

**FINAL**

**CORRECTIVE ACTION PLAN**

**BUILDING AS-4151  
MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA**

**CONTRACT TASK ORDER 0270**

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*Prepared For:*

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## TABLE OF CONTENTS

|                                                              | <u>Page</u> |
|--------------------------------------------------------------|-------------|
| <b>1.0 INTRODUCTION .....</b>                                | <b>1-1</b>  |
| 1.1 Site Location .....                                      | 1-1         |
| 1.2 Site Description .....                                   | 1-1         |
| 1.3 Purpose of CAP .....                                     | 1-2         |
| 1.4 Site History .....                                       | 1-3         |
| 1.4.1 ATEC Associates, Inc .....                             | 1-3         |
| 1.4.2 Baker Environmental, Inc. - Pipeline Assessment .....  | 1-3         |
| 1.4.3 Baker Environmental, Inc. - Phase I .....              | 1-4         |
| 1.4.4 Baker Environmental, Inc. - Phase II .....             | 1-5         |
| 1.5 Site Geologic Conditions .....                           | 1-6         |
| 1.6 Site Hydrogeologic Conditions .....                      | 1-7         |
| 1.6.1 Flow Characterization .....                            | 1-7         |
| 1.6.2 Aquifer Drawdown and Recovery Tests .....              | 1-8         |
| 1.7 Subsurface Soil Contamination .....                      | 1-8         |
| 1.8 Groundwater Contamination .....                          | 1-10        |
| <b>2.0 OBJECTIVES .....</b>                                  | <b>2-1</b>  |
| 2.1 Remediation Objectives .....                             | 2-1         |
| 2.2 Remediation Endpoints .....                              | 2-2         |
| 2.3 Remediation Schedule .....                               | 2-3         |
| <b>3.0 EXPOSURE ASSESSMENT .....</b>                         | <b>3-1</b>  |
| 3.1 Evaluation of Contaminant Levels .....                   | 3-1         |
| 3.1.1 Soil Contamination .....                               | 3-1         |
| 3.1.2 Groundwater Contamination .....                        | 3-1         |
| 3.2 Fate and Transport of Petroleum in the Environment ..... | 3-4         |
| 3.3 Identification of Human Exposure Pathways .....          | 3-8         |
| 3.4 Identification of Receptors .....                        | 3-9         |
| 3.5 Potential Effects of Contaminated Soil .....             | 3-9         |
| 3.6 Risk Evaluation .....                                    | 3-10        |
| <b>4.0 EVALUATION OF REMEDIAL ALTERNATIVES .....</b>         | <b>4-1</b>  |
| 4.1 Remedial Options .....                                   | 4-1         |
| 4.1.1 Soil Remediation Technologies .....                    | 4-1         |
| 4.1.2 Free Product Recovery .....                            | 4-5         |
| 4.1.3 Groundwater Recovery Technologies .....                | 4-5         |
| 4.1.4 Fluid Disposal Alternatives .....                      | 4-7         |
| 4.2 Selected Remediation and Disposal Alternatives .....     | 4-10        |
| <b>5.0 PROPOSED CORRECTIVE ACTION .....</b>                  | <b>5-1</b>  |
| 5.1 Pipeline Abandonment .....                               | 5-1         |
| 5.2 Soil Excavation .....                                    | 5-1         |
| 5.2.1 Excavation and On-Site Testing .....                   | 5-2         |
| 5.2.2 Off-Site Treatment .....                               | 5-2         |
| 5.2.3 Site Restoration .....                                 | 5-3         |

# **TABLE OF CONTENTS** (Continued)

|                                                                 | <u>Page</u> |
|-----------------------------------------------------------------|-------------|
| 5.3 Groundwater Recovery .....                                  | 5-3         |
| 5.3.1 Trench Installation .....                                 | 5-3         |
| 5.3.2 Subsurface Trenching .....                                | 5-4         |
| 5.3.3 Pneumatic Pumping System .....                            | 5-4         |
| 5.4 Groundwater Treatment .....                                 | 5-5         |
| 5.5 Remediation Construction Concerns .....                     | 5-6         |
| 5.5.1 Site Access .....                                         | 5-7         |
| 5.5.2 Construction Worker Health and Safety .....               | 5-7         |
| 5.5.3 Utility Clearance .....                                   | 5-7         |
| 5.5.4 Equipment Installation Considerations .....               | 5-8         |
| 5.5.5 System Startup and Operation .....                        | 5-9         |
| 5.5.6 Temporary Soil Stockpiling .....                          | 5-9         |
| 5.5.7 Effect of CAP on Activity Personnel .....                 | 5-10        |
| 5.6 System Monitoring .....                                     | 5-10        |
| 5.6.1 Soil Monitoring .....                                     | 5-10        |
| 5.6.2 Groundwater Monitoring .....                              | 5-11        |
| 5.6.3 System Effluent Monitoring .....                          | 5-11        |
| 5.6.4 Post-Operational Monitoring .....                         | 5-12        |
| 5.7 Monthly Reporting Requirements .....                        | 5-12        |
| 5.8 Annual Reporting Requirements .....                         | 5-13        |
| 5.9 Field Monitoring Procedures and QA/QC Considerations .....  | 5-13        |
| 5.10 Completion of Corrective Action and Site Restoration ..... | 5-13        |
| 5.11 Cost Estimate .....                                        | 5-14        |
| <br>6.0 PERMITS .....                                           | <br>6-1     |
| 6.1 NPDES Permit .....                                          | 6-1         |
| 6.2 Air Quality Permit .....                                    | 6-1         |
| 6.3 Well Construction Permit .....                              | 6-1         |
| 6.4 Certificate of Approval .....                               | 6-2         |
| <br>7.0 REFERENCES .....                                        | <br>7-1     |
| <br><b>APPENDICES</b>                                           |             |
| A Soil Disposal Documentation                                   |             |
| B Site Sensitivity Evaluation                                   |             |
| C Remediation Equipment                                         |             |
| D Standard Operating Procedures                                 |             |
| E Model Results                                                 |             |
| F Cost Estimate                                                 |             |

## LIST OF TABLES

- 1-1 Summary of Chemical Analyses for Soil Samples Collected During Pipeline Investigation
- 1-2 Summary of Chemical Analyses for Groundwater Samples Collected During Pipeline Investigation
- 1-3 Summary of Well Construction Details - June 1992
- 1-4 Summary of Well Construction Details - January 1993
- 1-5 Summary of Fluid Level Measurements - February 7, 1993
- 1-6 Summary of Hydraulic Conductivity Tests
- 1-7 Summary of Soil Analyses - June 1992
- 1-8 Summary of Soil Analyses - January 1993
- 1-9 Summary of Chemical Analyses for Groundwater Samples - June 1992
- 1-10 Summary of Chemical Analyses for Groundwater Samples - January 1993
  
- 2-1 Groundwater Remediation Endpoints
  
- 3-1 Major Components of JP-5 Jet Fuel
- 3-2 Concentrations of Selected Water Soluble Components of JP-5
- 3-3 Physical-Chemical Properties and Relative Mobility Indices for JP-5 Constituents
- 3-4 Records of Wells Identified in the Vicinity of Building AS-4151
- 3-5 Preliminary Exposure Assessment Summary
  
- 4-1 Screening of Potential Soil Remediation Options
- 4-2 Screening of Groundwater Remediation Alternatives
  
- 5-1 Monitoring Plan Summary
  
- 6-1 NPDES Permit Monitoring Requirements

## LIST OF FIGURES

- 1-1 Site Location Map
- 1-2 Campbell Street Fuel Farm Pipeline
- 1-3 Site Plan
- 1-4 Location of Underground Utilities
- 1-5 Previous Assessment Activities
- 1-6 Pipeline Repair Activities
- 1-7 Hydrogeologic Cross-Section Location Map
- 1-8 Hydrogeologic Cross-Section A-A' with Soil and Groundwater Analytical Results
- 1-9 Hydrogeologic Cross-Section B-B' with Soil and Groundwater Analytical Results
- 1-10 Potentiometric Surface Map, February 7, 1993
- 1-11 TPH Concentrations in Soils
- 1-12 Benzene and Total VOC Concentrations in Groundwater
  
- 3-1 Supply Wells in Site Vicinity
  
- 5-1 Recommended Site Remediation Plan
- 5-2 Diagram for Temporary Containment of Petroleum-Contaminated Soil
- 5-3 Schematic of Groundwater Interceptor Trench
- 5-4 Recommended Groundwater Treatment System Process Schematic

## 1.0 INTRODUCTION

This report presents the Corrective Action Plan (CAP) developed by Baker Environmental, Inc. (Baker), for the remediation of petroleum contamination at Building AS-4151 at the Marine Corps Air Station (MCAS) New River in Jacksonville, North Carolina. This CAP has been prepared for the Department of the Navy's Naval Facilities Engineering Command Atlantic Division (LANTDIV).

### 1.1 Site Location

Building AS-4151 is located along the western side of White Street at MCAS New River, Jacksonville, North Carolina. The location of the site is shown on Figure 1-1.

As shown on Figure 1-2, Building AS-4151 is located approximately 500 feet south of the intersection of White Street and Campbell Street. On the northwest corner of the Campbell and White Street intersection is the Campbell Street Fuel Farm. The fuel pipeline that extends from the fuel farm to the flightline parallels White Street and is located east of Building AS-4151. The location of Building AS-4151 and the fuel pipeline are shown on Figure 1-2.

### 1.2 Site Description

Building AS-4151 is a steam-generating plant for building operations in the MCAS area. The building operates three 100,000-gallon ASTs for No. 6 fuel oil. These ASTs are located west of Building AS-4151 as shown on Figure 1-3. The facility also operates a 1,000-gallon UST system located on the western side of Building AS-4151; this UST stores No. 2 fuel oil for an emergency generator located on site.

Facility personnel have indicated that a waste oil AST was formerly located on the west side of Building AS-4151. However, this AST was removed approximately five years ago.

As described earlier, a JP-5 fuel line passes beneath the eastern portion of the Building AS-4151 site. The fuel line extends from the Campbell Street Fuel Farm to the aircraft direct refueling stations approximately 0.7 miles southeast of the site. The fuel line was installed in 1985 adjacent to the old fuel line system which was abandoned in place near AS-4151.

The area surrounding the site generally consists of military buildings that support flight operations. Some undeveloped areas exist further west of Building AS-4151. A surface water drainage ditch parallels the eastern side of White Street, as shown on Figure 1-3.

Land cover in the subject area is mixed urban. Local land uses are limited to military activities. Undeveloped, wooded land is located west of the site. As stated earlier, the Campbell Street Fuel Farm is located approximately 500 feet north of Building AS-4151. The fuel farm operates four ASTs with capacities of 215,000 gallons each.

There are underground utilities in the immediate vicinity of the site that could potentially assist in contaminant migration. These lines and trenches include potable water, wastewater and storm water lines; telephone lines; an active JP-5 fuel line which services the aircraft direct refueling stations; and an abandoned JP-5 fuel line. The locations of these lines are shown on Figure 1-4. These utility lines have probably been backfilled with more permeable soils than the native soils; this increased permeability in a continuous, oriented line may facilitate contaminant transport.

### 1.3 Purpose of CAP

The purpose of this CAP is to describe and provide supporting documentation for the corrective action alternative selected for the remediation of petroleum-contaminated soils and groundwater at Building AS-4151.

The specific objectives of this CAP are to: (1) provide background assessment information; (2) provide measures to adequately protect human health and the environment; (3) present the corrective action to be undertaken at the site; (4) outline a monitoring plan to evaluate the progress of the corrective action, and (5) comply with applicable Federal and State regulations.

This CAP has been prepared based on the North Carolina Department of Environment, Health, and Natural Resources (DEHNR), "Groundwater Section Guidelines for the Investigation and Remediation of Soils and Groundwater." The guidelines, developed by the DEHNR Division of Environmental Management - Groundwater Section, was published in March 1993.

## **1.4     Site History**

The following sections discuss the results of previous assessment activities performed at the site.

### **1.4.1     ATEC Associates, Inc**

ATEC Associates, Inc., (ATEC) installed one monitoring well southeast of Building AS-4151 as part of an earlier investigation. Details of the well installation and purpose are not clear at this time. The location of the monitoring well is shown on Figure 1-5.

### **1.4.2     Baker Environmental, Inc. - Pipeline Assessment**

On December 9, 1991, Baker initiated an investigation of the JP-5 pipeline that extends from the Campbell Street Fuel Farm to the rapid refueling stations. The JP-5 fuel line parallels the western side of White Street and passes beneath the eastern portion of the Building AS-4151 site. This investigation included the following activities:

- Inoculation of the fuel supply at the fuel farm with a tracer compound. This tracer compound was allowed to spread through the fuel system. A soil gas survey was later performed along the pipeline to determine if the tracer compound was detected and to evaluate if the pipeline was leaking.
- Completion of 20 penetrometers (hydropunches) along the pipeline to evaluate groundwater conditions. Three of these hydropunches (13HP-2, 13HP-3, and 13HP-4) were performed in the vicinity of Building AS-4151 (Figure 1-5).
- Installation of seven shallow groundwater monitoring wells. One monitoring well, 13MW-1, was installed east of Building AS-4151 (Figure 1-5).
- Installation of four deep groundwater monitoring wells. One deep monitoring well, 13DW-1, was installed east of Building AS-4151 (Figure 1-5).
- Advancement of four soil test borings along the pipeline. None of these locations were in the vicinity of Building AS-4151.



- Collection of selected soil and groundwater samples for chemical analyses.

The field activities concluded on February 6, 1992. Baker submitted the Final Site Assessment Report (SAR) for these activities on August 12, 1992.

The soil gas survey activities did not detect releases from the active pipeline in the vicinity of Building AS-4151. However, some soil and groundwater contamination was detected in the vicinity of Building AS-4151 by the monitoring wells.

During this investigation, the maximum total petroleum hydrocarbon (TPH) concentration detected in the soil samples in the vicinity of Building AS-4151 was 391.1 milligrams per kilogram (mg/kg) in soil boring 13MW-1 (2.0 - 4.0 foot) and 28.73 mg/kg in soil boring 13DW-1 (2.0 - 4.0 foot). The chemical analyses of soil samples obtained in the vicinity of Building AS-4151 during this investigation are summarized on Table 1-1.

Groundwater samples from the monitoring wells and hydropunch locations indicate that groundwater contamination is present in the vicinity of Building AS-4151. Benzene concentrations ranged from non-detectable concentrations to a maximum of 3.16 microgram per liter ( $\mu\text{g/L}$ ) in monitoring well 13DW-1. Total volatile organic concentrations (VOCs) ranged from 0.55  $\mu\text{g/L}$  in hydropunch location 13HP-3 to a maximum concentration of 146.07  $\mu\text{g/L}$  in monitoring well 13MW-1. The chemical analyses of groundwater samples obtained in the vicinity of Building AS-4151 during this investigation are summarized on Table 1-2.

#### **1.4.3 Baker Environmental, Inc. - Phase I**

On June 15, 1992, Baker initiated assessment activities to evaluate the subsurface conditions in the vicinity of Building AS-4151. During this investigation, Baker performed the following activities:

- Installation of seven shallow groundwater monitoring wells (122MW-1 through 122MW-7).
- Installation of two deep groundwater monitoring wells (122DW-1 and 122DW-2).
- Collection of selected soil and groundwater samples for chemical analyses.

During this investigation, the Baker drilling subcontractor, ATEC, struck and damaged the active JP-5 pipeline. Baker repaired the pipeline and obtained four additional soil samples from the excavation to document the condition of the soils. It is estimated that less than 50 gallons of JP-5 fuel was released during this incident. Soil contamination, not related to the pipeline damage, was observed in the excavation.

During repair operations, Baker excavated and disposed of 27.61 tons of soil. Soils were disposed at a State-permitted bioremediation facility, McGill Environmental Systems, located in Rose Hill, North Carolina. Documentation of the soil disposal activities is provided in Appendix A. The extent of soils excavated during the pipeline repair operations are shown on Figure 1-6.

The location of the monitoring wells installed during this investigation are shown on Figure 1-5. The well construction details for the nine monitoring wells installed during this phase of assessment activities are summarized on Table 1-3.

Field activities were concluded on June 25, 1992. Baker submitted a Draft SAR describing the field activities and results on July 31, 1992. LANTDIV requested that additional field activities be performed. These additional activities were to be combined with the first phase of assessment activities to develop an revised SAR. Therefore, a Final SAR for the July 1992 assessment activities was not submitted.

#### **1.4.4 Baker Environmental, Inc. - Phase II**

The second phase of field activities commenced on January 11, 1993. During this investigation, Baker performed the following activities:

- Performed five soil test borings (122SB-1 through 122SB5).
- Installed seven shallow groundwater monitoring wells (122MW-8 through 122MW-14).
- Installed one 6-inch monitoring well (122RW-1) and attempted an aquifer test.
- Collected selected soil and groundwater samples for chemical analyses.

- Performed in-situ hydraulic conductivity tests in selected monitoring wells.

The locations of these soil borings and monitoring wells are shown on Figure 1-5. The well construction details for the eight monitoring wells installed during this phase of assessment activities are summarized on Table 1-4.

## 1.5 Site Geologic Conditions

According to Water-Resources Investigations Report 89-4096 published by the U.S. Geological Survey (1989), the shallow subsurface comprises undifferentiated layers of sands and silts to depths between 50 and 100 feet. These contain the surficial water-bearing layer, and are of Pleistocene and Holocene age. Underlying these deposits are the Belgrade and River Bend Formations of Oligocene age which contain the Castle Hayne Aquifer, the main water supply for the base.

Hydrogeologic cross-sections were generated based on information obtained during advancement of the soil borings. As shown on Figure 1-7, two hydrogeologic cross-sections, A to A' and B to B', traverse the site to illustrate horizontal and vertical subsurface soil conditions. In general, traverse A to A' was made south to north, with traverse B to B' west to east, across the site.

Cross Section A to A', Figure 1-8, depicts the geologic conditions encountered from soil boring 122MW-6 (south) to 122MW-13 (north). The upper zone of two to three feet contains primarily silts and sands with the exception of soil borings 122MW-9 and 122RW-1. The sands encountered in soil borings 122MW-9 and 122RW-1 appear to be backfill for the utility trenches at the site and extend approximately ten feet below ground surface. The dominant soil type along the traverse is a soft to stiff clay encountered approximately two to three feet below ground surface and extending at least to 17 feet. This clay generally increases in thickness from north to south.

Figure 1-9 depicts the geologic cross-section B to B' for conditions encountered from boring 122MW-3 (west) to 122DW-1 (east). As shown in cross-section B to B', the subsurface soil conditions are similar to those shown on cross-section A to A'. The deep soil borings for monitoring wells DW-1 and DW-2 indicate that a medium to fine-grained sand was between the elevations of 3 feet above and 10 feet below MSL (approximately 18 to 30 feet below ground

surface). This medium to fine sand overlies a layer of sand and gravel that indicates the beginning of the Castle Hayne Aquifer.

## **1.6 Site Hydrogeologic Conditions**

The hydrogeologic characteristics of the shallow water table are influenced, in part, by various land development activities at Building AS-4151. Considering surface water factors discussed in Section 1.2, most of the groundwater recharge would migrate laterally towards naturally and artificially-developed discharge areas along the water table. Downward movement of groundwater would be hindered by an aquitard of relatively impermeable sediments.

Groundwater was generally encountered beneath the site at approximately three to four feet below ground surface in the shallow wells, and four to five feet in the deep wells. Table 1-5 summarizes fluid level measurements and groundwater elevations for the site obtained on February 7, 1993. As shown on Table 1-5, free product was detected only in monitoring well 122MW-9; product thickness was recorded as 0.19 feet.

### **1.6.1 Flow Characterization**

Based on the February 7, 1993, elevation data, shallow groundwater appears to flow east across the site, as shown on Figure 1-10. Based on measurements obtained on February 7, 1993, the horizontal groundwater gradient in the shallow water-bearing zone was calculated at 0.0097.

Based upon the hydraulic conductivity tests performed on February 9, 1993, the average hydraulic conductivity for the shallow water-bearing zone is 0.14 ft/day. These values were calculated using the Geraghty and Miller aquifer test solver (AQTESOLV) program which uses the Bouwer and Rice (1976) method for unconfined aquifers. The average values calculated are consistent with expected values of hydraulic conductivity for the clays encountered at the site (Fetter, 1980). The results of the hydraulic conductivity test are summarized on Table 1-6.

Using the calculated gradient and the average hydraulic conductivity determined for the site, the average groundwater flow velocity can be estimated using a variation of Darcy's equation:

$$V = Ki/ne$$

Where: V = the estimated groundwater flow velocity  
K = hydraulic conductivity  
i = the groundwater gradient  
ne = the average effective porosity, as a decimal fraction

Using the average value  $K = 0.14$  feet/day calculated from the hydraulic conductivity test, a groundwater gradient of 0.0097, and an estimated effective porosity of 0.34 (Fetter 1980), the average groundwater flow velocity is calculated as  $4.0 \times 10^{-3}$  feet/day or 1.5 feet/year.

### 1.6.2 Aquifer Drawdown and Recovery Tests

Aquifer characterization tests (drawdown and recovery) were attempted in monitoring well 122RW-1 on February 7-9, 1993. The purposes of these tests were to evaluate the hydrologic properties of the water-bearing zones underlying the site, and to investigate the effect of pumping on the groundwater flow conditions.

A step-drawdown test was conducted at the site on February 7, 1993. At a flow rate of 0.25 gallons per minute (gpm) monitoring well 122RW-1 was pumped dry in approximately 37 minutes. The pump could not operate at a rate lower than 0.25 gpm and, therefore, the test was abandoned. An In-Situ, Inc. SE-2000 Environmental Data Logger, equipped with electric pressure transducers, was allowed to collect recharge data at the site, but after 48 hours the groundwater within monitoring well 122RW-1 had only recovered approximately 75% of its initial height.

Although a constant rate test could not be conducted and detailed calculations of aquifer parameters made at the site, the data collected during groundwater recharge indicates that the soils at AS-4151 have very low permeabilities. Correspondingly low groundwater flow rates are expected.

### 1.7 Subsurface Soil Contamination

Subsurface soil samples were collected from the 22 soil boring locations (122SB-1 through 122SB-5, 122MW-1 through 122MW-14, 122DW-1, 122DW-2 and 122RW-1). Two soil samples from each boring were collected and submitted for chemical analysis. Additionally, four grab samples were collected from the JP-5 fuel line excavation during repair work. Each of the soil samples were analyzed for total petroleum hydrocarbon (TPH); one sample from each of nine

selected soil borings was analyzed for pH and flashpoint. Additionally, four samples were collected as duplicates for TPH analysis. Soil analytical results for the Phase I and Phase II assessment activities are presented on Tables 1-7 and 1-8, respectively.

TPH results were divided into two categories, low to medium range boiling point petroleum hydrocarbons (gasoline type fuels), analyzed using EPA Method 8015/5030, and medium to high range boiling point petroleum hydrocarbons (diesel type fuels), analyzed using EPA Method 8015/3550. The detected TPH concentrations ranged from 0.68 mg/kg in 122DW-2 (4.0 to 6.0 foot) to 15,000 mg/kg in 122MW-9 (4.0 to 6.0 foot). The TPH detected in these soils were representative of No. 2 fuel oil, gasoline, diesel and JP-5. From the excavated area, TPH contamination ranged from 1.78 mg/kg in the bottom of the excavation to 4,833 mg/kg in the sample from the west wall (right wall) of the excavation. The TPH detected in these soils were representative of jet fuel.

The laboratory analytical results for pH ranged from 3.50 at soil boring 122MW-14 (6.0 to 8.0 feet) to 5.99 at soil boring 122MW-11 (3.5 to 4.0 feet). No soil sample was detected to have a flashpoint less than 220 degrees Fahrenheit.

Figure 1-11 shows the estimated extent of soil TPH contamination based upon the maximum TPH analyses detected within each soil boring. This includes both the low to medium boiling point TPH values and the medium to high boiling point TPH values. TPHs were detected at concentrations ranging from 0.68 mg/kg in soil boring 122DW-2 (4.0 to 6.0 feet) to 15,000 mg/kg in soil boring 122MW-9 (4.0 to 6.0 feet). As shown on Figure 1-11, the extent of TPH contamination which exceeds the site action level of 40 mg/kg appears to be located in the vicinity of the JP-5 fuel line.

Soil TPH analyses indicate that petroleum contamination extends to the water table (4.0 to 6.0 feet below ground surface) in borings 122SB-2, 122MW-7, 122MW-8, 122MW-9, 122DW-2, and 122RW-1. Soil samples collected during the fuel line repair indicated that contamination extends to the water table in the vicinity of the excavation. With little exception, TPH concentrations increase with depth, with the highest concentrations detected just above the water table.

Using the DEHNR procedure to evaluate soil remediation levels, a Site Sensitivity Evaluation (SSE) score was calculated for the site. The site received a score of 130, this combined with the site classification of Category D results in a final cleanup level of 40 mg/kg TPH in the soils.

As shown on Tables 1-7 and 1-8, of the 52 soil samples analyzed (including duplicate samples) from the soil borings and excavation, 17 were found to have TPH contamination and 15 samples had TPH contamination greater than the site cleanup level of 40 ppm. The SSE form and calculations are provided in Appendix B.

### 1.8 Groundwater Contamination

Groundwater samples were collected from the seven shallow and two deep wells installed during the first phase of field work conducted at the site (122MW-1 through 122MW-7, 122DW-1 and 122DW-2) on June 25, 1992. Groundwater samples from each monitoring well were analyzed by EPA Method 602. Additionally, one duplicate sample from monitoring well 122MW-7 was collected and analyzed for EPA Method 602. Groundwater samples from three monitoring wells (122MW-4, 122MW-5 and 122MW-7) were selected for analyses by EPA Method 625 (polynuclear aromatic hydrocarbons [PAH]).

Groundwater samples were collected from the eight wells installed during the second phase of field work (122MW-8 through 122MW-14 and 122RW-1) as well as two wells from the previous phase of work (122MW-2 and 122MW-3). A sample was collected from monitoring well 122MW-2 to confirm the presence of benzene detected during the first phase of work. Additionally, a sample was collected from monitoring well 122MW-3 to replace the samples damaged during transit to the laboratory during the first phase of work. Groundwater samples from each monitoring well were analyzed by EPA Method 602 and EPA Method 610 (PAH). Additionally, one duplicate sample was collected and analyzed for EPA Method 602 (monitoring well 122MW-12) and EPA Method 610 (monitoring well 122MW-9).

Analytical results for the groundwater sampling from Phase I and Phase II assessment activities summarized on Tables 1-9 and 1-10, respectively. As shown on Tables 1-9 and 1-10, concentrations of volatile organic compounds (VOCs) were detected in eight of the monitoring wells sampled, 122MW-2, 122MW-4, 122MW-7, 122MW-8, 122MW-9, 122MW-12, 122MW-14, and 122RW-1. The VOCs detected were benzene, toluene, ethylbenzene, xylene, ethylene dibromide (EDB), methyl tertiary butyl ether (MTBE), 1,3-dichlorobenzene, 1,4-dichlorobenzene, and 1,2-dichlorobenzene.

The benzene concentration detected in 122MW-2 (1st phase), 122MW-4, 122MW-9, 122MW-14 and 122RW-1 exceeded the North Carolina Water Quality Standard (WQS) of 1.0 µg/L. The benzene concentration detected in 122MW-2, 122MW-4 and 122MW-9 exceeded the Federal

Maximum Contaminant Level (MCL) of 5.0 µg/L. Although samples collected during the first phase of work from well 122MW-2 contained benzene contamination at concentrations above the Federal MCL and the North Carolina WQS, the groundwater sample collected from the well during the second phase did not contain concentrations of benzene above the detection limit of 0.75 µg/L.

PAH constituents were not found in any of the groundwater samples collected during the first phase of work. As shown on Table 1-10, PAH compounds were detected in monitoring wells 122MW-9 and 122MW-12 during the Phase II activities. The PAH compounds detected were phenanthrene, acenaphthene, anthracene, fluorene, acenaphthylene, and naphthalene. No State WQSs or Federal MCLs exist for these compounds.

As shown on Figure 1-12, the extent of benzene contamination is limited to an area located east of Building AS-4151. The source of the contamination contributing to the plume is expected to be the abandoned fuel line.

