational facilities. Open range/farm land lies to the north, south, and west of the base, while residential and commercial areas lie to the east. Some private residences are located within a few thousand feet of the southwestern boundary of the base.

It is likely that Area D, which is located in the north-central portion of Ellsworth AFB, will remain as an industrial area with limited access. Area D is an active yard and is essential to flight operations at the base. Should portions of Ellsworth AFB be scheduled for transfer to civilian authorities some time in the future, it is not likely that residential development will occur in Area D or within areas downgradient from Area D. Most of the properties currently adjacent to the base boundary are either light commercial/industrial or undeveloped, potential agricultural land. Although limited residential development has occurred in isolated areas near the base (e.g., the extreme southwestern boundary of the base), any future residential development will most likely occur in more attractive areas closer to Rapid City. Further, the current land use trends in the immediate environs indicate that the areas likely to be affected by site-related contamination will not be available or desirable for residential development.

It is important to note that the residential criteria are intended to be protective of any future uncontrolled land use, not just human habitation. This broad interpretation means that no controls would be imposed on any activity. While this is the most conservative (health-protective) exposure scenario, it is not reasonable and representative of the likely future uses of most of Area D and downgradient environs. It is probable that Area D, currently an active fuel storage and aircraft re-fueling center, will not be available for residential development, but will be maintained as an industrial property. Ellsworth AFB could reasonably apply more stringent land use restrictions or institutional controls to source areas and areas of higher contamination. In this case, this area should be conservatively evaluated using the light industrial/commercial worker exposure scenario. Additionally, there are no current uses of shallow ground water on-base. Ellsworth AFB currently receives its domestic water supply from the Rapid City Water Service. These water supplies are considered to be sufficient to meet at least a 10 percent increase in the served population in the region (personal communication, Rapid City Water Service 1994). The work plan for the OU-11 baseline risk assessment also does not identify any uses of on-base ground water (EA, 1994). Therefore, on-base use of shallow ground water will not be factored into the exposure assumptions for both current and future scenarios for Area D and environs immediately downgradient. It may be appropriate to include land-use restrictions in the remedial alternative for these areas to ensure that the site remains industrial.

However, ground water is used as a source of potable water for individual residences off-base. Thus, the remediation goals for Area D must be protective enough to allow uncontrolled use of ground water resources in areas that may be available for unrestricted use (i.e., not maintained as an industrial facility; not under land use restrictions). Quantitative fate and transport analyses and exposure estimates will be conducted as part of this demonstration project to ensure that established remediation goals are adequate to protect human health and the environment given the likely use of the land in question (i.e., industrial use only for Area D and areas immediately downgradient, and uncontrolled use further downgradient and off-base).

Current human receptors for contamination from Area D are assumed to include individuals working within Area D and in nearby areas at Ellsworth AFB, particularly those located downwind of Area D. Area D is approximately 400 feet from other base office buildings and occupied work areas. Potential future human receptors will include both on-base industrial/commercial workers for Area D source areas and immediate environs, and on-base and off-base residents for downgradient and downwind areas. This approach is consistent with both the likely use of land in the area and the planned OU-11 baseline risk assessment.

A variety of animals potentially inhabit, or migrate through, the Ellsworth AFB region. At least 50 species of large and small mammals could potentially occur on or near the base, including whitetail and mule deer, coyote, raccoon, porcupine, eastern cottontail, northern pocket gopher, white-footed mouse, masked shrew, and prairie vole. Bird life is also diverse in the area. Threatened and endangered species are not known to live on Ellsworth AFB, although there is the possibility of transients occurring in the area (US Air Force, 1989). Potential transients include the peregrine falcon, bald eagle, and whooping crane. The bald eagle may also be a winter resident of the area (EA, 1994).

For the purposes of this demonstration project, ecological receptors will be limited to those terrestrial organisms that may contact or incidentally ingest contaminated soil. Although this approach is consistent with those likely to be used to evaluate ecological risk at specific OUs at Ellsworth AFB (EA, 1994), it is likely that a more detailed analysis of the fate and transport processes at Area D will indicate that even these exposure pathways are incomplete. As noted previously, ground water migration to or direct discharge into surface water is considered an incomplete migration pathway for Area D. However, this potential migration pathway will be fully evaluated as part of this demonstration project. Additionally, even if the data indicate that the COCs are transported to a potential exposure point, the chemicals may not be bioavailable. Available toxicity data for plants and animals do not suggest that VOCs such as the BTEX compounds and naphthalene can be bioaccumulated or bioconcentrated. Section 4 of this work plan identifies the need to obtain existing data on potential ecological receptors to determine what populations, if any, could be exposed to site contamination in the event that an exposure pathway were complete.

3.1.7 Exposure Points and Exposure Routes

An exposure point is a location at which any potentially exposed receptor could come into contact with site-related contamination. On-base contaminated media will be considered possible exposure points only for those base personnel who currently have access to Area D and for potential future residents should downgradient areas be opened for civilian development. Potential exposure points initially included in this CSM include Area D and the environs

downgradient of the site (including nearby base office buildings and occupied work areas) that are likely to be affected by contamination at or migrating from source area. Several of these potential exposure points may be eliminated from the final evaluation should fate and transport data demonstrate that site-related contamination could not reach these locations (i.e., the exposure pathway is incomplete).

Probable exposure routes are dependent upon which receptors come into contact with what contaminated media. Exposure routes considered for human receptors in this CSM are limited to inhalation of contaminants volatilizing from soil, inhalation of VOCs accumulating within structures, incidental ingestion of contaminated soil (as particulates), and dermal contact with contaminated soil. Any direct exposure routes involving ground water will not be included as possible exposure routes for the following reasons: (1) shallow ground water is not likely to be encountered during normal construction activities, (2) shallow ground water is not currently used to meet on-base water demands, (3) existing sources of potable water are considered sufficient to meet expanding population requirements, and (4) future probable uses of Area D source areas and areas immediately downgradient will remain industrial (i.e., no use of shallow ground water). Ground water remediation goals will be established to protect human health and the environment in downgradient areas that may be open for unrestricted use of ground water resources.

Probable exposure routes for ecological receptors will be limited to direct routes only; that is, routes of exposure for ecological receptors may include incidental ingestion of and dermal contact with contaminated soil. As noted previously, however, it is possible that the ecological exposure pathways may be incomplete. Further quantitative information on ground water migration is required.

3.1.8 Target Remediation Goals

The risk analysis approach to be used to screen, evaluate, select, design, and implement the most cost-effective remedial alternative at a site is addressed in Section 5 of this work plan. In general, a three-tiered approach will be used, involving (1) trigger or "evergreen" levels, (2) initial quantitative exposure assessment and chemical-specific remediation goals, and (3) more complex quantitative exposure assessment and chemical-specific remediation goals which include partial source removal.

Site-specific concentrations will first be compared to "evergreen" cleanup goals as an initial step to determine if continued investigation of remedial alternatives is warranted. If this comparison indicates the need for a more site-specific analysis (i.e., generic trigger levels are exceeded), then a quantitative exposure assessment designed to investigate governing fate and transport mechanisms and the potential effectiveness of intrinsic remediation (see Section 3.2) will be completed. Results of this evaluation will be compared to site-specific remediation goals rather than "evergreen" levels to assess whether intrinsic remediation coupled with long-term monitoring will be sufficient to protect human health and the environment. If this second analysis suggests the need for additional remediation to meet cleanup goals for the site, the remedial alternative evaluation will be expanded to include an iterative, quantitative analysis of the effectiveness of other remedial technologies.

The goal of this tiered approach is to quickly identify which media and COCs may or will pose a risk to receptors so that a remedial alternative can be developed to minimize or abate these risks. Section 5 of the work plan contains a more detailed description of the risk analysis methods

to be used in this demonstration project. The following sections briefly discuss several concepts that may drive the development of chemical-specific remediation goals for Area D, and guide the risk analysis for the EE/CA.

The first step in the tiered approach is comparing site concentrations to levels that would not trigger further action. Chemical-specific screening levels (formerly known as trigger levels) are defined by EPA or are some other promulgated standards that can be used to quickly identify contaminated media that require further investigation and eliminate other media that do not warrant additional study (e.g., EPA, 1993). Using chemical-specific screening levels at this first step focuses data collection and analysis on those chemicals, media, and areas within a site that may warrant concern, and eliminates unnecessary and costly investigation efforts. These chemical-specific screening levels are often called "evergreen" as they mark levels below which few people would argue about the need for remediation, regardless of site-specific circumstances. However, concentrations in environmental media that exceed these chemical-specific "evergreen" screening levels do not automatically designate the site as "dirty" or trigger the need for a response action. Exceedances indicate only the need for further study to establish whether site-specific concentrations are protective of human health and the environment (EPA, 1993).

Table 3.2 presents the soil-specific screening (evergreen) levels for the COCs assuming unrestricted residential land use at Area D. These soil screening levels are designed to be protective of human health. Development of soil "evergreen" levels that are protective of ground water quality (commonly called cross-media contamination levels) presume human ingestion at some close downgradient point. As this is not an appropriate or representative exposure assumption for Area D given current or probable future exposure conditions at the site, these levels represent the most conservative or worst-case screening levels. Chemical-specific screening levels most appropriately applied to this site would be designed to protect some other environmental quality, such as ground water further downgradient that may be used to meet potable water demands.

In any event, these soil "evergreen" levels can still be used to determine which soils at Area D do not warrant additional study under even the most conservative exposure assumptions. If concentrations in specific environmental medium at Area D do not exceed these "evergreen" levels, no further study or remedial action is warranted. Comparison of "evergreen" soil benzene values to the soil contamination levels presented in Table 2.1 indicate the need for additional study to quantify site-specific release and transport mechanisms and to develop final concentration goals that are protective of human health and the environment. Further, as noted previously, benzene exceeded its "evergreen" ground water level (its MCL) of 5 $\mu\text{g/L}$ at several locations, suggesting the need for more evaluation. The risk-based approach to remediation for Area D has been designed to satisfy these data objectives.

Chemical-specific remediation goals are for specific medium and land use combinations. These chemical-specific remediation goals are more site-specific than "evergreen" screening levels in that they reflect site-specific conditions. These goals are necessary to identify, evaluate, and select an appropriate remedial alternative for Area D. Identification of these chemical-specific, site-specific criteria depend upon which chemicals are present at the site, which environmental media are or may become contaminated, land use assumptions, and exposure assumptions. For example, chemical-specific remediation goals developed for Area D may include a fate and transport model component so that the cleanup goal can be met at a potential exposure point rather than requiring

TABLE 3.2

**SUMMARY OF SOIL AND GROUND WATER "EVERGREEN" LEVELS
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA**

Parameter	Soil (Inhalation) (mg/kg)	Soil (Ground Water Protection) (mg/kg)	Ground Water MCLs (μ g/L)
Benzene	3.2	0.1	5
Toluene	330	36	1,000
Ethylbenzene	330	33	700
Xylenes	100	570	10,000
Napthalene	3100	250	--

Sources: EPA (1993) OSWER Soil Screening Levels
56 *Federal Register* 20 (1/30/91)

all media at the site to be remediated to this level. Final chemical-specific, site-specific remediation goals for Area D will be based on current and future exposure assumptions most appropriate for the site.

Chemical-specific concentration goals can either be risk-based or based on promulgated criteria. This demonstration will develop risk-based human health remediation goals for each COC for each contaminated environmental medium (e.g., vadose zone soil, ground water) using carcinogenic and/or noncarcinogenic toxicity values, land-use assumptions, and exposure assumptions. Risk-based remediation goals are calculated only for human receptors. Human health remediation goals may also be developed from appropriate promulgated standards. However, noncompound-specific remediation criteria such as TPH standards will not be identified as appropriate remediation goals for Area D (e.g., SD PENR, 1992, Chapter 74:03:32). Ecological remediation goals, if necessary, will be developed using soil toxicological guidance or literature values. Further details on how site-specific remediation goals will be developed for Area D are presented in Section 5 of this work plan.

3.2 INTRINSIC REMEDIATION AND THE BIOPLUME II MODEL

After Area D has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and whether any exposure pathway for human or ecological receptors is complete. The Bioplume II model has proved useful for predicting BTEX plume migration and contaminant attenuation by natural biodegradation. The Bioplume II model (Rifai et al., 1988) can be used to evaluate critical ground water fate and transport processes that may be involved in some of the migration pathways to human and ecological receptors. Other quantitative models potentially suitable to simulate fate and transport in soil and air are presented in Section 3.3 of this work plan. More representative remediation goals that are protective of human health and the environment can be developed by quantitatively incorporating fate and transport processes into the evaluation of potential risks associated with site-related contamination. Quantitative fate and transport analyses and risk calculations can then be coupled to determine what level and extent of remediation is required. These calculations can also be useful in developing and negotiating final concentration goals that are protective of human health and the environment given the site-specific conditions.

An important consideration in determining whether fuel hydrocarbon contamination presents a substantial threat to human health and the environment and what type of remedial alternative will be most cost effective in eliminating or abating these threats is an accurate estimate of the potential for natural biodegradation of BTEX compounds in the soil and ground water. Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons (Lee, 1988). This process occurs naturally when sufficient oxygen, other electron acceptors such as nitrate and sulfate, and nutrients are available in the soil and ground water. The rate of natural biodegradation is generally limited by the lack of oxygen rather than by the lack of nutrients such as nitrogen or phosphorus.

Biodegradation of fuel hydrocarbons occurs when microorganisms catalyze the transfer of electrons from electron donors to electron acceptors during respiration. Electron donors can be organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons can be completely degraded or detoxified if they are used as the primary electron donor for microbial metabolism. Electron acceptors are elements or compounds that occur in relatively oxidized states and include oxygen,

nitrate, sulfate, manganese, ferric iron, and carbon dioxide. Microorganisms exhibit a preferential use of terminal electron acceptors when metabolizing fuel hydrocarbons (Bouwer, 1992). Dissolved oxygen is used first as the prime electron acceptor. However, once the available oxygen is depleted and anaerobic conditions dominate in the subsurface, anaerobic microorganisms can use other electron acceptors in the following order of preference: nitrate, sulfate, manganese, ferric iron, and finally carbon dioxide.

The supply of oxygen to unsaturated soil can be renewed by vertical diffusion from the atmosphere. The supply of oxygen and other electron acceptors to a shallow, fuel-contaminated aquifer can be renewed by the influx of upgradient flow and the vertical diffusion of oxygen from the unsaturated soil zone into the ground water (Borden and Bedient, 1986). The rate of natural biodegradation in unsaturated soil and shallow aquifers is largely dependent upon the rate at which oxygen and other electron acceptors enter the contaminated media.

3.2.1 Biodegradation of Soil Contamination

The rate of vertical diffusion of oxygen into unsaturated, contaminated soil is a function of both the air permeability of the soil and the concentration gradient between the ambient atmosphere and the soil. In general, downward natural diffusion processes are rate-limiting and do not substantially enhance potential natural biodegradation processes within unsaturated soils. Natural biodegradation is not expected to rapidly reduce soil contamination. It is possible, however, to optimize both of these conditions by introducing oxygen into the unsaturated soil via a low-rate injection system. This innovative technology, called bioventing, supplies oxygen to soil bacteria employed in the biodegradation of fuel hydrocarbons. The radius of influence of each injection system point depends upon the operational parameters of the engineered bioventing system and the physical, chemical, and biological characteristics of the contaminated, unsaturated soil. The positive influences of oxygenating shallow unsaturated soil are considered an engineered source removal technology. Results of bioventing pilot testing at Area D are described in Section 4.

3.2.2 Biodegradation of Dissolved-Phase Contamination

Several well-documented and widely-accepted numerical models are available for modeling the fate and transport of fuel hydrocarbons under saturated conditions and accounting for the influences of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. The positive effect of these processes on reducing the actual mass of fuel-related contamination dissolved in ground water has been termed intrinsic remediation. In some cases, intrinsic remediation will reduce the dissolved-phase contaminant concentrations to below concentration levels warranting remedial action (i.e., trigger or screening levels), even if little or no source removal/reduction is implemented. In situations where intrinsic remediation will not reduce contaminant concentrations to below these levels, it may be possible to negotiate less stringent, site-specific final remediation goals that are still protective of human health and the environment given the type and magnitude of exposures most representative of current and potential future site conditions.

The advantages of intrinsic remediation include: (1) contaminants are transformed to innocuous byproducts (e.g., carbon dioxide and water), not just transferred to another phase or location within the environment; (2) current pump-and-treat technologies are energy intensive and generally not as effective in reducing residual contamination; (3) the process is nonintrusive (i.e., involves minimal drilling and support equipment) and allows continuing use of the land during

remediation; (4) current engineered remedial technologies may pose a greater risk to potential receptors than intrinsic remediation because contaminants may be transferred into the atmosphere during remediation activities; and (5) intrinsic remediation is far less costly than conventional, engineered remedial technologies. The main limitation of intrinsic remediation is that it is a long-term solution which requires regular monitoring to confirm its progress.

To estimate the impact of natural biodegradation on the fate and transport of BTEX compounds in ground water at a site, two important lines of evidence will be demonstrated as part of this project (Wiedemeier et al., in progress). The first is soil and ground water monitoring to document the ongoing biodegradation of contaminants. Dissolved-phase concentrations of biologically-recalcitrant tracers found in most fuel contamination are used in conjunction with aquifer hydrogeologic parameters such as ground water seepage velocity and dilution to demonstrate that a reduction in the total contaminant mass is occurring at the site. The second line of evidence involves the use of chemical analytical data in mass-balance calculations to show that a decrease in contaminant and electron acceptor (e.g., oxygen, nitrate, sulfate) concentrations can be correlated to increases in metabolic fuel degradation byproduct concentrations (e.g., carbon dioxide, methane, ferrous iron). With this site-specific information, the Bioplume II computer model can be used to simulate the transport of dissolved-phase BTEX compounds under the influence of natural biodegradation. Microcosm studies will not be a component of this field test.

The Bioplume II model is based upon the US Geological Survey (USGS) two-dimensional (2-D) solute transport model MOC, which has been modified to include a biodegradation component that is activated by a superimposed plume of dissolved oxygen. However, as part of this demonstration project, the biodegradation of fuel contamination will be activated by a superimposed plume of both oxygen and nitrate. Work completed as part of the Natural Attenuation (Intrinsic Remediation) demonstration program, also sponsored by AFCEE, suggests that these compounds are the primary electron donors at a fuel-contaminated site based on both thermodynamic and kinetic considerations. Use of both oxygen and nitrate in the Bioplume II model should provide a better estimate of the effectiveness of natural attenuation processes at the site in minimizing contaminant migration and reducing contaminant mass and toxicity. Use of both primary electron acceptors should also provide a better estimate of response time. Use of oxygen as the only electron acceptor can seriously underestimate the effects of natural degradation processes. The impact of including both in the Bioplume II model for this site may be a reduction in the source removal activities and time required to achieve site-specific remediation goals.

Bioplume II solves the USGS 2-D solute equation twice, once for hydrocarbon concentrations in the ground water and once for the electron acceptor plume. The two plumes are then combined using superposition at every particle move to simulate biological reactions between fuel products and the electron acceptors. Using even the most realistic worst-case data, Bioplume II generally predicts very limited migration of BTEX plumes due to natural attenuation processes. Bioplume II has been used to simulate the potential effectiveness of intrinsic remediation at several sites (e.g., Wilson et al., 1986; Chiang et al., 1989; Rifai et al., 1988; Malone et al., 1993; Wiedemeier et al., 1993).