In addition to the dissolved groundwater contamination detected, weathered free product was observed in monitoring well 122MW-9 (0.19 feet) and on the water seeping into the excavation during the repair of the fuel line. Fluid level measurements, obtained on February 7, 1993, for all monitoring wells installed in the vicinity of Building AS-4151 are summarized on Table 1-5.



## 2.0 OBJECTIVES

This section discusses the remediation objectives of the CAP and the proposed cleanup levels.

### 2.1 Remediation Objectives

Soil and groundwater contamination have been identified in the eastern portion of the site in the vicinity of the abandoned JP-5 pipeline. The extent of the soil and groundwater contaminant plume has been defined. The results of the risk assessment (Section 3) conducted for this site suggest that the contaminants present do not pose an immediate health risk, and that the likelihood of contamination from the site affecting human receptors is minimal. The limited risk is primarily due to the low permeabilities of the soils in the area of contamination. In addition, the contamination is present in the shallow water-bearing layer, potable supply wells in the area obtain water from the deeper Castle Hayne Aquifer.

The assessment activities performed at Building AS-4151 identify one area of the site as requiring soil and/or groundwater remediation. This area is located west of White Street and extends from monitoring well 122MW-7 to near monitoring well 122MW-10.

In general, the cleanup goals of the remediation approach are as follows:

- Remove potential sources of contamination from the area.
- Remove measurable free product from the water table.
- Reduce TPH concentrations in soils in the vicinity of the abandoned pipeline to State approved levels; these levels will be based on the DEHNR SSE format.
- Reduce groundwater contaminant concentrations in the area to levels acceptable to the North Carolina WQSs.

Due to the numerous utilities located in the vicinity of Building AS-4151 and the low permeability of the shallow soils, contaminated soils (TPH >40 mg/kg) that are readily accessible will be actively addressed. The soils with the highest TPH concentrations will be excavated. The areas with less contaminated soils that are left in-situ will naturally degrade

naturally over time. By removing the soils with the highest levels of contamination, the greatest impact to the environment will also be reduced.

The pipeline may still contain some amounts of JP-5. If this is the actual case, the pipeline is a source of contamination to the area. The pipeline should be cleaned to confirm that all petroleum has been removed.

Petroleum contamination that has already migrated to the water table (dissolved contamination and free product) must be remedied to State-accepted levels. Due to soil conditions at the site and the nature of the contaminants, it is unlikely that the groundwater contamination levels can be reduced to the State-specified WQs. However, efforts will be made to lower these concentrations to asymptotic levels and remove free product.

## **2.2 Remediation Endpoints**

The groundwater remediation endpoints are based on State guidelines and established WQs. The WQs will be used as the initial groundwater remediation endpoints. The results of the risk assessment calculated that the impacts of the petroleum contaminants to human and ecological receptors at Building AS-4151 were limited. With this consideration, and if it is determined that attaining the WQs is not practical, remediation activities will continue until contaminant concentrations reach asymptotically low levels. Table 2-1 summarizes the maximum concentration of groundwater contaminants in comparison to established State WQs.

Using the State WQs and soil SSE procedure, remediation endpoints were evaluated and established to address each phase of petroleum contamination to comply with State regulations. The remediation endpoints are:

Groundwater: Groundwater was impacted at this site from direct contamination and from leaching of petroleum constituents from contaminated soils. Groundwater remediation was evaluated using the State WQs. If it is determined that attaining the WQs is not practical, remediation activities will continue until contaminant concentrations are reduced to asymptotic conditions.

Soil: Using the SSE, an evaluation score of 130 was calculated. This high score is primarily due to the sandy soils located along the JP-5 pipeline; soils away from the

pipeline are mostly silts and clays. Because the site has no contaminated water supply well within 1,500 feet and has a sufficient potable water supply, the site was classed as a Category D site. With this consideration, the site has a soil remediation level of 40 mg/kg TPH. A copy of the SSE used to determine the remediation endpoint for soil is provided in Appendix B.

Soils with TPH concentrations that exceed 40 mg/kg and are not removed by excavation activities will be permitted to naturally degrade. Only the soils along the abandoned pipeline and highly contaminated areas will be excavated.

Product: Free product was detected in one monitoring well, 122MW-9 (0.19 feet). The remediation endpoint for free product will be less than 0.01 feet of free product present on the water table.

### 2.3 Remediation Schedule

To achieve the remediation goals established in this CAP, the excavation of petroleum-contaminated soils, the installation of a groundwater recovery system, and the recovery and treatment of groundwater will be required. To perform these tasks, it will be necessary for the U.S. Government to procure several contractors. This procurement process will extend the amount of time required to complete the remediation activities.

Other concerns will also influence the remediation schedule for the site. Building AS-4151 is located in an active area; this is in a very industrialized area of the MCAS. It is vital that the flightline activities are not disrupted during remediation.

The following schedule provides a general timeframe for the completion of major tasks associated with implementing the remediation plan.

#### July 1994

- Acceptance of CAP by North Carolina DEHNR.
- U.S. Navy submits National Pollutant Discharge Elimination System (NPDES) permit application for the site remediation system.
- Procure contractor to design remediation system.
- Design engineer performs groundwater modeling of the recovery area.

#### November 1994

- Procure contractor to construct and install remediation system.

#### February 1995

- Clean abandoned JP-5 pipeline.
- Begin excavation of contaminated soils as required for the installation of the groundwater recovery system.
- Cap ends of the abandoned pipeline that is to remain in place.
- Dispose of excavated soils at State-permitted facility.
- Contractor procure necessary remediation equipment for groundwater recovery and treatment.
- Initiate groundwater monitoring program.

#### April 1995

- Excavation activities completed for installation of interceptor trench.
- Install recovery wells as necessary within the interceptor trench.
- Continue groundwater monitoring program as necessary.

#### May 1995

- Install groundwater recovery and treatment equipment.
- Continue groundwater monitoring program as necessary.

#### June 1995

- Complete installation of groundwater recovery and treatment system.
- Activate groundwater recovery and treatment system.
- Continue groundwater monitoring program as necessary.

#### June 1997

- Continue operation of the groundwater remediation system.
- System shutdown and post operational monitoring will begin once remediation goals have been met.

The actual length of time to achieve the remediation endpoints is unknown. It is anticipated that the remediation system will be in operation for a minimum of two years.

### **3.0 EXPOSURE ASSESSMENT**

This section discusses the results of the preliminary exposure assessment performed for Building AS-4151 during the earlier site assessment activities. The topics that will be addressed in this section are: (1) evaluation of contaminant levels; (2) fate and transport of petroleum in the environment; (3) identification of human exposure pathways; and (4) the identification of receptors.

#### **3.1 Evaluation of Contaminant Levels**

The following sections discuss the level of contamination detected in both the soil and groundwater at the site.

##### **3.1.1 Soil Contamination**

The soil analytical data identified TPH concentrations in 17 of the 52 soil samples (including duplicate samples). The detected TPH concentrations ranged from 0.68 mg/kg in 122DW-2 (4.0 to 6.0 foot interval) to 15,000 mg/kg in 122MW-9. The TPH detected in these soils were representative of No. 2 fuel oil, gasoline, diesel and JP-5. From the excavated area, TPH contamination ranged from 1.78 mg/kg in the bottom of the excavation to 4,833 mg/kg in the sample from the west wall (right wall) of the excavation. The TPH detected in these soils were representative of jet fuel. Fifteen soil samples exceeded the DEHNR remediation level of 40 mg/kg for TPH in soil, established by the SSE.

The detection of petroleum products identified as diesel fuel is likely the result of weathered JP-5 present in the sample. Weathered JP-5 would have very few volatile compounds remaining and could be identified by the gas chromatograph (GC) as diesel fuel.

##### **3.1.2 Groundwater Contamination**

Three different analytical methods were applied to evaluate the organic chemical concentrations in the groundwater at Building AS-4151. EPA Methods 602, 610, and 625 were used to detect VOCs and PAHs.

Groundwater samples from all 17 monitoring wells were analyzed for VOCs using EPA Method 602. Groundwater samples from three monitoring wells (122MW-4, 122MW-5, and

122MW-7) were analyzed for PAHs using EPA Method 625 during Phase I activities. All ten monitoring wells sampled during Phase II activities were analyzed for PAHs using EPA Method 610.

For the groundwater samples analyzed for PAHs, monitoring well 122MW-9 had the highest concentrations. Six PAHs were identified: anthracene (2 µg/L), acenaphthylene (10 µg/L), acenaphthene (3 µg/L), fluorene (4 µg/L), naphthalene (313 µg/L), and phenanthrene (2 µg/L). All six PAHs are constituents of petroleum fuels and are noncarcinogenic. At the present time there are no Federal MCLs or North Carolina WQSs for these constituents.

As presented on Tables 1-9, and 1-10, VOCs analyzed using EPA Method 602 had been detected in 8 of the 17 monitoring wells (9 of the 19 groundwater samples). EPA Method 602 utilizes the GC to identify compounds. The GC procedure identifies compounds based upon their retention times. Due to the similarities in solubilities of certain compounds, some tend to elute at the same time, making it difficult to differentiate compound identities by this method of analysis. This is the case for toluene and ethylene dibromide (EDB). As a result, the laboratory reported the concentration of these pairs as a combined value during Phase I activities. Since all of these chemicals have State and Federal standards, a conservative resolution to this issue of combined values would be to attribute all of the contamination to the chemical constituent with the most stringent standard. This is the approach that has been taken for this qualitative risk assessment. Laboratory results from the Phase II activities differentiated these compounds.

The following is a summary, by compound, of the purgeable aromatic compounds identified at Building AS-4151:

- Benzene was detected in 5 of the 19 groundwater samples collected. The detected concentrations ranged from 1.2 µg/L in 122MW-14 to 11.9 µg/L in 122MW-4. Monitoring well 122MW-2 was detected to have 9.53 µg/L of benzene in Phase I, but no detectable benzene in Phase II. Only three of the samples (including 122MW-2 Phase I results) exceeded the Federal MCL of 5.0 µg/L. All five of the groundwater samples exceeded the State WQS of 1.0 µg/L.
- Toluene/EDB was not detected during the Phase I sampling activities. Toluene was detected in two of the 10 groundwater samples collected during Phase II, at 1.6 µg/L in 122MW-8 and to 7.9 µg/L in 122MW-12. The MCL and WQS for toluene are

1,000 µg/L; neither of the groundwater samples exceeded this concentration. EDB was detected in one monitoring well (122MW-12) during the Phase II activities. The detected concentration was 0.98 µg/L. The MCL for EDB is 0.05 µg/L and the State WQS is 0.0005 µg/L, this sample exceeded the State and Federal standards for EDB.

- Ethylbenzene was not detected during the Phase I sampling activities. Ethylbenzene was detected in 3 of the 10 groundwater samples during Phase II activities. The detected concentrations ranged from 3.1 µg/L in 122MW-12 to 28 µg/L in 122RW-1. None of the concentrations exceeded ethylbenzene's MCL of 700 µg/L or the State WQS of 29 µg/L.
- Xylenes (total) were not detected during the Phase I activities and were detected in 2 of the 10 monitoring wells sampled during Phase II. The detected concentrations were 44 µg/L in 122RW-1 and 46 µg/L in 122MW-9. Xylenes (total) have an MCL of 10,000 µg/L and a State WQS of 400 µg/L; neither of the groundwater samples exceeded this concentration.
- 1,2-dichlorobenzene was detected in two groundwater samples during Phase I (monitoring well 122MW-7 and its duplicate sample) and one groundwater sample in Phase II. The detected concentrations ranged from 0.90 µg/L in 122MW-12 to 4.57 µg/L in 122MW-7. The MCL for 1,2-dichlorobenzene is 600 µg/L and the WQS is 620 µg/L; none of the detected concentrations exceeded these standards.
- 1,3-dichlorobenzene was detected in two groundwater samples during Phase I (monitoring well 122MW-7 and its duplicate sample) and one groundwater sample in Phase II. The detected concentrations ranged from 1.4 µg/L in 122MW-9 to 3.91 µg/L in 122MW-7. The MCL for 1,3-dichlorobenzene has not been established while the WQS is 620 µg/L; none of the detected concentrations exceeded the WQS standard.
- 1,4-dichlorobenzene was detected in one monitoring well during Phase I (122MW-4) and was not detected during Phase II activities. The detected concentration was 3.33 µg/L. This did not exceed the MCL for of 75 µg/L but did exceed the state level of 1.8 µg/L.
- MTBE was detected in two monitoring wells, 122MW-2 (3.70 µg/L) and 122MW-4 (5.08 µg/L) during Phase I. No MTBE was detected in samples obtained during

Phase II. The concentrations detected were below the State WQS of 50.0 µg/L. There currently is no MCL established for MTBE.

Table 2-1 summarizes the analytical data from both phases of field activities and compares this information with State WQSs.

### **3.2 Fate and Transport of Petroleum in the Environment**

Petroleum products are complex mixtures of hydrocarbons; more than one hundred compounds can be found in a typical fuel (EPRI, 1989). Each constituent has different chemical and physical properties that control the ultimate fate and transport of the petroleum products in the soil. In general, when petroleum hydrocarbons are released into unsaturated soils, they tend to migrate vertically under the force of gravity, with some slight lateral spread (Schwendeman, 1989). This migration pathway may be interrupted by adsorption to soil particles, inhibition by a geologic formation (i.e., low transmissive capability) or by cultural features (i.e., pipe channels or foundations). The subsurface transport of contaminants is also controlled by complex interactions between chemical, physical, and biological processes. Some conditions which affect migration are:

- Soil texture
- Soil uniformity or nonuniformity
- Soil layer configuration
- Depth to water table
- Soil structure
- Flow stability
- Soil moisture

The major constituents of JP-5 jet fuel are presented in Table 3-1. Table 3-2 presents the concentrations of water soluble components of JP-5 jet fuel detected in a mixture of 1 part JP-5 to 1,000 parts water. The chemicals, toluene, ethylbenzene, xylenes, naphthalene and methylnaphthalene, account for approximately 75 percent of the water soluble constituents of JP-5.

The physical and chemical properties of a compound are responsible for its mobility in the environment. These properties, in conjunction with site conditions, determine whether a chemical will readily volatilize into the air or be transported via advection or diffusion



through the soil, groundwater, and surface water. These characteristics also describe the tendency of a chemical to adsorb onto soil/sediment particles. Environmental mobility can correspond to either an increased or decreased potential to affect human health.

Persistence of a chemical in the environment is also important in the potential risk and depends on factors such as the microbial content of soil and water, organic carbon content, the concentration of the chemical, climate, and the ability of the microbes to degrade the chemical under site conditions. In addition, chemical degradation (e.g., hydrolysis), photochemical degradation and certain fate processes such as sorption may contribute to the elimination or retention of a particular compound in a given medium.

The environmental mobility of a chemical is influenced primarily by its physical and chemical properties and the site chemistry. The following sections evaluate the properties of the chemicals or groups of chemicals detected, with emphasis on potential environmental mobility and persistence.

The following text summarizes physical and chemical properties for the primary constituents of JP-5 which directly affect the persistence and mobility of these constituents identified at Building AS-4151. Table 3-3 presents the physical and chemical properties associated with the chemicals detected at the site including: specific gravity; vapor pressure; water solubility; octanol/water partition coefficient; organic carbon adsorption coefficient, Henry's law constant; and mobility index. A discussion of the environmental significance of each of these properties follows.

### **Specific Gravity**

Specific gravity is the ratio of the weight of a given volume of pure chemical at a specified temperature to the weight of the same volume of water at a given temperature. Its primary use is to determine whether a constituent will have a tendency to "float" or "sink" (as an immiscible liquid) in water only if it exceeds its corresponding water solubility. Specific gravity of a constituent must be assessed along with the constituents water solubility to produce a qualitative estimation of movement in the water column. For example, the maximum groundwater analytical results for the constituent benzene was 73 µg/L. The specific gravity for the compound is 0.879 g/cm<sup>3</sup> suggesting that the chemical would float in the saturated zone. However, its water solubility of 1,780 mg/L is roughly 24,000 times

greater than its maximum detected value. Under these circumstances, the chemical will tend not to float but disperse throughout the aquifer.

### **Vapor Pressure**

Vapor pressure provides an indication of the rate at which a chemical may volatilize. It is of primary significance at environmental interfaces such as surface soil/air and surface water/air. Volatilization is not as important when evaluating groundwater and subsurface soils. Vapor pressures for monocyclic aromatics and chlorinated ethenes or ethanes are generally higher than vapor pressures for semivolatiles. Chemicals with higher vapor pressures are expected to enter the atmosphere much more readily than chemicals with lower vapor pressures.

### **Water Solubility**

The rate at which a chemical is leached from soil by infiltrating precipitation and its behavior in a water column is a function of its water solubility. More soluble chemicals are usually more readily leached than less soluble chemicals. For example, the water solubilities presented in Table 3-3 indicate that the volatile organic chemicals, (monocyclic aromatics), are usually several orders-of-magnitude more soluble than certain semivolatile compounds.

### **Octanol/Water Partitioning Coefficient**

The octanol/water partition coefficient ( $K_{ow}$ ) is a measure of the equilibrium partitioning of chemicals between octanol and water. The coefficient is also useful in characterizing the sorption of compounds by organic soils where experimental values are not available.

### **Organic Carbon Adsorption Coefficient**

The organic carbon adsorption coefficient ( $K_{oc}$ ) indicates the tendency of a chemical to adhere to soil particles containing some amount of organic carbon. Chemicals with high soil/sediment adsorption coefficients generally have low water solubilities and vice versa. For example, chemicals such as the semivolatiles are relatively immobile in the environment with respect to the volatile organics and are preferentially bound to the soil. These compounds are not as inherently likely to experience aqueous transport to the extent of compounds with higher

water solubilities. Erosional properties of surface soils and the presence of dissolved organic macromolecules in groundwaters may enhance the mobility of these bound soil chemicals.

### Henry's Constant

Both vapor pressure and water solubility are of use in determining volatilization rates from surface water bodies and from groundwater. These two parameters can be used to estimate an equilibrium concentration of a constituent in the water phase and in the air directly above the water. This can be expressed as Henry's Constant. As a rule, constituents having a Henry's Constant exceeding  $10^{-3}$  volatilize readily from surface water bodies. Therefore, the constituents detected at the facility will tend to leave the water column at atmospheric pressure (i.e., shallow, unconfined aquifer or surface waters).

### Mobility Indices

A quantitative assessment of mobility has been developed that uses water solubility (S), vapor pressure (VP) and organic carbon partition coefficient ( $K_{oc}$ ) (Laskowski, 1983). This value is referred to as the Mobility Index (MI). It is defined as:

$$MI = \log((S \times VP)/K_{oc})$$

A scale to evaluate MI is presented by Ford and Gurba (1984):

| <u>Relative MI</u> | <u>Mobility Description</u> |
|--------------------|-----------------------------|
| >5                 | extremely mobile            |
| 0 to 5             | very mobile                 |
| -5 to 0            | slightly mobile             |
| -10 to -5          | immobile                    |
| <-10               | very immobile               |

The MIs for the chemicals selected using prevalence criteria are also presented in Table 3-3.

The following paragraphs summarize the general fate and transport data for JP-5 constituents at the site.

## **Volatile Organic Compounds (VOCs)**

VOCs (i.e. benzene) tend to be relatively mobile in environmental media as indicated by their presence in groundwater. Their inherent mobility and their relatively high MIs result from high water solubilities, high vapor pressures, low  $K_{ow}$  and  $K_{oc}$  values.

Benzene does not tend to persist in environmental media because photolysis, oxidation, and biodegradation figure significantly in their removal, and they are seldom detected in surface soils where volatilization and other removal processes predominate. Benzene has a soil half-life of 16 days and a groundwater half-life of 128 days (Howard et al., 1991).

## **Polynuclear Aromatic Hydrocarbons (PAHs)**

The PAH is generally less mobile than the VOC benzene. Naphthalene (-2.5) is slightly mobile by virtue of its water solubility and vapor pressure.

PAHs also tend to be more persistent environmentally. Photolysis and biodegradation figure to be the most significant removal processes. Naphthalene has a half-life of approximately 48 days in soil, and 252 days in groundwater (Howard et al., 1991).

### **3.3 Identification of Human Exposure Pathways**

Potential inhalation of volatile organic compounds from groundwater, ingestion of groundwater, dermal contact with soil and inhalation of particulates are plausible exposure pathways. One drinking water well is located approximately 800 feet southeast of the site. However, because all drinking water at the Base is obtained from the deep Castle Hayne Aquifer or supplied by public water sources, exposure to shallow groundwater is unlikely.

Construction information for the supply well located 800 feet southwest of the site is provided on Table 3-4. The location of the supply well is shown on Figure 3-1.

The site is covered dominantly by grass and asphalt; accordingly, the potential for soil dispersion as fugitive dust may exist and potential dermal exposure to contaminated soils may occur if site soils are disturbed during remediation or construction activities.

### 3.4 Identification of Receptors

Potential groundwater receptors cannot be identified in this area. Groundwater in the area is supplied by public water sources. Receptors to possibly contaminated soil in the area are limited to workers who may perform remediation or construction at the site.

### 3.5 Potential Effects of Contaminated Soil

Since not all of the contaminated ( $> 40$  mg/kg for TPH) soil will be removed from the site, these soils will remain as a potential source of groundwater contamination. Therefore, this potential source was evaluated to determine the effect of these soils on the environment. A naphthalene "leachate" was calculated based on the amount of soil TPH contamination present in the areas that will not be remediated, and the values of water soluble compounds of JP-5 listed on Table 3-2. A detailed description of these calculations is included in Appendix E.

The SLUG2D (version 2.03) analytical model for solute transport was used to evaluate the migration of a naphthalene "leachate" to determine the future contaminant concentrations at the site. This compound was chosen based on its frequency and the levels detected at the site.

The SLUG2D simulation of the fate and transport problem is based on the generalized advection-dispersion equation by Wilson and Miller (1978). It computes the two-dimensional advective transport of contaminants in the shallow water bearing zone over a given distance with respect to time. All model assumptions and input parameters are included in Appendix E. The model assumptions provide a conservative estimate of the potential contaminant migration.

The model was used to simulate the migration of contaminants for periods of 0.5, 1, 5, 10, and 25 years. Based on the results included in Appendix E, potential naphthalene concentrations identified by the model ranged from 0.0001 mg/L (each interval) to 0.0114 mg/L (0.5-year model). Additionally, a comparison of model results indicated that the naphthalene concentrations will decrease with respect to time. The maximum concentration predicted in the 0.5-year model is 0.0114 mg/L, while the maximum concentration estimated in the 25-year model is 0.0012 mg/L. Therefore, although naphthalene will leach from the contaminated soil left on site, the effects on the environment should be minimal.

### 3.6 Risk Evaluation

Based on a qualitative perspective, the low levels of contaminants detected do not appear to pose a potential public concern. Exposure to contaminants at the site will likely occur if remediation or construction activities are performed at the site. In the event that such activities are performed at the site, appropriate health and safety procedures developed for the protection of human health should be followed. Low levels of volatile contamination detected in the groundwater do not present a potential problem unless water from the shallow water-bearing zone is used for public drinking water supplies. Results of the preliminary exposure assessment are summarized on Table 3-5.

## **4.0 EVALUATION OF REMEDIAL ALTERNATIVES**

This section of the CAP discusses the type and extent of soil and groundwater contamination in the vicinity of Building AS-4151, and evaluates applicable remediation alternatives for soil and groundwater remediation. A remediation alternative consists of a combination of technologies or a single technology capable of addressing the site-specific contamination at the site. Several different types of soil and groundwater remediation alternatives have been screened for the site. Each alternative that was selected as suitable was further evaluated based upon site conditions, contaminant type, and costs. A site-specific alternative was then selected to address the contamination present.

### **4.1 Remedial Options**

#### **4.1.1 Soil Remediation Technologies**

The objectives for the remediation of soils are to reduce the level of contaminated soils that exceed the soil remediation endpoint established by the SSE, and to reduce or eliminate the effects that excessively contaminated soils have on the groundwater. The determination of the SSE score is presented in Appendix B.

Table 4-1 presents demonstrated technologies for soil remediation including an evaluation of each of technology based on applicability to the site, feasibility, and costs. Based on this evaluation, several technologies appear to be potentially applicable to the Building AS-4151 site. These soil remediation technologies are indicated, briefly discussed, and further evaluated below. As a result, the most applicable technologies will be recommended.

##### **4.1.1.1 In-Situ Leaching**

In-situ leaching is a process which involves extracting contaminants from soil by "washing" or "flushing," using water or more typically, a water-surfactant mixture. The process involves injecting or spraying a solution onto the area of contamination; the solution then percolates downward through the soil, adsorbing hydrocarbons from the soil. The mixture leaches through the soil under the influence of gravity until it reaches the groundwater table. The leached solution is then collected and pumped to the surface for removal or on-site treatment and reinjection. The use of this technology for soil remediation at a site is dependent on the

nature of the contamination and the permeability of the site soils. Costs to perform this type of remediation can range from \$150 to \$200 per cubic yard of soil.

The major advantage of in-situ leaching is that the contaminant source area can be remediated in-situ (i.e., without excavation). System application is fairly simple and a variety of solutions can be used. The major disadvantage is that it is very dependent upon site geologic conditions. Also, a disadvantage is the necessity of using this technique in conjunction with a recovery system which would require the treatment and/or disposal of recovered liquids.

Evaluation/Recommendation: The type and low permeability of soils at shallow depths reduces the effectiveness of this technology. The shallow depth to groundwater at the site is also not favorable for this alternative. The low permeability of the soils would reduce the ability of the treated fluids to "flush" out contaminants. The numerous subsurface utilities in the area may also divert injected fluids from the zone of contamination. Remediation using this method may require an extended period of time. This option may be expensive as compared to other alternatives, and may not be the best alternative for this site. Therefore, in-situ leaching is not considered an applicable technology for the site.

#### 4.1.1.2 In-Situ Bioremediation

In-situ bioremediation is a process which relies on naturally occurring or genetically altered microorganisms to break down or transform contaminants to less hazardous compounds. The use of this technology may require the addition of nutrients and oxygen to the soil to enhance the biodegradation process. These additives are typically mixed into a water source which is introduced to the subsurface by leaching through the soil under the influence of gravity.

When this method is used in conjunction with groundwater remediation efforts, groundwater is typically extracted from the subsurface, mixed with nutrients and an oxygen source, and reintroduced into the subsurface via an infiltration gallery or injection system located upgradient of the contaminated area. The typical costs for remediation using this type of alternative is \$75 per cubic yard.

Major advantages to this method include: it will remediate the source area in-situ; it does not require treatment or disposal of water; it is unobtrusive and is not labor intensive. The major



disadvantage to this method is (depending on the nature of the contaminant and host soil) the time span needed to reduce the contaminant concentration to an acceptable level.

**Evaluation/Recommendation:** The amount of silt and clay in the soil at the site reduces the effectiveness of this technology. The low permeability of the soils and shallow depth to groundwater at the site further reduces the suitability of this method. This option has high capital costs and may require a lengthy period of time for to reduce contaminant concentrations to the desired levels. Therefore, this technology is not recommended for the Building AS-4151 site.

#### 4.1.1.3 Vacuum Extraction

Vacuum extraction (or in-situ venting) is a method that vents soil by volatilizing the contaminants in the soil from a liquid phase to a vapor phase, with removal of the vapor phase contaminants from the soil atmosphere. The process involves application of a vacuum through a network of wells. The vapors are drawn through the soil air spaces to the wells, where they are captured and brought to the surface. Once the contaminant-saturated vapors are brought to the surface, additional treatment may be required. This technology may be enhanced through injection of volatile-free air into the zone of contamination. The use of this technology for soil remediation at the site also appears to be an option given the moderate hydraulic conductivity of the soils, the shallow depth to groundwater, and the apparently limited area of contamination. Costs for implementing the vacuum extraction technique may range from \$50 to \$75 per cubic yard.

The major advantage of this method is that it removes the volatile components of hydrocarbon contaminated soil (which contribute to groundwater contamination) in-situ. Disadvantages include that it will not impact the nonvolatile components of hydrocarbon contaminated soil and it requires vapor phase treatment of groundwater off-gases.

**Evaluation/Recommendation:** Because the petroleum contamination in the vicinity of Building AS-4151 is weathered JP-5, vacuum extraction technology may not be feasible to reduce the contamination, a majority of the weathered JP-5 has already volatilized. In addition, the low permeability of the soils reduces the effectiveness of this technology. Due to these low permeability soils, the extraction points would require close spacing and result in increased installation and operation costs. This technology is not recommended due to the condition of the petroleum contamination, costs, and unsuitable soil conditions.

#### 4.1.1.4 Excavation

Excavation of hydrocarbon contaminated soil (> 40 mg/kg TPH) would eliminate the source of groundwater contamination. The excavated material could be handled in the following ways:

- Disposal-excavated material transported to an authorized off-site landfill.
- "Landfarming" - spreading the soil on the surface and mixing it to increase volatilization and biodegradation of the contaminant. This activity could be performed at an off-site bioremediation facility located near the activity.
- Low temperature thermal reduction (LTTR) - excavated soil placed into an apparatus where the contaminants are driven from the soil through enhanced volatilization by the application of heat. This activity may be performed at an off-site facility or a mobile unit may be brought on site. For the later case, the treated soil could be used for backfill.

Evaluation/Recommendation: Due to the extent of contamination observed in the Building AS-4151 area, widespread excavation of soils above 40 mg/kg is not feasible. Numerous utilities in the area eliminates the this extent of excavation activities. However, the greatest TPH concentrations were detected along the abandoned pipeline. It would be beneficial to excavate soils along a portion of the pipeline where the contamination is the greatest. Soils beyond the extent of excavation would be permitted to degrade naturally over time.

Excavation with treatment either off site at an bioremediation facility or a LTTR facility, or on site treatment using a mobile LTTR unit are the recommended technologies for the disposal of soils. This type of treatment would be effective on the low permeable soils present at the site. Excavation with treatment of the highest contaminated soils would effectively reduce elevated levels of petroleum contamination and reduce further migration of contaminants into the water table.

Excavation activities could be completed within a one month period if soils are hauled off-site. The cost of off-site disposal is \$28 per ton at nearby bioremediation and LTTR facilities. With transportation and backfilling expenses, the overall cost for the alternative would range from \$50 to &70 per cubic yard.

Although feasible alternatives, landfarming and landfill disposal were not selected based upon site requirements and suitability to the U.S. Navy. The use of a landfill would not eliminate future liability associated with the contamination.

#### **4.1.2 Free Product Recovery**

Free product was detected in one monitoring well (0.19 feet in monitoring well 122MW-9). However, pipeline repair activities indicated that additional free product is present in the area. The largest amount of free product is likely located along the abandoned pipeline.

Excavation of the soils (proposed earlier to address contamination along the abandoned pipeline) would have several purposes:

- It is anticipated that the majority of saturated soils associated with the free product would be removed; this could also remove highly contaminated soils that continue to leach free product and dissolved contamination to the groundwater.
- The excavated area could be backfilled in such a manner that would assist in the recovery of free product that may remain in the area. Any remaining free product that may be present at the site will be addressed by the proposed groundwater recovery system.

#### **4.1.3 Groundwater Recovery Technologies**

As discussed in Section 3.0, several petroleum constituents exceeded established WQSa established by the State. Based on these standards it will be necessary to remedy the groundwater at the site. Several potential technologies that may be applicable for the recovery of groundwater have been screened based on capability and limitations and are presented on Table 4-2. The technologies which appear to be potentially applicable to the site will be evaluated (with respect to advantages and disadvantages) in the following subsections. Please note that generic recovery technologies and not specific variations on each type of technology have been included in the following discussions.

#### 4.1.3.1 Well Points

Well point technology consists of installation of a number of small diameter recovery wells on the perimeter of the free phase product plume. This technology is best suited for sandy soil conditions.

Evaluation/Recommendation: This option may have high initial capital costs to cover well installation and recovery equipment costs. Due to the geologic setting present, this method cannot be the best alternative for this site.

#### 4.1.3.2 Recovery Wells

Recovery wells are a conventional, demonstrated technology, which is useful with sandy aquifers. A typical recovery well would likely be 6 to 12 inches in diameter and extend 10 feet to 20 feet into the water table. The distance between the wells and the flow rates would be dependent on geologic conditions. A considerable quantity of groundwater would also be generated by this process depending on the geologic conditions.

Evaluation/Recommendation: The results of an eight-hour aquifer test performed at the site during the second phase of assessment activities, indicate that soil conditions are not suitable for this technology. A recovery well cannot generate a significant radius of influence at the site. The low permeability of the soils would require several recovery wells at the site, with a close spacing pattern to affect the groundwater at the site. The costs associated with installing and maintaining each recovery well with the necessary equipment does not make this option suitable for the site.

#### 4.1.3.3 Interceptor Trenches

An interceptor trench is excavated downgradient of a plume for the purpose of intercepting and preventing further migration of free-phase product. The trench is dug to a depth several feet below the water table and long enough to intercept the full lateral extent of the plume. The trench should also be perpendicular to local groundwater flow directions. As the product plume migrates, free product accumulates in the trench and can be recovered manually or with pumps. An impermeable liner can be placed on the downstream side of the trench to eliminate free product moving past the trench. Sumps or wells may also be installed in the trench to increase the rate of recovery (EPA, 1990).

Evaluation/Recommendation: This is an effective technology at sites which have silt or clay soils present. The shallow groundwater present at the site adds to the suitability of this approach. This option can inhibit the migration of the product plume.

This alternative is the recommended option for remediation at the site. As soils are excavated to remove contaminated soils, the excavation will be backfilled with a gravel material, producing a zone of high permeability. Recovery wells installed within the trench will lower the water level within the trench, creating a local depression. This will permit groundwater and free product from both sides of the trench to migrate into this permeable trench where product may be recovered. By influencing the water level to migrate to the trench, contamination in the soils beyond the trench will not migrate further and will degrade naturally.

#### **4.1.4 Fluid Disposal Alternatives**

Several methods of treated groundwater disposal were evaluated. These disposal methods include:

- Disposal through infiltration galleries
- Disposal by injection well system
- Disposal to a wastewater treatment plant
- Disposal to a surface water or drainage ditch

Each disposal method was evaluated based upon cost (design, installation, maintenance, and monitoring), feasibility, and consideration to the impact to future land uses in the area. Each disposal alternative and associated evaluation is described below.

##### **4.1.4.1 Infiltration Gallery**

An infiltration gallery is an area where a permeable media, such as gravel or sand, is installed within an area of low permeability soils. The design of an infiltration gallery is similar to a trench or septic drainage field. The increased surface area of the gallery permits the infiltration of water into the soils. The treated water is discharged over the media and allowed to infiltrate into the underlying soils.

In North Carolina the gallery must operate as a "closed loop" system, (i.e. fluids introduced into the subsurface will be captured through the recovery portion of the remediation system). The installation requires documentation (computer models, results of previous pilot studies, published reports, etc.) that both supports the effectiveness of the proposed process and demonstrates that applicable water, air, or land quality will not be contravened. The level of treatment of the contaminated groundwater, prior to discharge into a gallery located outside the contaminant plume, must not contain concentrations of contaminants in excess of those specified in the groundwater quality standards (15A NCAC 2L.0202). If the treated water is infiltrated within the contaminant plume, the water shall not contain more than five percent of the concentration of contaminants in the groundwater influent.

Evaluation/Recommendation: The infiltration gallery is an acceptable method of fluid disposal in low permeability soils. However, given the soil conditions of the site, the shallow groundwater conditions, and the available land space and usages in the area, the use of a infiltration gallery is not recommended.

#### 4.1.4.2 Injection Well

An injection well pumps fluids into underlying geologic zones or aquifers. According to North Carolina regulations, the injection well must be constructed and operated such that: (1) the injected liquid does not exit the well bore above or below the demonstrated vertical extent of the contaminant plume, (2) operation of the remediation system will not result in a contravention of groundwater quality standards at the compliance boundary (15A NCAC 2C.0107), and (3) the operation is a "closed loop" system.

The level of treatment of the contaminated groundwater, prior to discharge into an injection well located outside the contaminant plume, must not contain concentrations of contaminants in excess of those specified in the groundwater quality standards (15A NCAC 2L.0202). If the treated water is infiltrated within the contaminant plume, the water shall not contain more than five percent of the concentration of contaminants in the groundwater influent.

Evaluation/Recommendation: Given the state requirements that the injected liquid does not exit the well bore above or below the demonstrated vertical extent of the contaminant plume, the suitability of injection wells at the site is not feasible. The shallow groundwater and low permeability of the shallow soils are not suitable for this alternative.

#### 4.1.4.3 Wastewater Treatment Plant

This fluid disposal option uses existing sanitary sewer lines to receive treated groundwater discharge. The groundwater is treated, discharged into the sewer line, and then further treated at a municipal wastewater treatment facility. Discharge into the sewer lines is not possible without authorization from the wastewater treatment facility.

Evaluation/Recommendation: MCB Camp Lejeune operates several wastewater treatment plants. The White Street area is served by the Camp Geiger Wastewater Treatment Plant. Sewage lines for the wastewater treatment plant are located in the vicinity. However, the lines in this area are reportedly near capacity. The MCB does not want to increase the flow within the lines by receiving waste streams from remediation systems. Therefore, this disposal alternative is not acceptable.

#### 4.1.4.4 Surface Water and Drainage Ditches

This disposal option results in treated groundwater being discharged to a surface water or drainage ditch. To utilize this option, a NPDES General Permit is required. This general permit is not acceptable for contaminants other than petroleum. Design and operation of the remediation systems that utilize this option must accord with 15A NCAC 2B.0100 (Wastewater Discharged to Surface Water). Major permitting considerations include (but are not limited to) types and concentrations of contaminants, and daily volume of discharge.

Evaluation/Recommendation: Although there may be significant delays in receiving a NPDES permit, this alternative is the most suitable for the site. A drainage ditch is located in the immediate vicinity (eastern side of White Street) of Building AS-4151. In addition, a storm sewer is located along the western side of White Street. The storm sewer eventually discharges into the drainage ditches near the intersection of White Street and Campbell Street.

The anticipated low flow rates of the remediation system (5 to 10 gpm) will not impact the carrying capacity of the storm sewer line or the drainage ditch. In addition, the treated groundwater will not adversely impact the quality of the water within the ditch.

Due to traffic concerns and additional costs associated with installing a subsurface line beneath White Street, discharge into the drainage ditch on the east side of the street is not

recommended. Discharge should be to the storm sewer located on the western side of the street.

#### 4.2 Selected Remediation and Disposal Alternatives

Based upon the results of the two phases of site assessment activities performed at the site, and the evaluation of potential remediation technologies, the following remediation alternatives were selected for the site:

- Clean the abandoned JP-5 pipeline of any remaining petroleum products.
- Remove the portion of the abandoned pipeline and excavate soils beneath the pipeline in the vicinity of Building AS-4151.
- Within the excavation area, install an interceptor trench for the recovery of free product and petroleum-contaminated groundwater.
- Contain recovered free product and treat groundwater.
- Discharge treated groundwater to the storm sewer located along western side of White Street.

The treatment process for the recovered groundwater would consist of an oil/water separator, followed by a low-profile air stripper, and finally a carbon adsorption treatment. Filters will also be installed within the system to reduce the potential of sediments or metals fouling the system.

The oil/water separator is recommended to remove free product that migrates to the interceptor trenches and is recovered. Because of the low flow rates anticipated from the combined discharge of the recovery wells within the interceptor trench (5 to 10 gpm) and the low concentrations of organic compounds present, it is anticipated that a low-profile air stripper be used to reduce organic concentrations. Two carbon adsorption units in series would be used to treat groundwater after the air stripper and prior to discharge. Although it is anticipated that the air stripper will adequately reduce organic concentrations, the carbon adsorption unit will "polish" the treated water before discharge to the storm sewer.



## **5.0 PROPOSED CORRECTIVE ACTION**

This section of the CAP presents a discussion of the proposed remediation alternative for Building AS-4151. The following subsections discuss the design of the remediation alternative; remediation construction concerns; and proposed system monitoring approach.

The recommended corrective action for the site is the proper abandonment of the JP-5 pipeline; the removal of petroleum contaminated soils along the abandoned pipeline in the vicinity of Building AS-4151; and the recovery and treatment of free product and petroleum-contaminated groundwater from the trench. The remediation alternatives are discussed below.

### **5.1 Pipeline Abandonment**

The entire length of the abandoned Campbell Street Fuel Farm Pipeline should be cleaned and all remaining JP-5 removed. The pipeline will be cleaned by sending remote-control devices into the pipeline. The cleaning will be performed by a firm experienced in this type of service.

All recovered JP-5 and wash fluids will be recovered for proper disposal. After cleaning services are completed, MCAS may want to consider grouting the abandoned pipeline so it does not assist the migration of other contaminant fluids or vapors in the vicinity of Building AS-4151 or other areas along the pipeline.

### **5.2 Soil Excavation**

The JP-5 pipeline and petroleum-contaminated soils located beneath the pipeline will be excavated from the area east of Building AS-4151. It is anticipated that the excavation activities will not remove all petroleum-contaminated soils above the remediation endpoint. However, it will remove the soils with the highest TPH concentrations and soils that contain free product.

The proposed extent of soil excavation activities is shown on Figure 5-1. The extent of this area was based on soil samples obtained in the area and the presence of underground utilities located in the area. The extent of the excavation will not be based on the soil remediation endpoint established by the SSE.

The excavated soils will be transported off-site to either a LTTR facility or a bioremediation facility. The excavated trench will be three feet wide and ten feet deep (except at the recovery well locations). With the limits of the excavation shown on Figure 5-1, 230 cubic yards of soil will be removed.

#### **5.2.1 Excavation and On-Site Testing**

The area delineated on Figure 5-1 will be excavated several feet beneath the groundwater surface. It is anticipated that upon removal of the soil and on site field testing, the soil will be transported off site. Therefore, dewatering of the excavated soil will not be required. Contaminated soils will be loaded into lined dump trucks and transported to the disposal facility. If soils cannot be placed directly into the dump trucks, it may be necessary to temporarily store them at Building AS-4151. These soils will be stored in the area east of Building AS-4151. To prevent contamination of stormwater runoff and underlying soils, the soils will be covered in a temporary containment area, as shown on Figure 5-2.

If necessary, temporary shoring will be provided around exposed utilities. The excavation will continue to the extent shown on Figure 5-1 unless site conditions (free product observed in the soils) necessitate extending the length of the excavation. It is anticipated that the extent of the excavation will not include asphalt or concrete roadway areas of the site.

The final extent of the soil excavation and periodic sections along the trench will be sampled for chemical analyses. The sampling activities are to confirm the condition of the soils that remain in place. The results are not to be used to require additional excavation activities.

It is not anticipated that the excavation activities will damage or destroy the monitoring wells located at the site. If excavation activities require that a monitoring well be removed or accidentally damage a well, the monitoring well will be properly abandoned.

#### **5.2.2 Off-Site Treatment**

Due to the close proximity of off-site soil recycling companies, such as McGill Environmental Systems in Rose Hill and American Soils Corporation in New Bern, North Carolina, off-site treatment is recommended for the disposal of soils generated during excavation activities. Soils located above the pipeline may be separated from other soils until laboratory analyses confirm the TPH concentration limits. Soils above 40 mg/kg will be disposed at an off-site

facility. The contaminated soils shall be placed into trucks with covers, and hauled to the disposal facility.

### **5.2.3 Site Restoration**

All temporary shoring will be removed upon replacement with fill material. Topsoil will be placed on disturbed areas and graded to match the surrounding terrain, and the area will be revegetated. The temporary soil stockpiling containment structure will be decontaminated and dismantled. The components of the containment structure will be properly disposed. General site clean up and equipment demobilization will occur upon completion of all remediation activities.

## **5.3 Groundwater Recovery**

The following section describes the construction details associated with groundwater recovery operations.

### **5.3.1 Trench Installation**

As discussed in Section 4.0, an interceptor trench will be used to recover groundwater. The interceptor trench was selected over other remediation alternatives due to the shallow depth to groundwater and the low permeability of the soils. The interceptor trench will create an area of higher permeability. As groundwater is removed from the trench, groundwater from the adjacent silt and clay soils will migrate into the trench, and the cycle repeated.

Two recovery wells will be installed within the interceptor trench. The proposed location of the interceptor trench and the two recovery wells are shown on Figure 5-1. The actual length of the trenches will depend upon soil and groundwater conditions encountered during construction. If free-product saturated soils are detected, the length of the trench may be extended. However, the actual length of the trench will ultimately depend upon other site conditions such as subsurface utilities, disruption of Building AS-4151 services, traffic concerns, etc.

The trench will be three feet wide with a depth of ten feet. The trench will be excavated to 14 feet at the recovery well locations to allow additional room within the well for the pump.

The interceptor trenches shall be backfilled with gravel suitable for the well screen and geologic conditions. The gravel backfill shall extend 1/2 foot above the well screen. A geotextile fabric will be placed over the gravel fill to prevent shallow backfill soils from migrating into the gravel zone.

The recovery wells will be completed below grade within a lockable vault box or manhole that is capable of containing the necessary pump controls. A schematic of an interceptor trench is shown on Figure 5-3.

### **5.3.2 Subsurface Trenching**

Subsurface trenching connecting the recovery wells with the air compressor and remediation system will be required. Compressed air and recovered groundwater lines will be placed within a 4-inch PVC pipe. The piping will be installed within the subsurface trenches and covered with compacted backfill.

A portion of this subsurface trench will extend to the storm sewer line located along the western side of White Street. Access of the discharge line to the storm sewer will be required to complete the remediation system.

### **5.3.3 Pneumatic Pumping System**

#### **5.3.3.1 Pneumatic Pump**

A pneumatic pump will be installed within each recovery well. The pneumatic pump will be designed to recover free product and petroleum contaminated groundwater. The pump must be constructed of a material that is resistant to petroleum products (JP-5). All fittings and product return lines associated with the pump must also be resistant to petroleum products.

Several companies manufacture pumps that meet the product recovery requirements for this site. Examples of such manufacturers are QED Environmental Systems, Inc., (QED) of Ann Arbor, Michigan, and Ejector Systems of Chicago, Illinois. Pneumatic pump information supplied by Ejector Systems is provided in Appendix C.

#### 5.3.3.2 Air Compressor

The pneumatic pumps for both recovery wells will be powered by a single air compressor. The air compressor will be an electric type of sufficient horsepower to operate both pumps, and be equipped with an appropriately sized receiver tank.

#### 5.3.3.3 Equipment Storage Building

A prefabricated equipment storage building will be constructed to house the recovery pump control panel, the electric air compressor, the oil/water separator, product storage tank, air stripper, and carbon adsorption unit. The storage building will be constructed and equipped at the factory for immediate installation and operation at the site. The building shall already be internally wired and constructed on a skid mounted platform for movement to other facilities once remediation is completed at Building AS-4151.

A chain-link fence will enclose the equipment storage building for added security. The fence will have a gate constructed on the two opposite sides to permit access to the equipment storage building. Each gate will be constructed to swing a minimum of 90 degrees so equipment may be replaced or repaired if needed.

#### 5.4 Groundwater Treatment

Aquifer testing performed at the site during the second phase of assessment activities (Baker 1993), indicated that low flow rates are anticipated for the treatment system. Based upon the aquifer test results, it is estimated that the flow rate for the system will be less than 5 to 10 gallons per minute (gpm). The treatment system will be designed to treat a maximum flow rate of 15 gpm.

Before actual construction is performed at the site, it is recommended that some type of groundwater modeling be performed to estimate in greater detail the flow rate of the recovery system.

Based on this maximum flow rate of 15 gpm, the treatment system will have the following processes for treating groundwater:

- The pneumatic pumps will recover groundwater and direct it to the treatment system. The groundwater will first pass through an oil/water separator.
- Effluent from the oil/water separator will be sent to a low-profile air stripper.
- Effluent from the air stripper will be sent to a suspended solid/iron removal filter. The suspended solids/iron removal filter will consist of a series of replaceable filter plates, or a cartridge-type filter system. This filtration system is necessary to remove suspended solids prior to the carbon adsorption system.
- Effluent from the filter will be pumped through two liquid-phase granular activated carbon (GAC) adsorbers installed in series. The GAC will reduce any remaining volatile and semivolatile compounds in the groundwater within acceptable discharge requirements.
- The treated groundwater will be pumped to the storm sewer located east of the site as shown on Figure 5-1.

Several companies manufacture equipment for the treatment of petroleum contaminated groundwater. Information from one such company, Ejector Systems, for the equipment discussed above is provided in Appendix C.

The proposed treatment equipment will be located within the storage building. The equipment will be preassembled by the manufacturer and ready to place into service with a minimum amount of field construction time. All electrical components will have an explosion-proof rating. A schematic of the proposed recovery system is shown on Figure 5-4.

## 5.5 Remediation Construction Concerns

Logistical and construction issues associated with the implementation of the recommended remedial actions should be addressed prior to initiation of construction activities. These include site access, construction worker health and safety, utility clearance, and temporary soil stockpiling, and are addressed below.

#### **5.5.1 Site Access**

The remediation contractor will have to make arrangements with the Activity for daily access to the site, and for access to the site outside normal working hours.

#### **5.5.2 Construction Worker Health and Safety**

The contractor will be required to prepare a site-specific Health and Safety Plan (HASP) to provide for the safety of construction workers during construction activities. The plan will include but is not limited, to the following items:

- An outline of the tasks to be conducted at the site and the associated physical and health hazards of these tasks.
- The potential risks to the health and safety of the construction worker.
- The physical and chemical properties of the contaminants at the site.
- Measures to detect the presence of contamination.
- Standard operating procedures for protection against hazards and a contingency plan for responding to accidents.

The HASP should be reviewed by all construction workers at the site, and should be updated as activities or conditions warrant. Only workers with the appropriate health and safety training will be permitted to work at the site.

#### **5.5.3 Utility Clearance**

A primary concern during site preparation and actual remediation activities will be locating and identifying all underground utilities in the work area. The MCB Camp Lejeune Public Works Department will provide utility clearance for those areas that will be disturbed prior to construction. A plan of the study area with approximate subsurface utility locations is provided on Figure 1-4.

#### 5.5.4 Equipment Installation Considerations

The installation of the equipment recommended for the groundwater recovery and treatment system will include conventional construction techniques such as: installation of underground piping in utility trenches, installation of an equipment storage building, and installation of the necessary electric service, power panels and controls. The main components necessary for the groundwater treatment and recovery system is as follows:

- Installation of groundwater interceptor trench.
- Installation groundwater recovery pneumatic pumps.
- Installation of subsurface trenching to connect pumps with treatment system.
- Installation of an equipment storage building which will contain the air compressor, oil/water separator, air stripper, carbon adsorption unit, and control board.

Figures 5-1 and 5-4 show the site plan and process schematic of the recommended system, respectively. Construction considerations for the major components of the system are discussed below.

The equipment storage building will be located southeast of Building AS-4151. This location is proposed due to the available space and close proximity of the drainage ditch. The equipment storage building will contain the remediation equipment such as: air compressor, oil/water separator, air stripper, carbon adsorption unit, and control board.

The equipment storage building will be located in a manner that will not interfere with MCAS New River activities and will be designed to permit easy access for construction and service vehicles. The storage building will be secured with locking door. A chain-link fence will surround the building as an additional safety precaution.

Electric service of sufficient capacity will be brought to a pole or pad mounted transformer next to the equipment storage building. The power distribution and controls for the equipment should have an explosion-proof rating.



### **5.5.5 System Startup and Operation**

The groundwater recovery system should operate continuously 24 hours a day, seven days a week. Startup of the groundwater recovery system will be the responsibility of a contractor selected by the U.S. Navy. The contractor will be required to initially operate the equipment during the initial startup. During this startup period, the contractor will be responsible for making any necessary equipment adjustments or repairs. The contractor will also be required to provide a detailed system operation and maintenance (O&M) manual to the Activity.

### **5.5.6 Temporary Soil Stockpiling**

Temporary soil stockpiling will be necessary during trenching or excavation activities. A method to temporarily stockpile soils is shown on Figure 5-2. Excavated soils must be sampled before being used as clean backfill. A minimum of one composite sample for every 100 cubic yards of stockpiled soil will be obtained to evaluate the condition of the soils. If the soil contains TPH concentrations above 40 mg/kg, it will be removed from the site and disposed at a State-permitted LTTR or bioremediation facility.

Soils being considered for off-site disposal will be collected and analyzed for the following analytical parameters:

- Percent moisture (EPA Method 160)
- Total organic halogens (EPA Method 9020)
- TPH (EPA Method 418.1)
- VOCs (EPA Method 8020)
- Toxicity characteristic leaching procedure (TCLP) metals (these include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver)
- Polychlorinated biphenols (PCBs) (EPA Method 8080)

A minimum of one composite sample will be collected for every 100 cubic yard of soil to be disposed.

#### **5.5.7 Effect of CAP on Activity Personnel**

The implementation of the remediation alternative will affect Activity personnel who work in the area. These personnel will be notified by their supervisor of the planned corrective action, and what effects it may have on their daily routine. Workers will be notified of the potential physical hazards posed during the construction and implementation of the remediation alternatives. Examples of such hazards are open trenches and excavations, exposed underground utilities, exposure to odors during excavation and the movement of construction vehicles.

In addition, workers will receive instruction on the potential hazards associated with the operation of the groundwater recovery system. These hazards include air emissions from the air stripper.

### **5.6 System Monitoring**

An outline of the monitoring plan, including sampling frequency, sample locations, parameters to be measured, levels to be reported, and data submittal requirements, is presented for the selected remediation alternative in the following sections. Reporting requirements are discussed in Sections 5.6.2 and 5.6.3. Standard operating procedures (SOPs) suggested for the monitoring requirements are listed in Section 5.6.4, and included in Appendix D.

Under the proposed remediation alternative, soil excavation and groundwater treatment will be performed to remedy the petroleum contamination. The monitoring plan has been designed to confirm that the designated remediation endpoints for soil and groundwater contamination have been met and that the remediation system is operating effectively. The components of the monitoring plan (sampling locations, sampling frequency, and method of analysis) are summarized on Table 5-1.

#### **5.6.1 Soil Monitoring**

Once the full extent of the excavation has been reached, confirmatory soil samples shall be obtained from the side walls of the excavation. One soil sample shall be taken every 50 feet along the excavation wall. Sampling locations will be staggered along both sides of the trench

so actually a soil sample will be recovered every 25 feet along the excavation. One soil sample will also be recovered from each end of the excavation. Based upon Figure 5-1, it is estimated that 10 soil samples will be obtained to confirm the condition of the soils not excavated.

Each soil sample selected will be analyzed in the laboratory for TPH using EPA Method 8015 (5030/3550). The laboratory detection limit will be a no greater than 10.0 mg/kg.

#### **5.6.2 Groundwater Monitoring**

Groundwater quality monitoring will be conducted on a quarterly basis following the initiation of remediation activities, and then on a quarterly basis. Samples will be collected from existing monitoring wells 13MW-1, 13DW-1, 122MW-3, 122MW-4, 122MW-7, 122MW-8, 122MW-9, and 122MW-11. The purposes of the monitoring activities are to evaluate the organic concentrations within the groundwater and the effectiveness of the remediation system.

Groundwater samples from the selected monitoring wells will be analyzed for volatile organics using EPA Method 602. In addition, groundwater samples from monitoring wells 13DW-1 and 122MW-9 will also be analyzed for PAHs using EPA Method 610. The laboratory detection limit for the volatile organic and PAH analyses will be a no greater than 0.001 mg/L.

Fluid level measurements will be obtained monthly from the monitoring wells which will be sampled, and the following additional wells: 122MW-5, 122MW-6, 122MW-13, 122MW-14, 122RW-1, and the two recovery wells within the interceptor trench. Fluid level measurements shall include thickness of free product in addition to groundwater elevations. This information shall be used to evaluate the effectiveness of the remediation system and determine if adjustments in flow rates may be required.

#### **5.6.3 System Effluent Monitoring**

The discharge flow rate of the treatment system will be monitored weekly as specified by the NPDES permit requirements. In addition, effluent samples shall be obtained monthly and analyzed for toluene, benzene, and MTBE using EPA Method 602.