The risk-based approach to remediation is aimed at providing scientific evidence in support of the positive effects of intrinsic remediation and other innovative source removal technologies.

The type and magnitude of these effects will be factored into the development of a final remedial alternative for the site. It is likely that intrinsic remediation alone will be insufficient at many fuel hydrocarbon-contaminated sites to reduce or eliminate contaminant migration and receptor risks. Other innovative source removal technologies, such as bioventing, will be included in the fate and transport calculations, risk analysis, and remedial design as necessary to ensure that the final remedial alternative will protect current and future receptors from adverse exposures to any site-related contamination (e.g., soil gas, soil, and ground water). Section 5 provides more detail on how quantitative models such as Bioplume II will be used to assess how well various remedial technologies eliminate or reduce contaminant migration and receptor risks.

3.3 OTHER QUANTITATIVE FATE AND TRANSPORT MODELS

The Summers model can be used to evaluate the potential impact of contaminated soil on ground water quality via downward precipitation infiltration (EPA, 1989a). This model may be useful to determine the potential for cross-media contamination, which may act as a continuing source of ground water contamination. The Summers model assumes that a percentage of precipitation at the site will infiltrate and desorb contaminants from the soil based on equilibrium partitioning between soil and liquid phases. Application of a fuel/water partitioning model such as that developed by Bruce et al. (1991) may also be required to provide a conservative estimate of how free-phase JP-4 jet fuel dissolves into ground water.

Soil gas concentrations cannot be directly used to assess potential air impacts without first accounting for VOCs diffusing upward through the vadose zone and their dilution in the atmosphere or air exchanges in buildings. ES will use flux isolation chambers to collect air samples from the ground surface at several locations throughout the area. These actual flux samples taken over areas of known soil contamination will be used to estimate concentrations of VOCs entering the atmosphere and potentially entering occupied buildings via diffusion. Preferential soil gas migration routes (e.g., utilities) will also be considered, as necessary. Additional details on soil flux methods are included in Section 4. Several air diffusion and dispersion models recommended by the EPA (1992c) are available to determine air concentration levels in the atmosphere at several exposure points and accumulating in buildings. Actual flux concentrations will be coupled with a distance-related attenuation/dispersion equation to estimate the concentration in the air that an off-site receptor may reasonably be expected to inhale. To estimate VOC concentrations in the atmosphere due to molecular diffusion through contaminated soil, this flux rate will be incorporated into a simple virtual upwind point-source dispersion equation recommended by the EPA to characterize potential air quality impacts (EPA, 1981 and 1992c). Because this is an active fuel transfer station, the relative contribution of soil gas contamination must be compared to routine VOC emissions from fueling activities.

To determine if soil and ground water concentrations could present a threat to individuals who may work or reside within buildings constructed on or adjacent to Area D, it may be necessary to use a simple diffusion/intrusion model to estimate the average annual VOC concentration that could accumulate in buildings due to upward contaminant flux from soil. The results of the flux monitoring described previously are then used as the input parameters for this model, which minimizes the effects of dispersion under atmospheric conditions by containing the flux within a structure. All of these models have been used successfully at many sites to quantitatively estimate the fate, transport, and impact of soil and ground water contamination on air quality. Because

this is an active fueling area, "background" concentrations of VOCs must be statistically verified to accurately account for VOCs emitted from soil contamination.

SECTION 4

PROPOSED SITE CHARACTERIZATION ACTIVITIES

To facilitate development and implementation of a risk-based remedial action for Area D, additional site-specific environmental media data will be collected. Soil gas, soil, and ground water will be sampled to (1) delineate the nature and extent of contamination, (2) support fate and transport analyses, (3) develop appropriate exposure-point concentrations to compare to final remediation goals, and (4) evaluate and design an appropriate remedial alternative for the site. A sufficient number of samples from background and contaminated areas will be collected and analyzed for individual and indicator compounds to accurately assess the risk to human health and the environment posed by the site and to demonstrate the attainment of final cleanup levels.

Noncompound-specific analytical procedures (e.g., TRPH) will be used as screening methods to aid in the determination of the lateral and vertical extent and volume of contaminated media at Area D. These noncompound-specific analyses will be supplemented with compound-specific analyses. Development of a risk-based remedial alternative for Area D will require an analysis of the potential chemical-specific threats posed to human health and the environment by individual compounds. Therefore, analytical data collected for the site will include a determination of the presence and concentration of individual chemicals.

4.1 GENERAL DATA NEEDS

Several data needs were identified as a result of developing the CSM for Area D and assessing the input requirements for the quantitative fate and transport models. These data are necessary to prepare an EE/CA in support of a risk-based remedial action for Area D. Existing information on potential ecological receptors at Area D will be collected from base personnel. Additional soil gas, soil, and ground water sampling will be performed. New ground water monitoring wells and bioventing wells will be installed. Aquifer testing and limited source removal technology feasibility analyses will also be completed. Any additional existing information not incorporated into this work plan will also be reviewed and used to the extent practicable to evaluate and design an appropriate remedial alternative for Area D which eliminates or abates risks to human health and the environment to the maximum extent practicable. The site characteristics listed below will be determined during the field work phase of the risk-based approach to remediation.

Soil gas measurements will be used to determine the following site characteristics:

- Air-filled porosity of the first 2 feet of soils;
- Estimated flux rate of VOCs to the surface, if any;
- Efficiency of ongoing bioventing pilot-scale test in reducing soil gas BTEX;

- Soil gas oxygen concentrations by depth (current and prior to bioventing tests);
- Soil gas carbon dioxide concentrations by depth (current and prior to bioventing tests); and
- Concentrations of TVH and the BTEX compounds, by depth (current and prior to bioventing tests).

Characteristics of surficial soil, defined as the top 2 feet of soil at the site, to be determined through soil sampling and analysis include:

- Estimated effective porosity and air permeability;
- Total organic carbon (TOC) content and pH;
- Nature and extent of any surficial soil contamination; and
- Concentrations of TRPH and the BTEX compounds.

Vadose zone (unsaturated) and phreatic zone (saturated) soil characteristics to be determined include:

- Detailed stratigraphic analysis of subsurface media;
- Air-filled and/or effective porosity;
- Estimated moisture content (unsaturated only);
- TOC content and pH;
- Concentrations of TRPH and the BTEX compounds;
- Estimated vertical extent of free product smear zone;
- Radius of oxygen influence of existing bioventing pilot system; and
- Estimation of fuel biodegradation rates within the bioventing radius of influence.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the ground water surface;
- Depth from measurement datum to the base of the shallow saturated zone (i.e., the top of the competent Pierre Shale) where feasible;
- Location of potential ground water recharge and discharge areas;
- Hydraulic conductivity as estimated through slug tests; and
- Dispersivity (estimated).

Physiochemical hydrogeologic characteristics to be determined include:

- Determination of extent and thickness of free product, if any;
- Dissolved oxygen, sulfate, and nitrate/nitrite concentrations;
- Dissolved carbon dioxide, total alkalinity as carbonate and bicarbonate, methane concentrations, and ferrous iron;
- Concentrations of each of the BTEX compounds and screening for naphthalene;
- Temperature;
- Specific conductance;
- TOC content and pH; and

- Chemical analysis of free product, if any, to determine the mass fraction of BTEX and possible PAH compounds.

Table 4.1 lists the chemical analytical protocol for each of the environmental medium to be sampled in support of a risk-based remedial design for Area D. This table also presents the detection limits required to support quantitative fate and transport analyses and calculation of exposure-point concentrations to compare to final remediation goals. Additional site-specific data necessary to support preparation of the EE/CA include (1) general climatic data, including prevailing wind speed and direction, average precipitation (as snow and rain), and temperature range; (2) existing and proposed land use plans for portions of Ellsworth AFB, including Area D and downgradient environs; (3) presence or suspected presence of sensitive subpopulations such as threatened or endangered species, or special-concern habitats; (4) ground water well locations and use information for areas likely to be affected by ground water migration; and (5) additional site-specific data necessary to justify site-specific land-use and exposure assumptions.

4.2 SAMPLING STRATEGY

The existing bioventing pilot system at Area D, which consists of two bioventing wells and three monitoring points, will be turned off at least 14 days before initiation of field work described herein to ensure data are representative of passive (at equilibrium) conditions at the site. Field investigation efforts will be completed in the following sequence: (1) soil gas survey, (2) soil gas sampling for compound-specific analysis, (3) soil gas flux sampling, (4) drilling, soil sampling, and well installation in least contaminated areas, (5) drilling, soil sampling, and well installation in most contaminated areas, (6) well development, (7) collection of physical ground water data from least to most contaminated areas, excluding slug tests, (8) collection of ground water sample from least to most contaminated areas for chemical analyses, and (9) slug tests. Several of these activities can be conducted concurrently at the discretion of the ES site manager to expedite the field work phase of this project. However, care must be taken to minimize cross-contamination and other medium-specific effects that could complicate data evaluation. Appendix A to this work plan is the detailed site-specific SAP. Specific procedures and protocols for each type of field activity to be completed at Area D, including quality assurance requirements, are presented in this appendix.

4.2.1 Soil Gas Sampling

Shallow soil gas probes will be used to better define the aerial extent of soil gas contamination and the potential for lateral and upward diffusion of soil contamination in the soil-pore vapors at the site. The shallow soil gas probe will be pushed to a depth of approximately 2 to 3 feet bgs, soil gas will be withdrawn, and field screened for concentrations of TVH. The data collected using the shallow soil gas probes will be used to supplement soil gas measurements from permanent vapor monitoring points installed at Area D as part of the bioventing pilot test.

It is anticipated that 10 to 15 temporary soil gas locations will be sampled in a grid covering the known area of contamination at Area D. These soil gas locations are indicated on Figure 4.1. The results of this non-compound-specific survey will be used to identify the three to four

TABLE 4.1

SOIL GAS, SOIL, AND GROUND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Matrix: Soil Gas

Analysis	Method	Required Detection Limit	Field or Laboratory	Analysis Classification *	Data Use
Carbon dioxide content	Direct reading meter	0.2%	F	A	To determine carbon dioxide gradient with depth and to infer biological degradation of fuel- related compounds.
Oxygen content	Direct reading meter	0.2%	F	A	To determine oxygen gradient with depth, the presence or absence of aerobic degradation processes, and/or the effect of engineered systems on increasing oxygen content in soil.
Fuel hydrocarbon vapor content	Total combustible hydrocarbon meter	1 ppmv	F	A	A field screening method to determine extent of soil contamination, the need for source removal, and the effect of source removal techniques on soil contamination.
Benzene	EPA TO-3	0.01 µg/L	L	B	Quantitative analysis to determine the nature and extent of soil contamination, the potential for adverse air quality effects, the need for source removal, and the effect

TABLE 4.1 (Continued)

**SOIL GAS, SOIL, AND GROUND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA**

Matrix: Soil Gas

Analysis	Method	Required		Field or Laboratory	Analysis Classification*	Data Use
		Detection Limit				
Toluene	EPA TO-3	0.01 µg/L		L	B	of source removal techniques on specific compounds.
Ethylbenzene	EPA TO-3	0.01 µg/L		L	B	Same as benzene.
Xylene	EPA TO-3	0.05 µg/L		L	B	Same as benzene.
TVH	EPA TO-3	0.1 ppmv		L	B	Noncompound-specific analysis to determine the extent of soil contamination, the need for source removal, and the effect of source removal techniques at reducing fuel-related contamination.

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited.

TABLE 4.1 (Continued)

**SOIL GAS, SOIL, AND GROUND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA**

Matrix: Soil

Analysis	Method	Required Detection Limit		Field or Laboratory	Analysis Classification *	Data Use
Total combustible hydrocarbons	Direct reading meter	low	reading	F	A	A field screening method to determine the extent of soil contamination, the need for source removal, and the effect of source removal techniques on soil contamination.
Benzene	GC Method SW8020	10 µg/kg		L	B	Quantitative analysis to determine the nature and extent of soil contamination, the mass of contaminant present, the degree of weathering, the need for source removal, and the effect of source removal techniques on specific compounds.
Toluene	GC Method SW8020	10 µg/kg		L	B	Same as benzene.
Ethylbenzene	GC Method SW8020	10 µg/kg		L	B	Same as benzene.
Xylene	GC Method SW8020	30 µg/kg		L	B	Same as benzene.
Trimethylbenzene isomers	GC Method SW8020	10 µg/kg		L	B	Tracers to aid data evaluation on soil contamination and potential impact to ground water.
pH	E150.1	0.2		L	C	Aerobic and anaerobic processes are pH-sensitive.

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND GROUND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Matrix: Soil

Analysis	Method	Required Detection Limit		Field or Laboratory	Analysis Classification *	Data Use
TRPH	Modified SW8015	10 mg/kg		L	C	A noncompound-specific method to determine the extent of soil contamination, the need for source removal, and the effect of source removal techniques on soil contamination.
TOC	Modified SW9060	20 mg/kg		L	D	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of fuel-related compounds in ground water is dependent upon the amount of TOC in phreatic soils; the rate of release of fuel-related compounds from the source to ground water is in part dependent on the amount of TOC in the unsaturated soil.
Classification	ASTM D422	--		L	D	Aids evaluation of potential contaminant migration behavior and remedial technology effectiveness.

TABLE 4.1 (Continued)

**SOIL GAS, SOIL, AND GROUND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA**

Matrix: Soil

Analysis	Method	Required		Field or Laboratory	Analysis Classification *	Data Use
		Detection Limit	Limit			
Moisture	ASTM D2216	--		L	D	To determine effective porosity and ability of material to transport contamination as dissolved-phase; aerobic and anaerobic microorganisms require moisture.

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited.

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND GROUND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Matrix: Ground Water

Analysis	Method	Required Detection Limit	Field or Laboratory	Analysis Classification*	Data Use
Depth to water	Water probe	0.01 ft	F	A	Hydrogeological characterization; well development.
Thickness of product	Oil/water probe	0.01 ft	F	A	To determine extent of potential continuing source to ground water, the mass of source contamination, and the need for source removal.
Temperature	E170.1	0.2°C	F	A	Well development.
DO content	Downhole DO probe	0.2 mg/L	F	A	Data input to Bioplume II model; depleted levels generally indicate inhibited aerobic degradation and potential presence of anaerobic degradation processes; concentrations less than 1 mg/L correlate well to elevated dissolved- phase BTEX contamination.
pH	E150.1/direct reading	0.2	F	A	Aerobic and anaerobic processes are pH-sensitive.
Benzene	GC Method SW8020	1 µg/L	L	B	Primary compound-specific analytes used to estimate and monitor intrinsic remediation; used to determine nature and extent of contamination; the degree of

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND GROUND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Matrix: Ground Water

Analysis	Method	Required		Field or Laboratory	Analysis Classification*	Data Use
		Detection	Limit			
Toluene	GC Method SW8020	1 $\mu\text{g/L}$	L	B		weathering; and used to establish and demonstrate compliance with site-specific remediation goals.
Ethylbenzene	GC Method SW8020	1 $\mu\text{g/L}$	L	B		Same as benzene.
Xylenes	GC Method SW8020	3 $\mu\text{g/L}$	L	B		Same as benzene.
4-10 Trimethylbenzene isomers	GC Method SW8020	--	L	B		To monitor and correct for plume dilution effects in Bioplume II model setup.
Napthalene	HPLC Method SW8310	5 $\mu\text{g/L}$	L	C		To determine nature and extent of such contamination; the degree of weathering; and to establish and demonstrate compliance with site-specific remediation goals.
Alkalinity	Colorimetric E310.2	--	F/L	C		To verify that ground water samples are obtained from same system and to measure the buffering capacity of the aquifer.
Nitrate	Colorimetric E353.2	2 mg/L	F/L	C		Secondary substrate (electron acceptor) for microbial respiration if

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND GROUND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Matrix: Ground Water

Analysis	Method	Required		Field or Laboratory	Analysis Classification*	Data Use
		Detection Limit				
Sulfate	HACH SulfaVer 4	--		F	C	oxygen is depleted; data input to Bioplume II model.
Carbon dioxide	HACH RSKSOP 147	--		F	C	Potential substrate for anaerobic microbial respiration; will be used semi-quantitatively when evaluating intrinsic remediation.
				L		Carbon dioxide can be an electron acceptor for anaerobic microbial respiration; the presence of free carbon dioxide dissolved in ground water is unlikely given natural buffering capacities. If detected, concentrations will be compared to background levels to determine if they are elevated, which could suggest aerobic degradation.
Methane	RSKSOP 147	--		L	C	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis). If detected, concentrations will be compared to background levels to determine if

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND GROUND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Matrix: Ground Water

Analysis	Method	Required Detection		Field or Laboratory	Analysis Classification *	Data Use
		Limit				
Total hydrocarbons	GC Method SW8015	--		L	C	they are elevated, which could suggest anaerobic degradation.
						To estimate the extent of contamination and to monitor the reduction in fuel-related contamination due to natural attenuation.
Ferrous iron (Fe^{2+})	HACH 25140-25	0.06 mg/L		F	C	May indicate an anaerobic degradation process as a result of depletion of other electron acceptors such as oxygen and nitrate.
Aquifer slug test	Appendix A, Section A.5	--		F	D	Hydrogeologic characterization

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited.

LEGEND

- MONITORING WELL
- ◆ BOREHOLE
- - - JET FUEL LINES
- ++++ RAILROAD TRACKS
- Ⓢ PROPOSED SOIL GAS MONITORING LOCATION
- Ⓣ PROPOSED FLUX SAMPLING LOCATION

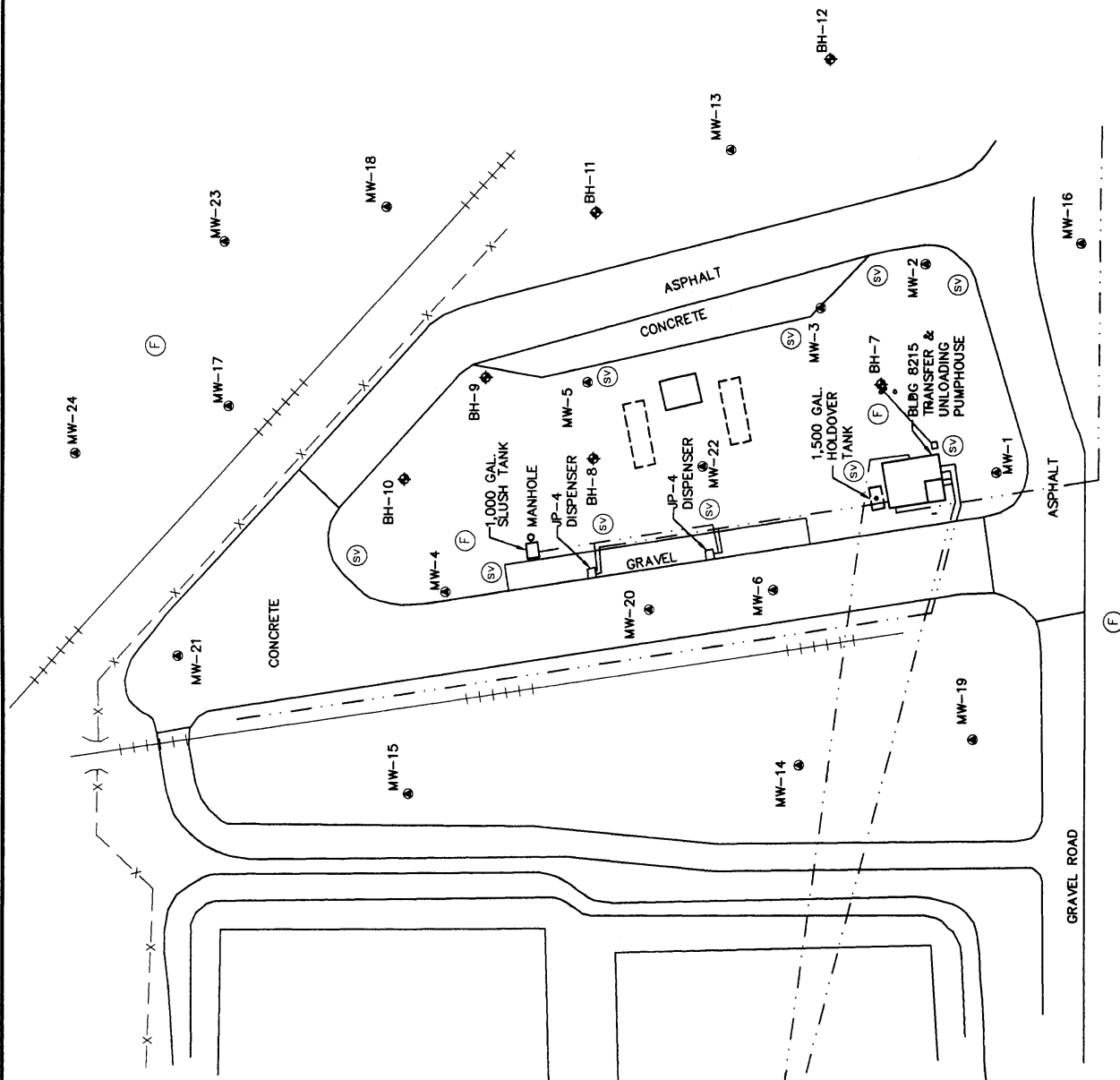


FIGURE 4.1

LOCATION OF ADDITIONAL SHALLOW GAS SAMPLES

EE/CA Work Plan
Risk-Based Approach to Remediation
Area D, Ellsworth AFB, South Dakota

ENGINEERING-SCIENCE, INC.
Denver, Colorado

locations that indicate the highest TVH measurements. These locations will be re-sampled and quantitatively analyzed for specific compounds as prescribed in Table 4.1. This two-phase soil gas survey is necessary to supplement existing and proposed non-compound-specific data with compound-specific results. TVH measurements are not sufficient to establish final remediation goals and design a remedial action for this site. Analytical soil gas samples will also be collected from the three existing vapor monitoring points (MPA, MPB, MPC) at the shallow depths (approximately 5 feet bgs) associated with the ongoing bioventing pilot study.

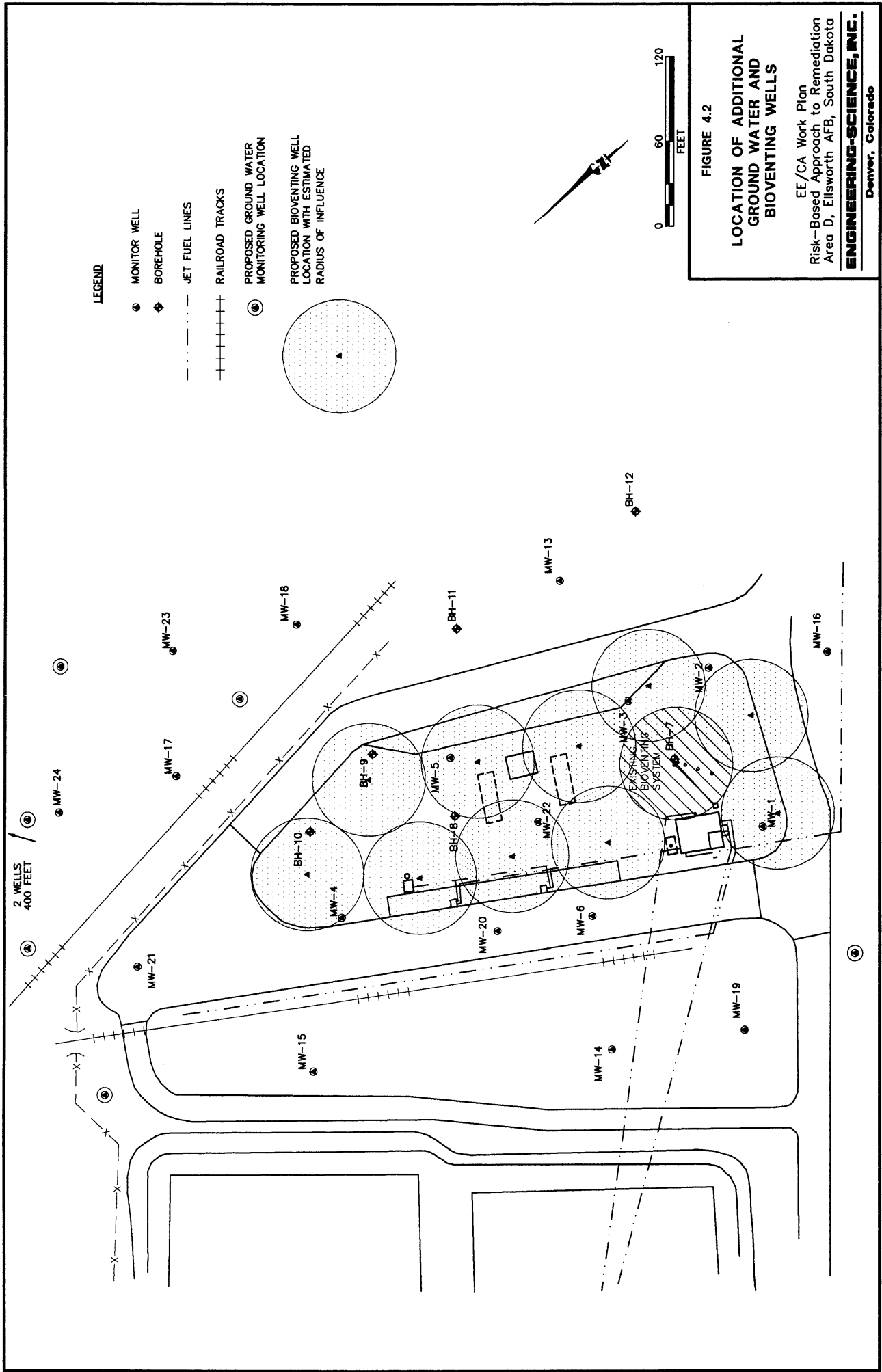
Flux sampling will also be conducted at four separate locations as shown in Figure 4.1. One of these locations is located in a background area with clean soil; one is located near the existing bioventing system to evaluate off-gas potential; one is located in an area of known soil and ground water contamination; and the last location is in an area of contaminated ground water and clean soil. The purpose of flux sampling in these areas will be to more accurately estimate the upward diffusion of VOCs from the soil into the atmosphere or potentially into buildings downgradient of the source area.

Soil gas and flux sampling will be conducted by qualified ES scientists and technicians trained in the conduct of soil gas shallow probe sampling and soil flux measurement. In addition, sampling personnel will have thoroughly reviewed this work plan, including Appendix A, prior to sample acquisition and will have a copy of both available onsite for reference.

4.2.2 Soil Sampling

Soil drilling and sampling will also be necessary to characterize the nature and extent of vadose and phreatic zone soil contamination at and immediately downgradient of Area D. Continuous soil cores will be taken at up to 16 locations, identified on Figure 4.2. If it becomes apparent during drilling activities that certain areas are not contaminated (based on field screening and previous data), borings will not be completed as wells. Permanent bioventing wells or ground water monitoring wells will be installed at each of the soil boring locations. Soil cores will be carefully evaluated to determine the stratigraphy of the sample location and the vertical depth of any measurable or visible contamination, possibly sampled for laboratory analyses, and then composited for headspace readings. One soil sample will be taken for analytical analysis per soil core. If it becomes apparent during the site investigation that all 16 borings will not be drilled, more than one sample may be collected from other contaminated borings. The soil sample selected for analytical analysis will be subsampled for chemical analysis from a 2-foot interval of core. The location of the required samples will depend on the extent of apparent soil contamination (as indicated by olfactory, visual, or volatile organic analyzer inspection). Soil borings which exhibit an interval of vadose zone soil contamination exceeding 2 feet will be converted to 4-inch-diameter bioventing air injection wells. Where appropriate borings with minimum soil contamination will be converted into 2-inch-diameter permanent ground water monitoring wells. Soil samples will be analyzed as prescribed in Table 4.1. The new soil sampling locations were selected to provide additional information about site stratigraphy, background concentrations, the extent of contamination within the grassy area, and the extent of ground water contamination downgradient of Area D.

Soil sampling will be conducted by qualified ES scientists and technicians trained in the conduct of soil drilling, sampling, and chain-of-custody procedures. In addition, sampling



personnel will have thoroughly reviewed this work plan, including Appendix A, prior to sample acquisition and have a copy of both available onsite for reference.

4.2.3 Ground Water and Product Sampling

New ground water monitoring wells will be constructed at each soil boring location not completed as bioventing air injection wells to further delineate the nature and extent of ground water contamination at the site. All new wells will be developed and sampled for laboratory analysis. Additionally, all existing wells that are found to be in good condition will be field screened as indicated in Table 4.1. Based on these field screening results, a maximum of five existing wells will be resampled for analytical analysis. All screening and analytical results will be used to further delineate probable source areas of contamination, the aerial extent of the dissolved-phase plume, and other hydrogeologic characteristics. All ground water monitoring wells and bioventing wells will be used to characterize physical ground water characteristics, such as depth to the ground water surface.

Emphasis will also be placed on defining the estimated extent of any remaining free fuel product that may act as a continuing source of soil gas and ground water contamination. Free product can be physically identified using an oil/water interface probe. Moreover, any ground water samples showing a benzene concentration equal to or greater than 178 mg/L (10 percent of its maximum solubility in water) will be operationally defined as potential fringe areas to oily-phase contamination (or underlying significant residual soil contamination).

Figure 4.2 identifies the locations of the new ground water monitoring wells. Ground water samples taken as part of this field effort will be analyzed as prescribed in Table 4.1. Data from previous investigations will be incorporated into the final analysis to the extent practicable to avoid unnecessary duplication of field results. At least one free-phase product sample will be recovered, if possible, and subjected to a full chemical constituent analysis to determine how free fuel constituents will partition into the ground water and contribute to the dissolved-phase plume.

4.2.4 Aquifer Testing

Aquifer testing will be completed using ground water monitoring wells MW-2, MW-22, MW-24, and two new monitoring wells to be installed during the field investigation. The exact two new wells to be used in aquifer testing will be determined in the field. Both bioventing wells and ground water wells can be used in this effort since both will be completed below the water table surface. The objective of these tests is to provide additional information on the hydrogeologic conditions specific to Area D and the areas suspected to be immediately downgradient of probable source areas. These field tests are necessary to support quantitative fate and transport analyses using the Bioplume II model.

4.2.5 Surface Water Sampling

No surface water samples will be taken in support of site characterization efforts at Area D. Additional existing information and data will be collected on surface water bodies in the area during the field investigation at Area D to confirm the apparent lack of hydrologic communication between ground water and surface water in the area.

4.3 SOURCE REMOVAL FEASIBILITY TESTING

It is anticipated that some level of soil or ground water remediation may be required to reduce the source of BTEX contamination migrating away from Area D and to reduce potential exposures to these compounds. Total BTEX concentrations as high as 382 mg/kg exist at Area D at various depths (ES, 1993). Because this soil contamination may represent a significant source of future ground water and soil gas contamination, some level of remediation may be warranted. Free product is also present in at least one area of the site (refer to Section 2).

In addition to intrinsic remediation, three active remediation methods will be considered during the EE/CA process. The three technologies are *in situ* bioventing of soils, limited free product recovery, and air sparging to promote VOC removal from the ground water and to add dissolved oxygen (DO) to the aquifer. Additional data is required to complete an accurate evaluation of these source removal methods.

4.3.1 Initial Bioventing Results

Bioventing is an innovative technology which uses low rates of air injection to supply oxygen to soil bacteria employed in the biodegradation of fuel hydrocarbons. The Air Force has successfully used bioventing for remediation of several JP-4 spill sites (Downey et al., 1993). A bioventing pilot test was initiated at Area D in August 1993 to determine the feasibility of using this technology for reducing BTEX and total petroleum hydrocarbons in contaminated soils (ES, 1993). Two air injection vent wells (VW-1 and VW-2) and three vapor monitoring points (MPA, MPB, and MPC) were installed near soil boring BH-7 (Figure 2.2).

Test procedures outlined in the Air Force bioventing protocol document (Hinchee et al., 1992) were followed, and included an air permeability test, oxygen influence test, and *in situ* respiration test. Results of the air permeability test indicated an average soil permeability of 1.3 darcys with a pressure influence extending at least 25 feet from the air injection well at a soil depth below 10 feet bgs. Air flow through coarse-grained soils 10 to 17 feet bgs was also observed, as was an increase in soil gas oxygen. A second vent well, screened from 5 to 10 feet bgs, was installed to remediate potential contamination in the lean clay layer at Area D. Pressure and oxygen influence were lower in this tighter soil above the coarse sand and gravel. However, a beneficial amount of pressure and oxygen influence was seen in the monitoring points at approximately 5 feet bgs.

Initial soil gas measurements indicated depleted oxygen conditions in soils below approximately 10 feet bgs. Surficial soil and vadose soils above this level had oxygen levels typical of clean soils. Test results indicate that the depleted oxygen below 10 feet bgs was limiting the rate of biological fuel degradation. The biological uptake of oxygen by soil bacteria was measured at both the 10- and 14-foot depth interval by injecting air into vapor monitoring points and then measuring the uptake of oxygen by soil bacteria. Rapid uptake was observed at all points indicating a significant population of hydrocarbon-degrading bacteria in the soil. Based on oxygen uptake rates, potential hydrocarbon degradation was estimated at 1,510 to 2,720 mg of fuel per kg of soil per year (ES, 1993).

This pilot-scale system is currently undergoing extended testing. A respiration test performed in April 1994 indicated that microbial respiration was continuing in the deeper soil intervals. During this test it was apparent that the radius of oxygen influence was approximately 20 feet

throughout the entire soil profile. The system is scheduled for final testing in September 1994. At this time, confirmatory soil and soil gas samples will be collected.

The performance of the bioventing system will be analyzed as part of the field work phase of this demonstration at Area D. The radius of oxygen influence will be verified in the deep (>10 feet bgs) and shallow (approximately 5 feet bgs) vapor monitoring points. Soil gas will be analyzed to estimate the reduction in soil BTEX that has occurred during the first year of pilot testing.

4.3.2 Free Product Recovery

If analysis reveals that a significant BTEX source remains in free product, it is likely that additional product recovery will be required in the source area. To date, no free product recovery activities have been attempted at Area D. During future fieldwork, ES will carefully examine the saturated zone in all new boreholes to determine if free product extends beyond the well MW-6 area. Bail down tests will be performed at any well containing free product to determine the rate of free product recovery that may be feasible at this site.

4.3.3 Biosparging Test

Biosparging involves the injection of air into saturated soils with the purpose of increasing DO levels and removing a portion of the BTEX from the source area groundwater through volatilization. Biosparging is under consideration at this site because initial measurements indicate that less than 2 mg/L of DO is available throughout most of the source area.

A single sparging point will be established near MW-1 to measure the potential upgradient and downgradient impact of air injection. The sparging point will be constructed of 1-inch, Schedule 80 PVC with a 2-foot screened interval placed at a depth of 18 to 20. An oilless, rotary-vane compressor will be used to inject air at an estimated 3 to 5 standard cubic feet per minute (scfm) into the shallow aquifer. The required injection pressures will be measured for various flow rates. Initial and daily DO readings will be made at MW-1 to estimate the radius of oxygen influence from a single sparging point. Data from this test will be used in the event that a larger biosparging system is required to provide additional oxygen to the shallow aquifer to promote more rapid biodegradation of BTEX compounds.

SECTION 5

REMEDIAL OPTION EVALUATION AND EE/CA REPORT

Upon completion of the field work in support of the risk-based approach, a quantitative source and release analysis using simple partitioning models and Bioplume II will be completed to determine the fate and transport of fuel-hydrocarbon contamination at the site and to estimate the effectiveness of intrinsic remediation. For example, the Bioplume II model will be used to investigate whether natural attenuation is occurring at the site, and if so, to what extent this process is minimizing contaminant migration. Based upon model predictions of contaminant concentrations and distributions in various media through time, an exposure pathway assessment will be conducted. If the model predictions suggest that contamination may exist at or migrate to an exposure point, the exposure pathway will be considered complete. To identify the type and magnitude of remediation that may be required to protect human health and the environment, appropriate numerical remediation goals for each environmental medium and COC that are protective of human health and the environment will be identified. Data from the models used to determine whether an exposure pathway may be complete will also be used to estimate exposure-point concentrations using the guidance developed by EPA (1992b) concerning reasonable maximum exposure concentrations.

A qualitative screening of the various remedial technologies will be conducted to narrow the list to only those that are likely to address the principal threats posed by the site. These remedial technologies will then be combined as necessary to create a remedial alternative (e.g., alternative 1: bioventing, intrinsic remediation, long-term monitoring, and deed restriction recordation). An iterative, quantitative evaluation of the effectiveness of these final remedial alternatives in achieving these site-specific remediation goals will then be completed.

5.1 EE/CA OBJECTIVES

The objectives of this demonstration project and the EE/CA are to evaluate, select, design, and implement the remedial alternative that:

- Meets the cleanup goals for the site,
- Is permanent or achieves the highest degree of long-term effectiveness possible, and
- Is cost effective in that it achieves the best balance between long-term effectiveness and cost.

The EE/CA prepared as part of this project will also provide a quantitative estimate of any risks posed by existing contamination as well as risks posed by residual contamination after implementation of the remedial option. The EE/CA will contain complete information on all

aspects of the final remedial alternative recommended for the site, including quantitative and other evaluation data, long-term monitoring requirements, and any long-term land use restrictions.

5.2 MAJOR COMPONENTS OF THE EE/CA

The following sections briefly present the major components of an EE/CA. The EE/CA report will contain detailed information on field and laboratory analytical results; quantitative source, release, fate, and transport analyses; exposure-point concentrations; receptors; toxicity data; risk characterization information; identification of appropriate remediation goals; and the factors affecting and methods used to evaluate potential remedial alternatives for the site. The EE/CA will also recommend and present a design for the most appropriate remedial alternative for the site. Construction of required source removal systems will begin immediately following base and regulatory approval of the EE/CA report.

5.2.1 Data Presentation

The EE/CA report will be structured to clearly and concisely present the approach and results of each of the major steps completed to select, design, and implement an appropriate remedial alternative for the site which minimizes risks to human health and the environment to the extent practical. Figure 5.1 presents an example EE/CA report outline that will guide the development of data and supporting text. The EE/CA report will be structured to place emphasis on the results of field work, risk analysis, and remedial alternative evaluation. Detailed information on the methodologies used in each of these steps will be contained in appendices to the EE/CA report. This approach should streamline the final report to focus on the results of the evaluation. In this way, regulators and other decision-makers will not have excessive documentation to review to determine whether the recommended remedial alternative meets the stated objectives of the project.