#### **5.6.4 Post-Operational Monitoring**

Post-operational monitoring will be conducted at the site after the remediation goals for soil and groundwater contamination have been met. The post-operational monitoring may begin after soil and groundwater remediation endpoints have been met for one full year.

Post-operational monitoring will include sampling the selected monitoring wells for the presence of volatile organics and PAHs. The groundwater sampling activities will be performed quarterly for one year after the operation of the groundwater treatment system has been terminated.

Groundwater samples will be obtained from the same monitoring wells that were sampled during the operational monitoring period. The groundwater samples will be obtained quarterly until the post-operational monitoring period is terminated. If during the year of post-operational monitoring the groundwater remediation endpoints are exceeded, the operation of the groundwater treatment system may be resumed.

#### **5.7 Monthly Reporting Requirements**

MCB Camp Lejeune will submit monthly reports to the DEHNR regional office. These monthly reports will summarize the results of the groundwater and effluent monitoring activities performed at the site. The following information will be included in the monitoring reports:

- The results of all monitoring data, including monitoring well gauging, free product levels (if detected), effluent analytical results, and groundwater analytical results if quarterly sampling occurred during that month.
- Remediation system performance and air emissions monitoring results.
- If applicable for the reporting period, a description of the circumstances or events that caused mechanical problems with the remediation system, including dates and times of nonoperation, and actions taken or planned to correct the problem.

In addition to the monthly monitoring reports, MCB Camp Lejeune personnel will report to the DEHNR Regional Office any unpermitted or unusual discharge that may enter or affect

State waters, or may endanger public health. Such reporting shall be made within 24 hours from the time the Activity becomes aware of the discharge or release.

#### **5.8     Annual Reporting Requirements**

In addition to the monthly monitoring reports, an annual report will be submitted to the DEHNR. The annual report will include monitoring results, evaluate the effectiveness of the remediation alternative and its progress toward achieving the cleanup endpoints. The first report shall be submitted within 12 months of initiation of remediation activities, and yearly thereafter, if necessary.

#### **5.9     Field Monitoring Procedures and QA/QC Considerations**

Example standard operating procedures (SOPs) for the collection of samples and field data have been included in this CAP in Appendix D. These examples may be used as guidelines to implement the monitoring plan:

- F102    Soil and Rock Sample Acquisition
- F104    Groundwater Acquisition
- F201    On-site Water Quality Testing
- F202    Water Level, Water-Product Level, and Well Depth Measurements
- F203    Photoionization Detector (PID)
- F204    Flame Ionization Detector (FID)
- F301    Sample Preservation and Handling
- F302    Chain-of-Custody
- F304    QA/QC Samples
- F502    Decontamination of Sampling and Monitoring Equipment

#### **5.10    Completion of Corrective Action and Site Restoration**

The corrective action will be complete after demonstrating that the site-specific remediation endpoints (no free product, 40 mg/kg TPH in the soil, and specified organic concentrations in groundwater) have been met for twelve consecutive months. A request may then be submitted to the State to end remediation activities, and begin post operational monitoring.

Post operational monitoring will be conducted quarterly for a one year period after shut down of the groundwater treatment system. If levels of volatile organic concentrations in groundwater greater than the specified endpoints (or agreed upon asymptotic concentrations with the State) are detected during the post operational monitoring, the remediation system will again be activated and the operational treatment system monitoring plan implemented.

Site restoration activities will commence after all confirmatory sampling results have been evaluated to verify that contamination exceeding the remediation endpoint is removed.

Following equipment demobilization and removal of all subsurface remediation equipment and piping, the disturbed area(s) will be graded to match the previously existing ground cover. Finally, general site cleanup activities will be performed.

#### **5.11 Cost Estimate**

A cost estimate was prepared for the proposed remediation alternative (Appendix F). The estimate includes labor and equipment costs for: site preparation, soil excavation and disposal, recovery trench installation, pipe subsurface trenching, remediation equipment (i.e., air stripper, pumps, filters, carbon adsorbers) and system operation and monitoring. all assumptions are listed in appendix E. The estimated cost to install and operate the system is \$309,779.

## **6.0 PERMITS**

Because of the remediation alternative selected for the site; soil excavation, groundwater extraction and treatment, and discharge to a drainage ditch, several permits are required from the State of North Carolina. These permits include:

- NPDES permit
- Air quality permit/registration
- Well construction permit
- Certificate of approval

### **6.1 NPDES Permit**

Because the treatment system shall be discharging to a storm sewer, a NPDES permit will be required. The permit shall require weekly monitoring of the discharge rate of the treatment system. In addition, monthly chemical sampling of the system effluent shall be required. The chemical analyses to be performed, effluent limitations, and other monitoring requirements are summarized on Table 6-1.

### **6.2 Air Quality Permit**

The treatment system shall utilize a low profile air stripper. This stripper will generate volatile emissions into the atmosphere. As required by the State of North Carolina, the air stripper must be registered with the State. However, an air quality permit shall not be required to operate the unit. Based on the organic concentrations observed in the groundwater, emissions of total organics and individual constituents such as benzene, toluene, chlorobenzene, total xylenes, and 1,2-, 1,3- and 1,4-dichlorobenzene will not exceed de minimis emission rates established by the State.

### **6.3 Well Construction Permit**

Recovery wells shall be installed within the interceptor trench at two locations. Because water will be extracted from the wells, a well construction permit shall be required by the State of North Carolina.

#### 6.4 Certificate of Approval

Disposal of petroleum contaminated soils at an off-site treatment facility requires approval from the state of North Carolina. Approval of the certificate is automatic when the soils are stored on site less than 45 days and they are stored as shown on Figure 5-2. The off-site disposal facility must be permitted to dispose of petroleum contaminated soils.



## 7.0 REFERENCES

Baker Environmental Inc. March 1993. Draft Site Assessment Investigation, Building AS-4151 - The Steam Generating Plant. Marine Corps Air Station, New River, Jacksonville, North Carolina. Contract N62470-89-D-4814, Contract Task Order 0122.

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**TABLE 1-1**  
**SUMMARY OF CHEMICAL ANALYSES FOR**  
**SOIL SAMPLES COLLECTED DURING PIPELINE INVESTIGATION**  
**BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0270**

| Boring<br>No. | Field Sample No. | Parameter                                     |                               |                   |                    | Sample Depth<br>(feet, below<br>ground surface) |
|---------------|------------------|-----------------------------------------------|-------------------------------|-------------------|--------------------|-------------------------------------------------|
|               |                  | Total<br>Petroleum<br>Hydrocarbons<br>(mg/kg) | Petroleum Type <sup>(1)</sup> | pH                | Flashpoint<br>(°F) |                                                 |
| 13MW-1        | PL-S-MW1-01      | 391.10                                        | Weathered jet fuel            | NA <sup>(3)</sup> | NA                 | 2.0 - 4.0                                       |
| 13MW-1        | PL-S-MW1-02      | .. <sup>(2)</sup>                             | NA                            | 6.85              | > 140              | 4.0 - 6.0                                       |
| 13DW-1        | PL-S-DW1.01      | 3.27                                          | Weathered jet fuel            | NA                | NA                 | 0.0 - 2.0                                       |
| 13DW-1        | PL-S0DW1.02      | 28.73                                         | Weathered jet fuel            | NA                | NA                 | 2.0 - 4.0                                       |

**Notes:**

- (1) EPA Method 8015 (5030/3550) estimated range of petroleum type
- (2) - = Not detected at method detection limit
- (3) NA = Not Analyzed

Total petroleum hydrocarbons analyzed using EPA Method 8015 (5030/3550).  
pH analyzed using Method SW-9047.  
Flashpoint analyzed using Method SW-1010.

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814,  
Contract Task Order 0122).

TABLE 1-2

**SUMMARY OF CHEMICAL ANALYSES FOR  
GROUNDWATER SAMPLES COLLECTED DURING PIPELINE4 INVESTIGATION  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270**

| Method/Contaminant               | 13MW-1 | 13DW-1 | 13HP-2 | 13HP-3 | 13HP-4 | Maximum<br>Concentration<br>Level<br>(µg/L) | NC Water<br>Quality<br>Standard<br>(µg/L) |
|----------------------------------|--------|--------|--------|--------|--------|---------------------------------------------|-------------------------------------------|
| <b>EPA Method 601</b>            |        |        |        |        |        |                                             |                                           |
| Purgeable Halocarbons (1)        | --(2)  | NA(3)  | NA     | NA     | NA     |                                             |                                           |
| <b>EPA Method 602 (4) (µg/L)</b> |        |        |        |        |        |                                             |                                           |
| Volatile Organic Compounds       |        |        |        |        |        |                                             |                                           |
| MTBE (5)                         | --     | --     | --     | --     | 0.34   | NE(6)                                       | 50(7)                                     |
| Benzene                          | 2.26   | 3.16   | 0.87   | --     | --     | 5.0                                         | 1.0                                       |
| Toluene/EDB (8)                  | --     | 7.35   | 0.57   | --     | 0.18   | 1,000/0.05                                  | 1,000/0.0005                              |
| Ethylbenzene                     | 5.72   | 1.88   | 0.15   | 0.55   | 0.28   | 700                                         | 29                                        |
| m-, p- Xylene and Chlorobenzene  | 2.75   | 2.05   | 1.09   | --     | 1.05   | 10,000/100                                  | 400/300                                   |
| o-Xylene                         | 0.74   | 1.14   | --     | --     | 2.47   | 10,000(9)                                   | 400                                       |
| 1,3 & 1,4-Dichlorobenzene        | 63.75  | 18.28  | --     | --     | --     | NE/75                                       | 620/1.8                                   |
| 1,2-Dichlorobenzene              | 70.85  | 5.29   | --     | --     | --     | 600                                         | 620                                       |
| Total VOCs (10)                  | 146.07 | 39.15  | 2.68   | 0.55   | 4.32   | NE                                          | NE                                        |
| <b>EPA Method 625(11)</b>        |        |        |        |        |        |                                             |                                           |
| PAHs (µg/L)                      | 48     | NA     | NA     | NA     | NA     | NE                                          | NE                                        |
| Naphthalene                      |        |        |        |        |        |                                             |                                           |

**Notes:**

(1) Purgeable Halocarbons analyzed using EPA Method 601. No purgeable halocarbons were detected.

(2) -- Less than method detection limit.

(3) NA - Not Analyzed.

(4) Purgeable aromatics analyzed by EPA Method 602 in µg/L.

(5) MTBE - Methyl Tertiary Butyl Ether.

(6) NE = Not Established.

(7) MTBE WQS is an Interim Standard.

(8) EDB - Ethylene Dibromide. Method could not resolve Toluene and EDB. Concentrations reported as a combined value.

(9) The MCL for Xylene (Total) Includes Meta, Para, and Ortho Xylenes.

(10) Sum of total volatile organic compounds detected using EPA Method 602.

(11) Polynuclear Aromatic Hydrocarbons (PAHs) analyzed by EPA Method 625. Only one PAH compound (naphthalene) was detected.

Table reflects only those parameters which were detected.

**Source:**

Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-3

**SUMMARY OF WELL CONSTRUCTION DETAILS - JUNE 1992  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270**

| Well No. | Date Installed     | Top of Casing Elevation <sup>(1)</sup> (feet, above MSL) | Ground Surface Elevation (feet, above MSL) | Boring Depth (feet, below ground surface) | Depth of Outer Casing (feet, below ground surface) | Well Depth (feet, below ground surface) | Screen Interval Depth (feet, below ground surface) | Depth to Sand Pack (feet, below ground surface) | Depth to Bentonite (feet, below ground surface) |
|----------|--------------------|----------------------------------------------------------|--------------------------------------------|-------------------------------------------|----------------------------------------------------|-----------------------------------------|----------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 122MW-1  | 6-18-92            | 22.75                                                    | 20.0                                       | 16.5                                      | NA <sup>(2)</sup>                                  | 16.0                                    | 6.0 - 16.0                                         | 4.0                                             | 1.5                                             |
| 122MW-2  | 6-18-92            | 22.48                                                    | 19.9                                       | 20.0                                      | NA                                                 | 18.7                                    | 8.0 - 18.0                                         | 6.0                                             | 4.0                                             |
| 122MW-3  | 6-18-92            | 22.23                                                    | 19.0                                       | 14.5                                      | NA                                                 | 14.2                                    | 4.0 - 14.0                                         | 3.0                                             | 1.0                                             |
| 122MW-4  | 6-18-92            | 19.60                                                    | 19.8                                       | 14.5                                      | NA                                                 | 14.2                                    | 4.0 - 14.0                                         | 3.0                                             | 1.5                                             |
| 122MW-5  | 6-19-92            | 18.60                                                    | 18.7                                       | 13.5                                      | NA                                                 | 13.2                                    | 3.0 - 13.0                                         | 2.0                                             | 1.0                                             |
| 122MW-6  | 6-20-92            | 18.38                                                    | 18.7                                       | 14.5                                      | NA                                                 | 13.9                                    | 3.6 - 13.6                                         | 3.0                                             | 1.0                                             |
| 122MW-7  | 6-20-92            | 18.37                                                    | 18.5                                       | 14.5                                      | NA                                                 | 14.0                                    | 3.8 - 13.8                                         | 2.0                                             | 1.0                                             |
| 122DW-1  | 6-20-92<br>6-23-92 | 18.72                                                    | 18.9                                       | 44.0                                      | 31.0                                               | 43.9                                    | 38.6 - 43.6                                        | 36.5                                            | 31.5                                            |
| 122DW-2  | 6-23-92<br>6-24-92 | 22.68                                                    | 20.1                                       | 45.0                                      | 31.0                                               | 42.2                                    | 37.0 - 42.0                                        | 34.0                                            | 30.0                                            |

Notes: (1) MSL - Mean Sea Level

(2) NA = Not Applicable

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-4

**SUMMARY OF WELL CONSTRUCTION DETAILS - JANUARY 1993**  
**BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0270**

| Well No. | Date Installed | Top of Casing Elevation <sup>(1)</sup> (feet, above MSL) | Ground Surface Elevation (feet, above MSL) | Boring Depth (feet, below ground surface) | Depth of Outer Casing (feet, below ground surface) | Well Depth (feet, below ground surface) | Screen Interval Depth (feet, below ground surface) | Depth to Sand Pack (feet, below ground surface) | Depth to Bentonite (feet, below ground surface) |
|----------|----------------|----------------------------------------------------------|--------------------------------------------|-------------------------------------------|----------------------------------------------------|-----------------------------------------|----------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| 122MW-8  | 1-14-93        | 21.25                                                    | 18.88                                      | 12.0                                      | NA <sup>(2)</sup>                                  | 12.0                                    | 2.0-12.0                                           | 1.5                                             | 0.5                                             |
| 122MW-9  | 1-13-93        | 18.94                                                    | 19.48                                      | 14.0                                      | NA                                                 | 14.0                                    | 4.0-14.0                                           | 3.0                                             | 1.0                                             |
| 122MW-10 | 1-12-93        | 21.48                                                    | 18.71                                      | 11.8                                      | NA                                                 | 11.8                                    | 1.8-11.8                                           | 1.5                                             | 0.5                                             |
| 122MW-11 | 1-13-93        | 21.37                                                    | 18.87                                      | 12.0                                      | NA                                                 | 6.0                                     | 1.0-6.0                                            | 1.0                                             | 0.5                                             |
| 122MW-12 | 1-14-93        | 20.72                                                    | 18.26                                      | 14.0                                      | NA                                                 | 14.0                                    | 4.0-14.0                                           | 3.0                                             | 1.5                                             |
| 122MW-13 | 1-14-93        | 20.51                                                    | 18.07                                      | 13.0                                      | NA                                                 | 13.0                                    | 3.0-13.0                                           | 1.5                                             | 0.5                                             |
| 122MW-14 | 1-13-93        | 23.41                                                    | 20.80                                      | 16.0                                      | NA                                                 | 15.0                                    | 5.0-15.0                                           | 3.0                                             | 1.0                                             |
| 122RW-1  | 1-31-93        | 18.87                                                    | 19.41                                      | 15.5                                      | NA                                                 | 15.5                                    | 2.5-12.0                                           | 2.0                                             | 1.0                                             |

Notes: (1) MSL - Mean Sea Level

(2) NA = Not Applicable

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-5

**SUMMARY OF FLUID LEVEL MEASUREMENTS - FEBRUARY 7, 1993**  
**BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0270**

| Well No. | Top of Casing<br>Elevation <sup>(1)</sup><br>(feet, above MSL) | Depth to<br>Product<br>(feet, below<br>top of casing) | Depth to<br>Groundwater<br>(feet, below<br>top of casing) | Product<br>Thickness<br>(feet) | Product<br>Elevation<br>(feet, above MSL) | Groundwater<br>Elevation<br>(feet, above MSL) | Corrected<br>Groundwater<br>Elevation <sup>(2)</sup><br>(feet, above MSL) |
|----------|----------------------------------------------------------------|-------------------------------------------------------|-----------------------------------------------------------|--------------------------------|-------------------------------------------|-----------------------------------------------|---------------------------------------------------------------------------|
| 122MW-1  | 22.75                                                          | --(3)                                                 | 5.25                                                      | --                             | --                                        | 17.50                                         | --                                                                        |
| 122MW-2  | 22.48                                                          | --                                                    | 6.38                                                      | --                             | --                                        | 16.10                                         | --                                                                        |
| 122MW-3  | 22.23                                                          | --                                                    | 5.18                                                      | --                             | --                                        | 17.05                                         | --                                                                        |
| 122MW-4  | 19.60                                                          | --                                                    | 4.16                                                      | --                             | --                                        | 15.44                                         | --                                                                        |
| 122MW-5  | 18.60                                                          | --                                                    | 4.37                                                      | --                             | --                                        | 14.23                                         | --                                                                        |
| 122MW-6  | 18.38                                                          | --                                                    | 3.57                                                      | --                             | --                                        | 14.81                                         | --                                                                        |
| 122MW-7  | 18.37                                                          | --                                                    | 3.40                                                      | --                             | --                                        | 14.97                                         | --                                                                        |
| 122MW-8  | 21.25                                                          | --                                                    | 6.96                                                      | --                             | --                                        | 14.29                                         | --                                                                        |
| 122MW-9  | 18.94                                                          | 4.71                                                  | 4.90                                                      | 0.19                           | 14.23                                     | 14.04                                         | 14.20                                                                     |
| 122MW-10 | 21.48                                                          | --                                                    | 6.78                                                      | --                             | --                                        | 14.70                                         | --                                                                        |
| 122MW-11 | 21.37                                                          | --                                                    | 6.67                                                      | --                             | --                                        | 14.70                                         | --                                                                        |
| 122MW-12 | 20.72                                                          | --                                                    | 5.55                                                      | --                             | --                                        | 15.17                                         | --                                                                        |
| 122MW-13 | 20.51                                                          | --                                                    | 5.34                                                      | --                             | --                                        | 15.17                                         | --                                                                        |
| 122MW-14 | 23.41                                                          | --                                                    | 6.73                                                      | --                             | --                                        | 16.68                                         | --                                                                        |
| 122DW-1  | 18.72                                                          | --                                                    | 4.44                                                      | --                             | --                                        | 14.28                                         | --                                                                        |
| 122DW-2  | 22.68                                                          | --                                                    | 8.18                                                      | --                             | --                                        | 14.50                                         | --                                                                        |
| 013DW-1  | 22.17                                                          | --                                                    | 7.79                                                      | --                             | --                                        | 14.38                                         | --                                                                        |
| 013MW-1  | 21.84                                                          | --                                                    | 6.26                                                      | --                             | --                                        | 15.58                                         | --                                                                        |
| 122RW-1  | 18.87                                                          | --                                                    | 4.69                                                      | --                             | --                                        | 14.18                                         | --                                                                        |

Notes: (1) MSL - Mean Sea Level

(2) Corrected groundwater elevations were determined by using the following equation:

$$\text{Corrected groundwater elevation} = \text{apparent groundwater elevation} + (\text{product thickness} \times 0.82)$$

where 0.82 is the estimated specific gravity for JP-5 jet fuel.

(3) -- = Not Detected

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).



**TABLE 1-6**

**SUMMARY OF HYDRAULIC CONDUCTIVITY TESTS  
BUILDING AS-4151 - MCAS NEW RIVER  
JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270**

| Well No. | Hydraulic Conductivity<br>Falling Test |                      | Hydraulic Conductivity<br>Rising Test |                      |
|----------|----------------------------------------|----------------------|---------------------------------------|----------------------|
|          | ft/day                                 | cm/sec               | ft/day                                | cm/sec               |
| 122MW-3  | 0.25                                   | $8.8 \times 10^{-5}$ | $1.5 \times 10^{-2}$                  | $5.3 \times 10^{-6}$ |
| 122MW-5  | 0.47                                   | $1.7 \times 10^{-4}$ | $3.4 \times 10^{-2}$                  | $1.2 \times 10^{-5}$ |
| 122MW-12 | $6.8 \times 10^{-2}$                   | $2.4 \times 10^{-5}$ | $8.5 \times 10^{-3}$                  | $3.0 \times 10^{-6}$ |

Hydraulic conductivity average for site: 0.14 ft/day ( $5.0 \times 10^{-5}$  cm/sec)

Notes: Hydraulic conductivity test results analyzed using Bouwer and Rice method as presented in the Geraghty & Miller "AQTESOLV" program, Version 1.10.

Hydraulic conductivity tests conducted on February 9, 1993, using an In-Situ Environmental Data Logger (Model SE-1000C) and pressure transducer.

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-7

**SUMMARY OF SOIL ANALYSES - JUNE 1992**  
**BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0270**

| Boring No. | Field Sample No.           | Parameter                            |                               |                               |                   |                 | Sample Depth (feet, below ground surface) |
|------------|----------------------------|--------------------------------------|-------------------------------|-------------------------------|-------------------|-----------------|-------------------------------------------|
|            |                            | Total Petroleum Hydrocarbons (mg/kg) |                               | Petroleum Type <sup>(1)</sup> | pH                | Flashpoint (°F) |                                           |
|            |                            | Boiling Point low-med (5030)         | Boiling Point med-high (3550) |                               |                   |                 |                                           |
|            |                            |                                      |                               |                               |                   |                 |                                           |
| 122MW-1    | SPG-S-MW101                | -- <sup>(2)</sup>                    | --                            | Not Applicable                | NA <sup>(3)</sup> | NA              | 2.0-4.0                                   |
| 122MW-1    | SPG-S-MW102                | --                                   | --                            | Not Applicable                | 5.28              | > 220           | 4.0-6.0                                   |
| 122MW-2    | SPG-S-MW201                | --                                   | --                            | Not Applicable                | NA                | NA              | 2.0-4.0                                   |
| 122MW-2    | SPG-S-MW202                | --                                   | --                            | Not Applicable                | 4.23              | > 220           | 6.0-8.0                                   |
| 122MW-3    | SPG-S-DW301                | --                                   | --                            | Not Applicable                | NA                | NA              | 2.0-4.0                                   |
| 122MW-3    | SPG-S-DW302                | --                                   | --                            | Not Applicable                | 3.61              | > 220           | 4.0-6.0                                   |
| 122MW-4    | SPG-S-DW401                | --                                   | --                            | Not Applicable                | NA                | NA              | 2.0-4.0                                   |
| 122MW-4    | SPG-S-DW402                | --                                   | --                            | Not Applicable                | 4.72              | > 220           | 4.0-6.0                                   |
| 122MW-5    | SPG-S-MW501                | --                                   | 8.24                          | No. 2 Fuel Oil                | NA                | NA              | 2.0-4.0                                   |
| 122MW-5    | SPG-S-MW502                | --                                   | --                            | Not Applicable                | 3.86              | > 220           | 4.0-6.0                                   |
| 122MW-6    | SPG-S-MW601                | --                                   | --                            | Not Applicable                | NA                | NA              | 2.0-4.0                                   |
| 122MW-6    | SPG-S-MW801 <sup>(4)</sup> | --                                   | --                            | Not Applicable                | NA                | NA              | 2.0-4.0                                   |

Notes: (1) EPA Method 8015 (5030/3550) estimated range of petroleum type

(2) -- = Less than method detection limit

(3) NA = Not Analyzed

(4) Duplicate sample of Field Sample Number SPG-S-MW601

(5) Duplicate sample of Field Sample Number SPG-S-MW702

(6) \* = Sample from excavation

Total Petroleum Hydrocarbons analyzed using EPA Method 8015 (5030/3550); pH analyzed using Method SW-9047; flashpoint analyzed using Method SW-1010.

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-7 (Continued)

SUMMARY OF SOIL ANALYSES - JUNE 1992  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270

| Boring No.  | Field Sample No.           | Parameter                                  |                    |                               |                   |                 | Sample Depth<br>(feet, below<br>ground surface) |
|-------------|----------------------------|--------------------------------------------|--------------------|-------------------------------|-------------------|-----------------|-------------------------------------------------|
|             |                            | Total Petroleum<br>Hydrocarbons<br>(mg/kg) |                    | Petroleum Type <sup>(1)</sup> | pH                | Flashpoint (°F) |                                                 |
|             |                            | low-med<br>(5030)                          | med-high<br>(3550) |                               |                   |                 |                                                 |
|             |                            |                                            |                    |                               |                   |                 |                                                 |
| 122MW-6     | SPG-S-MW602                | -- <sup>(2)</sup>                          | --                 | Not Applicable                | 4.10              | > 220           | 4.0-6.0                                         |
| 122MW-7     | SPG-S-MW701                | --                                         | --                 | Not Applicable                | NA <sup>(3)</sup> | NA              | 2.0-4.0                                         |
| 122MW-7     | SPG-S-MW702                | 0.85                                       | 6.72               | No. 2 Fuel Oil                | 4.16              | > 220           | 4.0-6.0                                         |
| 122MW-7     | SPG-S-MW802 <sup>(5)</sup> | --                                         | --                 | Not Applicable                | NA                | NA              | 4.0-6.0                                         |
| 122DW-1     | SPG-S-DW101                | --                                         | --                 | Not Applicable                | 5.12              | > 220           | 2.0-4.0                                         |
| 122DW-1     | SPG-S-DW102                | --                                         | --                 | Not Applicable                | NA                | NA              | 4.0-6.0                                         |
| 122DW-2     | SPG-S-DW201                | --                                         | --                 | Not Applicable                | 5.40              | > 220           | 2.0-4.0                                         |
| 122DW-2     | SPG-S-DW202                | --                                         | 0.68               | Not<br>Distinguishable        | NA                | NA              | 4.0-6.0                                         |
| Curb Right* |                            | --                                         | --                 | N/A                           | NA                | NA              | 3.0                                             |
| Curb Left*  |                            | 64.1                                       | 1715               | Jet Fuel                      | NA                | NA              | 3.0                                             |
| Bott Right* |                            | 1.78                                       | 8.08               | Jet Fuel                      | NA                | NA              | 3.0                                             |
| Right Wall* |                            | 419                                        | 4833               | Jet Fuel                      | NA                | NA              | 3.0                                             |

Notes: (1) EPA Method 8015 (5030/3550) estimated

range of petroleum type

(2) -- = Less than method detection limit

(3) NA = Not Analyzed

(4) Duplicate sample of Field Sample Number SPG-S-MW601

(5) Duplicate sample of Field Sample Number SPG-S-MW702

(6) \* = Sample from excavation

Total Petroleum Hydrocarbons analyzed using EPA Method 8015 (5030/3550); pH analyzed using Method SW-9047; flashpoint analyzed using Method SW-1010.