5.2.2 Data Evaluation and Modeling

Data from field work conducted in support of the risk-based remediation project that will be used in quantitative analyses will be gathered and sorted by environmental medium. Any analytical data used in this demonstration project will be evaluated in terms of their quality. 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 evaluation will be a data set appropriate to support quantitative fate and transport analyses and risk analysis. The data evaluation methods defined by EPA (1989b) in OSWER Directive 9285.7-01a, *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual* (EPA/540/1-89/002), and OSWER Directive 9285.7-09a, *Guidance for Data Usability in Risk Assessment* (EPA, 1992a) will be used as appropriate. By using the analytical methods and quantitation limits defined in this work plan (see Table 4.1), the data collected during the field work phase of this demonstration project are designed to satisfy the rigorous data requirements of quantitative fate and transport modeling and risk analysis. Results of the data evaluation will be summarized in the EE/CA report. Data will be used as input parameters to the various quantitative models discussed in Section 3.2 and 3.3 and, as necessary, to explore potential exposure pathways that may or will be completed at the site. Models which require a single-point concentration value (e.g., air dispersion) will use

FIGURE 5.1

**EXAMPLE EE/CA REPORT OUTLINE
RISK-BASED APPROACH TO REMEDIATION
AREA D, ELLSWORTH AFB, SOUTH DAKOTA**

Executive Summary

- 1.0 Introduction**
 - 1.1 Purpose and Scope
 - 1.2 Site Background
 - 1.3 Report Organization
- 2.0 Site Description**
 - 2.1 Physical Setting
 - 2.2 Nature and Extent of Contamination
 - 2.2.1 Previous Investigations
 - 2.2.2 Recent Data
 - 2.3 Indicator Analyte Data
 - 2.4 Discussion of Evidence of Intrinsic Remediation
- 3.0 Evaluation Methods and Criteria**
 - 3.1 Remedial Action Objectives
 - 3.2 Potential Exposure Pathways for Human/Ecological Receptors
 - 3.3 Site-Specific Fate and Transport Models
 - 3.4 Site-Specific Cleanup Goals
 - 3.5 Review of Evaluation Criteria
 - 3.5.1 Protectiveness
 - 3.5.2 Implementability
 - 3.5.3 Cost
- 4.0 General Description of Potential Remedial Alternatives (Examples)**
 - 4.1 Alternative 1: Intrinsic Remediation/Long-term Monitoring
 - 4.2 Alternative 2: Bioventing to Remove Soil Source(s)/Intrinsic Remediation/Long-Term Monitoring
 - 4.3 Alternative 3: Remove Free Product/Intrinsic Remediation/Long-Term Monitoring
 - 4.4 Alternative 4: Soil Vapor Extraction/Ground Water Pump and Treat
- 5.0 Comparative Analysis of Remedial Alternatives**
 - 5.1 Protectiveness
 - 5.2 Implementability
 - 5.2.1 Technical
 - 5.2.2 Administrative
 - 5.3 Cost
 - 5.3.1 Capital Costs
 - 5.3.2 Operating Costs
 - 5.3.3 Present Worth Cost
- 6.0 Recommended Remedial Alternative**
- 7.0 References**

Appendix A: Data Evaluation for Risk Analysis

Appendix B: Development of Site-Specific Cleanup Goals

Appendix C: Quantitative Exposure Assessment Data (Model Simulations)

exposure-point concentrations developed using the EPA (1992b) *Supplemental Guidance to RAGS: Calculating the Concentration Term* (Publication 9285.7-081). This guidance is designed to assist in the development of an exposure concentration that represents the highest exposure that could reasonably be expected to occur for a given reasonable maximum exposure duration. This value is intended to account for both the uncertainty in environmental data and the variability in exposure parameters.

More complex models such as Bioplume II do not require single-point values. In these cases, unadjusted field data will be used to simulate the fate and transport of contamination in the ground water. If model predictions demonstrate that an exposure pathway involving ground water is not complete, it will be unnecessary to develop exposure-point concentrations to compare to appropriate cleanup goals. Conversely, if model predictions show that an exposure pathway involving ground water is or may be completed, data from model sensitivity runs at the point of exposure will be statistically evaluated to determine a single-point exposure concentration. The goal of this approach is to factor model uncertainty into the development of an exposure-point concentration that is most representative of the reasonable maximum exposure at the site. Again, EPA (1992b) guidance will be followed to develop exposure concentration values suitable for comparison to appropriate cleanup concentration goals.

5.2.3 Method of Risk Analysis

The risk-based approach to remediation improves upon traditional approaches by using the tools of risk assessment to identify the remedial alternative that best balances risk reduction and remediation costs. The risk analysis to be completed in support of this project encompasses the four basic components of a traditional risk assessment: data evaluation, exposure assessment, toxicity assessment, and risk characterization. These components will be used to evaluate the long-term risks associated with the various remedial alternatives that could be used at a site (hence the name, risk-based approach). The risk analysis will then be used to identify which remedial alternative best addresses site-specific risks. The methods of risk analysis employed will be generally consistent with the risk assessment methods described in RAGS, Volume I (EPA, 1989b), and analogous to those used to evaluate long-term risks associated with various remedial alternatives. Figure 5.2 summarizes the risk analysis method.

5.2.3.1 Exposure Pathway Evaluation

As described in Section 3, an exposure assessment identifies the potential human and ecological receptors that could come into contact with site-related contamination and the pathways through which these receptors might be exposed. To have a completed exposure pathway, there must be a source of contamination, a mechanism of release, a receptor, and a route through which the contamination could reach the receptor. The risk-based approach to remediation is designed to use quantitative field data and models to characterize both the existing nature and extent of contamination and what effect various remedial technologies such as intrinsic remediation will have on the fate and transport of contaminants in the environment through time. The CSM presented in Section 3 of this work plan identifies potential sources and release mechanisms, current and potential future receptors, exposure points, and exposure routes that may be involved in current or future land-use scenarios for the site. This CSM was developed to

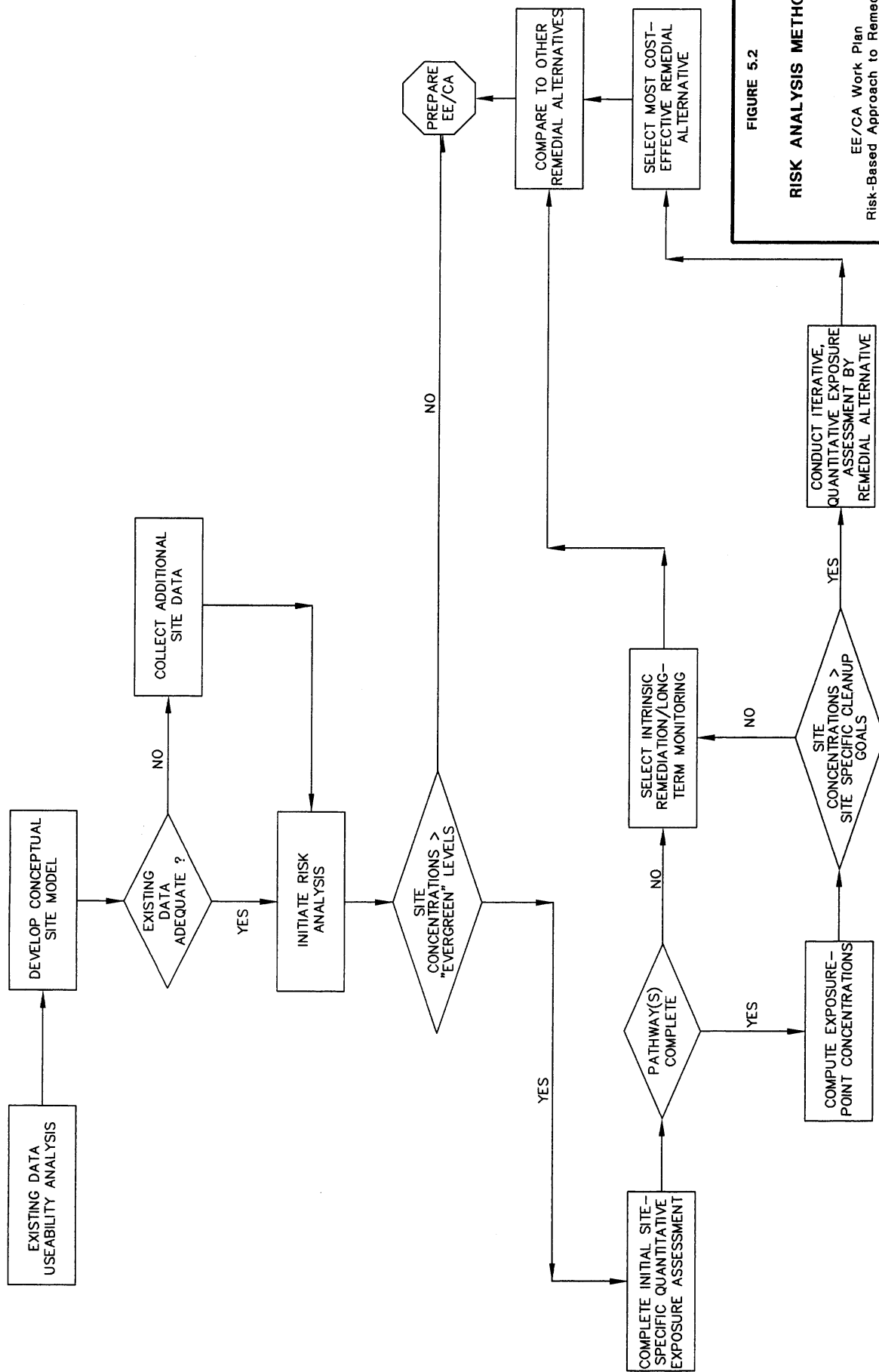


FIGURE 5.2

RISK ANALYSIS METHOD

EE/CA Work Plan
Risk-Based Approach to Remediation
Area D, Ellsworth AFB, South Dakota

ENGINEERING-SCIENCE, INC.

Denver, Colorado

ensure that adequate data are collected to support a quantitative evaluation of the potential for exposure pathway completion at the site.

Field data and model simulations which account for the physical setting and characteristics of the site will be used to estimate whether any exposure pathway is completed and, if so, to quantify the COC concentrations at the point of exposure. The method of risk analysis to be used as part of this demonstration project hinges on achieving remediation goals for each environmental medium.

If an exposure pathway is determined to be completed, the exposure assessment will be expanded to calculate exposure point concentrations. As discussed in Section 5.2.2, field data and model simulation results will be statistically evaluated using EPA (1992b) guidance on how to calculate a single-point concentration level that represents the highest concentration to which a receptor could reasonably be exposed given site conditions (i.e., the RME). Using modeled data in the calculation of the exposure-point concentration is designed to account for the positive effects of natural attenuation processes that may be operating at the site. This approach also appears to be consistent with that to be used to estimate potential future risks associated with base-wide shallow ground water at Ellsworth AFB (EA, 1994).

5.2.3.2 Identifying Cleanup Goals

To evaluate, select, and design an appropriate remedial alternative for the site, long-term target remediation goals must be defined. Achievement of these remediation goals should result in residual contaminant levels that are protective of human health and the environment. Use of these cleanup goals to screen remedial technologies early in the process will streamline the decision-making process. Chemical-specific cleanup goals for each environmental medium can either be based on promulgated standards such as MCLs or based on site-specific risks. Identification of site-specific criteria depend upon which chemicals are present at the site, which environmental medium are or may become contaminated, land-use assumptions, and exposure assumptions. One of the key objectives of the risk-based approach to remediation is to provide a more flexible and scientifically supportable basis for making remedial decisions. Identifying appropriate cleanup goals for a site depends on site-specific data on probable land use and how potential receptors can and cannot come into contact with site-related contamination.

The sources for toxicity information will be limited to IRIS (Micromedix Inc., 1994) and the Health Effects Assessment Summary Tables (HEAST) (EPA, 1994). No attempt will be made to develop toxicity values from any other sources as part of this demonstration. Any uncertainties associated with developing remediation goals will be identified and discussed in the EE/CA. The potential impact of these uncertainties on the development of appropriate remediation goals will also be qualitatively evaluated.

The risk-based approach to remediation provides a more flexible and scientifically supportable basis for making remedial decisions. Identifying appropriate cleanup goals for a site depends on site-specific data on probable land use and how potential receptors can and cannot come into contact with site-related contamination.

5.2.3.2.1 Air. Determination of air cleanup goals for a site depends on the current and probable land use of the area. For areas within or immediately downgradient of Area D which may be

available for residential use, air concentrations will not exceed an excess upperbound lifetime cancer risk of between one-in-10,000 (10^{-4}) and one-in-1,000,000 (10^{-6}) for known or suspected carcinogens. Air concentrations of any COCs which are systemic toxicants will not present an appreciable risk of deleterious effect during a lifetime or part of a lifetime. Nonsystemic toxicant effects are factored into risk-based cleanup goals through the use of a hazard index. A hazard index is the sum of all hazard quotients for a single or multiple systemic toxicants which affect the same target organ or act by the same method of toxicity. A hazard index of 1 or less indicates that no appreciable noncarcinogenic risk due to inhalation exists. For areas that are demonstrated to be unavailable for uncontrolled use (e.g., through institution controls), concentrations of contaminants in air (either during or after remediation) will not exceed either Occupational Safety and Health Administration (OSHA) permissible exposure limits, threshold limit values, or other criteria applicable to an industrial exposure setting.

5.2.3.2.2 Soil. Risk-based remediation goals may be the only human health comparison criteria appropriate for soil at the site, as no appropriate promulgated standards may exist. Human health risk-based remediation goals can be developed for all COCs by setting the carcinogenic target risk level at 10^{-6} and the hazard index at 1 for each group of the systemic toxicants which affect the same target organ or act by the same method of toxicity (EPA, 1991a).

Human health risk-based remediation goals for soil will be calculated using standard exposure assumptions appropriate for the exposure scenarios most representative of both current and potential future site conditions. The industrial land-use assumption will be used for sources areas within and areas immediately downgradient of Area D. The exposure pathways that are most likely to be incorporated into the soil remediation goals for the COCs include incidental ingestion of soil, inhalation of dust particulates, and inhalation of volatilizing COCs. In this way, the potential for cross-media contamination of air is included in the development of cleanup goals for soils. Standard default exposure variables recommended by EPA (1991d) will be used to develop risk-based soil cleanup goals.

Cross-media contamination of ground water from contaminated soil will also be factored into the development of soil cleanup goals to ensure that soil is remediated to a level protective of ground water quality. Soil cleanup goals will also be determined to protect air quality. Fate and transport models, such as the Summers model and the air dispersion model discussed in Section 3.3, may be incorporated into this analysis to ensure that the selected remedial alternative minimizes cross-media contamination.

Chemical-specific concentration goals for soils that are protective of potential ecological receptors can be estimated by using chemical-specific ecological comparison criteria such as certain toxicological values documented in the scientific literature intended to be environmentally protective. As noted earlier, however, there are few or no toxicological data for the COCs for terrestrial plants and animals. Although these contaminants may be bioavailable for uptake by plants and/or animals, VOCs generally do not bioaccumulate in tissues or biomagnify through the food web. However, available data will be screened to identify potential ecological comparison criteria for any potential ecological receptors. Observed or modeled concentrations at the point of exposure in the environmental media of concern (e.g., soil) will then be compared to available comparison criteria. If contaminant concentrations meet or exceed available comparison criteria

designed to be protective of ecological receptors, quantitative data will be used to determine the type and magnitude of remediation necessary to minimize risks.

5.2.3.2.3 Ground Water. Chemical-specific concentration goals for ground water can also be risk-based or based on promulgated standards, whichever are most appropriate for the site. Federal water quality and state drinking water standards are common promulgated remediation goals used to set ground water concentration goals. In addition, other types of laws, such as state antidegradation laws, may drive development of ground water remediation goals if they are accompanied by allowable concentrations of a chemical (i.e., qualitative direction is not equivalent to quantitative standards).

However, the shallow ground water underlying Area D and Ellsworth AFB is not currently used to meet potable water demands. Further, given the location of Area D on Ellsworth AFB, shallow ground water within the industrial source area and immediately downgradient of the site is not likely to be available for uncontrolled use in the future. Ground water underlying the source area and immediately downgradient of the site should not be classified as having beneficial use as a drinking water supply, suitable for human consumption, due to the land use restrictions imposed by site location and other institutional controls deemed necessary to prevent uncontrolled use of natural ground water resources on-base. Additionally, the limited hydrogeologic evidence at Area D suggests that this aquifer could not yield an adequate water source for even a small residence. Risk-based ground water cleanup goals will be developed to reflect site-specific conditions using the procedures described in EPA (1991a) OSWER Directive 9285.7-01B entitled *Human Health Evaluation Manual, Part B: Development of Risk-based Preliminary Remediation Goals*. EPA Directive 9481.00-6C will also be useful in developing risk-based ground water cleanup goals that ensure that the contaminant plume does not increase in size or concentration above allowable environmental exposure levels.

Ground water downgradient from this area will be designated as having potential future beneficial use as a drinking water supply. Point-of-compliance wells will be installed to monitor ground water quality over time at the furthest upgradient point where no controls on activities will be maintained. Ground water quality at and downgradient of the point-of-compliance will not degrade beyond allowable concentrations specified in 74:03:15:03 (SD DENR, 1992) as a direct result of Area D activities. The remediation approach for Area D will be sufficient to protect downgradient ground water resources in hydrologic communication with ground water underlying source areas within and immediately downgradient of Area D.

Section 3 of this work plan presents a more detailed discussion of probable land use in and downgradient of the site. This project will provide sufficient data to demonstrate that proposed ground water remediation goals, which may be area-specific, are consistent with the letter and intent of guidance on ground water concentration goals. All ground water remediation goals will also account for technology limitations.

5.2.3.2.4 Surface Water. It is possible that surface water standards may also govern the development of ground water concentration goals for Area D if the ground water migrates to and discharges into drainage culverts or other downgradient surface water bodies. However, as described in Section 2.3.4, it is not likely that ground water will impact any surface water bodies downgradient of the site. This exposure pathway is considered incomplete. Section 4 of this

work plan describes what data will be gathered at the site to support this determination. If the exposure pathway is incomplete, development of cleanup goals that are protective of surface water resources will not be necessary.

5.2.3.3 Risk Determination

The goal of this project is not to determine whether remedial action is warranted at the site, but rather to determine the type and magnitude of remedial action required to minimize risks to human health and the environment to the maximum extent practicable. The potential risks to human and ecological receptors will be determined by comparing the calculated exposure concentrations derived from quantitative fate and transport analyses to the cleanup goals identified to be protective of human health and the environment. If this comparison indicates that natural attenuation of site COCs is occurring and is sufficient to reduce the potential risks to human health and the environment, ES may recommend implementation of natural attenuation with long-term monitoring as the preferred remedial alternative. The EE/CA prepared to demonstrate the effectiveness of the intrinsic remediation will satisfy the requirements of a corrective action plan as specified in Chapter 74:03:28:21 (SD DENR, 1991).

5.2.4 Evaluation of Source Removal/Risk Reduction Options

To provide adequate data and analyses in support of the selection, design, and implementation of an appropriate remedial alternative for Area D, it will be necessary to critically evaluate single or combined remedial technologies in terms of long-term effectiveness, implementability, and cost. Field data, quantitative fate and transport modeling designed to explore the potential effectiveness of natural attenuation processes, and several other institutional and engineering technologies will be evaluated for their risk reduction potential. Combinations of institutional controls and cost-effective site remediation methods will be evaluated following the EE/CA process described in this section. Based on guidance from AFCEE, a minimum of three options will be evaluated for a site. Each option will be evaluated against three primary criteria: effectiveness in protecting human health and the environment, implementability, and cost.

Effectiveness - Each remedial alternative will be analyzed to determine how effectively it will protect both current and future receptors from potential risks associated with COCs. This analysis will be based on determining whether the remedial alternative can achieve and maintain final cleanup goals. Protectiveness will also include permanence and ability to reduce contaminant mass, volume, and toxicity. Section 5.2.3 provides a more detailed description of the risk methods that will be used to determine the effectiveness of protection.

Implementability - The technical implementation of each remedial option will be evaluated. The expected technical effectiveness of each remedial alternative will be described. Potential shortcomings and difficulties in construction, operations, and monitoring will be presented and weighed against perceived benefits. The administrative implementation (regulatory and community acceptance) of each remedial approach also will be discussed. This is an important element of the EE/CA, particularly when intrinsic remediation is determined to be the most cost-effective method of risk reduction.

Cost - The estimated cost of each remedial option will be presented. Both capital and operating costs will be estimated along with a present-worth cost estimate for the predicted

operating life of each option. Cost assumptions will be clearly stated, and the cost sensitivity of assumptions will be discussed.

It is important to note, however, that the most effective remedial technology or remedial alternative may not be the most cost-effective option for the site. Because the objective of this project is to identify, design, and implement the most cost-effective remedial alternative at Area D, it will be necessary to apply the test of cost effectiveness. A cost-effective remedial alternative is one that achieves the best balance between long-term effectiveness and cost of all the remedial alternatives which meet the cleanup objectives for the site. The test of cost effectiveness may be more extensive for a range of remedial alternatives which vary only in degree of long-term effectiveness, but which will all achieve the site cleanup goals. The remedial alternative which achieves the site cleanup goals at the lowest cost will be identified. The total cost for the other remedial alternatives will also be estimated, and all remedial alternatives will be ranked according to their degree of long-term effectiveness. The remedial alternative that provides the best balance between long-term effectiveness and cost would be the most cost effective.

The following sections describe the remedial options that will, at a minimum, be considered for Area D in accordance with the statement of work (SOW) and subsequent AFCEE project direction.

5.2.4.1 Intrinsic Remediation Only with Long-Term Monitoring

Fate and transport models described in Section 3.2 and 3.3 will be used to estimate the natural reduction of contaminants of concern due to biodegradation, adsorption, and dilution. The ability of this remedial option to naturally reduce risk under the scrutiny of long-term monitoring will be described. If sufficient risk reduction cannot be achieved through intrinsic remediation alone, the potential for unacceptable risk will be discussed along with institutional controls which could be implemented to eliminate or reduce contact between the COCs and any at-risk receptors.

5.2.4.2 Limited Source Removal

If the intrinsic remediation option does not provide adequate protection of human health or the environment, additional removal of the contaminant source will be required. Even if intrinsic remediation appears to be protective, the uncertainties of fate and transport models may necessitate that some level of active remediation be completed to reduce uncertainties associated with the long-term source of contamination. In these situations, the value of low-cost source removal technologies such as bioventing, free product removal, or biosparging will be evaluated. The selection of an appropriate source removal action will begin with a review of the site cleanup goals for soil and ground water. Using these cleanup goals, it will be possible to estimate the amount of additional source removal required to minimize risks to potential receptors and to protect environmental resources. In the case of downgradient ground water contamination, the Bioplume II data set will be modified to include the reduced source concentrations anticipated from the remedial option. The resulting reductions in soil and downgradient plume concentrations will then be compared against site-specific cleanup goals. Source removal will be increased until predicted concentrations are significantly less than the cleanup goals. In some cases, two or more source removal technologies will be integrated in this option.

5.2.4.3 Intensive Source Removal and Ground Water Pumping

Immediate reductions in contamination can be achieved through more intensive source removal options such as soil vapor extraction and the extraction and treatment of contaminated ground water. Although this intensity of treatment may not be required based on the current or future risks posed by site contaminants, AFCEE has requested that the benefits and additional costs of intensive treatment be evaluated in the EE/CA.

5.2.5 Selection of a Recommended Approach

Based on an evaluation of the protectiveness, implementability, and cost of each option, ES will recommend the option which provides the greatest protection for the lowest cost. If remediation of the source area is recommended, a conceptual design of the remediation system will be prepared and included in the EE/CA for Air Force and regulatory review. If intrinsic remediation is an integral part of the recommended option, a long-term monitoring plan will be developed to ensure both soil and ground water contamination are decreasing according to the remediation strategy.

5.2.6 Long-Term Monitoring Plan

Upon completion of the field work phase of this demonstration project, quantitative fate and transport models will be coupled with the CSM to complete an exposure assessment for the site. As described in this work plan, a tiered approach will be used to assess the potential effectiveness of various remedial alternatives at reducing or eliminating risks to potential receptors. If this analysis indicates that intrinsic remediation is sufficient to reduce the potential risk to human health and the environment, the most cost-effective remedial alternative for the site will be intrinsic remediation and long-term monitoring. A site-specific, long-term monitoring plan will be included as part of the EE/CA which specifies the location of confirmation, point-of-compliance (POC) wells, and other long-term monitoring wells and the sampling frequencies necessary to demonstrate long-term effectiveness and permanence of the selected remedial alternative.

Confirmation wells will be located immediately downgradient (i.e., within 1 or 2 years) of the existing plume and will provide for early confirmation of model and engineering predictions. The POC wells will be located further downgradient (e.g., along the property boundary; approximately 5 years downgradient of the current plume; 1 or 2 years upgradient of the nearest potential receptor of ground water contamination). The exact location of POC wells will be established in concert with regulatory authorities to be protective of any potential receptor. The long-term monitoring plan will specify which existing wells will be used to monitor the effectiveness of intrinsic remediation processes at the site. At a minimum, the wells to be included in long-term monitoring plans will be located upgradient of the source area, within the anaerobic treatment zone, and within the aerobic treatment zone. Confirmation and POC wells will also be included in the network of long-term monitoring wells for the site. The sampling frequency of the well network will depend on their exact location, risk reduction and other regulatory considerations.

If quantitative data analysis indicates that intrinsic remediation will be insufficient alone to minimize receptor risks, other innovative source removal technologies such as bioventing or biosparging will be evaluated. The reduction of source and dissolved COCs should result from additional remedial activities will be used in the quantitative fate and transport analyses for the

site. Thus the models will be used to predict exposure pathway completion and exposure point concentrations resulting from supplementing intrinsic remediation with other source removal technologies. Again, once the most cost-effective remedial alternative is identified, the EE/CA will include a long-term monitoring plan which will contain any recommended plans for extended tests and sampling required to demonstrate the anticipated long-term effectiveness and permanence of the selected remedial alternative.

Following the implementation of any required source removal technologies at the site, ES will operate the source removal system for a total of 600 days. At the end of the 600 days of treatment, ES will return to the site and resample soils in the source area to determine the degree of COC removal and evaluate the potential impact of source removal on the long-term fate and transport of dissolved or vapor phase contamination. A letter report will be prepared outlining the interim source removal results and the potential impact on the ground water plume, and making recommendations for continued source removal if required.

5.3 REGULATORY COORDINATION STRATEGY

The risk-based approach described in this work plan conforms to both EPA risk assessment guidance and verbal guidance received from representatives from SD DENR. On 18 May 1994, an initial coordination meeting was held in Pierre, South Dakota at the offices of the SD DENR to describe, and obtain general concurrence with, the risk-based approach for Area D. Representatives from AFCEE, Ellsworth AFB, SD DENR, and ES were present. The general approach was approved. Representatives from the SD DENR requested an informational copy of this work plan when it was available. Following AFCEE and base review of this work plan, an informational copy will be forwarded to Mr. Ron Holm of the SD DENR.

The EE/CA report will serve as the primary document for obtaining regulatory approval for the risk-based remediation approach. This document will contain all of the supporting data to satisfy the requirements of relevant EPA (1989-1993) risk assessment guidance material, and will provide sufficient evidence to state regulatory authorities to support the selection of the recommended remedial alternative. The EE/CA report will provide quantitative evidence of intrinsic remediation and develop final cleanup goals for each affected medium based on risk criteria. If source removal is required, the EE/CA report will provide a conceptual design that is sufficient in detail to gain regulatory approval to proceed with the remediation. A long-term monitoring plan will be provided to ensure that the predictions of fate and transport modeling can be verified and that COCs do not migrate at concentrations which could cause an unacceptable risk to human or ecological receptors. Confirmation and point-of-compliance wells will be established to verify that intrinsic remediation is occurring and that plume migration is limited.

Following AFCEE and base review of the draft EE/CA report, their comments will be incorporated into a final draft for regulatory review and approval. When the final draft is completed, AFCEE and ES will provide a technical presentation to base officials and regulatory agencies to familiarize them with the key findings and recommendations of the EE/CA report. Copies of the EE/CA report will be provided to regulators at the meeting, and a 30-day review will be requested.

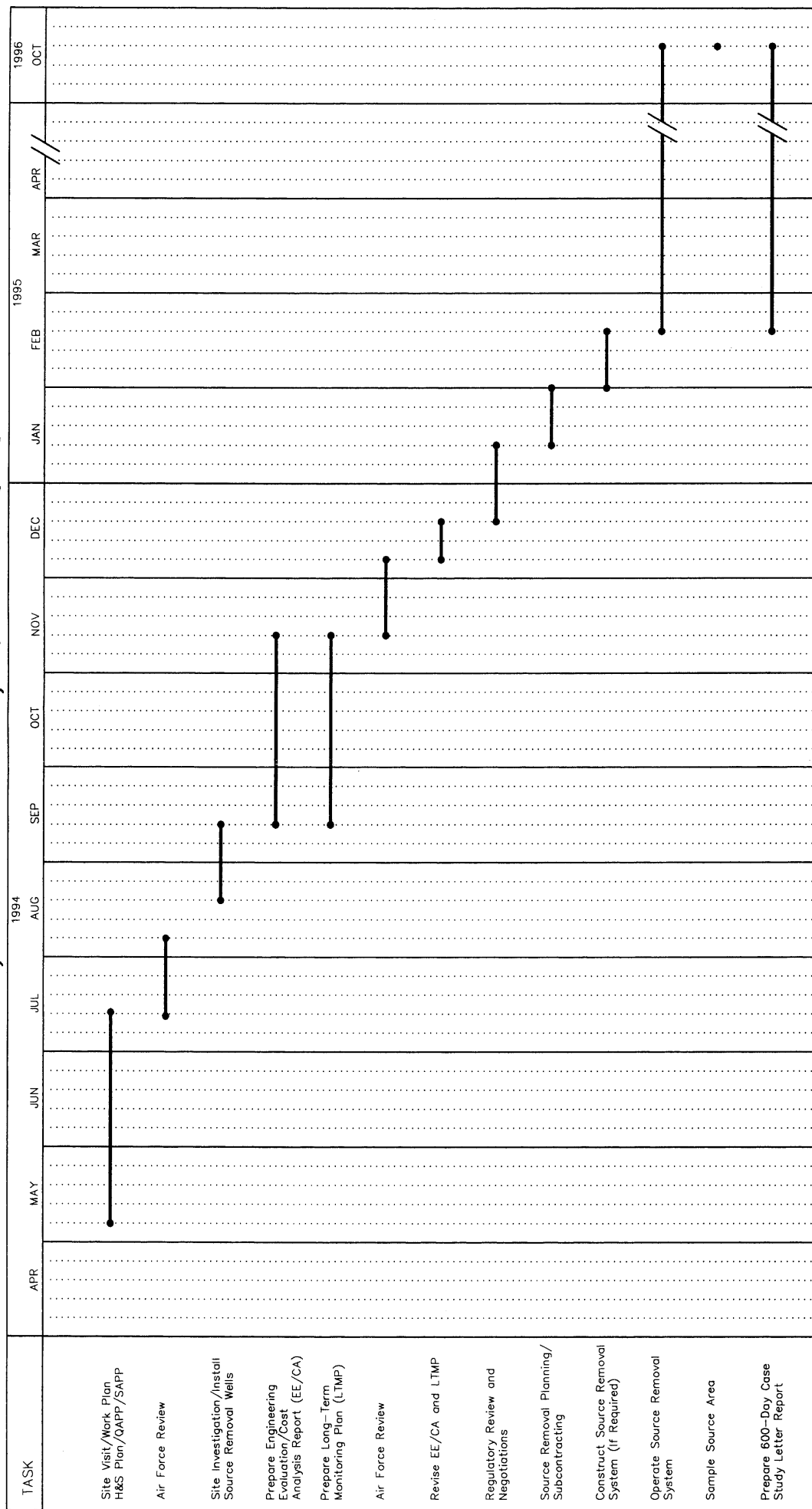
SECTION 6

PROPOSED PROJECT SCHEDULE

The timeline presented in Figure 6.1 details the proposed duration of and date of completion for each of the major tasks involved in evaluating, selecting, designing, and implementing a remedial alternative for Area D which minimizes contaminant migration and risks to potential receptors. Each of these major tasks is described in other sections of this work plan.

FIGURE 6.1

RISK-BASED DEMONSTRATION SCHEDULE AREA D, ELLSWORTH AFB, SOUTH DAKOTA



SECTION 7

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SITE SAMPLING AND ANALYSIS PLAN
FOR
RISK-BASED REMEDIATION DEMONSTRATION
AT AREA D, ELLSWORTH AFB, SOUTH DAKOTA

Prepared for:

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The purpose of this site-specific sampling and analysis plan (SAP) is to provide the procedures to be followed when collecting additional data in support of the risk-based approach to remediation at Area D. Details on analytical requirements, desired quantitation (detection) limits, and proposed sample locations are identified within section 4 of the work plan. Specific health and safety requirements are described in both the program health and safety (H&S) plan and the site-specific addendum (Appendix B). The need to collect additional samples to meet quality assurance requirements are described in the program quality assurance project plan (QAPP). Specific quality assurance sampling requirements for Area D 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.

Soil gas sampling is described in Section 1; soil flux sampling is described in Section 2; drilling, soil sampling, lithologic logging, and bioventing and ground water monitoring well installation procedures are described in Section 3; ground water sampling procedures are described in section 4; aquifer testing procedures are described in Section 5; and field quality assurance/quality control (QA/QC) samples are described in Section 6.

A.1 SOIL GAS SAMPLING

Soil gas will be used as an indicator of subsurface hydrocarbon contamination and to assess the feasibility of using bioventing to remove source contamination at the site. The use of soil gas to delineate potential subsurface contamination and to determine bioventing feasibility has several economic and technical advantages over more traditional drilling and soil sampling techniques. The labor and equipment cost can be significantly less than a conventional drilling and sampling team. Many new hydraulically driven, multi-purpose probes can be used for soil gas sampling. These probes can be advanced as quickly as conventional augers and do not produce drill cuttings which can require expensive analysis and disposal. Further, soil gas sampling can represent the average chemistry of several cubic feet of soil as compared to a discrete soil sample, which can only describe a few cubic inches of the subsurface. This is of particular importance in risk-based remediation projects where the extent of COC contamination and the degree of removal of COCs can most accurately be determined by using multiple soil gas sampling locations.

However, collection of soil gas from very moist soils and particularly fine-grained units can be technically infeasible. Moreover, collection of soil gas samples from low-permeability soils often result in the leakage of atmospheric air into the sampling system and causes inaccurate results. Deep contamination and contamination in tight or cobble soil are still best assessed using standard drilling techniques rather than soil gas probes.

The test equipment and methods that will be required to conduct field soil gas surveys as part of the risk-based remediation at this site are described fully in the AFCEE document *Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential* (AFCEE, 1994). In summary, the soil gas survey will be conducted first at this site to determine the areal extent and possible shallow vertical extent of soil gas and soil contamination. Results from this survey will be used to guide soil drilling, sampling, and well installation. Data from this survey will also be used to determine if bioventing is a necessary and feasible source removal technique

for the site. For example, if the soil gas survey indicates that sufficient oxygen (O_2) is naturally available and distributed throughout the subsurface, bioventing may not be required to enhance fuel biodegradation rates (AFCEE, 1994).

Soil gas sampling will be conducted using small-diameter [approximately 5/8- to 1-inch outside-diameter (OD)] stainless steel probes. The typical probe consists of a drive point with a retractable, perforated tip that is threaded onto a series of drive rod extensions. The soil probe is fitted with a replaceable stainless steel screen to prevent fine-grained soils from clogging the perforations. Before use, 1/8-inch-diameter flexible Tygon™ tubing is connected to the soil probe and passed through the center of the drive rods. The 1/8-inch Tygon™ tubing, which is used to collect the soil gas samples, extends from the soil probe to the purge pump or sampling device at the surface. A new section of Tygon™ tubing will be used for each sampling point.

A digging permit from Ellsworth AFB and utility clearances must be obtained prior to probe use. All necessary digging and drilling permits will be obtained by Ellsworth AFB personnel prior to ES mobilizing to the field. The primary utilities in the investigation area are buried fuel transfer lines and tanks, buried electrical lines, and overhead utilities. Temporary probes utilize either a hand-driven electric hammer or a hydraulic ram. Soil texture and sample depth requirements must be evaluated before determining which probe is best for the site. A hand-driven electric hammer soil gas probe should be sufficient for the conditions and data needs at Area D at Ellsworth AFB.

Gaseous concentrations of carbon dioxide and oxygen will be analyzed onsite using an O_2/CO_2 analyzer. The analyzer will generally have an internal battery-powered sampling pump and range settings of 0 to 25 percent for both oxygen and carbon dioxide. Before analyzing samples collected with the soil gas probe, the analyzer must be checked for battery charge level. The analyzer will also be calibrated daily using atmospheric conditions of oxygen (20.9 percent) and carbon dioxide (0.05 percent) and a gas standard containing 0.0 percent oxygen and 5.0 percent carbon dioxide.

Total volatile hydrocarbon (TVH) concentrations will be used as the primary screening tool at this site. The TVH analyzer used at Area D will be capable of measuring hydrocarbon concentrations in the range of 1 to 20,000 parts per million, volume per volume (ppmv). The analyzer must also distinguish between methane and non-methane hydrocarbons. The battery charge level on the TVH analyzer will be checked prior to analysis of each collected soil gas sample. The TVH analyzer will also be calibrated daily using a hexane calibration gas.

All soil gas samples taken during the first-phase of the planned soil gas survey will be collected using 3-liter Tedlar™ bags and vacuum chambers. The soil gas sample will then be analyzed by attaching the O_2/CO_2 and TVH analyzers directly to the Tedlar™ bag. Those sample locations identified for compound-specific analysis will be re-sampled using 3-liter Tedlar™ bags and vacuum chambers. The sample will then be transferred to 1-liter SUMMA™ canisters and shipped to the laboratory for compound-specific analysis using EPA method TO-3 (see Table 4.1 in the work plan).

Field QA/QC procedures for soil gas will include collection of one field duplicate, one sampling equipment blank, 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., soil gas), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used.

In order to determine if sampling equipment is free from contamination, a sampling equipment blank will be collected. The sampling equipment blank will be collected by assembling the sampling probe and collecting an ambient air sample in a Tedlar™ bag. The equipment blank will be analyzed in the field using the TVH analyzer. An ambient air reading using the TVH analyzer will be obtained immediately prior to obtaining the reading from the Tedlar™ bag containing the sampling equipment blank. A comparison between the TVH analyzer readings for the ambient air and sampling equipment blank will give an indication if the sampling equipment is free from contamination.

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.