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-8

SUMMARY OF SOIL ANALYSES - JANUARY 1993  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270

| Boring No. | Field Sample No. | Parameter                            |                                |                               |                   |                 | Sample Depth (feet, below ground surface) <sup>(4)</sup> |
|------------|------------------|--------------------------------------|--------------------------------|-------------------------------|-------------------|-----------------|----------------------------------------------------------|
|            |                  | Total Petroleum Hydrocarbons (mg/kg) |                                | Petroleum Type <sup>(1)</sup> | pH                | Flashpoint (°F) |                                                          |
|            |                  | Boiling Points low-med (5030)        | Boiling Points med-high (3550) |                               |                   |                 |                                                          |
| 122SB-1    | 122-SB1-S-01     | --                                   | --                             | -- <sup>(2)</sup>             | NA <sup>(3)</sup> | NA              | 2.0-2.5                                                  |
| 122SB-1    | 122-SB1-S-02     | --                                   | --                             | --                            | NA                | NA              | 2.5-3.0                                                  |
| 122SB-2    | 122-SB2-S-01     | --                                   | --                             | --                            | NA                | NA              | 2.0-3.0                                                  |
| 122SB-2    | 122-SB2-S-02     | 120                                  | 35.0                           | Diesel Fuel                   | NA                | NA              | 4.5-5.5                                                  |
| 122SB-3    | 122-SB3-S-01     | --                                   | --                             | --                            | NA                | NA              | 2.0-3.0                                                  |
| 122SB-3    | 122-SB3-S-02     | --                                   | --                             | --                            | NA                | NA              | 3.0-3.5                                                  |
| 122SB-4    | 122-SB4-S-01     | --                                   | --                             | --                            | NA                | NA              | 1.5-2.0                                                  |
| 122SB-4    | 122-SB4-S-02     | --                                   | --                             | --                            | NA                | NA              | 2.0-2.5                                                  |
| 122SB-5    | 122-SB5-S-01     | --                                   | --                             | --                            | NA                | NA              | 1.5-2.0                                                  |
| 122SB-5    | 122-SB5-S-02     | --                                   | --                             | --                            | NA                | NA              | 2.0-3.0                                                  |

Notes: (1) EPA Method 8015 (5030/3550) estimated range of petroleum type

(2) -- = Less than method detection limit

(3) NA = Not Analyzed

(4) Sample intervals differ due to encountering groundwater at various depths at different boring locations.

Total Petroleum Hydrocarbons analyzed using EPA Method 8015 (5030/3550); pH analyzed using Method SW-9047; flashpoint analyzed by Method SW-1010.

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-8 (Continued)

**SUMMARY OF SOIL ANALYSES - JANUARY 1993**  
**BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0270**

| Boring No. | Field Sample No. | Parameter                                  |                                        |                         |        |                    | Sample Depth<br>(feet, below<br>ground surface)<br>(4) |
|------------|------------------|--------------------------------------------|----------------------------------------|-------------------------|--------|--------------------|--------------------------------------------------------|
|            |                  | Total Petroleum<br>Hydrocarbons<br>(mg/kg) |                                        | Petroleum<br>Type(1)    | pH     | Flashpoint<br>(°F) |                                                        |
|            |                  | Boiling<br>Point<br>low-med<br>(5030)      | Boiling<br>Point<br>med-high<br>(3550) |                         |        |                    |                                                        |
| 122MW-8    | 122-MW8-S-01     | --                                         | --                                     | -- (2)                  | NA (3) | NA                 | 2.0-3.0                                                |
| 122MW-8    | 122-MW8-S-02     | 22.0                                       | --                                     | Gasoline                | NA     | NA                 | 4.5-5.5                                                |
| 122MW-8    | 122-MW8-S-03(5)  | 53.0                                       | --                                     | Gasoline                | NA     | NA                 | 4.5-5.5                                                |
| 122MW-9    | 122-MW9-S-01     | 5.49                                       | 140                                    | Diesel/JP-5             | NA     | NA                 | 2.0-4.0                                                |
| 122MW-9    | 122-MW9-S-02     | 2308                                       | 6000                                   | Diesel/JP-5             | 5.76   | >220               | 4.0-6.0                                                |
| 122MW-9    | 122-MW9-S-03(6)  | 7302                                       | 15000                                  | Diesel/JP-5<br>Gasoline | NA     | NA                 | 4.0-6.0                                                |
| 122MW-10   | 122-MW10-S-01    | 10.2                                       | 46                                     | Diesel/JP-5             | NA     | NA                 | 2.0-3.0                                                |
| 122MW-10   | 122-MW10-S-02    | --                                         | --                                     | --                      | NA     | NA                 | 4.5-5.5                                                |
| 122MW-11   | 122-MW11-S-01    | --                                         | --                                     | --                      | NA     | NA                 | 1.5-2.0                                                |
| 122MW-11   | 122-MW11-S-02    | 11.0                                       | --                                     | Gasoline                | 5.99   | >220               | 3.5-4.0                                                |

Notes: (1) EPA Method 8015 (5030/3550) estimated range of petroleum type (5) Duplicate of Sample No. 122-MW8-S-02  
(2) -- = Less than method detection limit (6) Duplicate of Sample No. 122-MW9-S-02  
(3) NA = Not Analyzed  
(4) Sample intervals differ due to encountering groundwater at various depths at different boring locations.

Total Petroleum Hydrocarbons analyzed using EPA Method 8015 (5030/3550); pH analyzed using Method SW-9047; flashpoint analyzed by Method SW-1010.

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-8 (Continued)

SUMMARY OF SOIL ANALYSES - JANUARY 1993  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270

| Boring No. | Field Sample No. | Parameter                                  |                                         |                      |        |                    | Sample Depth<br>(feet, below<br>ground surface)<br>(4) |
|------------|------------------|--------------------------------------------|-----------------------------------------|----------------------|--------|--------------------|--------------------------------------------------------|
|            |                  | Total Petroleum<br>Hydrocarbons<br>(mg/kg) |                                         | Petroleum<br>Type(1) | pH     | Flashpoint<br>(°F) |                                                        |
|            |                  | Boiling<br>Points<br>low-med<br>(5030)     | Boiling<br>Points<br>med-high<br>(3550) |                      |        |                    |                                                        |
| 122MW-12   | 122-MW12-S-01    | --                                         | --                                      | -- (2)               | NA (3) | NA                 | 2.0-4.0                                                |
| 122MW-12   | 122-MW12-S-02    | --                                         | --                                      | --                   | 4.26   | >220               | 4.0-6.0                                                |
| 122MW-13   | 122-MW13-S-01    | 17.0                                       | --                                      | Gasoline             | NA     | NA                 | 2.0-4.0                                                |
| 122MW-13   | 122-MW13-S-02    | --                                         | --                                      | --                   | 3.53   | >220               | 4.0-6.0                                                |
| 122MW-14   | 122-MW14-S-01    | --                                         | --                                      | --                   | NA     | NA                 | 2.0-4.0                                                |
| 122MW-14   | 122-MW14-S-02    | --                                         | --                                      | --                   | 3.50   | >220               | 6.0-8.0                                                |
| 122RW-1    | SGP-RW1-S-01     | 510                                        | 2800                                    | JP-5                 |        | NA                 | 2.0-4.0                                                |
| 122RW-1    | SGP-RW1-S-02     | 5378                                       | 8300                                    | JP-5                 | NA     | NA                 | 4.0-6.0                                                |

Notes: (1) EPA Method 8015 (5030/3550) estimated range of petroleum type

(2) -- = Less than method detection limit

(3) NA = Not Analyzed

(4) Sample intervals differ due to encountering groundwater at various depths at different boring locations.

Total Petroleum Hydrocarbons analyzed using EPA Method 8015 (5030/3550); pH analyzed using Method SW-9047; flashpoint analyzed by Method SW-1010.

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-9

SUMMARY OF CHEMICAL ANALYSES FOR GROUNDWATER SAMPLES - JUNE 1992  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270

| Method/Contaminant              | Well Number |         |             |         |         |         |         |            |         |         | Trip Blank | MCL Maximum Contaminant Level (µg/L) | NC Water Quality Standard (µg/L) |
|---------------------------------|-------------|---------|-------------|---------|---------|---------|---------|------------|---------|---------|------------|--------------------------------------|----------------------------------|
|                                 | 122MW-1     | 122MW-2 | 122MW-3(11) | 122MW-4 | 122MW-5 | 122MW-6 | 122MW-7 | 122MW-8(6) | 122DW-1 | 122DW-2 |            |                                      |                                  |
| PA Method 602(1) (µg/L)         |             |         |             |         |         |         |         |            |         |         |            |                                      |                                  |
| Purgeable Aromatic Hydrocarbons |             |         |             |         |         |         |         |            |         |         |            |                                      |                                  |
| MTBE(2)                         | -- (3)      | 3.70    | NA          | 5.08    | --      | --      | --      | --         | --      | --      | --         | NE(9)                                | 50(10)                           |
| Benzene                         | --          | 9.53    | NA          | 11.90   | --      | --      | --      | --         | --      | --      | --         | 5.0                                  | 1.0                              |
| Toluene/EDB(4)                  | --          | --      | NA          | --      | --      | --      | --      | --         | --      | --      | --         | 1,000/0.05                           | 1,000/0.0005                     |
| Ethylbenzene                    | --          | --      | NA          | --      | --      | --      | --      | --         | --      | --      | --         | 700                                  | 29                               |
| m-, p-Xylene                    | --          | --      | NA          | --      | --      | --      | --      | --         | --      | --      | --         | 10,000(7)                            | 400                              |
| o-Xylene                        | --          | --      | NA          | --      | --      | --      | --      | --         | --      | --      | --         | 10,000(7)                            | 400                              |
| Chlorobenzene                   | --          | --      | NA          | --      | --      | --      | --      | --         | --      | --      | --         | 100                                  | 300                              |
| 1,2-Dichlorobenzene             | --          | --      | NA          | --      | --      | --      | 4.57    | 4.32       | --      | --      | --         | 600                                  | 620                              |
| 1,3-Dichlorobenzene             | --          | --      | NA          | --      | --      | --      | 3.64    | 3.91       | --      | --      | --         | NE                                   | 620                              |
| 1,4-Dichlorobenzene             | --          | --      | NA          | 3.33    | --      | --      | --      | --         | --      | --      | --         | 75                                   | 1.8                              |
| Total VOCs (8)                  | --          | 13.23   | NA          | 20.31   | --      | --      | 8.21    | 8.23       | --      | --      | --         | NE                                   | NE                               |
| PA Method 625(5) (µg/L)         |             |         |             |         |         |         |         |            |         |         |            |                                      |                                  |
| PAHs                            | NA          | NA      | NA          | --      | --      | NA      | --      | NA         | NA      | NA      | --         |                                      |                                  |

NA = Not Analyzed.

NE = Not Established

Notes: (1) Volatile organic compounds analyzed by EPA Method 602.

(2) MTBE = Methyl Tertiary Butyl Ether.

(3) -- = Less than method detection limit.

(4) EDB = Ethylene Dibromide. Method could not distinguish a difference between toluene and EDB. Laboratory reported the concentrations as a combined value.

(5) Polynuclear Aromatic Hydrocarbons (PAHs) analyzed using EPA Method 625. No PAHs were detected.

(6) 122MW-8 is a duplicate of 122MW-7.

(7) The MCL for Xylene (Total) includes Meta, Para, and Ortho Xylenes.

(8) Sum of total organic compounds detected by EPA Method 602.

(9) MCL not established.

(10) MTBE WQS is an Interim Standard.

(11) Sample damaged during transport to laboratory.

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).

TABLE 1-10

**SUMMARY OF CHEMICAL ANALYSES FOR GROUNDWATER SAMPLES - JANUARY 1993**  
**BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0270**

| Method/Contaminant              | Well Number |         |         |         |             |          |          |          |          |          | Federal Maximum Concentration Level (µg/L) | NC Water Quality Standard (µg/L) |
|---------------------------------|-------------|---------|---------|---------|-------------|----------|----------|----------|----------|----------|--------------------------------------------|----------------------------------|
|                                 | 122MW-2     | 122MW-3 | 122MW-3 | 122MW-9 | 122MW-25(7) | 122MW-10 | 122MW-11 | 122MW-12 | 122MW-13 | 122MW-14 | 122RW-1                                    | Trip Blank                       |
| <b>EPA Method 602 (µg/L)</b>    |             |         |         |         |             |          |          |          |          |          |                                            |                                  |
| Purgeable Aromatic Hydrocarbons |             |         |         |         |             |          |          |          |          |          |                                            |                                  |
| MTBE(1)                         | -- (5)      | --      | --      | --      | --          | --       | --       | --       | --       | --       | --                                         | --                               |
| Benzene                         | --          | --      | --      | 7.6     | --          | --       | --       | --       | --       | 1.2      | 3.4                                        | 50.0                             |
| Toluene                         | --          | 1.6     | --      | --      | --          | --       | --       | 7.9      | --       | --       | --                                         | 1.0                              |
| Ethylbenzene                    | --          | --      | --      | 26.0    | --          | --       | --       | 3.1      | --       | --       | --                                         | 1,000                            |
| Xylenes                         | --          | --      | --      | 46.0    | 1.7         | --       | --       | --       | --       | --       | 28.0                                       | 29                               |
| EDB(2)                          | --          | --      | --      | --      | 0.76        | --       | --       | --       | --       | --       | 44.0                                       | 400 (6)                          |
| Chlorobenzene                   | --          | --      | --      | --      | 0.98        | --       | --       | 0.90     | --       | --       | --                                         | 0.0005                           |
| 1,3-Dichlorobenzene             | --          | --      | --      | --      | --          | --       | --       | --       | --       | --       | --                                         | 300                              |
| 1,4-Dichlorobenzene             | --          | --      | --      | --      | 1.4         | --       | --       | --       | --       | --       | --                                         | 620                              |
| 1,2-Dichlorobenzene             | --          | --      | --      | --      | 0.9         | --       | --       | 0.90     | --       | --       | --                                         | 1.8                              |
| Total VOCs(3)                   | --          | 1.6     | 79.6    | 5.74    | 0.9         | --       | --       | 12.8     | --       | 1.2      | 75.4                                       | 620                              |
| <b>EPA Method 610(4) (µg/L)</b> |             |         |         |         |             |          |          |          |          |          |                                            |                                  |
| Base Neutral Extractables       |             |         |         |         |             |          |          |          |          |          |                                            |                                  |
| Phenanthrene                    | --          | --      | --      | 2       | --          | --       | --       | --       | --       | --       | --                                         | NE                               |
| Acenaphthene                    | --          | --      | --      | 3       | --          | --       | --       | --       | --       | --       | --                                         | NE                               |
| Anthracene                      | --          | --      | --      | 2       | --          | --       | --       | --       | --       | --       | --                                         | NE                               |
| Fluorene                        | --          | --      | --      | 4       | --          | --       | --       | --       | --       | --       | --                                         | NE                               |
| Acenaphthylene                  | --          | --      | --      | 2       | 10          | --       | --       | --       | --       | --       | --                                         | NE                               |
| Naphthalene                     | --          | --      | --      | 300     | 313         | --       | --       | 15.0     | --       | --       | --                                         | NE                               |

Notes: NA - Not Analyzed.

NE = Not Established.

(1) MTBE = Methyl Tertiary Butyl Ether

(2) EDB = Ethylene Dibromide.

(3) Sum of total volatile organic compounds detected using EPA Method 602.

(4) Polynuclear Aromatic Hydrocarbons analyzed by EPA Method 610.

(5) -- = Less than method detection limit.

(6) The MCL and WQS for Xylene (Total) Includes Meta, Para, and Ortho Xylenes.

(7) Sample 122MW-25 is the duplicate sample of monitoring wells 122MW-9 (EPA Method 610 analysis) and 122MW-12 (EPA Method 602 analysis).

Source: Baker Environmental, Inc., March 12, 1993, "Draft Site Assessment Investigation," (Contract 62470-89-D-4814, Contract Task Order 0122).



TABLE 2-1

**GROUNDWATER REMEDIATION ENDPOINTS  
BUILDING AS-4151 - MCAS NEW RIVER  
JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270**

| Parameter           | NC Water quality Standard (µg/L) | Maximum Concentration Detected (µg/L) | Sampling Point with Highest Concentration | Number of Sampling Points above WQS (µg/L) |
|---------------------|----------------------------------|---------------------------------------|-------------------------------------------|--------------------------------------------|
| MTBE                | 50.0                             | 5.08                                  | 122MW-4                                   | 0                                          |
| Benzene             | 1.0                              | 11.90                                 | 122MW-4                                   | 5                                          |
| Toluene             | 1,000                            | 7.9                                   | 122MW-12                                  | 0                                          |
| Ethylbenzene        | 29                               | 28                                    | 122RW-1                                   | 0                                          |
| Xylenes             | 400                              | 46                                    | 122MW-9                                   | 0                                          |
| EDB                 | 0.0005                           | 0.98                                  | 122MW-9 <sup>(1)</sup>                    | 2                                          |
| Chlorobenzene       | 300                              | ND                                    | NA                                        | 0                                          |
| 1,2-Dichlorobenzene | 620                              | 4.57                                  | 122MW-7                                   | 0                                          |
| 1,3-Dichlorobenzene | 620                              | 3.91                                  | 122MW-8                                   | 0                                          |
| 1,4-Dichlorobenzene | 1.8                              | 3.33                                  | 122MW-4                                   | 0                                          |
| Naphthalene         | NE                               | 313 <sup>(1)</sup>                    | 122MW-9                                   | NA                                         |
| Acenaphthylene      | NE                               | 10                                    | 122MW-9                                   | NA                                         |

Notes: ND = Not Detected  
 NE = Not established  
 MTBE = Methyl Tertiary Butyl Ether  
 EDB = Ethylene Dibromide  
 NA = Not Applicable

<sup>(1)</sup> Detected in Duplicate Sample

NC Water Quality Standard shall be used as the initial groundwater remediation endpoints

**TABLE 3-1**

**MAJOR COMPONENTS OF JP-5 JET FUEL  
BUILDING AS-4151 - MCAS NEW RIVER  
JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270**

|                            |                                  |
|----------------------------|----------------------------------|
| Benzene                    | Naphthalene                      |
| Toluene                    | 2-Methylundecane                 |
| Ethylbenzene               | n-Dodecane                       |
| n-Octane                   | 2,6-Dimethylundecane             |
| 1,3,5-Trimethylcyclohexane | 1,2,4-Triethylbenzene            |
| 1,1,3-Tremethylcyclohexane | 2-Methylnaphthalene              |
| 3-Methyloctane             | 1-Methylnaphthalene              |
| 2,4,6-Trimethylheptane     | 1-Tridecene                      |
| o-Xylene                   | Phenylcyclohexane                |
| p-Xylene                   | n-Tridecane                      |
| m-Xylene                   | 1-t-Butyl-3,4,5-trimethylbenzene |
| n-Nonane                   | n-Heptylcyclohexane              |
| 1,2,4-Trimethylbenzene     | n-Heptylbenzene                  |
| n-Decane                   | Biphenyl                         |
| n-Butylcyclohexane         | 1-Ethyl-naphthalene              |
| 1,3-Diethylbenzene         | 2,6-Dimethylnaphthalene          |
| 1,4-Diethylbenzene         | n-Tetradecane                    |
| 4-Methyldecane             | 2,3-Dimethylnaphthalene          |
| 2-Methyldecane             | n-Octylbenzene                   |
| 1-Ethylpropylbenzene       | n-Pentadecane                    |
| n-Undecane                 | n-Hexadecane                     |
| 2,6-Dimethyldecane         | n-Heptadecane                    |
| 1,2,3,4-Tetramethylbenzene |                                  |

Source: "Analysis and Environmental Fate of Air Force Distillate and High Density Fuels."  
SRI International. October 1981.

**TABLE 3-2**

**CONCENTRATIONS OF SELECTED WATER SOLUBLE  
COMPONENTS OF JP-5  
BUILDING AS-4151 - MCAS NEW RIVER  
JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270**

| Constituent         | Concentration<br>(mg/L) <sup>(1)</sup> |
|---------------------|----------------------------------------|
| Toluene             | 0.6                                    |
| Ethylbenzene        | 0.3                                    |
| m,p-xylenes         | 0.16                                   |
| o-xylene            | 0.09                                   |
| Naphthalene         | 0.46                                   |
| 2-Methylnaphthalene | 0.23                                   |

Notes: (1) Concentration of the constituent detected in a mixture of 1 part JP-5 to 1,000 parts water

Benzene was not detected as a water soluble component.

Source: "Analysis and Environmental Fate of Air Force Distillate and High Density Fuels." SRI International. October 1981.

TABLE 3-3

PHYSICAL-CHEMICAL PROPERTIES AND RELATIVE MOBILITY INDICES FOR JP-5 CONSTITUENTS  
 BUILDING AS-4151 - MCAS NEW RIVER  
 JACKSONVILLE, NORTH CAROLINA  
 CONTRACT TASK ORDER 0270

| Constituent    | Molecular Weight (g/mol.) | Specific Gravity (g/cm <sup>3</sup> @ 20/4°C) | Water Solubility (ppm @ 20°C) | Vapor Pressure (mm Hg @ 25°C) | Henry's Law Coefficient (atm m <sup>3</sup> /mol-l) | log K <sub>ow</sub> | log K <sub>oc</sub> | Relative Mobility Index |
|----------------|---------------------------|-----------------------------------------------|-------------------------------|-------------------------------|-----------------------------------------------------|---------------------|---------------------|-------------------------|
| Benzene        | 78.1                      | 0.879                                         | 1,780                         | 76                            | 5.5 x 10 <sup>-3</sup>                              | 2.13                | 1.92                | 3.0                     |
| Toluene        | 92.13                     | 0.867                                         | 534.8 (25°C)                  | 28.7 (25°C)                   | 6.6 x 10 <sup>-3</sup>                              | 2.48                | 2.79                | 1.5                     |
| Ethylbenzene   | 106.16                    | 0.873                                         | 152                           | 7                             | 6.6 x 10 <sup>-3</sup>                              | 3.34                | 3.04                | -0.01                   |
| Xylene, Total  | 106.16                    | 0.870                                         | 180                           | 6                             | 4.64 x 10 <sup>-3</sup>                             | 2.84                | 3.02                | 0.19                    |
| Naphthalene    | 128.2                     | 1.162                                         | 31.7 (25°C)                   | 8.7 x 10 <sup>-2</sup>        | 4.6 x 10 <sup>-4</sup>                              | 3.29                | 2.97                | -2.5                    |
| Acenaphthylene | 152.2                     | 1.18                                          | 3.93 (25°C)                   | 2.9 x 10 <sup>-2</sup> (20°C) | 1.45 x 10 <sup>-3</sup>                             | 3.72                | 3.40                | -4.3                    |
| Acenaphthene   | 154.2                     | 1.189                                         | 3.42 (25°C)                   | 1.55 x 10 <sup>-3</sup>       | 9.1 x 10 <sup>-5</sup>                              | 3.98                | 3.66                | -5.9                    |

Notes: NC = Not calculated

References: USEPA, 1982. Aquatic Fate Process Data for Organic Priority Pollutants.  
 Verscheueren, 1983. Handbook of Environmental Data on Organic Chemicals. 2nd Edition.  
 Lyman, et al., 1982. Handbook of Chemical Property Estimation Methods.  
 Ford and Gurba, 1984. Methods of Determining Relative Contaminant Mobilities and Migration Pathways Using Physical-Chemical Data.

TABLE 3-4

RECORDS OF WELLS IDENTIFIED IN THE VICINITY OF BUILDING AS-4151  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270

| Well No.  | U.S.G.S. I.D. No. | Approximate<br>Distance/Direction Site<br>to Well | Year<br>Drilled | Depth<br>(feet) | Driller | Screen Interval<br>(feet below<br>surface) | Well<br>Diameter<br>(inches) | Water Level<br>(below land<br>surface in feet) |
|-----------|-------------------|---------------------------------------------------|-----------------|-----------------|---------|--------------------------------------------|------------------------------|------------------------------------------------|
| MCAS-4140 | 3442570772716.1   | 800 ft. southwest of site                         | --(1)           | --              | --      | --                                         | --                           | 20.3                                           |

Notes: Numbers shown on the well location map (Figure 3-2) are those assigned by the U.S. Marine Corps or its contractors to identify wells constructed at the base.

U.S.G.S. Identification Number: Numbers are comprised of degrees, minutes, and seconds of latitude (first six numbers) north of the equator and longitude (next seven numbers) west of the prime meridian. The number to the right of the decimal point is a sequential number for wells at a designated location.

(1) -- = No available data

Source: U.S.G.S., Water Resources Investigations Report 89-4096, "Assessment of Hydrologic and Hydrogeologic Data at Camp Lejeune Marine Corps Base, North Carolina," 1989

TABLE 3-5

**PRELIMINARY EXPOSURE ASSESSMENT SUMMARY**  
**BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0270**

| Exposure Pathways | Maximum Detected Levels (1)                                                                                                                         | Potential for Migration of Contaminants                                                                                                                                                                                                                                                    | Potential for Human Exposure                                                                                                                                                                                                                                                                              |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Soil              | TPH: 15,000 mg/kg<br>pH: 3.50<br>FP: No Flash<br>Only 13 of 52 samples had TPH values above 80 mg/kg (samples collected during both phases of work) | Soils are generally a mixture of silt and clay, underlain by a fine-grained sand. Because of the lesser permeability of the silt and clay soils, minimal migration through the soil is considered possible. In general, the highest concentrations were detected at depths of 4 to 6 feet. | Covered by grass top soil and concrete, the site poses no immediate exposure. If the site is disturbed due to construction or remediation activities, exposure to workers does exist by both direct contact and the inhalation of dust generated from the site.                                           |
| Groundwater       | Benzene: 11.9 µg/L<br>Toluene: 7.9 µg/L<br>Ethylbenzene: 28 µg/L<br>Xylene: 46 µg/L<br>Naphthylene: 313 µg/L                                        | Groundwater, on the average, was 4 to 6 feet below ground surface. It is believed that groundwater migration through this type of soil would be limited. However, this medium would allow for greatest contamination migration.                                                            | Because the base drinking water is supplied by the deeper Castle Hayne Aquifer and there are no water supply wells within 1/4-mile radius of the site in the surficial water-bearing layer, no groundwater exposure pathways are believed to exist.                                                       |
| Vapor             | No detection by use of Draeger tubes. Maximum vapor detected using PID is 160 ppm (Boring MW-9)                                                     | The type of soils present (silt/clay) may reduce the rate of vapor migration. However, subsurface utilities in the area may increase the rate of migration in portions of the site.                                                                                                        | The ground surface conditions at the site will promote the dispersion of vapors. Subsurface utility trenches may create areas for vapors to accumulate. In the event that the site is disturbed due to construction or remediation activities, inhalation from the volatilization of the TPH could occur. |

(1) Analytical Results listed are based on both phases of work.

(2) Concentrations were below detection limits.

TABLE 4-1

**SCREENING OF POTENTIAL SOIL REMEDIATION OPTIONS**  
**BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0270**

| Option                                                               | Process                                                                                                                                                           | Estimated Costs <sup>(1)</sup>                     | Practical Constraints                                                                                | Remarks                                                                                                 | Applicable to Site (Y/N) |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|--------------------------|
| Excavation and disposal as hazardous waste                           | Excavate and haul to Class I landfill; emplace and compact clean fill                                                                                             | \$300/yd <sup>3</sup>                              | Cradle-to-grave liability as waste generator                                                         | High cost                                                                                               | N                        |
| Excavation and disposal as solid waste (nonhazardous)                | Excavate and haul to Class III landfill; backfill with clean fill                                                                                                 | \$60/yd <sup>3</sup>                               | Location of a suitable landfill                                                                      | Economical on small projects                                                                            | Y                        |
| Excavation, aeration and disposal off site (off-site bioremediation) | Excavate and spread on site; turn repeatedly to aerate, haul to clean fill disposal site; emplace and compact new clean fill                                      | \$30/ton<br>Plus transportation and backfill costs | Emission considerations                                                                              | Technically feasible; permitted facilities located near activity; may require numerous analytical tests | Y                        |
| Excavation, landfarming and replacement                              | Excavate and spread on site; aerate and add nutrients and water; re-emplace and compact                                                                           | \$50/yd <sup>3</sup>                               | Emission considerations; leaves excavation open during treatment                                     | Technically feasible, permitting may be difficult; requires numerous analytical tests                   | N                        |
| Mechanically enhanced volatilization                                 | Excavate, pass through crusher, aerator, and re-emplace                                                                                                           | \$250/yd <sup>3</sup>                              | Requires dust control and vapor treatment                                                            | High cost, but suitable for specific locations                                                          | N                        |
| <i>In-situ</i> venting (vacuum extraction)                           | Investigate extent of contamination and soil conditions; design and install venting system; permit system; operate system; reinvestigate to monitor effectiveness | \$20-50/yd <sup>3</sup>                            | Fine-grained soils and low volatility of hydrocarbon in soils limit the effectiveness of this method | Not a technically viable option for sites with clayey soils; requires disposal of air filtration medium | Y                        |
| Excavation and low temperature thermal reduction (LTTR)              | Contamination in soil reduced through volatilization by the application of heat                                                                                   | \$50/ton + transportation                          | Emissions considerations                                                                             | Effective method of reducing contaminant concentrations                                                 | Y                        |

(1) Estimated costs reflect 1990 dollars.