Soil gas QA/QC sampling for analytical purposes will include only one duplicate. However, the laboratory should also plan to conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested for soil gas (i.e., required only once for soil gas extracted via soil gas probe or obtained via flux chamber).

A.2 SOIL FLUX SAMPLING

Several soil flux tests will be conducted at the site to determine the natural background emissions from the site. The purpose of these flux tests is to estimate potential air quality impacts from COC emissions from contaminated environmental medium. Flux samples will be collected at Area D using the procedures outlined in EPA guidance *Measurement of Gaseous Emissions Rates from Land Surfaces Using a Emission Isolation Flux Chamber* (EPA, 1985). The use of a flux box is the preferred method of measurement of surface emission rates of volatile contaminants. A flux box is used to isolate a known surface area from the ambient air, collect surface emissions, and mix the collected emissions with "sweep" air introduced into the chamber at a known flow rate. Data from the flux box can then be combined with a simple dispersion model (such as those described in section 3.3 of the work plan) to identify potential ambient air contamination impacts.

The detection limits presented in Table 4.1 within the work plan are sufficient for the required sensitivity for the compound-specific analysis using a flux box. Flux sample locations are identified on Figure 4.1 within the work plan. Sample locations have been sited in background, potential source areas, areas overlying potential dissolved-phase ground water contamination, and areas downgradient of suspected soil and ground water contamination. The emission rates will not be averaged on an area basis. Rather the data will be used to characterize potential rates of emission for different areas of the site. This approach will support establishment of site-specific remediation goals that are protective of air quality.

The procedures contained within EPA's protocol document on measuring emission rates (i.e., *Measurement of Gaseous Emission Rates from Land Surfaces using an Emission Isolation Flux*

Chamber (EPA/600/8-86/008)) will be followed. In summary, gaseous emissions will be collected from an isolated surface area using a flux chamber and monitored using both "real-time" and discrete methods. Real-time measurements will be made with a portable hydrocarbon analyzer to determine when the chamber reaches steady-state conditions. Discrete samples will then be collected for chemical analysis.

To reduce the potential for cross-contamination, which can occur whenever high level or low level samples are sequentially analyzed, the flux chamber will be purged and tested with a blank after each sample is conducted. Emission tests will only be conducted when soil moisture levels are normal. Increased ground moisture as a result of rain or heavy dew can bias (lower) emission rates.

The sweep air to be used will be dry, organic free air equal to or better than commercial ultra high purity grade (< 0.1 ppmv total hydrocarbon content). Discrete samples will be collected in SUMMA™ canisters and analyzed using EPA Method TO-3 to identify BTEX concentrations.

Field QA/QC procedures for soil flux sample will be identical to those required for soil gas. QA/QC requirements include collection of one field duplicate, 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., soil gas), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used.

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.

Soil flux QA/QC sampling will include only one duplicate. However, the laboratory should also plan to conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested for soil gas (i.e., required only once for soil gas extracted via soil gas probe or obtained via flux chamber).

A.3 DRILLING, SOIL SAMPLING, AND BIOVENTING AND GROUND WATER MONITORING WELL INSTALLATION

To further characterize the hydrogeologic conditions of the shallow soil and ground water for quantitative fate and transport analyses using the Bioplume II model, up to 16 new wells will be installed at Area D. The following sections describe the proposed well locations and completion intervals, equipment decontamination procedures, drilling and soil sampling, well installation, well development procedures, and well location and datum surveying. All drilling, soil sampling, and well installation will proceed from areas suspected to be least contaminated to areas suspected to be more contaminated.

A.3.1 Well Locations and Completion Intervals

Approximately 16 new wells will be installed to further characterize soil and ground water quality at the site, and support source removal activities if necessary. These wells will be screened from 3 feet above the ground water table to the well completion depth. Appropriate screen intervals will be placed in all new wells depending on their intended purpose. Depths to

ground water in the shallow aquifer range from 12 to 20 feet bgs. Well completion depths are expected to range between approximately 20 and 25 feet bgs. The new well locations were selected to provide the hydrogeologic data necessary for successful implementation of the Bioplume II model and to support source removal activities as necessary. Figure 4.2 in the body of the work plan shows the proposed well locations.

A.3.2 Drilling and Soil Sampling Procedures

This subsection addresses the procedures for drilling soil borings that will be used for soil sampling and completed as new wells. All new monitoring wells will be installed in accordance with general procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* (EPA, 1987).

A.3.2.1 Pre-Drilling Activities

All necessary digging, drilling, and well installation permits will be obtained by Ellsworth AFB personnel prior to ES mobilizing to the field. In addition, all utility lines will be located and proposed drilling locations cleared prior to any drilling activities.

A.3.2.2 Equipment Decontamination Procedures

Water to be used in drilling, equipment cleaning, or grouting will be obtained from one of the base's onsite water supplies. Ellsworth AFB personnel will assist ES field personnel in locating a suitable source. Water use approval will be verified by contacting the appropriate facility personnel. Only potable water will be used for the activities listed above. A decontamination water blank will be collected from the potable water source. The procedures for the collection of the decontamination water blank will be described in Section A.6. The ES field hydrogeologist will make the final determination as to the suitability of site water for these activities.

Prior to arriving at the site, and between each drilling site, the drill rig, augers, drilling rods, bits, casing, samplers, tools and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination.

During drilling operations, the drill rig, augers, and any down-hole drilling and/or sampling equipment will be decontaminated at a temporary decontamination pad that will be set up at Area D. The temporary decontamination pad will be constructed in a manner so as to contain all decontamination fluids. All decontamination fluids generated at the temporary decontamination pad will be placed in 55-gallon drums. The decontamination fluids will be disposed of following the procedures presented in Section A.3.5.

All sampling tools will be cleaned onsite, prior to use and between each sampling event, with a clean water/phosphate-free detergent mix and a clean water rinse. All well completion materials that are not factory sealed will be cleaned onsite prior to use with a high-pressure, steam/hot water wash using approved water. Materials that cannot be cleaned to the satisfaction of the ES field hydrogeologist will not be used. 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 borehole.

If contaminated soils are encountered during drilling (based on visual, olfactory, or volatile organic analyzer indications), and the potential for cross-contamination is anticipated, drilling

will be stopped and modified drilling procedures will be implemented to prevent the transfer of contaminants to deeper strata.

Fuel, lubricants, and other similar substances will be handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials will not be stored near or in areas which could be affected by these substances. The drill rigs will not be allowed onsite unless they are free from leaks in any hydraulic lines, and are free of any exterior oil and grease.

Surface runoff such as miscellaneous spills and leaks, precipitation, and spilled drilling fluid will not be allowed to enter any boring or well either during or after drilling/well construction. To prevent this from happening, starter casing, recirculation tanks, berms around the borehole, and surficial bentonite packs, as appropriate, will be used.

A.3.2.3 Drilling and Soil Sampling

Drilling in unconsolidated soils will be accomplished using hollow-stem augers. The borings will be drilled and continuously sampled to the proposed total depth of the monitoring well. A final borehole diameter of at least 10 inches will be required for the installation of bioventing air injection wells with 4-inch inside-diameter (ID) casing. Auger ID will not be less than 5 inches. For installation of ground water monitoring wells, the auger ID will not be less than 4 inches. Determination of well completion details will be at the discretion of the ES field hydrologist. It is likely that most boreholes will be drilled to a final diameter of 10 inches within the suspected source area.

If subsurface conditions are such that the planned drilling technique does not produce acceptable results (e.g. unstable borehole walls or poor soil sample recovery) another technique deemed more appropriate to the type of soils present will be used. Any alternate soil sampling procedure used must be approved by the ES field hydrogeologist and will be appropriate for the subsurface lithologies present at the site.

Continuous soil samples will be obtained using a CME[®] split-barrel continuous sampling device or another similar method judged acceptable by the ES field hydrogeologist. Samples will be collected in 2-foot intervals through the capillary fringe smear zone to below the ground water table. The ES field hydrogeologist will identify which samples from the continuous sampling device will be submitted for chemical analysis. Only soils that exhibit possible contamination will be retained for chemical analysis. One goal of the sampling is to collect at least one sample from the interval exhibiting the most concentrated fuel contamination. Soil samples which may be retained for chemical analysis will be placed in sample containers immediately after the core barrel is opened. A maximum of two soil samples for chemical analysis will be collected per borehole. All soil cores will be evaluated for lithologic characteristics, however. All soil samples collected will be removed from the continuous sampler and placed on clean aluminum foil for logging.

Every 2-foot soil sample recovered will be subsampled, composited, and placed in a clean container for PID or similar hydrocarbon vapor analyzer headspace measurements for VOCs. Representative portions of the soil samples collected for the headspace procedure will be quickly transferred to the sample containers, which will be sealed and held for 15 minutes at an ambient

temperature of 65 degrees Fahrenheit (°F) or greater. Semiquantitative measurements will be made by puncturing the container seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. The PID will be calibrated daily to 100 parts per million, volume per volume of isobutylene. It is anticipated that headspace measurements will be performed on all samples collected during the drilling operations to determine which soil samples will be submitted for chemical analysis. The PID will also be used to monitor the worker breathing zone.

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 duplicates will be sent to the laboratory. QA/QC sampling will include only one duplicate for soil samples (i.e., frequency of 10 percent), one rinseate samples (i.e., frequency of 10 percent), one field blank, and a trip blank for each individual cooler sent to the analytical laboratory. The procedures for the collection of field QA/QC samples are discussed below in Section A.6. Laboratory QA/QC procedures will include one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested.

The ES field hydrogeologist will be responsible for observing all drilling and well installation activities, maintaining a detailed descriptive log of subsurface materials recovered, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure A.1. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Soil or rock description, including: relative density, 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;
- Lithologic contacts: the depth of lithologic contacts and/or significant textural changes will be measured and recorded to the nearest 0.1 foot (1 inch); and
- Determination on whether soil sample will be submitted for chemical analysis or segregated as uncontaminated medium.

A.3.2.4 Minimization and Management of Drilling Residuals

Drilling activities will generate soil cuttings requiring proper handling and, if contaminated, proper disposal. Based on data from previous soil sampling efforts at the site, contamination exists in discrete intervals and only a small portion of the drill cuttings is expected to be contaminated. Care will be taken to segregate uncontaminated soils from soils containing fuel residuals. Soils will be screened using a PID or similar hydrocarbon vapor analyzer. Two roll-on/roll-off (RO/RO) containers will be used for cutting disposal. Clean soils will be stored in

GEOLOGIC BORING LOG

BORING NO. _____ CONTRACTOR: _____ DATE SPUD: _____
 CLIENT: _____ RIG TYPE: _____ DATE CMPL: _____
 JOB NO.: _____ DRLG METHOD: _____ ELEVATION: _____
 LOCATION: _____ BORING DIA.: _____ TEMP.: _____
 GEOLOGIST: _____ DRLG FLUID _____ WEATHER: _____
 COMMENTS: _____

Elev. (ft.)	Depth (ft.)	Pro- file	US CS	Geologic Description	Samples		Sample	Penet.	Remarks TIP = Bkgnd/Reading (ppm)
					No.	Depth (ft)	Type	Res.	
	1								
	5								
	10								
	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 recovery
 C - CORE
 G - GRAB Core lost

Water level drilled

Figure A.1
Geologic Boring Log

one RO/RO container while contaminated soils will be placed in another. Two composite samples will be collected from each RO/RO container and analyzed for BTEX, TRPH, halogenated solvents, and total metals. This limited drilling event will generate approximately 12 cubic yards of soil. If contaminant levels are minimal or not detected, ES will arrange to have the soil placed in a clean fill area designated by Ellsworth AFB personnel. If contaminant levels do not allow use as clean fill, the soil will be transported by ES to an on-base land farm for treatment.

A.3.3 Bioventing Well Installations

The potential for vadose soil contamination will be determined at 10 borings in the grassy area near the center of Area D. If continuous soil coring reveals that the fuel-contaminated interval exceeds 2 feet, that boring will be completed as a bioventing air injection well and later included in a possible full-scale bioventing system for reducing contamination in these source areas. These additional 4-inch-diameter bioventing wells will be completed using the same design as the existing pilot bioventing well at Area D (ES, 1993).

A.3.4 Ground Water Monitoring Well Installation

Ground water monitoring wells will be installed in each of the 10 soil borings not completed as bioventing wells at Area D. Additionally, six ground monitoring wells will be installed at Area D to delineate the extent of the dissolved phase plume in ground water. Except where specified, the entire thickness of the shallow aquifer will be screened. Detailed well installation procedures are described in the following paragraphs. A typical well completion diagram is included as Figure A.2.

A.3.4.1 Well Material Decontamination

Well completion materials will be inspected by the ES field hydrogeologist and determined to be clean and acceptable prior to use. If not factory sealed, casing, screen, and casing plugs and caps will be cleaned with a high-pressure, steam/hot water cleaner using approved water prior to use. Prepackaged sand, bentonite, and Portland[®] cement will be used in well construction, and the bags will be inspected for possible external contamination before use. Materials that cannot be cleaned to the satisfaction of the ES field hydrogeologist will not be used.

A.3.4.2 Well Casing

Upon completion of drilling to the proper boring termination depth, a monitoring well casing will be installed. Well construction details will be noted on a Monitoring Well Installation Record form, as shown in Figure A.3. This information will become part of the permanent field record for the site. Blank well casing will be constructed of Schedule 40 polyvinyl chloride (PVC) with an ID of 2 inches. All well casing sections will be flush-threaded; glued joints will not be used. The casing at each well will be fitted with a threaded bottom plug and a top cap constructed of the same type of material as the well casing. The top cap will be vented to maintain ambient atmospheric pressure within the well casing.

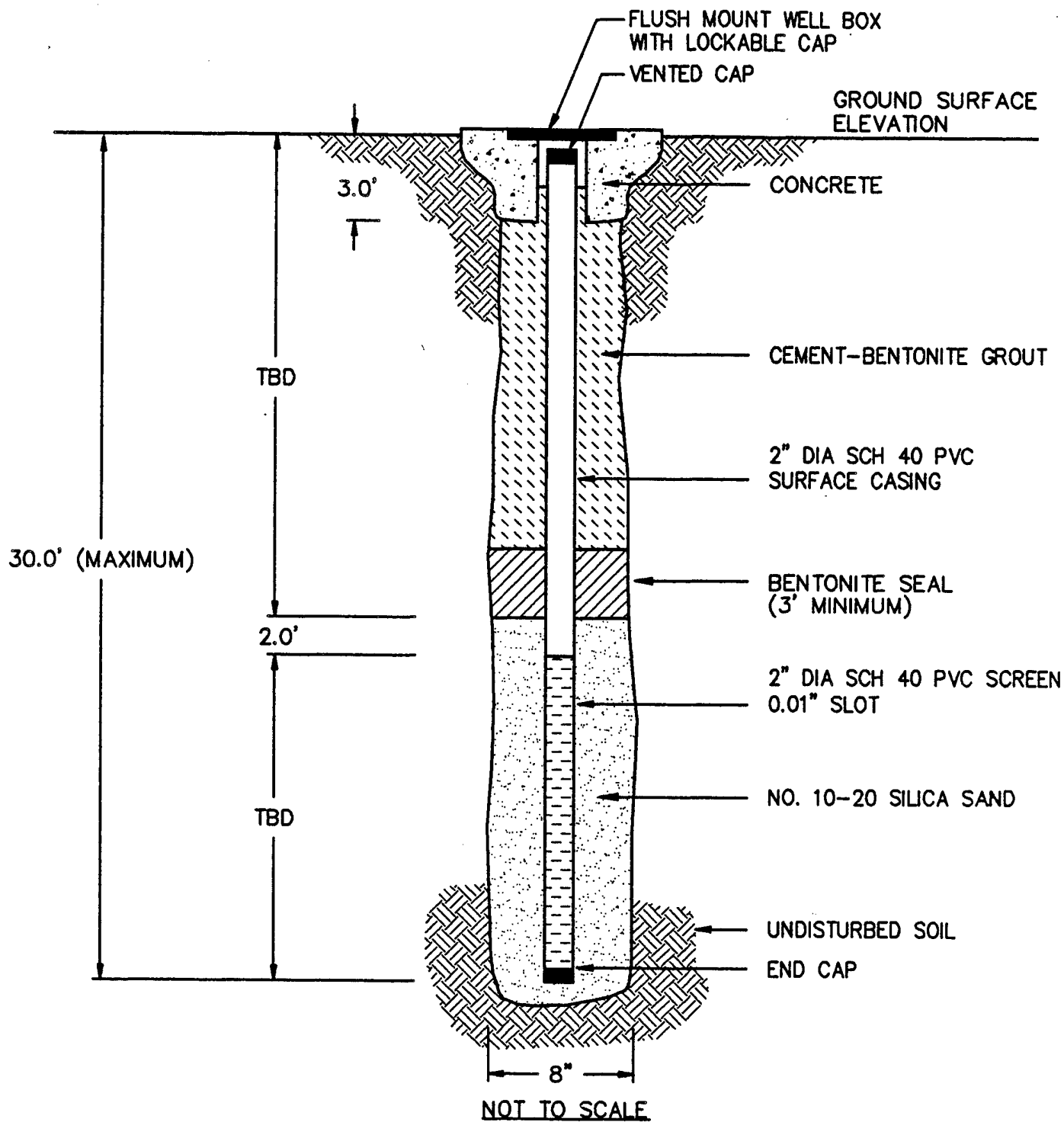


FIGURE A.2

**TYPICAL MONITORING WELL
COMPLETION DIAGRAM**

Risk-Based Approach to Remediation
Area D, Ellsworth AFB, South Dakota

ENGINEERING-SCIENCE, INC.

Denver, Colorado

WELL CONSTRUCTION FORM

Installation: _____
 Site: _____
 Well ID: _____
 Comp. started ____/____/____ (: m)

Project no. _____
 Drilling contractors: _____
 Comp. finished: ____/____/____ (: m)

Utility Box Y/N

Water-Tight Locking Cap with Neoprene Seal Y/N

Concrete

Ground Level

Ground Elevation: _____

Grout proportions: _____

Seal Type: _____

Source: _____

Amt. used: _____

Vol. fluid added: _____

Casing Type: _____

Diameter: _____

Bore Dia: _____

Centralizers Y/N

Design: _____

Composition: _____

Depths: _____

Coupling/Joint Design: _____

Gravel Pack (_____ Mesh)

Amt. used: _____

Source: _____

Screen Type: _____

Diameter: _____

Slot Size & Type: _____

Bottom cap Y/N

Top Screen Interval

Bottom Screen Interval

TD

Figure A.3
Monitoring Well Installation Record

The ES field hydrogeologist will verify and record the boring depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus casing and borehole wall. All lengths and depths will be measured to the nearest 0.1 foot.

A.3.4.3 Well Screen

Well screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 2 inches. The screens will be factory slotted with 0.010-inch openings. Each well will be screened so that seasonal fluctuations of the water table can be measured. The water level in the unconfined aquifer will be allowed to fluctuate within the screened interval. The position of the screen will be selected by the ES field hydrogeologist after consideration is given to the geometry and hydraulic characteristics of the stratum in which the well will be screened.

A.3.4.4 Sand Filter Pack and Annular Sealant

A graded sand filter will be placed around the screened interval and will extend at least 2 feet above the top of the screen. The sand filter will consist of 10-20 silica sand. An annular seal will be placed above the gravel pack using sodium bentonite pellets. The pellet seal will be a minimum of 2 feet thick and will be hydrated in place with potable water. The pellet seal will be overlain by a Portland[®] cement/sodium bentonite grout that will extend from the top of the pellet seal to approximately 3 feet bgs. The Portland[®] cement/sodium bentonite grout will consist of one 94-pound sack of cement and about 5 pounds of bentonite for each 7 gallons of water used. The bentonite content of the cement/bentonite will not exceed 8 percent by dry weight. The grout will be overlain with concrete to the ground surface. To reduce heaving of the newly-installed monitoring well caused by freeze-thaw processes, it is imperative that the uppermost concrete seal extend to at least the maximum frost line.

A.3.4.5 Flush-Mount Protective Cover

Each monitoring well will be completed with an at-grade (flush-mount) protective cover. In areas where pavement is present, the at-grade cover will be cemented in place using concrete which will be blended to the existing pavement. In areas where pavement is not already present, a 6-inch thick, 2-foot-diameter concrete pad will be constructed around the protective cover. In either case, the concrete immediately surrounding the well cover will be sloped gently away from the protective casing to facilitate runoff during precipitation events.

A.3.5 Well Development

Before any new well can be considered in proper condition for monitoring water levels or taking water samples, it must be developed. Development removes sediment from inside the well casing and flushes fines, cuttings, and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen. If a well is grouted prior to development, well development will occur no sooner than 48 hours after grouting of the annulus is completed.

Well development will be accomplished using dedicated disposable bailers or a peristaltic pump. The bailer or pump will be lowered to the bottom of the well so that fines which have accumulated in the bottom are agitated and removed from the well in the development water.

Development will be continued until a minimum of three casing volumes of water have been removed from the well and the water pH, temperature, and specific conductivity have stabilized.

Temperature, pH and specific conductivity will be monitored during development (one reading for each parameter per well volume). Pumping will continue until these parameters have stabilized to within 10 percent among three consecutive readings and the water is clear and free of fines. The pH and specific conductivity meters will be calibrated on a daily basis. The pH meter will be calibrated by laboratory-prepared standard solutions following the manufactures calibration procedures. The specific conductivity meter will be calibrated using laboratory-prepared known conductivity solutions. If the development water still is turbid after removal of three casing volumes, development will be continued until the water becomes clear or the turbidity of the water produced has been stable after the removal of several casing volumes.

The development procedure specifies that three casing volumes of water be removed from the well. However, some wells completed in marginal aquifers will go dry during well development prior to the recovery of three casing volumes. In these low-productivity wells, development activity may have to be staged over a period of time to allow water to refill the well bore. In the event three casing volumes of water cannot be recovered, the water volume recovered will be noted in the development records.

All well purge water will be placed in 55-gallon drums. At the end of the field sampling event the water in each drum will be sampled and disposed of in accordance with Ellsworth AFB policies and procedures.

A.3.6 Well Development Records

A record of well development will be maintained for each well. The well development record will be maintained in a bound field notebook by the field hydrogeologist. Figure A.4 is an example of the well development record. A summary well development record form will be prepared for each well and submitted with the EE/CA report. Development records will include:

- Well number;
- Date and time of development;
- Development method;
- Predevelopment water level and well depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and well depth; and
- Field analytical measurements, including pH and specific conductivity.

A.3.7 Water Level Measurements

Water levels at all wells will be measured within a short time interval so that the water-level data are comparable. Water levels in the new wells will not be measured until they are

Figure A.4
Well Development Record

WELL DEVELOPMENT RECORD

AFB	AFID
Location identification _____	LOCID _____
Date _____	LOGDATE _____
Time _____	LOGTIME _____

Development Method

☐ bail ☐ pump ☐ surge ☐ air lift
☐ other _____

Diameter (Inches)	Volume (Gals/ft)
2	0.16
4	0.65
6	1.47
8	2.61
10	4.08
12	5.88
14	8.00

VOLUME MEASUREMENTS

Casing inside diameter _____ in
 Static water level _____ ft
 Total casing depth _____ ft
 Length of water column _____ ft
 PURGE VOLUME (calculated at bottom) _____ gal

Development volume = _____ ft water column $\times$ 1/2/3/4/5
 borehole volumes (*circle one*) $\times$ [(_____ gals/ft. casing vol.) +
 (_____ gals/ft. borehole volume - _____ casing volume) _____ % porosity]
 = _____ gals.

PURGE RECORD

Time	Volume/Bail No.	Temp °F	pH	Elec Cond	Visual Appearance/Odor
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Weather: _____ Developed by: _____

developed and the water level has stabilized. The depth to water below the measurement datum will be made using an oil/water interface electric probe to the nearest 1/8 inch (0.01 foot). The oil/water interface probe will be decontaminated prior to use, and between each measurement, following the decontamination procedures presented in Section A.4.3. In addition, water level measurements will be made in all existing ground water monitoring wells at the site. This data will be used to calibrate the Bioplume II model and describe hydrogeologic characteristics.

A.3.8 Well Location and Datum Survey

The location and elevation of the new wells will be surveyed by a registered surveyor soon after well completion. Horizontal locations will be measured relative to established Ellsworth AFB coordinates. Horizontal coordinates will be measured to the nearest 0.01 foot. Vertical location of the ground surface adjacent to the well casing, the measurement datum (top of the interior casing), and the top of the outer well casing will be measured relative to a USGS MSL datum. The ground surface elevation will be measured to the nearest 0.1 foot, and the measurement datum, outer casing, and surveyor's pin (if present) elevation will be measured to the nearest 0.01 foot.

A.3.9 Site Restoration

After well installation and sampling is complete, each well site will be restored as closely to its original condition as possible.

A.4 GROUND WATER SAMPLING

This section describes the scope of work required for collecting ground water samples at each of the 16 new wells and select existing, usable ground water monitoring wells. All water samples collected from ground water monitoring wells or bioventing wells will be obtained using either disposable bailers or a thoroughly decontaminated peristaltic pump. In order to maintain a high degree of quality control during this sampling event, the procedures described in the following sections will be followed.

Ground water sampling will be conducted by qualified ES 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 ground water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the well integrity, including:
 - Protective cover, cap and lock,
 - External surface seal and pad,
 - Well stick-up, cap, and datum reference,
 - Internal surface seal,

- Condition of bladder pump if present;
- Ground water sampling, including:
 - Water-level measurements,
 - Visual inspection of borehole water,
 - Well casing evacuation,
 - Sampling;
- Sample preservation and shipment, including:
 - Sample preparation,
 - Onsite measurement of physical parameters,
 - Sample labeling;
- Completion of sampling records;
- Completion of chain-of-custody records; and
- Sample disposition.

Detailed ground water sampling and sample handling procedures are presented in following sections.

A.4.1 Ground Water Sampling Locations

Ground water samples will be collected from a maximum of 16 newly installed wells and 5 existing wells using either a disposable bailer or a thoroughly decontaminated peristaltic pump.

A.4.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all recordkeeping materials will be gathered prior to leaving the office.

A.4.3 Equipment Decontamination

All portions of sampling and test equipment that will contact the sample will be thoroughly cleaned before each use. This equipment includes the peristaltic pump and tubing, water-level probe and cable, oil/water interface probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof which will contact the samples. Based on the types of sample analyses to be conducted, the following decontamination protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent;
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with reagent-grade isopropanol; and
- Air dry the equipment prior to use.

All decontamination fluids will be contained in 55-gallon drums and sampled on-site and disposed of as described in Section A.3.5. Any deviations from these procedures will be documented in the field scientist's field notebook and on the ground water 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.

A.4.4 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 pH, electrical conductivity, and temperature.

A.4.5 Sampling Procedures

Special care will be taken to prevent contamination of the ground water 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 well total depth will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section A.4.3. 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 is sampled. Wells will be sampled sequentially from areas suspected to be least contaminated to areas suspected to be more contaminated.

The following paragraphs present the procedures that comprise ground water sample acquisition from all ground water sampling locations. These activities will be performed in the same order as presented below. Exceptions to this procedure will be noted in the ES field scientist's field notebook.

A.4.5.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well 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.

A.4.5.2 Water Level and Total Depth Measurements

Prior to removing any water from the well the static water level will be measured. An electrical water level probe will be used to measure the depth to ground water below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the well and the total well depth will be measured to the nearest 0.01 foot. Based on these measurements the volume of water to be purged from the well can be calculated.

Emphasis will also be placed on defining the probable areal extent of any remaining free fuel product that may act as a continuing source of contamination at the site. Free product can be physically identified during drilling and soil sampling and through the use of an oil/water interface probe. Moreover, ground water samples showing a benzene concentration equal to or

in excess of 178 mg/L (10 percent of its maximum solubility in water) will be operationally defined as potential fringe areas to oily-phase contamination (or underlying significant residual soil contamination).

A.4.5.3 Well Purging

The volume of water contained within the well casing at the time of sampling will be calculated, and three times the calculated volume will be removed from the well. The pH, temperature, and specific conductivity will be monitored during well purging. Purging will continue until these parameters have stabilized to within 10 percent among three consecutive readings. All purge water will be placed in 55-gallon drums and sampled on-site and disposed of as described in Section A.3.5. Disposable bailers or a thoroughly cleaned peristaltic pump will be used for well evacuation.

If a well is evacuated to a dry state during purging, the well will be allowed to recharge to 80 percent of its original water level and the sample will be collected as soon as sufficient water is present in the well to obtain the necessary sample quantity. Sample compositing, or sampling over a lengthy period by accumulating small volumes of water at different times to eventually obtain a sample of sufficient volume, will not be allowed.

A.4.5.4 Sample Extraction

Either disposable, polyethylene bailers or a thoroughly decontaminated peristaltic pump will be used to extract ground water samples from the well. Both types of extraction equipment will be lowered into the water gently to prevent splashing and extracted gently to prevent creation of an excessive vacuum in the well. The sample will be transferred directly to the appropriate sample container. The water sample will be transferred from the bottom of the bailer using a bottom emptying device to allow a controlled flow into the sample container. Water for the peristaltic pump can be directly discharged into the sample container. The water should be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

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 drums used for well purge waters and sampled on-site and disposed of as described in Section A.3.5.

A.4.6 Onsite Chemical Parameter Measurement

Dissolved oxygen (DO) measurements will be taken onsite using a meter with a downhole oxygen sensor. The DO meter will be decontaminated, prior to each use, following decontamination procedures described in Section A.4.3. DO measurements will be taken immediately following ground water sample acquisition. Where DO measurements will be taken in wells which have not been sampled, the well will be purged as described earlier prior to taking the DO measurement.

Because the pH, temperature, and specific conductance of a ground water sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container

separate from those intended for laboratory analysis and the measured values will be recorded in the ground water sampling record.

A.4.7 Sample Handling

This section describes the handling of samples from the time of sampling until the samples arrive at the laboratory.

A.4.7.1 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 A.4.5.4, and the container lids will be tightly closed. 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 (ground water, surface water, etc.);
- Sampling date;
- Sampling time;
- Preservatives added; and
- Sample collector's initials.

A.4.7.2 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 degrees centigrade (°C).

A.4.7.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the AFCEE-approved laboratory for this demonstration. 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.

A.4.7.4 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 contractor after sample delivery to the analytical laboratory, and the other two copies will be retained at 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;
- Chemical preservatives added;
- 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.

A.4.7.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the ES 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;
- Purge volume;
- Water level after purging;
- Well condition;
- Sampler's identification;
- Field measurements of pH, temperature, and specific conductivity; and
- Any other relevant information.

Ground water sampling information will be recorded on a ground water sampling form. Figure A.5 shows an example of the ground water sampling record.

A.4.8 Laboratory Analyses

Laboratory analyses will be performed on all ground water samples and the required QA/QC samples (see section A.4.9). The analytical methods and detection limit requirements for this sampling event are listed in Table 4.1 in the body of the work plan.

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, ice chests 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 laboratories.

A.4.9 Quality Assurance/Quality Control Samples

Field QA/QC procedures for ground water will include collection of field duplicates and rinseate, field 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., ground 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 a 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.

Figure A.5
Ground Water Sampling Record

SAMPLING LOCATION _____
SAMPLING DATE(S) _____

GROUND WATER SAMPLING RECORD - MONITORING WELL _____
(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: _____, 19____ a.m./p.m.
SAMPLE COLLECTED BY: _____ of _____
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 ☐ 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: _____

5 [] SAMPLE EXTRACTION METHOD:

[] Bailer made of: _____
[] Pump, type: _____
[] Other, describe: _____

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: _____ ° _____ Measured with: _____
pH: _____ Measured with: _____
Conductivity: _____ Measured with: _____
Other: _____

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:

Ground water QA/QC sampling will include duplicates for up to two wells (i.e., frequency of 10 percent), rinse blanks for up to two wells (i.e., frequency of 10 percent), one field blank, and a trip blank for each individual cooler sent to the analytical laboratory. The procedures for the collection of field QA/QC samples are described in Section A.6. The laboratory should plan to conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested.

A.5 AQUIFER TESTING

Slug tests will be conducted at five locations to estimate the hydraulic conductivity of the shallow saturated zone. Slug tests will be completed using ground water monitoring wells MW-2, MW-22, MW-24, and two new monitoring wells to be installed during the field investigation. Pumping tests will not be conducted because large quantities of potentially contaminated water is generated and must be treated or disposed. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests are best used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test; in this field investigation both methods will be used in sequence.

A.5.1 Definitions

- Hydraulic Conductivity (K). A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- Transmissivity (T). A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- Slug Test. Two types of testing are possible; a rising head or falling head test. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- Rising Head Test. A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing or removing a submerged slug from the well.
- Falling Head Test. A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

A.5.2 Equipment

The following equipment is needed to conduct a slug test:

- Teflon[®], PVC, or metal slugs,
- One-quarter-inch nylon or polypropylene rope,

- Oil/water interface electric water level indicator,
- Pressure transducer/sensor,
- Field logbook/forms, and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger, In-Situ, Inc. Model SE1000B or equal).

A.5.3 Test Methods, General

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Prior to testing, the monitoring well must be thoroughly developed as described in Section A.3.5 and water levels allowed to stabilize. Slug testing will proceed only after water level measurements show that static water level equilibrium has been achieved. During the slug test, the water level change should be influenced only by the introduction (or subtraction) of the slug volume. Other factors, such as inadequate well development, extended pumping, etc., may lead to inaccurate results. It is up to the ES field hydrogeologist to decide when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of the slug test, using the procedures described in Section A.4.3.

A.5.3.1 Falling Head Test

The falling head test is the first step in the two-step slug-testing procedure. The following steps describe the falling head test.

1. Decontaminate all down-hole equipment, following the decontamination procedures described in Section A.4.3, prior to initiating the test.
2. Open the well. Where wells are located within the 100-year flood plain, and equipped with water tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the Aquifer Test Data form (Figure A.6) with entries for:
 - Borehole/Well number;
 - Project number;
 - Project name;
 - Aquifer testing team;
 - Climatic data;
 - Ground surface elevation;
 - Top of well casing elevation;
 - Identification of measuring equipment being used;

Page _____ of _____

Well No _____ Distance from pumping well _____ Type of test: _____ Test No _____

Measuring equipment

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- Page number;
 - Static water level;
 - Date; and
 - Time intervals (0,1,3,5,7,9,10, and 12 minutes and every 3 minutes thereafter through 60 elapsed minutes, then in 10-minute intervals for the next hour, and in 30-minute intervals for the next 3 hours).
4. Measure the static water level in the well to the nearest 0.01 foot.
 5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by making periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
 6. Lower the decontaminated slug into the well to just above the water level in the well.
 7. Turn on the data logger, and quickly lower the slug below the water table being careful not to disturb the pressure transducer. Follow the owners' manual for proper operation of the data logger.
 8. Terminate data recording when the water level stabilizes in the well.

A.5.3.2 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the static water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the Owners Manual for proper operation of the Data Logger.
3. Terminate data recording when the water level stabilizes in the well. Remove the pressure transducer from the well and decontaminate.

A.5.3.3 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV and the method of Hvorslev (1951) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The standard slug test form (Figure A.7) is based on equations and test methods developed by Hvorslev (1951). Figure A.8 is the Bouwer and Rice Analysis Data Form. Figure A.9 contains the dimensionless parameters A, B, and C used for the Bouwer and Rice Analysis.

A.6 FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

As a check on field sampling, QA/QC samples, including trip blanks, field blanks, decontamination water blanks, equipment rinseate blanks, and field duplicates will be collected. Each type of QA/QC sample is described below.

HVORSLEV'S METHOD FOR K

LOCATION _____
ELEVATION _____



K=_____ FT/MIN K=_____ FT/DAY K=_____ CM/SEC

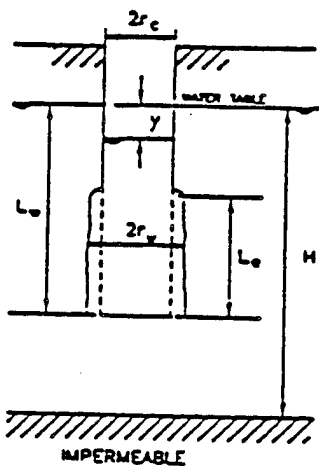


Bouwer and Rice Analyses Data Form

BOUWER AND RICE METHOD FOR K

(Reference: GROUNDWATER - May, June 1989, Vol. 27, No. 3)

PROJECT _____ LOCATION _____
WELL NUMBER _____ ELEVATION _____
DATE _____



STATIC HEAD

PIPE RADIUS (r_c) _____

BORE HOLE
RADIUS (r_w)

SATURATED SCREEN _____
LENGTH (L_s)

WELL DEPTH _____

HYDRAULIC CONDUCTIVITY:
(ASSUME $L_x = H$)

$$K = \frac{(r_c) \ln(R_c/P_w)}{2L_e} \quad \begin{bmatrix} 1 \\ 1 \end{bmatrix} \ln \begin{bmatrix} y_0 \\ y_1 \end{bmatrix}$$

K=_____

[illegible]

K=_____ FT/MIN K=_____ FT/DAY K=_____ CM/SEC

WHERE: $r_c = [(1-n)r_c^2 + nr_c^2]$
 $n = \text{POROSITY } (-30\%)$

* It TAKES INTO ACCOUNT THE RADII OF THE WELL AND THE THICKNESS AND POROSITY OF THE GRAVEL PACK. POROSITY OF THE GRAVEL PACK (n) IS ESTIMATED AS 20% USE THIS EQUATION IF A GRAVEL PACK IS PRESENT.

$$\text{ASSUME } L_w = 10 \text{ in } \frac{R_x}{r_w} = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{(L_w/r_w)} \right]^{-1} \quad C = 1.4$$

ASSUME L_w CH: $\ln \frac{R_p}{r_w} = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{A + B \ln[(H-L_w)/r_w]}{(L_w/r_w)} \right]^{-1}$