Source: Testa, Stephen M. and Duane L. Winegardner. Restoration of Petroleum-Contaminated Aquifers. Lewis Publishers, Inc., Chelsea, Michigan. 1991.

TABLE 4-1  
(Continued)  
SCREENING OF POTENTIAL SOIL REMEDIATION OPTIONS  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270

| Option                                                | Process                                                                                                                                                                                                                              | Estimated Costs <sup>(1)</sup> | Practical Constraints                                                                                                                                                                                                                                                                  | Remarks                                                                                                                         | Applicable to Site (Y/N) |
|-------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| <i>In-situ</i> biodegradation or chemical degradation | Investigate extent of contamination and soil and groundwater conditions; conduct feasibility study; design and install pumping and injection system; permit system; operate system; reinvestigate to monitor effectiveness           | \$75/yd <sup>3</sup>           | Fine-grained soils limit ability to inject and pump fluids through soils. System could be engineered to be installed and operated around existing facilities; requires ongoing operation and maintenance (O&M) and monitoring. Requires periodic soil sampling and final investigation | Overall effectiveness cannot be assured; pending results of pilot study; requires on site monitoring                            | Y                        |
| Steam injection and stripping                         | Investigate extent of contamination and soil and groundwater conditions; conduct feasibility study; design and install steam injection and recovery system; permit system; operate system; monitor effectiveness on an ongoing basis | \$100-200/yd <sup>3</sup>      | Fine-grained soils limit ability to inject steam and recover fluids from soils                                                                                                                                                                                                         | Overall effectiveness cannot be assured, pending pilot study results; O&M cost                                                  | N                        |
| Asphalt incorporation                                 | Excavate and transport                                                                                                                                                                                                               | \$125/ton                      | Soil must pass flash-test before acceptance                                                                                                                                                                                                                                            | Very good option for low-volatile hydrocarbon affected soils                                                                    | N                        |
| Passive remediation                                   | Passive remediation                                                                                                                                                                                                                  |                                | No risk to public health, safety and welfare. No risk to surface water or groundwater; considered of beneficial use                                                                                                                                                                    | Site-specific. High concentrations present at the site may require a significant period of time to degrade to acceptable levels | N                        |

(1) Estimated costs reflect 1990 dollars.

Source: Testa, Stephen M. and Duane L. Winegardner. Restoration of Petroleum-Contaminated Aquifers. Lewis Publishers, Inc., Chelsea, Michigan. 1991.



TABLE 4-1

(Continued)

**SCREENING OF POTENTIAL SOIL REMEDIATION OPTIONS**  
**BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0270**

| Option                           | Process                                                                                          | Estimated Costs <sup>(1)</sup> | Practical Constraints                                                                         | Remarks                                                                                    | Applicable to Site (Y/N) |
|----------------------------------|--------------------------------------------------------------------------------------------------|--------------------------------|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------|
| Soil washing/extraction          | Excavate, crush, mix with wash fluid, separate, replace, treat wash water                        |                                | Limited to granular soils, wash fluid treatment may be difficult                              | Technically feasible, high cost, limited applications                                      | N                        |
| In-situ leaching                 | Construct infiltration and recovery systems, irrigate washing fluid, retrieve fluid, treat fluid | \$150 to \$200/yd <sup>3</sup> | Limited to permeable soils, and higher solubility hydrocarbons                                | Often used in conjunction with biotreatment practices; permit approval may be difficult    | Y                        |
| Aboveground leaching/replacement | Excavate, crush, place over collector bed, flush with wash fluid, replace, treat fluid           |                                | Total washing fluid collection, temperature and odor control; requires fairly large open area | May be used in association with biotreatment, often effective; permitting not as difficult | N                        |

<sup>(1)</sup> Estimated costs reflect 1990 dollars.

Source: Testa, Stephen M. and Duane L. Winegardner. Restoration of Petroleum-Contaminated Aquifers. Lewis Publishers, Inc., Chelsea, Michigan. 1991.

TABLE 2

**SCREENING OF POTENTIAL GROUNDWATER RECOVERY ALTERNATIVES  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270**

| Alternative                            | Description                                                                                                | Capability                              | Limitation                                                                                                                                                | Evaluation                                                                                                    | Applicable to Site (Y/N) |
|----------------------------------------|------------------------------------------------------------------------------------------------------------|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|--------------------------|
| 1. Passive Remediation                 | Take no action - continue groundwater monitoring to determine if product plume is migrating off site.      | Simplest, least costly option           | Does not facilitate containment, control or recovery of product.                                                                                          | The option does not actively improve site groundwater quality.                                                | N                        |
| 2. Subsurface Flow Controls (barriers) | Install slurry, membrane or structural walls around plume to isolate it and preclude further migration.    | A conventional, demonstrated technology | This option is usually very expensive. Many slurry wall mixtures or membranes may not provide long-term durability.                                       | This option does not improve site groundwater quality. It may not provide long-term benefits.                 | N                        |
| 3. Well Points                         | Install several closely-spaced small diameter wells around the plume.                                      | A conventional, demonstrated technology | Requires a large number of well points to be effective. Large quantities of water would be generated. Requires frequent maintenance.                      | Effective for sites with high permeability and shallow water table.                                           | Y                        |
| 4. Recovery wells                      | Install groundwater/free product recovery wells at selected locations.                                     | A conventional, demonstrated technology | Several wells required to renovate the aquifer. Usually suited for use in sandy aquifers.                                                                 | Effective for sites with groundwater levels over 25 feet deep.                                                | Y                        |
| 5. Large-Diameter Sumps                | Install a few large diameter sumps at selected locations.                                                  | A conventional, demonstrated technology | Only effective in shallow aquifers with low permeabilities.                                                                                               | May be effective in shallow conditions where low permeabilities exist.                                        | N                        |
| 6. Interceptor Trenches                | Construct trenches with sumps at right angles to existing groundwater flow patterns.                       | A conventional, demonstrated technology | Only effective in shallow aquifers with low permeabilities. Construction may disrupt facility operations. Installation may not be possible in many areas. | May be effective in shallow conditions where low permeabilities exist. Construction is limited to open areas. | Y                        |
| 7. In-Situ Biotreatment                | Utilize recovery and injection wells along with a fixed film biotreatment unit to biodegrade contaminants. | A conventional, demonstrated technology | Requires large capital costs. Usually maintenance is extensive. Biotreatment is slow as compared to other remediation methods.                            | Presence of lead makes this option less effective.                                                            | N                        |

Note: Estimated costs for remediation alternatives are not possible due to variables such as volume of groundwater to be removed, number of pumps required,

TABLE 5-1  
MONITORING PLAN SUMMARY  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270

| PHASE OF CONTAMINATION                                 | PROPOSED CLEANUP ENDPOINTS                  | PROPOSED MONITORING TO ACHIEVE ENDPOINTS                                                                                                                  |                                        |                                                                                                             |                                                                                  |                                                                                                              | PROPOSED POST OPERATION MONITORING                                                                                                                                                                                                 |                                                                                                                                                                                   |
|--------------------------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|-------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                        |                                             | SAMPLING LOCATION                                                                                                                                         | SAMPLING FREQUENCY AND TYPE            | METHOD OF ANALYSIS                                                                                          | SCHEDULE TO ACHIEVE ENDPOINTS                                                    | SCHEDULE TO MAINTAIN ENDPOINTS                                                                               | SAMPLING FREQUENCY AND TYPE                                                                                                                                                                                                        | POST OPERATION MONITORING SCHEDULE                                                                                                                                                |
| Free Product- JP-5                                     | < 0.01 Feet                                 | Monitoring wells<br>122MW-3, 122MW-4,<br>122MW-5, 122MW-6,<br>122MW-7, 122MW-8,<br>122MW-9, 122MW-11,<br>122MW-13, 122MW-14,<br>122RW-1, 13MW-1<br>13DW-1 | Monthly<br>Free product<br>measurement | Electronic<br>interface probe<br>or<br>tape, chalk,<br>and water<br>indicating<br>paste<br>method           | Estimated that<br>remediation<br>system will<br>be in operation<br>for two years | 12 months                                                                                                    | Monthly<br>free product<br>measurement of all<br>13 monitoring wells<br>monitored during<br>system operation                                                                                                                       | Monitoring will<br>continue for 12<br>consecutive months<br>after remediation<br>system shut down.<br>No free product<br>detected during this<br>period or system<br>reactivated. |
| Dissolved Petroleum<br>Contamination<br>in Groundwater | State WQS<br>or<br>asymptotic<br>conditions | Monitoring wells<br>122MW-3, 122MW-4,<br>122MW-7, 122MW-8,<br>122MW-9, 122MW-11,<br>122MW-9, 122MW-11,<br>13MW-1, and<br>13DW-1                           | Quarterly<br>Grab                      | All<br>Monitoring wells<br>EPA Method<br>602<br>Monitoring wells<br>122MW-9 and<br>13DW-1<br>EPA Method 610 | Estimated that<br>remediation<br>system will<br>be in operation<br>for two years | Endpoints must<br>be maintained<br>for 12 months<br>before<br>post-operational<br>monitoring<br>is initiated | Quarterly sampling<br>of monitoring wells<br>122MW-3, 122MW-4,<br>122MW-7, 122MW-8,<br>122MW-9, 122MW-11,<br>122MW-9, 122MW-11,<br>13MW-1, and<br>13DW-1<br>System will not be in<br>operation during<br>post monitoring<br>period | Endpoints must<br>be maintained<br>for 12 months<br>before<br>post-operational<br>monitoring<br>is terminated                                                                     |
| Treated Effluent                                       | As specified<br>on<br>NPDES<br>Permit       | Effluent<br>discharge point                                                                                                                               | Monthly                                | EPA Method<br>602                                                                                           | System will<br>be in operation<br>for two years                                  | NA - Discharge<br>monitored<br>monthly                                                                       | System will not be in<br>operation during<br>post monitoring<br>period                                                                                                                                                             | NA (1)                                                                                                                                                                            |
| Residual Product<br>in Soils                           | TPH<br>40<br>(mg/kg)                        | One for every<br>50 ft. along<br>excavation wall                                                                                                          | At time of<br>excavation<br>Grab       | EPA Method<br>8015<br>(5030/3550)                                                                           | Excavation<br>activities will be<br>completed in<br>less than<br>30 days         | NA - Extent of<br>soil excavation<br>not based on soil<br>endpoint.                                          | Sampling will not be<br>performed during<br>post monitoring<br>period                                                                                                                                                              | NA                                                                                                                                                                                |

Notes:  
(1) NA - Not applicable

TABLE 6-1

**NPDES PERMIT MONITORING REQUIREMENTS  
BUILDING AS-4151 - MCAS NEW RIVER, JACKSONVILLE, NORTH CAROLINA  
CONTRACT TASK ORDER 0270**

| Effluent Characteristics    | Discharge Limitation |               | Monitoring Requirements |                   |                 |
|-----------------------------|----------------------|---------------|-------------------------|-------------------|-----------------|
|                             | Monthly Average      | Daily Maximum | Measurement Frequency   | Sample Type       | Sample Location |
| Flow                        |                      |               | Weekly                  | Pump or Meter Log | Effluent        |
| Toluene                     | 11 µg/L              | 22 µg/L       | Monthly                 | Grab              | Effluent        |
| Benzene                     | 71.4 µg/L            | 142.8 µg/L    | Monthly                 | Grab              | Effluent        |
| Methyl Tertiary Butyl Ether |                      |               | Monthly                 | Grab              | Effluent        |

There shall be no discharge of floating solids or visible foam in other than trace amounts.

Additional Chemical constituents analyzed by EPA Methods 602 and EPA Method 625 shall also be reported. No discharge limitations are specified for these constituents.

Source: State of North Carolina Department of Environment, Health, and Natural Resources ,  
Division of Environmental Management.

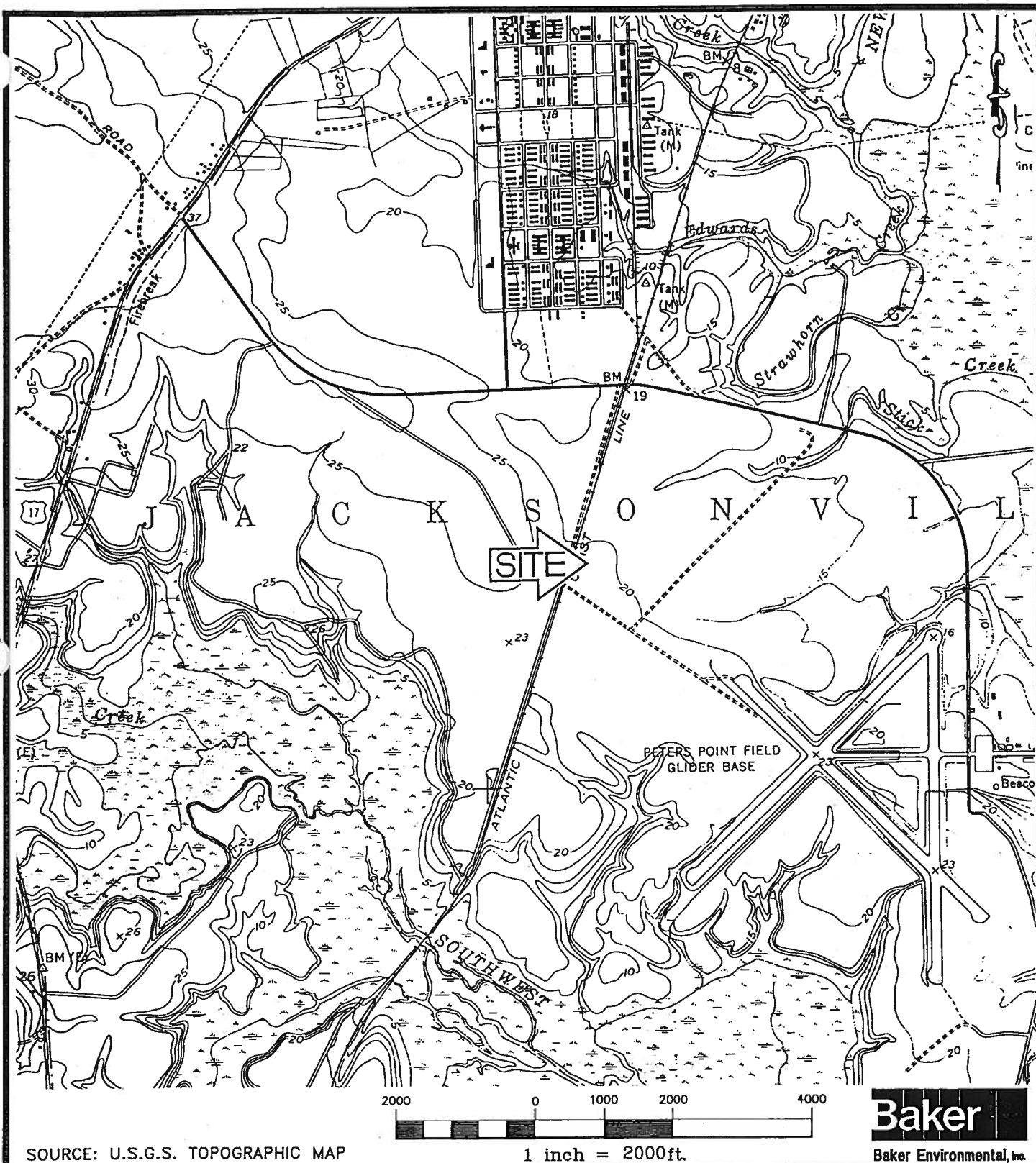
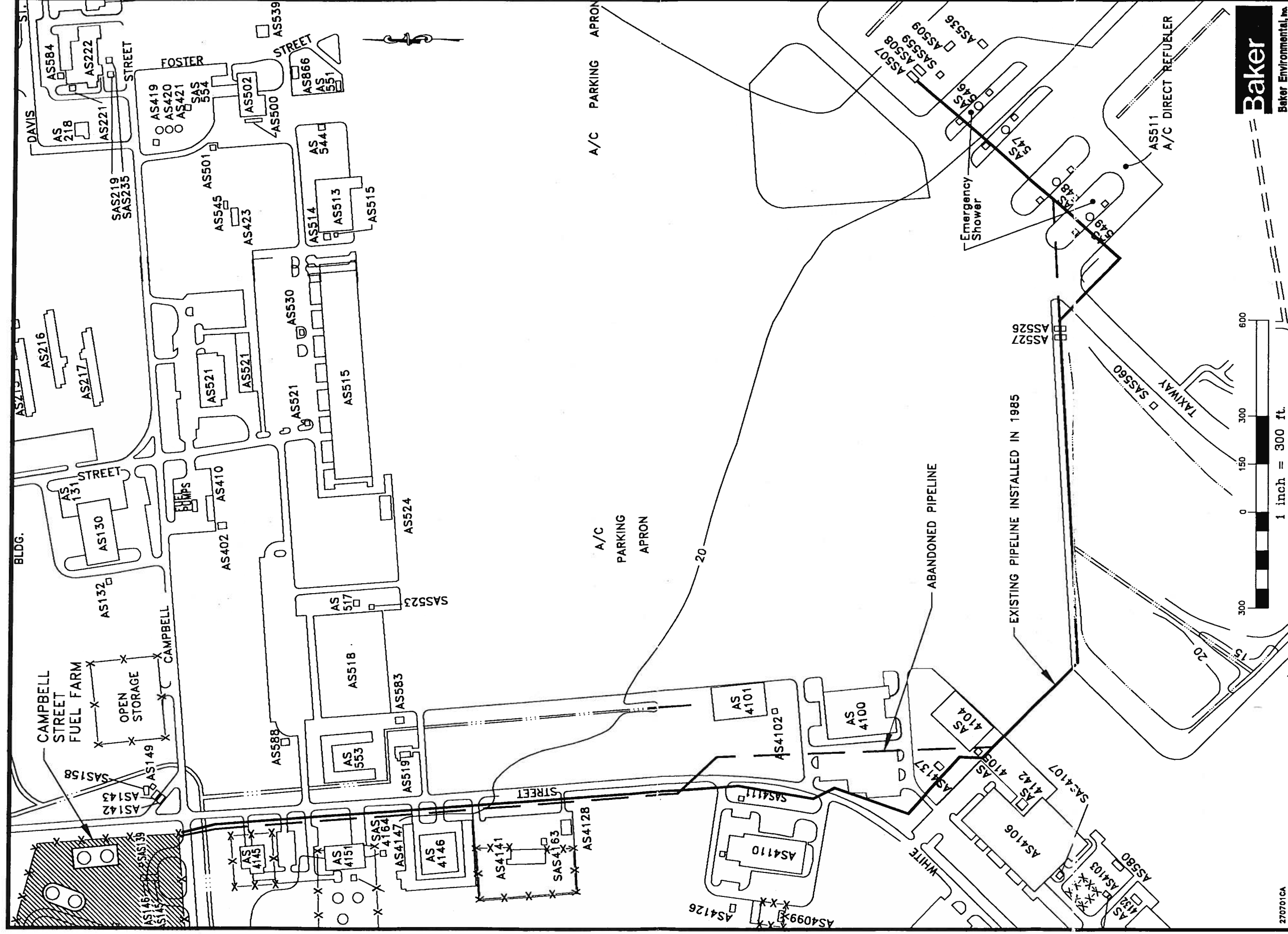


FIGURE 1-1  
SITE LOCATION MAP  
BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
CAMP LEJEUNE RESERVATION  
JACKSONVILLE, NORTH CAROLINA



LEGEND

- CAMPBELL STREET FUEL FARM
- ABANDONED PIPELINE
- EXISTING PIPELINE INSTALLED IN 1985

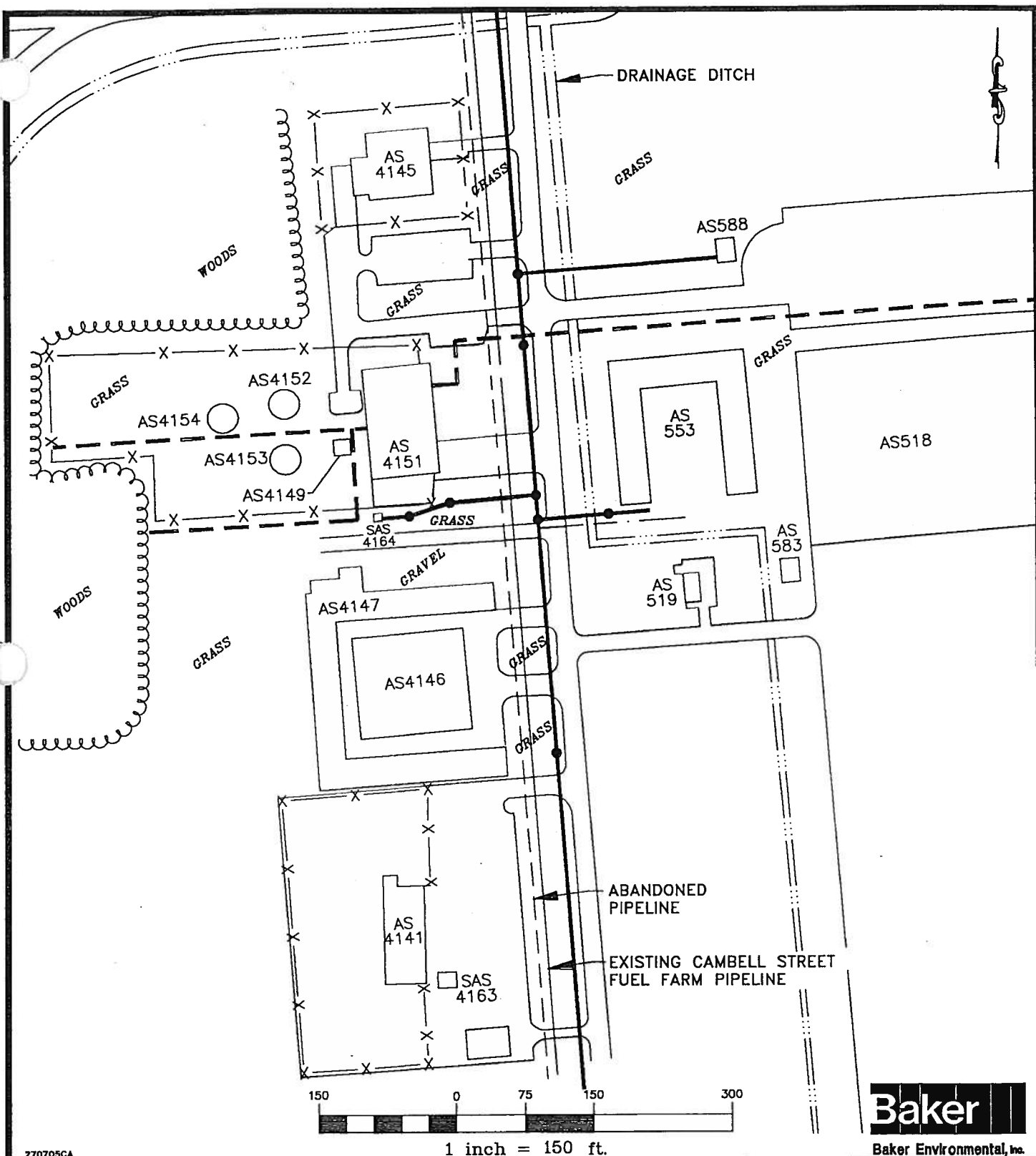
FIGURE 1-2  
CAMPBELL STREET FUEL FARM PIPELINE  
BUILDING AS-4151

SOURCE: LANTDIV, OCT. 1991; OBRIEN & GERE, "CORRECTIVE ACTION PLAN, JP-5 LINE AREA", JUNE 1991.

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA

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### LEGEND

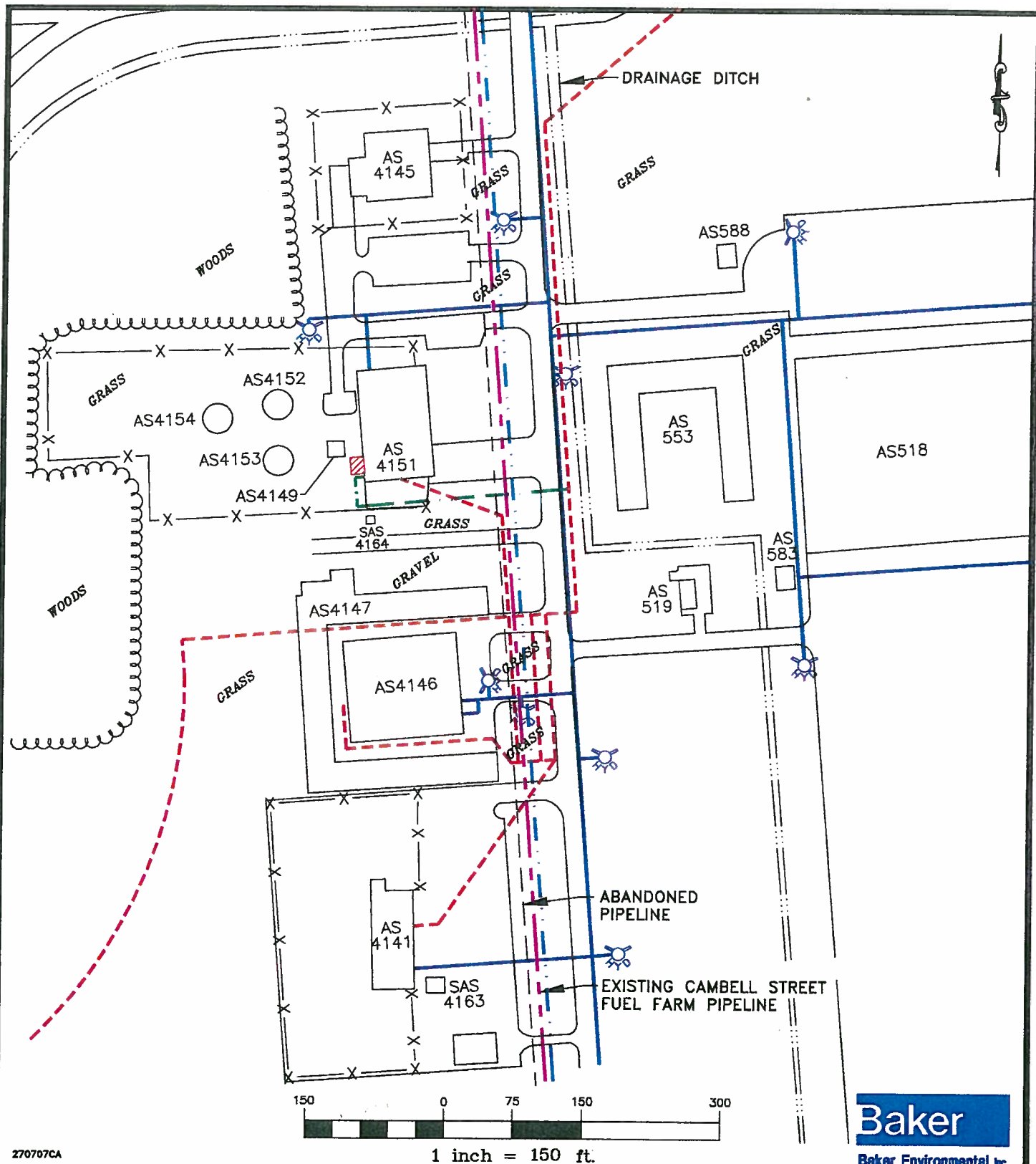
- OVERHEAD ELECTRIC LINES
- - - ABOVE GROUND STEAM LINES

FIGURE 1-3

SITE PLAN  
BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA





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#### LEGEND

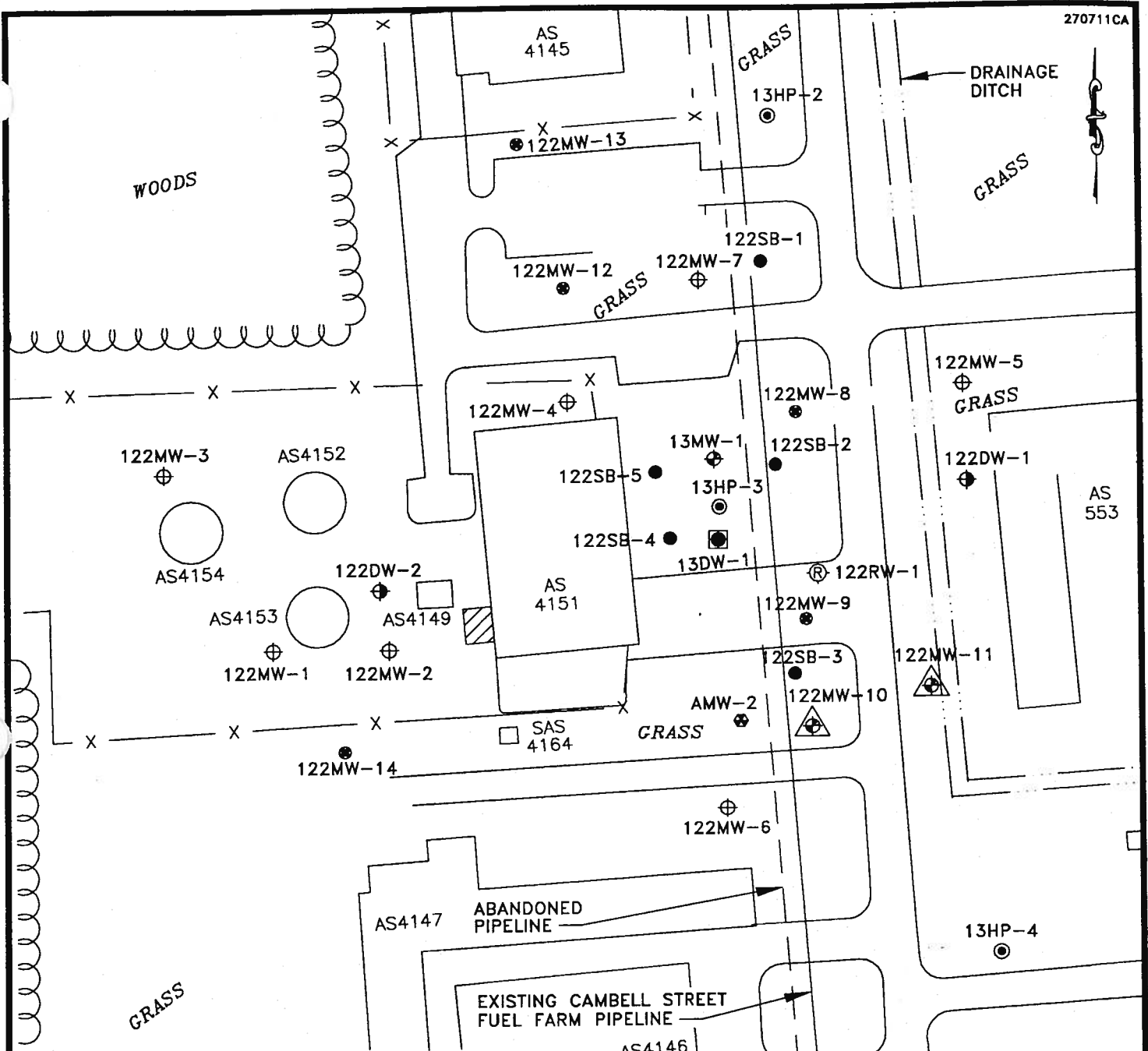
-  FIRE HYDRANT
-  APPROXIMATE LOCATION OF WATER LINE
-  APPROXIMATE LOCATION OF WASTEWATER LINE
-  APPROXIMATE LOCATION OF TELEPHONE LINE
-  EXISTING JP-5 FUEL PIPELINE
-  APPROXIMATE LOCATION OF STORMWATER LINE
-  APPROXIMATE LOCATION OF 1000 GAL. UST.

SOURCE: LANTDIV, OCT. 1991

FIGURE 1-4  
LOCATION OF UNDERGROUND UTILITIES  
BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA





# LEGEND

- 122MW-10 SHALLOW TYPE II GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC. VIA HAND AUGER, JANUARY 1993
- 122MW-8 SHALLOW TYPE II GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC. VIA DRILL RIG, JANUARY 1993
- 122SB-5 SOIL BORING ADVANCED BY BAKER ENVIRONMENTAL, INC. VIA HAND AUGER, JANUARY 1993
- 122RW-1 RECOVERY/PUMPING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC., JANUARY 1993
- AMW-2 EXISTING TYPE II GROUNDWATER MONITORING WELL INSTALLED BY ATEC ASSOC.
- 13MW-1 EXISTING TYPE II GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC., JANUARY 1992
- 13DW-1 EXISTING TYPE III GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC., JANUARY 1992
- 13HP-1 HYDROPUNCH PENETROMETER INSTALLED BY BAKER ENVIRONMENTAL, INC., JANUARY 1992
- 122MW-1 SHALLOW TYPE II GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC., JUNE 1992
- 122DW-1 DEEP TYPE III GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC., JUNE 1992
- APPROXIMATE LOCATION OF 1000 GAL. UST

SOURCE: LANTDIV, OCT. 1991



1 inch = 80 ft.

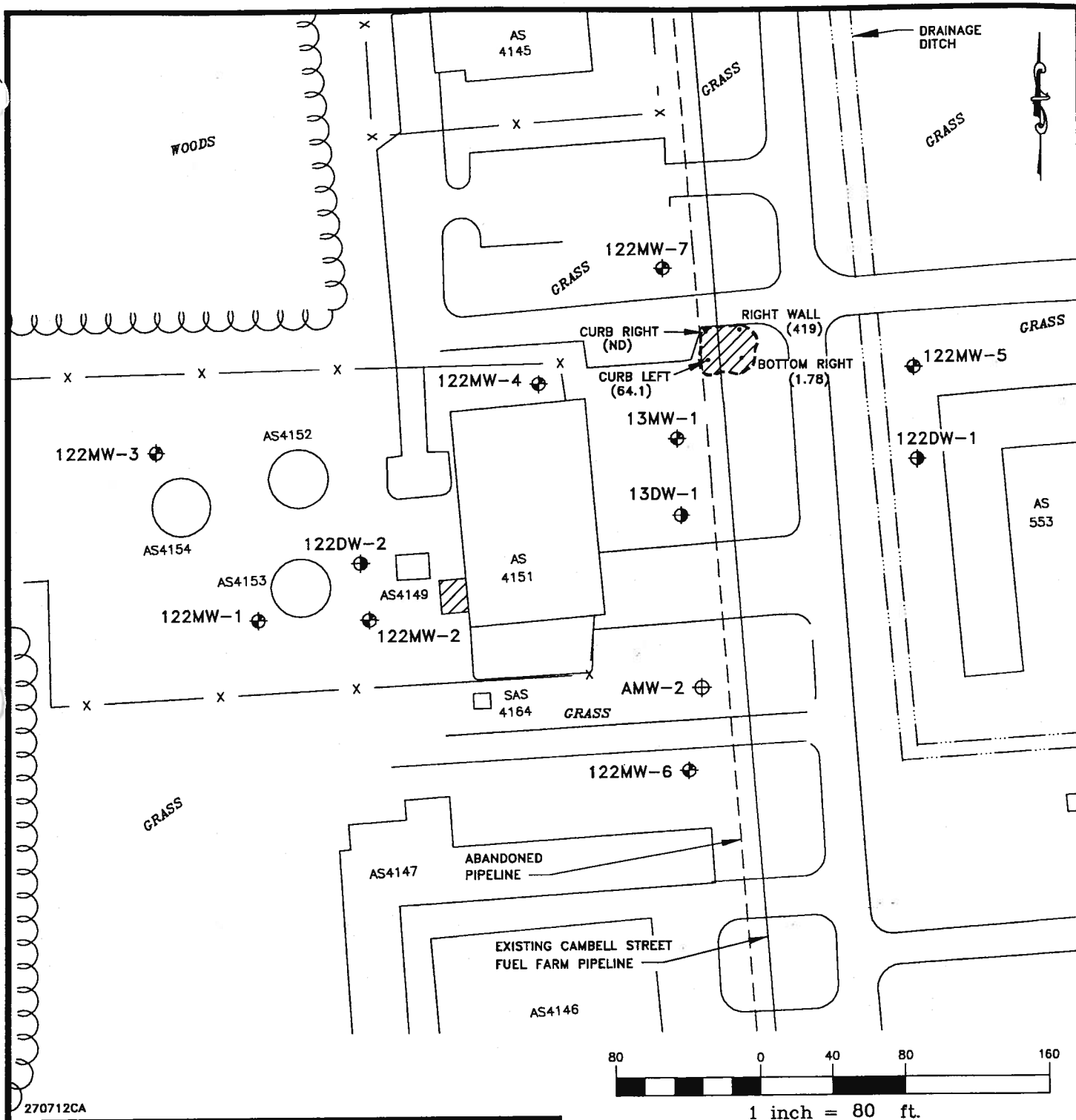
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FIGURE 1-5

## PREVIOUS ASSESSMENT ACTIVITIES BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA



#### LEGEND

- (ND) NOT DETECTED AT METHOD DETECTION LIMITS
- (120) GREATEST TPH CONCENTRATION DETECTED WITHIN SOIL BORING
-  EXTENT OF EXCAVATION
-  RIGHT WALL
-  SAMPLE LOCATION FROM EXCAVATION
- AMW-2 EXISTING TYPE II GROUNDWATER MONITORING WELL INSTALLED BY ATEC ASSOC.
-  13MW-1 SHALLOW TYPE II GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
-  122DW-1 DEEP TYPE III GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
-  APPROXIMATE LOCATION OF 1000 GAL. UST

SOURCE: LANTDIV, OCT. 1991

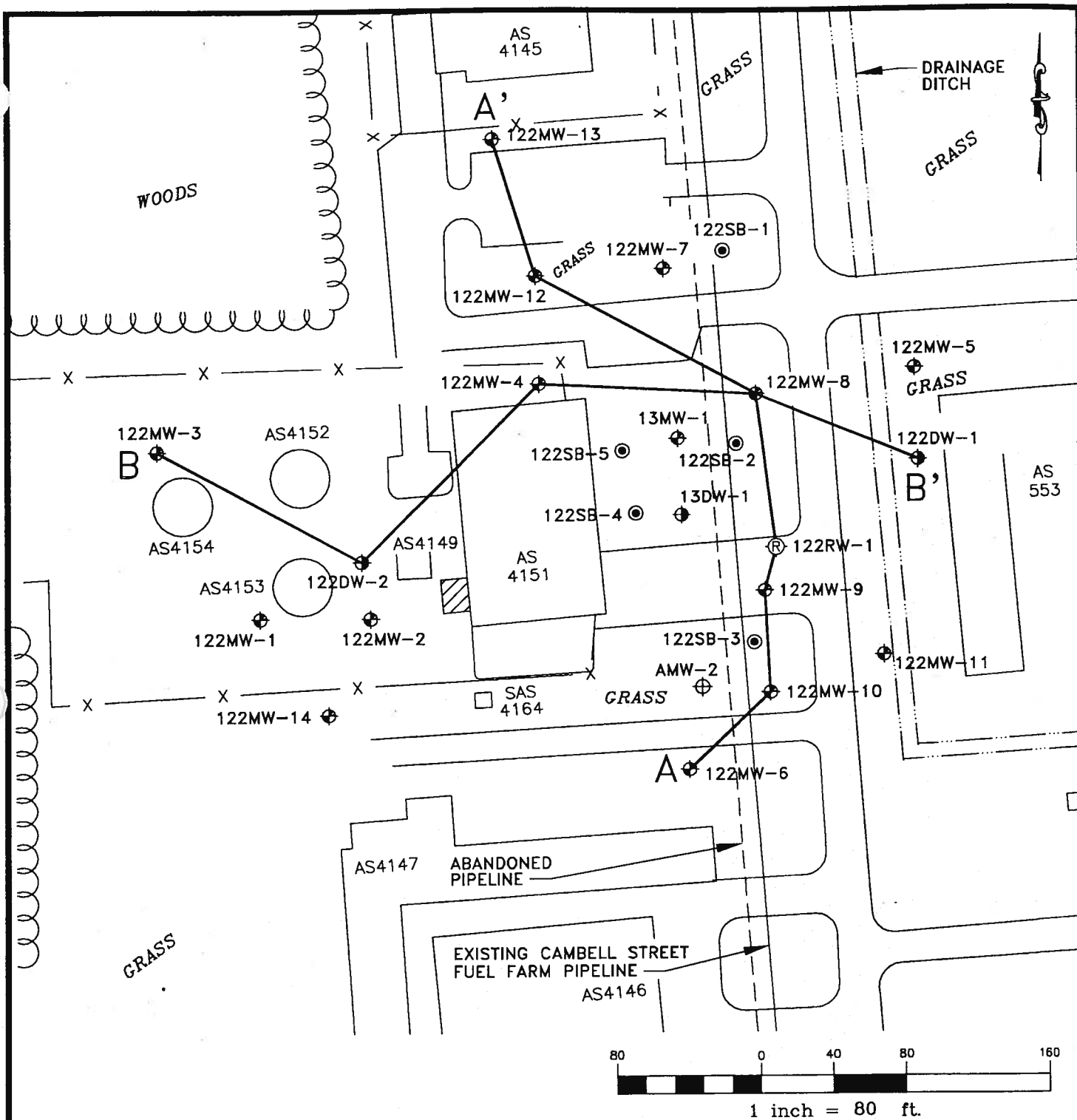
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FIGURE 1-6

### PIPELINE REPAIR ACTIVITIES BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA



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#### LEGEND

- 122SB-5 SOIL BORING ADVANCED BY BAKER ENVIRONMENTAL, INC. VIA HAND AUGER
- 122RW-1 RECOVERY/PUMPING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
- AMW-2 EXISTING TYPE II GROUNDWATER MONITORING WELL INSTALLED BY ATEC ASSOC.
- 13MW-1 SHALLOW TYPE II GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
- 122DW-1 DEEP TYPE III GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.



APPROXIMATE LOCATION OF 1000 GAL. UST

SOURCE: LANTDIV, OCT. 1991

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FIGURE 1-7

### HYDROGEOLOGIC CROSS-SECTION LOCATION MAP BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA

| LEGEND    |                                                                                                       |
|-----------|-------------------------------------------------------------------------------------------------------|
| <u>Y</u>  | GROUNDWATER ELEVATION RECORDED ON FEBRUARY 7, 1993                                                    |
| <u>Δ</u>  | GROUNDWATER ENCOUNTERED DURING DRILLING                                                               |
| B.T. X'   | BORING TERMINATED, ELEVATION MSL                                                                      |
| <u>ND</u> | BENZENE CONCENTRATIONS (ug/L) IN GROUNDWATER                                                          |
| <u>ND</u> | TOTAL VOC CONCENTRATIONS (ug/L) IN GROUNDWATER                                                        |
| <u>□</u>  | WELL SCREEN INTERVAL                                                                                  |
| ND        | NOT DETECTED AT METHOD DETECTION LIMITS                                                               |
| ESTIMATED | PROJECTED                                                                                             |
| [ND]      | TPH CONCENTRATIONS (mg/kg) IN SOILS [HIGHEST CONCENTRATION DETECTED WITH EPA METHOD 8015 (5030/3550)] |

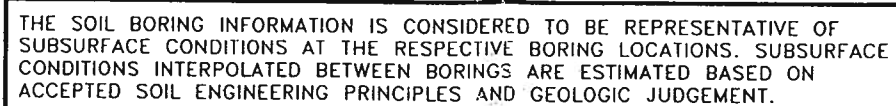
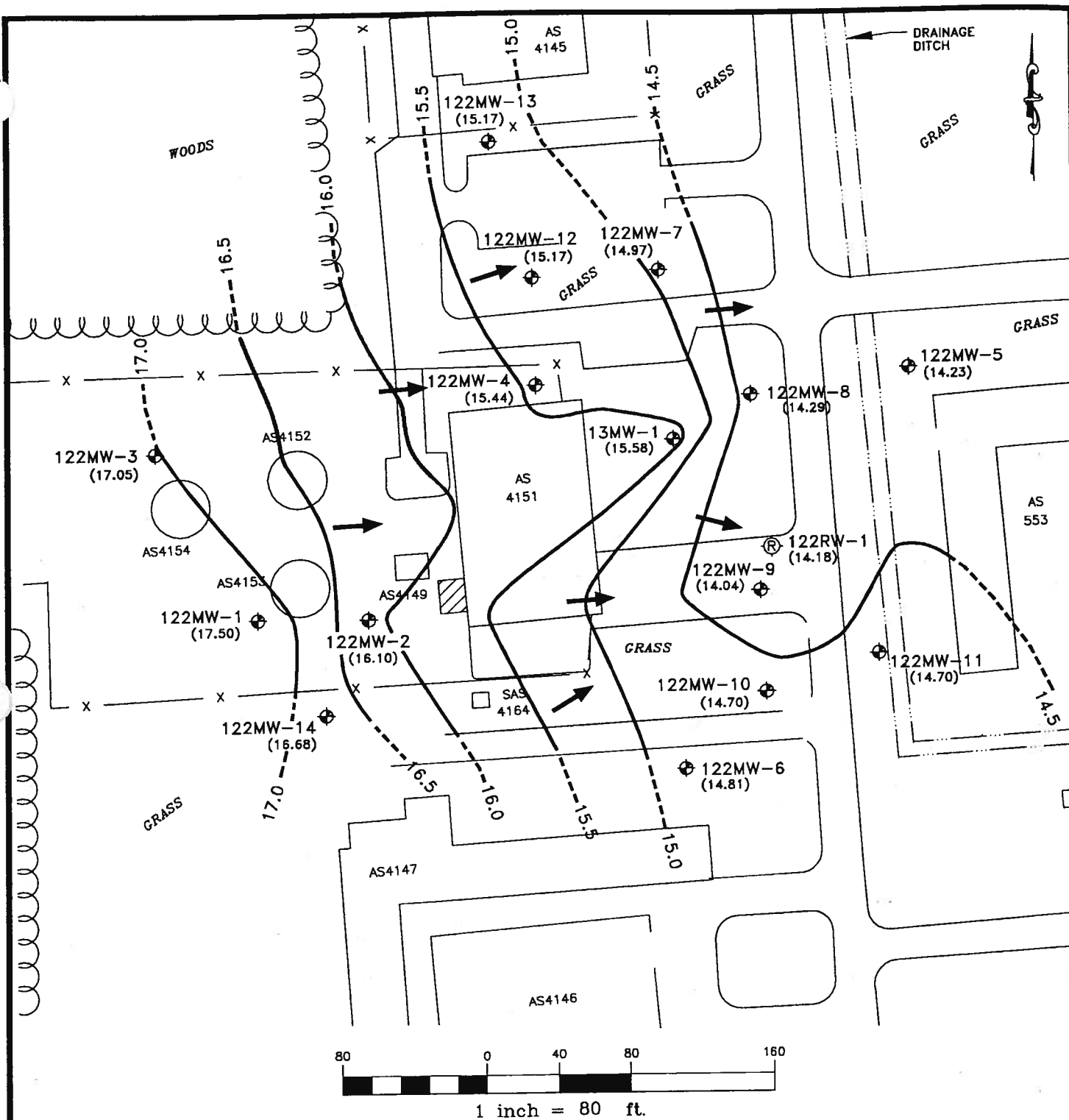


FIGURE 1-9

HYDROGEOLOGIC CROSS-SECTION B-B'  
WITH SOIL AND GROUNDWATER ANALYTICAL RESULTS  
BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA



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# **LEGEND**

(17.50) GROUNDWATER ELEVATION MEASURED ON FEBRUARY 7, 1993

122RW-1 RECOVERY/PUMPING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.

13MW-1 SHALLOW TYPE II GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.

→ ESTIMATED GROUNDWATER FLOW DIRECTION

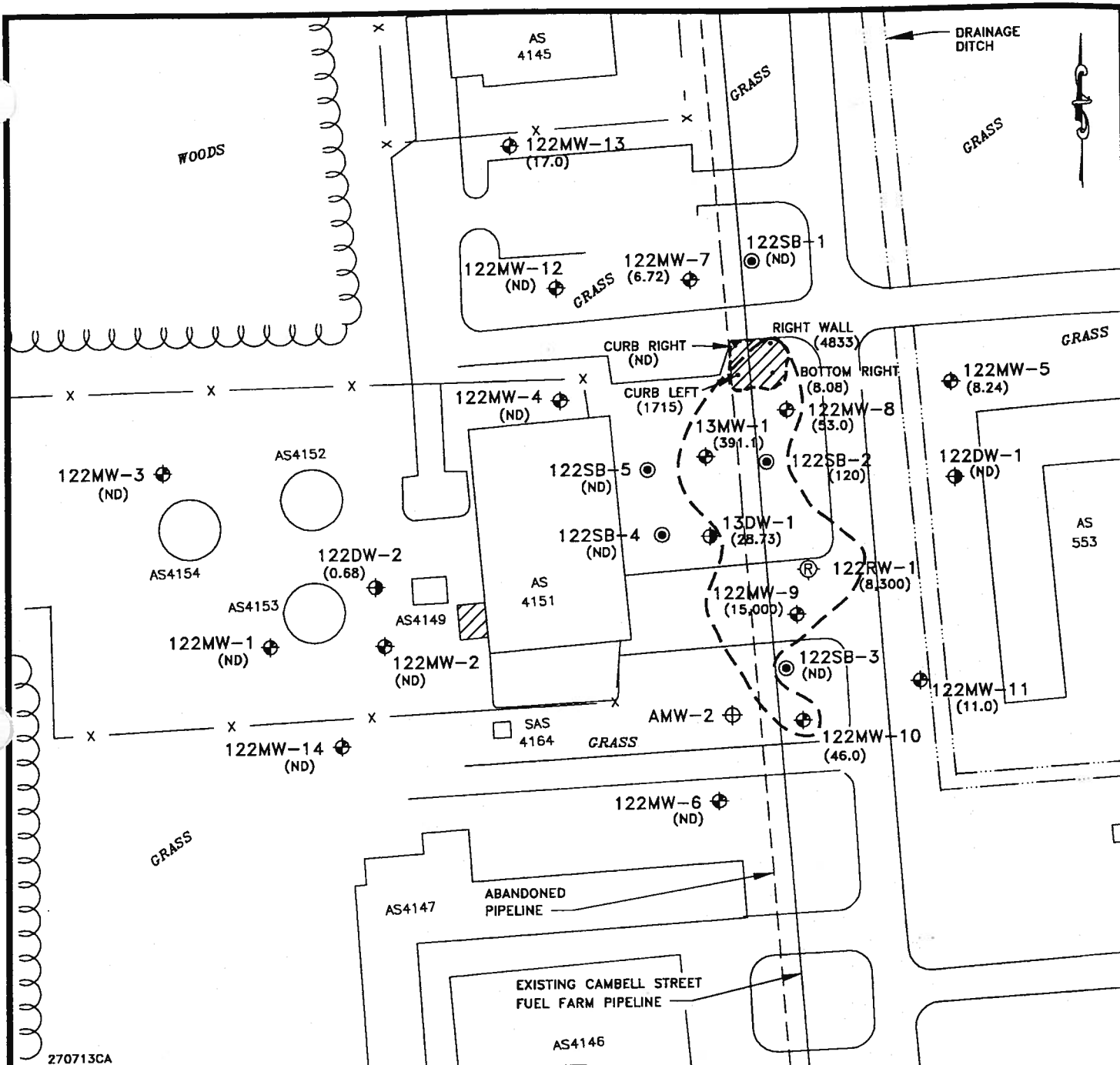
APPROXIMATE LOCATION OF 1000 GAL. UST

SOURCE: LANTDIV, OCT. 1991

FIGURE 1-10

POTENTIOMETRIC SURFACE MAP  
FEBRUARY 7, 1993  
BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA

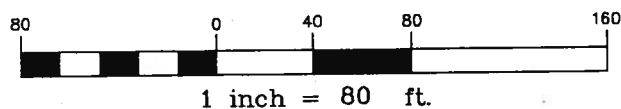


270713CA

#### LEGEND

- (ND) NOT DETECTED AT METHOD DETECTION LIMITS
- (120) GREATEST TPH CONCENTRATION DETECTED WITHIN SOIL BORING
- - - ESTIMATED EXTENT OF TPH CONTAMINATION > ACTION LIMIT (>40 mg/kg)
- RIGHT WALL
- SAMPLE LOCATION FROM EXCAVATION
- 122SB-5 SOIL BORING ADVANCED BY BAKER ENVIRONMENTAL, INC. VIA HAND AUGER
- 122RW-1 RECOVERY/PUMPING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
- AMW-2 EXISTING TYPE II GROUNDWATER MONITORING WELL INSTALLED BY ATEC ASSOC.
- 13MW-1 SHALLOW TYPE II GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
- 122DW-1 DEEP TYPE III GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
- ESTIMATED GROUNDWATER FLOW DIRECTION
- ▨ APPROXIMATE LOCATION OF 1000 GAL. UST

SOURCE: LANTDIV, OCT. 1991



**Baker**

Baker Environmental, Inc.

FIGURE 1-11

TPH CONCENTRATIONS IN SOILS  
BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA

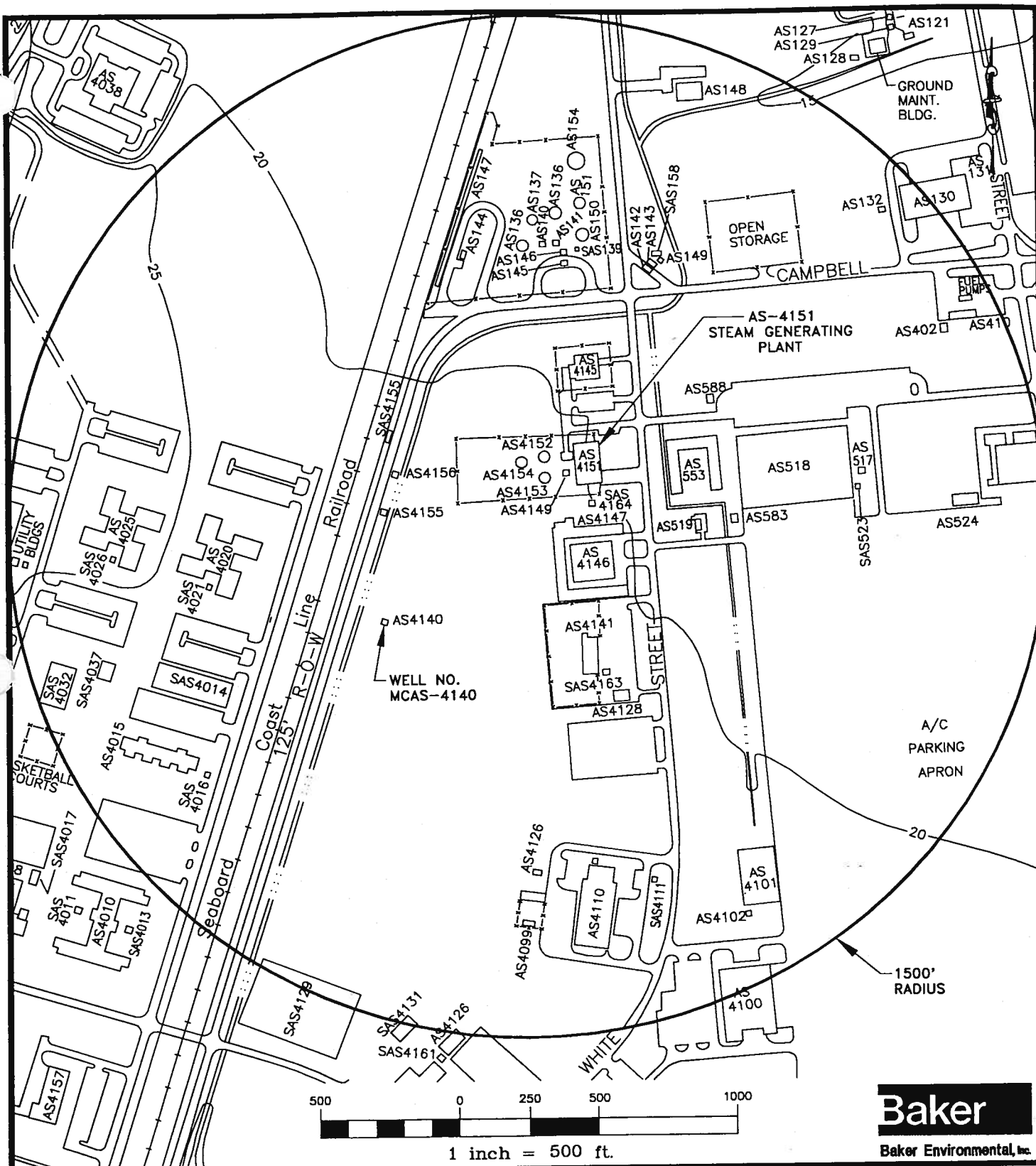


|                                                                                     |                                                                                                                  |
|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
|  | BENZENE CONCENTRATIONS IN GROUNDWATER >1 ( $\mu\text{g}/\text{l}$ )                                              |
|  | VOCs IN GROUNDWATER                                                                                              |
| ND                                                                                  | NOT DETECTED AT METHOD DETECTION LIMITS                                                                          |
| $\frac{7.6}{79.6}$                                                                  | BENZENE CONCENTRATION IN $\mu\text{g}/\text{l}$ (ppb)<br>TOTAL VOC CONCENTRATION IN $\mu\text{g}/\text{l}$ (ppb) |
| 13DW-1                                                                              | DEEP TYPE III GROUNDWATER MONITORING WELL INSTALLED<br>BY BAKER ENVIRONMENTAL, INC.                              |
|  |                                                                                                                  |
| AMW-2                                                                               | EXISTING TYPE II GROUNDWATER MONITORING WELL INSTALLED<br>BY ATEC ASSOC.                                         |
|  |                                                                                                                  |
| 122RW-1                                                                             | RECOVERY/PUMPING WELL INSTALLED BY<br>BAKER ENVIRONMENTAL, INC.                                                  |
|  |                                                                                                                  |
| 13MW-1                                                                              | SHALLOW TYPE II GROUNDWATER MONITORING WELL INSTALLED<br>BY BAKER ENVIRONMENTAL, INC.                            |
|  |                                                                                                                  |
|  | ESTIMATED GROUNDWATER FLOW DIRECTION                                                                             |
|  | APPROXIMATE LOCATION OF 1000 GAL. UST                                                                            |

SOURCE: LANTDIV, OCT. 1991



MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA



270706CA

# LEGEND

MCAS4140 WELL LOCATION

NUMBERS SHOWN AS WELL NUMBER ARE THOSE ASSIGNED BY THE U.S. MARINE CORPS OR ITS CONTRACTORS TO IDENTIFY WELLS CONSTRUCTED AT THE BASE.