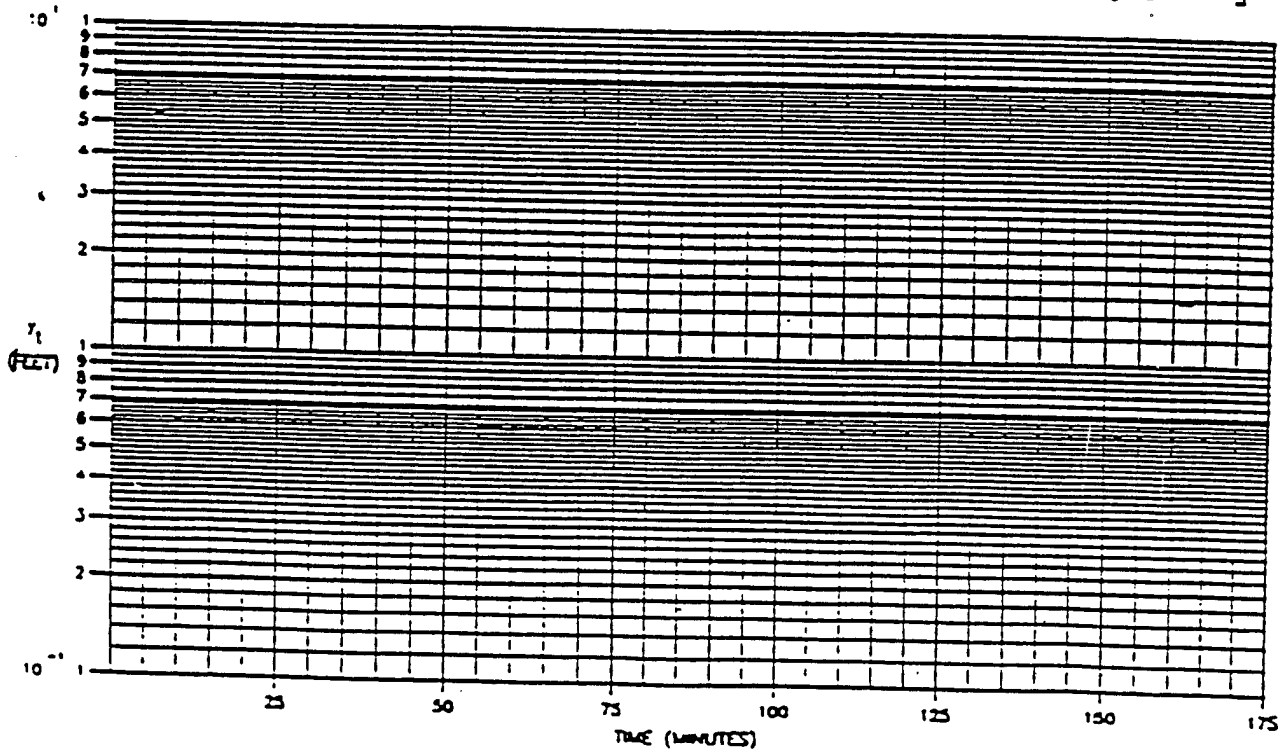
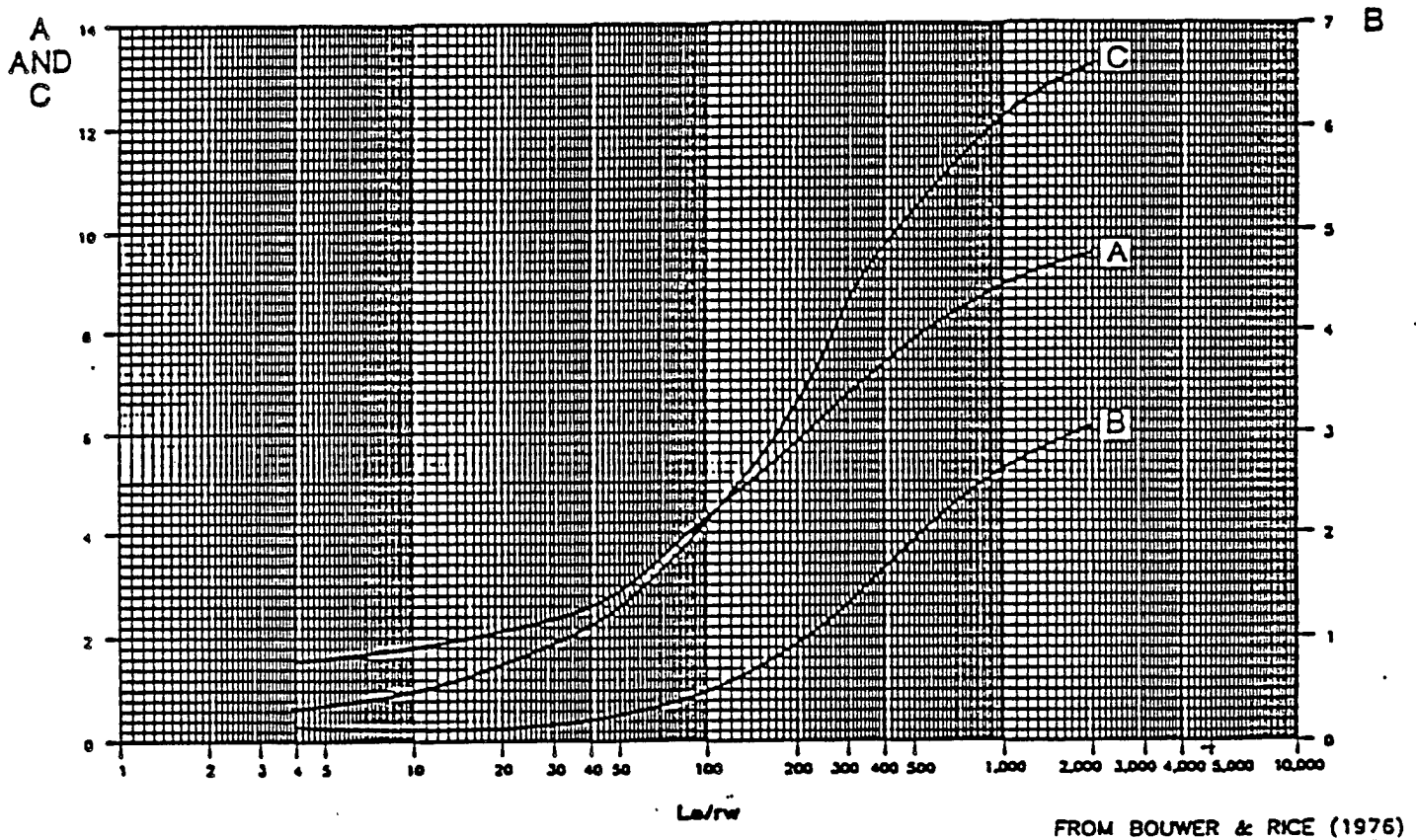


Figure A.9
Bouwer and Rice Analyses Dimensionless Parameters

DIMENSIONLESS PARAMETERS A, B, AND C
FOR AQUIFER TEST ANALYSIS



A.6.1 Trip Blanks

A trip blank is defined as a sample bottle filled by the laboratory with analyte-free laboratory reagent-grade water, transported to the site, handled like a sample but not opened, and returned to the laboratory for analysis. One trip blank will accompany every cooler of environmental samples sent to the laboratory. Trip blanks are analyzed only for Method SW8020.

A.6.2 Decontamination Water Blank

A decontamination water blank is designed to check the purity of potable water used for equipment decontamination during the field operation. One decontamination water blank will be collected for each water source used during the field work. 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.

A.6.3 Field Blanks

A field blank is designed to assess the effects of ambient field conditions on sample results. 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.

A.6.4 Equipment Rinseate Blanks

Equipment rinseate blanks will be collected from field equipment such as continuous core barrels. Equipment rinseate blanks are prepared by pouring distilled water over field equipment that has been decontaminated. The rinseate water is then collected, transferred to a sample bottle, and analyzed at the laboratory. The results of these sample analyses indicate how well the sampling equipment was decontaminated.

A.6.5 Field Duplicate Samples

A field duplicate is defined as two or more samples collected independently at the same sampling location during a single act of sampling. Soil samples are mixed and divided into two equal parts for analysis. Duplicates of water samples will be collected by filling additional sample containers at each duplicated sampling event.

Field duplicates will be indistinguishable from other samples by the laboratory. One complete sample set will be identified with a coded identifier, which will be in the same format as other identifiers used with this matrix. Both the coded and actual sample identifiers will be recorded in the field notebook. The coded identifier will be used on the chain-of-custody forms.

BASE NAME: ELLSWORTH AFB JOB #725521.02000

Rusty Frishmuth

John Deyoe
(605) 385-6618

Project Manager:

Date _____

Name

Date _____

1.0 INTRODUCTION

This addendum modifies the existing *Program Health and Safety Plan for Risk-Based Remediation Demonstrations* (Engineering-Science, Inc., 1994), for conducting progressive site investigations at United States Air Force facilities under contract number F41624-93-C-8044.

This addendum to the health and safety plan was prepared to address the upcoming field tasks at Ellsworth AFB, North Dakota. The site to be investigated through a risk-based remediation approach will include Area D, a petroleum, oil, and lubricant (POL) tank. Area D consists two aboveground fuel storage tanks (ASTs), two 25,000-gallon underground storage tanks (USTs), a 15,000-gallon UST, a 1,000-gallon UST, two JP-4 dispensers, and a railroad spur with fuel unloading headers.

The demonstration to be conducted at Area D of an innovative technology is being sponsored by the Air Force Center for Environmental Excellence (AFCEE) at Brooks AFB, Texas under Contract F41624-93-C-8004, "Risk-Based Approach to Fuel Spill Remediation."

Included or referenced in this addendum are site-specific descriptions, history and proposed activities; hazard evaluation of known or suspected chemicals; personal protective equipment (PPE); personnel decontamination procedures; site-specific training and medical monitoring requirements; air monitoring; site control procedures; employee exposure monitoring; and emergency response procedures.

In addition, all ES field team members will be properly trained in the use, care, disposal, limitations, and maintenance of personal protective equipment (PPE).

Site hazards will be assessed and communicated to the field team members to determine if hazards are present, or are likely to be present, which may necessitate the use of PPE.

2.0 SITE DESCRIPTION, HISTORY, AND SITE-SPECIFIC ACTIVITIES

The site description, history, and pilot test activities to be performed at this site are outlined in the site-specific work plan entitled *Draft Work Plan for Engineering Evaluation/Cost Analysis In Support of Risk-Based Approach to Remediation at Area D at Ellsworth Air Force Base, South Dakota*. A brief listing of planned site-specific activities follows.

Services to be performed by ES at Area D include sampling of soil, soil gas, and ground water.

A sufficient number of samples from background and contaminated areas will be collected and analyzed for individual and indicator compounds to accurately assess the risk to human health and the environment posed by the site and to demonstrate the attainment of final cleanup levels.

In order to facilitate implementation of the site evaluation, ES may be assisted by subcontractors to perform additional drilling and laboratory analysis of environmental samples.

In addition to the drilling vehicles and heavy equipment traditionally used on ES projects, a hydraulically driven Geoprobe® system may be used at the Ellsworth AFB Area D site to collect soil gas, soil, and groundwater samples. A hydraulic press has been mounted on the bed of an ES pick-up truck with power supplied to the cylinder via a power-take-off on the truck's engine.

A list of the manufacturer's operating safety instructions to be followed by all ES subcontract personnel on this project is provided below:

- Never operate controls without proper training.
- Always take vehicle out of gear and set emergency brake before engaging remote ignition.
- If vehicle is parked on a loose or soft surface, do not fully raise rear of vehicle with probe foot, as vehicle may fall or move, causing injury.
- Always extend the probe unit out from the vehicle and deploy the foot to clear vehicle roof line before folding the probe unit out.
- Operators should wear OSHA approved steel toed shoes and keep feet clear of prove foot.
- One person only should operate the probe machine and the assembly - disassembly of probe rods and accessories.
- Never place hands on top of a rod while it is under the machine.
- Turn off the hydraulic system while changing rods, inserting the hammer anvil, or attaching accessories.
- Operator must stand to the control side of the probe machine, clear of probe foot and mast, while operating controls.
- Wear safety glasses at all times during the operation of this machine.
- Never exert down pressure on the probe rod so as to lift the machine base over six inches off the ground.
- Never exert down pressure on a probe rod so as to lift the rear tires of the vehicle off the ground.
- Always remove the hammer anvil or other tool from the machine before folding the machine to the horizontal position.
- The vehicle catalytic converter is hot and may present a fire hazard when operating over dry grass or combustibles.
- Geoprobe® operators must wear hearing protection. OSHA approved hearing protection for sound levels exceeding 85 dB is mandatory.

- The location of buried or underground utilities and services must be known before starting to drill or probe.
- Shut down the hydraulic system and stop the vehicle engine before attempting to clean or service the equipment.
- Accidental engagement of this machine may cause injury.

3.0 SITE-SPECIFIC EMPLOYEE TRAINING AND MEDICAL MONITORING REQUIREMENTS

See Section 4 of the program health and safety plan (Engineering-Science, Inc., 1994) for guidance.

4.0 HAZARD EVALUATION

4.1 Chemical Hazards

General hazards are addressed in the program health and safety plan. Site-specific hazards are identified below.

Chemicals known or suspected to occur at Area D include petroleum hydrocarbon fuel components benzene, toluene, ethylbenzene, and xylenes (BTEX).

Health hazard qualities for these compounds are presented in Table 5.1 of the program health and safety plan.

4.2 Physical Hazards

Potential physical hazards at this site include risks associated with the installation/operation of bioventing equipment such as underground utilities; overhead utilities; drilling activities; electrical equipment; heavy equipment; motor vehicles; slip, trip, and fall hazards; noise; and heat stress.

Protection standards for physical hazards are contained in Section 7 of the program health and safety plan.

5.0 AIR MONITORING

During operations that disturb site soils, a hydrocarbon detector or photoionization detector (PID or equivalent) will be used to measure ambient air concentrations in the worker breathing zone. As shown in the attachment, if the hydrocarbon detector measures total fuel vapor concentrations of 0-5 ppm, site workers will continue air monitoring in a Level D ensemble. If total fuel vapor concentrations reach 5-25 ppm for more than 30 seconds, and benzene concentrations exceed 1 ppm, site workers will evacuate the site or upgrade to Level B ensemble, if trained to do so. If benzene concentrations are less than 1 ppm, the site crews may continue in Level D ensemble with periodic air monitoring. If total fuel vapor concentrations reach 25-50 ppm for greater than 30 seconds and benzene concentrations exceed 1 ppm, site crews will evacuate the site or upgrade to Level B ensemble. If benzene concentrations are less than 1 ppm and vapors are in the range of 25-50 ppm, site workers will don full facepiece air-purifying respirators (APR) equipped with organic vapor cartridges (NIOSH approved), and continue periodic air monitoring. If total fuel vapor concentrations reach 50-500 ppm for greater than 30 seconds, the site

crews will evacuate the site or upgrade to Level B ensemble. If total fuel vapor concentrations exceed 500 ppm for greater than 30 seconds, site crews will evacuate the site.

Before work can be performed in Level B respiratory protection the project manager must be notified. He will initiate the change order process with the Air Force or decide to halt activities at that site. (Level B operations require approval from corporate health and safety.) The site health and safety officer will determine whether it is safe to continue activities without respiratory protection or assign an upgrade to Level C protection. Flammable vapor monitoring will be conducted if potentially flammable atmospheres occur. See Sections 8 and 11 of the program health and safety plan for specific guidance.

6.0 SITE CONTROL PROCEDURES

Site control measures will be followed in order to minimize potential contamination of workers, protect the public from potential site hazards, and control access to the sites. Site control involves the physical arrangement and control of the operation zones the methods for removing contaminants from workers and equipment. See Section 9 of the program health and safety plan for guidance.

Specific site control procedures at this site will include establishment of site work zones whenever employees are wearing respiratory protection. Unauthorized personnel will be restricted from entering the immediate work area.

7.0 PERSONAL PROTECTIVE EQUIPMENT

It is anticipated that Level D respiratory protection, with a contingency provision for the use of Level C will be used at these sites. Additional guidelines for the selection of respiratory protection at these sites are contingent upon the discovery of benzene vapors in the worker breathing zone while performing site activities. Site crews will assess the need for respiratory protection, or PPE, as applicable.

Protective clothing to be used at these sites includes:

- Hard hats
- Safety glasses
- Suits (Tyvek® or Saranex®)
- Respirator, if needed (APR with combination organic vapor/HEPA cartridges)
- Inner gloves (Latex or Vinyl)
- Outer gloves (Nitrile or Neoprene)
- Boots (Safety boots with latex boot covers)
- Other

8.0 PERSONNEL DECONTAMINATION PROCEDURES

See Section 10 of the program health and safety plan for general procedures and guidance. Of the compounds being used for decontamination, methanol is considered

potentially hazardous. Methanol is volatile and flammable. The PEL for methanol is 200 ppm. An STEL of 250 ppm for 15 minutes is allowed for methanol. Exposure of the skin to methanol can result in skin burns and/or skin absorption.

The PEL for methanol can be reached when the PID is reading 8 ppm. This is because the relative response factor of methanol is 0.04 when the PID is equipped with a standard 10.2 or 10.6 eV lamp and is calibrated with 100 ppm isobutylene. Therefore, air monitoring should be performed when decontaminating equipment with methanol. If a respirator is needed during such operations, appropriate cartridges should be used. Nitrile gloves and chemical goggles should be used.

Methanol will be in plastic bottle jackets during use in the field. These bottle jackets will be properly labeled, and during transport into the field will be cushioned inside a larger locked-lid plastic carrying container that is secured in the vehicle. All chemical wastes (waste methanol) generated during decontamination will be collected in an empty manufacturer's chemical bottle with a bottle jacket, labelled with contents, dated, and transported as described above. Call the point-of-contact at the Air Force Base for proper disposal procedures and transport to the hazardous materials storage area.

9.0 EMPLOYEE EXPOSURE MONITORING

Employee exposure monitoring will be conducted on this site in accordance with Occupational Safety and Health Administration (OSHA) standards (29 CFR 1910) and the program health and safety plan.

10.0 EMERGENCY RESPONSE PLAN

10.1 Safe Distances and Places of Refuge

Prior to initiation of field activities, the field crew shall decide on safe distances to retreat to and select a place of refuge in the event of an emergency. This information shall be provided to all pilot test field personnel during weekly or daily site-specific safety briefings. All other guidelines established in the program health and safety plan for emergency planning, training, recognition, etc. shall be followed.

10.2 Emergency Information

Listed below are the name and phone numbers for medical and emergency services for this project.

Hospital	USAF Hospital Hospital/Ellsworth AFB
Address	Building 6000 Ellsworth AFB, South Dakota
Phone	(605) 385-3430

Description of the route to the hospital:

From Area D, follow Bergstrom Drive east to Ellsworth Drive. Take a left on Ellsworth Drive and follow to LeMay Boulevard. Go right on LeMay Boulevard and follow to Building 6000, Base Hospital.

From Area D, follow Bergstrom Drive east to Ellsworth Drive. Take a left on Ellsworth Drive and follow to LeMay Boulevard. Go right on LeMay Boulevard and follow to Building 6000, Base Hospital.

Other Emergency Numbers:

Fire Department (605) 385-1117
Security Police (605) 385-2100
Ambulance (605) 385-3430

Program Health and Safety Manager:

Tim Mustard work: (303) 831-8100
home: (303) 450-9778

Project Manager:

Doug Downey work: (303) 831-8100
home: (303) 670-0512

11.0 REFERENCES

- Engineering-Science, Inc. 1994. *Draft Work Plan for Engineering Evaluation/Cost Analysis In Support of Risk-Based Approach to Remediation at Area D at Ellsworth Air Force Base, Rapid City, South Dakota.* July.
- Engineering-Science, Inc. 1994. *Program Health and Safety Plan for the Risk-Based Remediation Demonstrations.* Denver, Colorado. June.

PLAN ACCEPTANCE FORM
PROJECT HEALTH AND SAFETY PLAN

Instructions: This form is to be completed by each person to work on the subject project work site and returned to the safety manager.

I have read and agree to abide by the contents of the Health and Safety Plan for the following project:

Signed

Date

RETURN TO:

Office Health and
Safety Representative
Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290