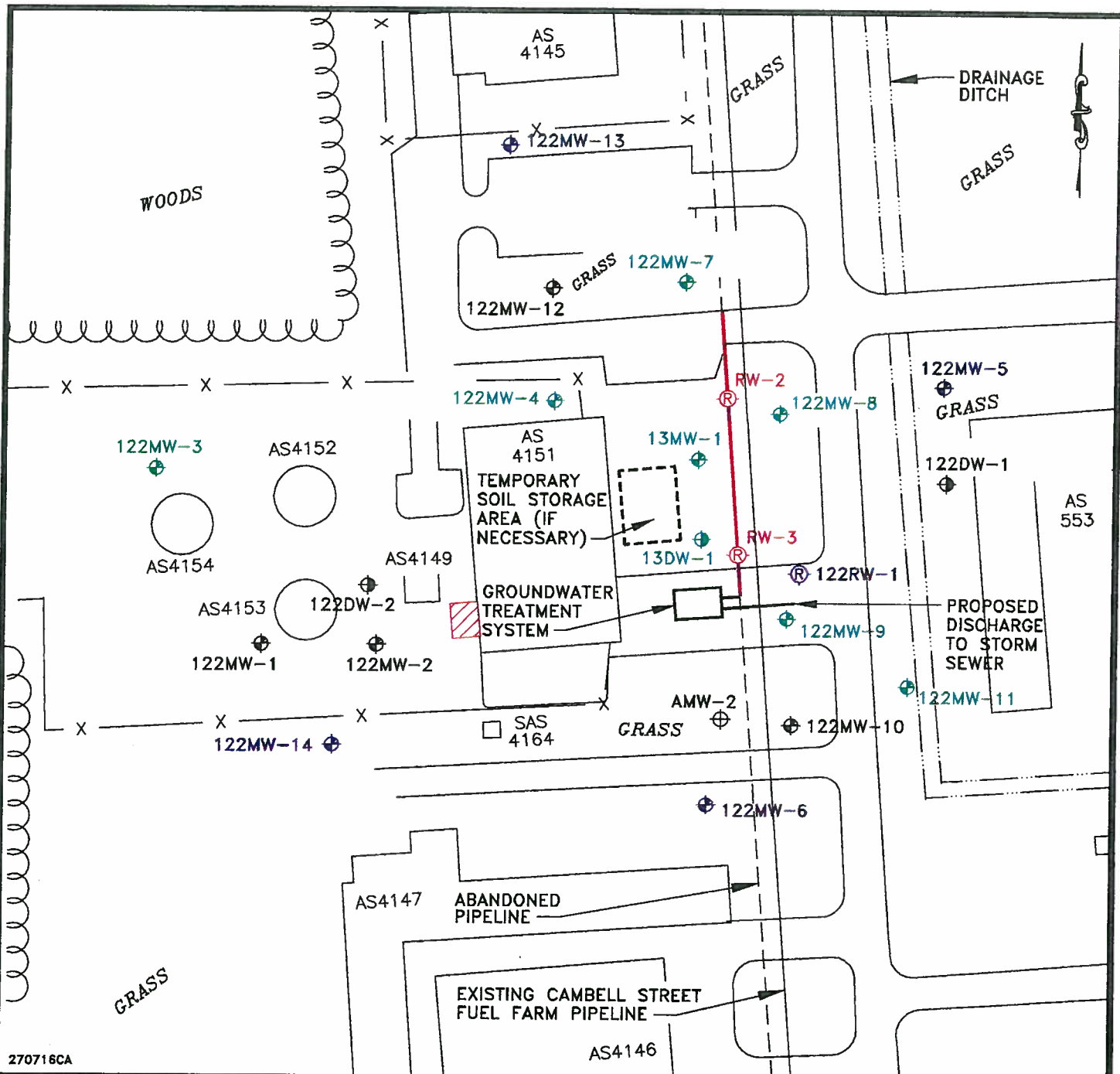
SOURCE: U.S.G.S. WATER RESOURCES INVESTIGATIONS REPORT 89-4096, 1989

## FIGURE 3-1

### SUPPLY WELLS IN SITE VICINITY BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA



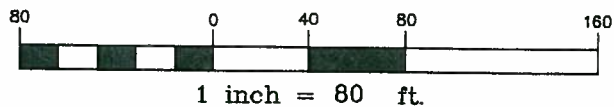


270716CA

### LEGEND

- SUBSURFACE TRENCHING
- PROPOSED INTERCEPTOR TRENCH LOCATION
- 13MW-1  
MONITORING WELLS TO BE SAMPLED IN QUARTERLY MONITORING PROGRAM AND MONITORED MONTHLY
- 122MW-13  
ADDITIONAL MONITORING WELLS TO BE MONITORED MONTHLY
- RW-2  
PROPOSED RECOVERY WELL LOCATION
- 122RW-1  
RECOVERY/PUMPING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
- AMW-2  
EXISTING TYPE II GROUNDWATER MONITORING WELL INSTALLED BY ATEC ASSOC.
- 122MW-1  
SHALLOW TYPE II GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
- 122DW-2  
DEEP TYPE III GROUNDWATER MONITORING WELL INSTALLED BY BAKER ENVIRONMENTAL, INC.
- APPROXIMATE LOCATION OF 1000 GAL. UST.

SOURCE: LAMTDRV, OCT. 1991

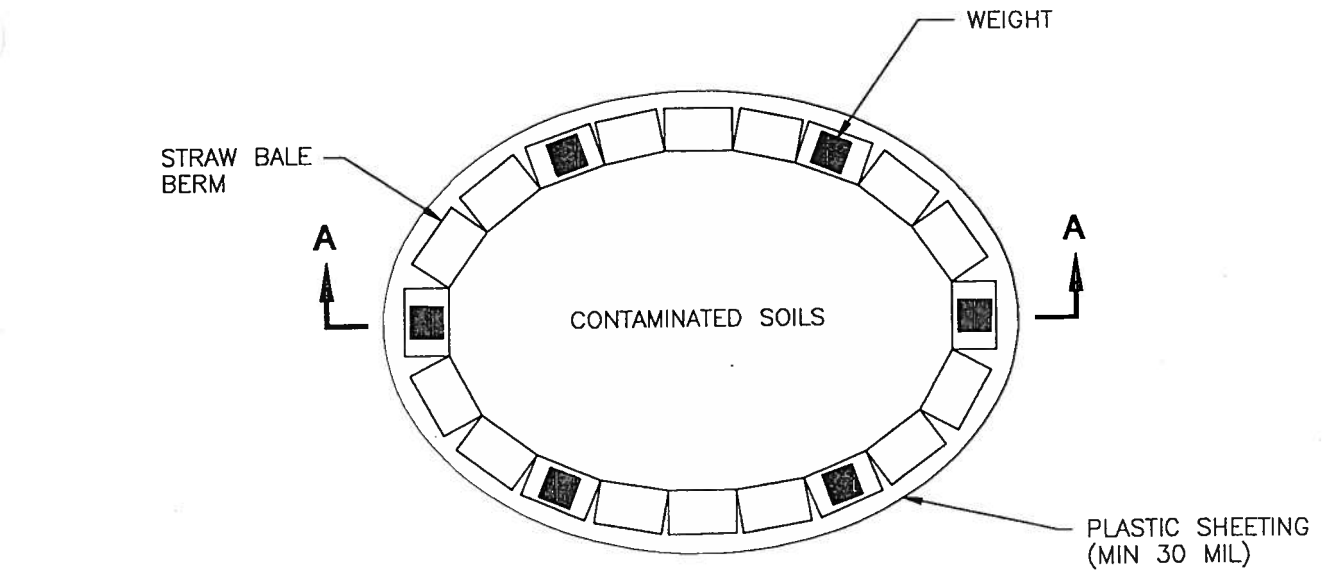


**Baker**  
Baker Environmental, Inc.

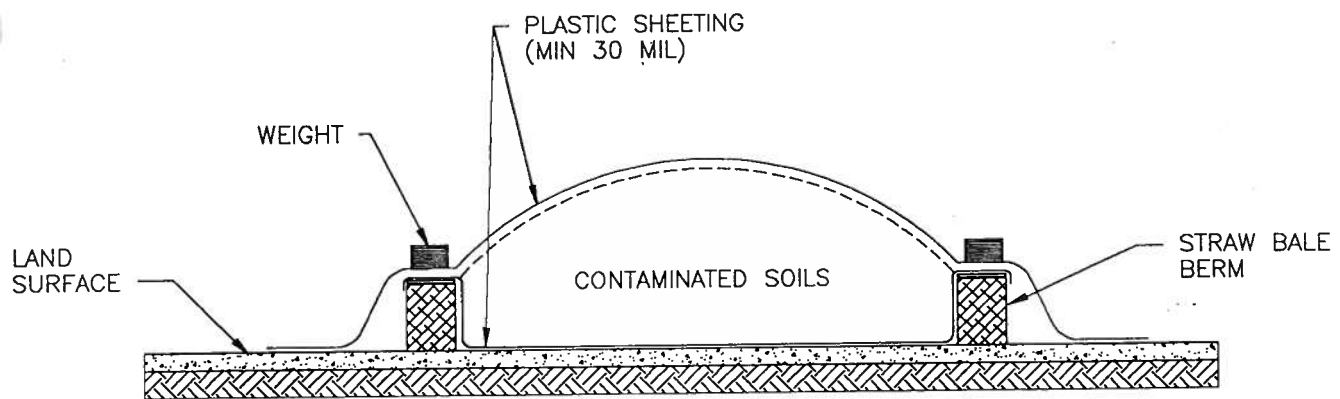
FIGURE 5-1

## RECOMMENDED SITE REMEDIATION PLAN BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA



PLAN VIEW

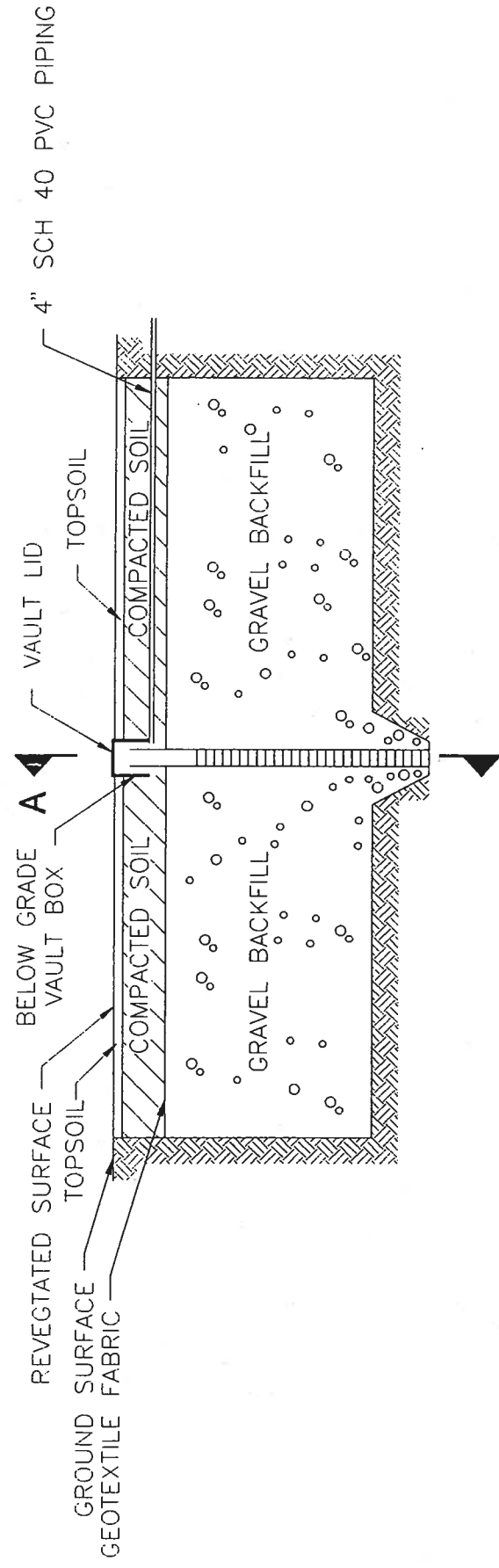
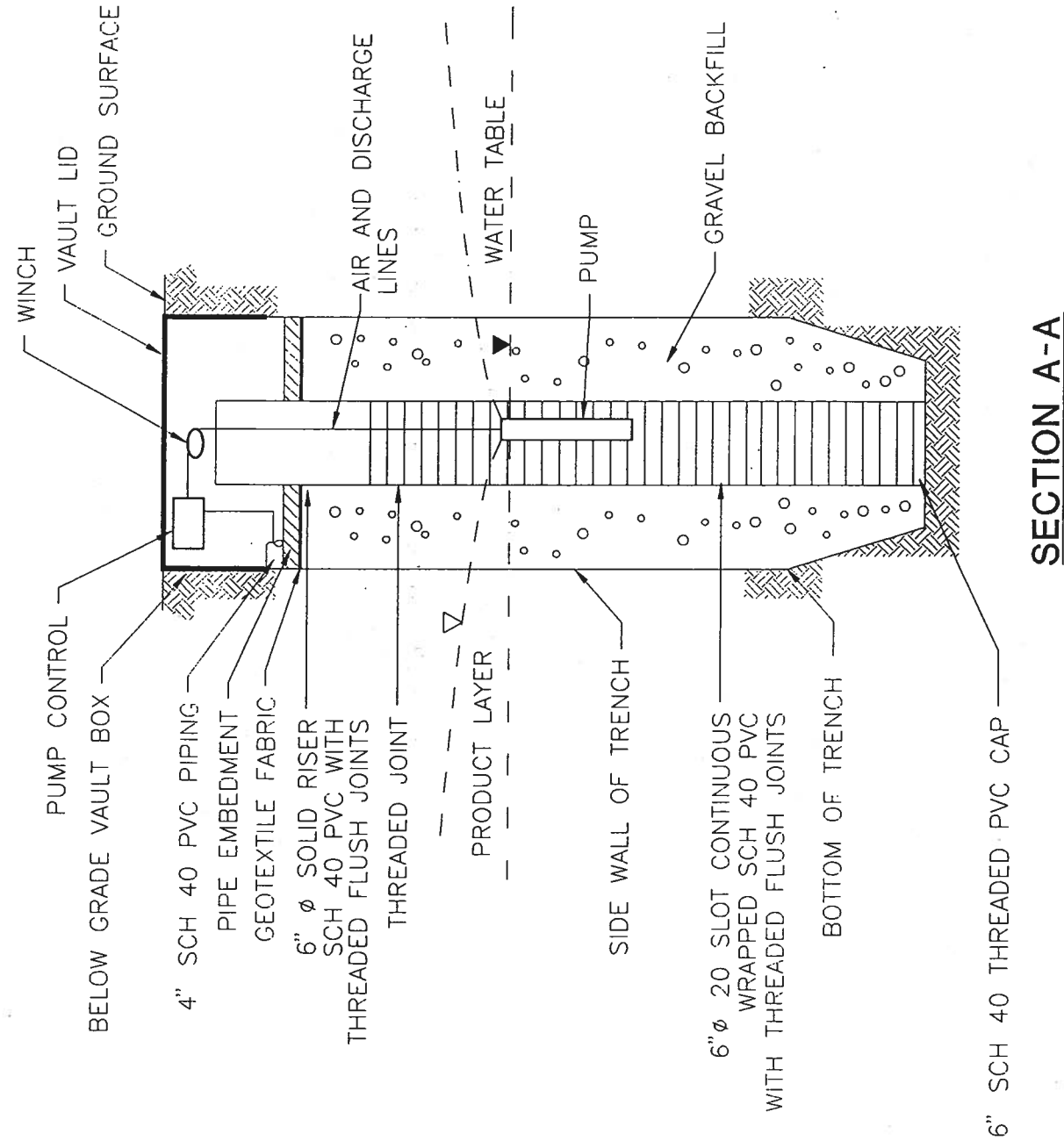


SECTION A-A

**Baker**  
Baker Environmental, Inc.

FIGURE 5-2  
DIAGRAM FOR TEMPORARY CONTAINMENT  
OF PETROLEUM CONTAMINATED SOIL  
BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA



INTERCEPTOR TRENCH DETAIL

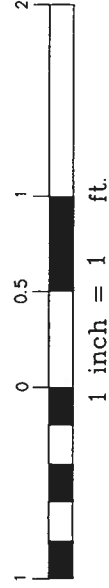
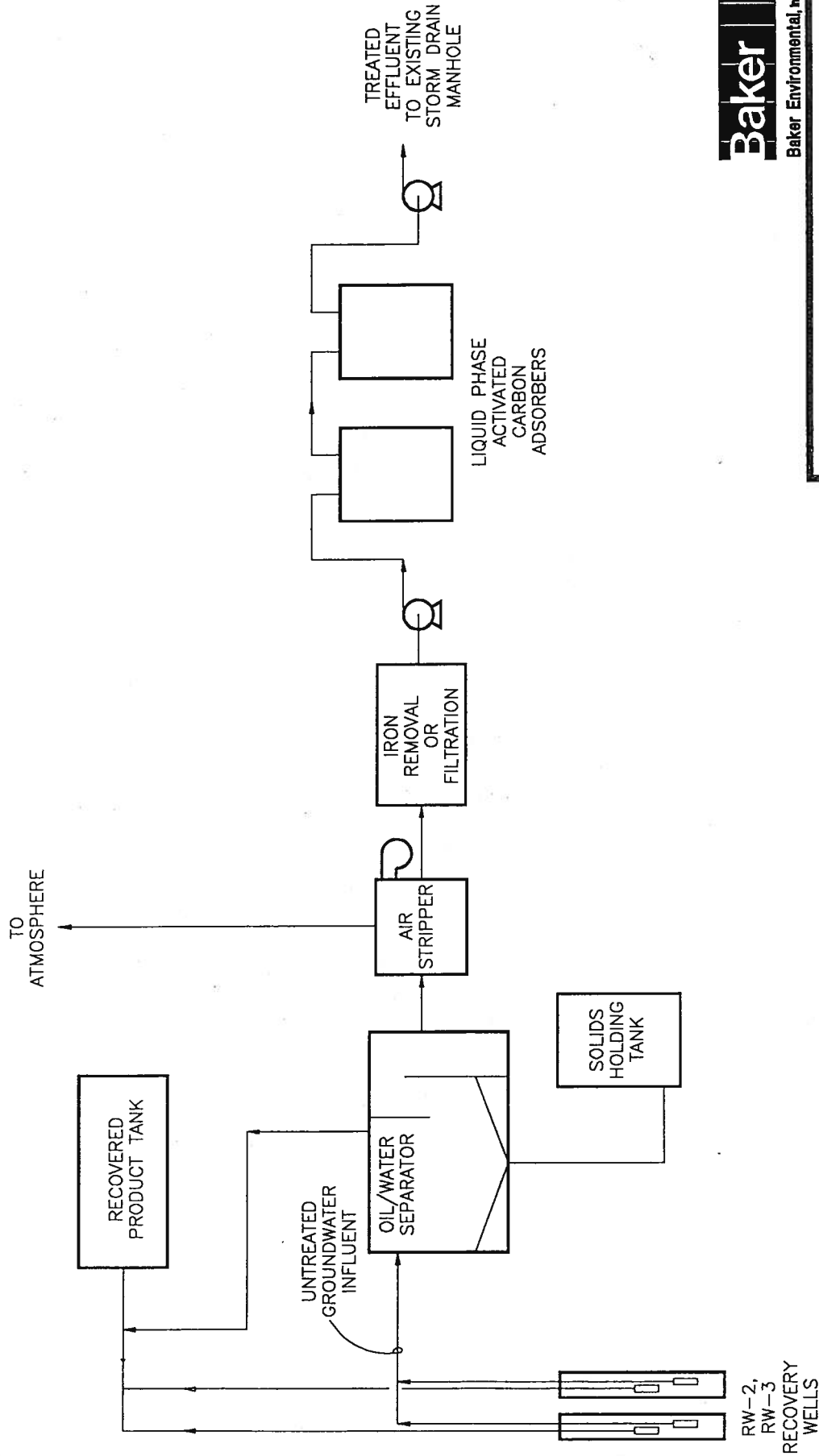


FIGURE 5-3  
SCHEMATIC OF GROUNDWATER  
INTERCEPTOR TRENCH  
BUILDING AS-4151

MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA



**Baker**  
Baker Environmental, Inc.

FIGURE 5-4  
RECOMMENDED GROUNDWATER  
TREATMENT SYSTEM PROCESS  
SCHEMATIC  
BUILDING AS-4151  
MARINE CORPS AIR STATION, NEW RIVER  
JACKSONVILLE, NORTH CAROLINA

**Appendix A**  
**Soil Disposal Documentation**

---

**Baker**

**Baker Environmental, Inc.**  
Airport Office Park, Building 3  
420 Rouser Road  
Coraopolis, Pennsylvania 15108

August 27, 1992

(412) 269-6000  
FAX (412) 269-2002

Commanding General  
Assistant Chief of Staff - EMD Building 1  
Marine Corps Base  
Camp Lejeune, North Carolina 28542-5001

Attn: Mr. Thomas Morris

Re: Contract N62470-89-D-4814  
Navy CLEAN, District III  
Underground Storage Tank (UST) Assessment Activities  
Disposal of Petroleum Contaminated Soils  
Camp Lejeune, North Carolina

Dear Mr. Morris:

Baker Environmental, Inc. (Baker) has completed the coordination of petroleum contaminated soil disposal at Camp Lejeune, North Carolina. These soils were generated during recent site assessment activities which were performed at six separate site locations within the Activity. All soils were transported to a state permitted bioremediation facility located in Rose Hill, North Carolina.

The following attachment summarizes the amount of soil transported from each site. The second attachment is the manifest and chain-of-custody (backside of page) which documents transportation and disposal of the soils.

The amount of soils removed from each site are as follows:

| LOAD NO. | CTO NO.*             | SITE NAME                                                                 | TONS  |
|----------|----------------------|---------------------------------------------------------------------------|-------|
| 1        | 0122                 | Building AS-4151 and<br>Campbell street Fuel Farm                         | 10.43 |
| 2        | 0124                 | Building AS-527                                                           | 11.70 |
| 3        | 0109<br>0110<br>0111 | Building A-47<br>Building 21, Wastewater Treatment Plant<br>Building H-28 | 10.00 |
| 4        | 0122                 | Building AS-4151, Pipeline Excavation                                     | 4.66  |
| 5        | 0122                 | Building AS-4151, Pipeline Excavation                                     | 22.95 |
| 6        | 0108                 | Building RR-72                                                            | 7.18  |

\*CTO denotes Contract Task Order

**Baker**

Mr. Thomas Morris  
August 27, 1992  
Page 2

If you have any questions concerning the soil disposal activities or the projects in general, please contact me at (412) 269-2026.

Sincerely,

BAKER ENVIRONMENTAL, INC.

*David J. Mamrose*

David J. Mamrose, P.E.  
UST Program Coordinator

DJM/nd  
Attachment - Bioremediation Invoice  
Attachment - Manifest/Chain-of-Custody

cc: Mr. Trueman Seamans, Code 1821  
Ms. Susan Clarke, Code 1821  
Ms. Nicola Gonzalez, Code 09

# BIOREMEDIATION INVOICE

MCGILL ENVIRONMENTAL SYSTEMS OF NC INC.  
 RT 1 BOX 212  
 ROSE HILL, NC 28458

TEL: 1-800-728-413  
 TEL: 1-919-532-253  
 FAX: 1-919-532-254

DATE OF TRANSACTION: August 5, 1992 INV #: 081792-01

CLIENT: Baker Environmental Inc. P.O.#: Camp Lejeune, NC  
 Airport Office Park #3  
 420 Rouser Rd. MCGILL  
 Coraopolis, PA 15108 PROJ #: 92026 Baker-LJ

CONTACT: David Mamrose  
 1-412-269-6000

| DESCRIPTION       | QUANTITY | UNIT | UNIT\$ | TOTAL   |
|-------------------|----------|------|--------|---------|
| Treatment of soil | 66.91    | tons | 28.00  | 1873.48 |

|          | TARE     | GROSS    | NET      | TONS  |
|----------|----------|----------|----------|-------|
| Load #01 | 45020.00 | 65870.00 | 20850.00 | 10.43 |
| Load #02 | 35640.00 | 59030.00 | 23390.00 | 11.70 |
| Load #03 | 25000.00 | 45000.00 | 20000.00 | 10.00 |
| Load #04 | 25000.00 | 34320.00 | 9320.00  | 4.66  |
| Load #05 | 35400.00 | 81300.00 | 45900.00 | 22.95 |
| Load #06 | 25000.00 | 39350.00 | 14350.00 | 7.18  |

TOTAL 66.91

TOTAL AMOUNT OF INVOICE 1873.48

TERMS: 30 Days

Thank-you for doing business with McGill Environmental Systems





ENVIRONMENTAL  
SYSTEMS OF NC INC.

Bioremediation  
and related UST services

Environmental  
Consulting

Commercial  
Composting

Rt. 1, Box 212  
Rose Hill, NC 28458  
1-800-728-4130

TEL: 919-532-2539  
FAX: 919-532-2542

# B I O R E M E D I A T I O N M A N I F E S T

MCGILL PROJECT ID#: 92026 Baker-LJ

TRANSPORT TO BEGIN: Wednesday, August 5, 1992

ESTIMATED QUANTITY: 60 tons

ACTUAL QUANTITY: 66.91 TONS

CONTAMINANT: Gasoline, #2 & #6 fuel oil, JP-5

LEVEL: 2577 ppm

1. SOIL SOURCE: Camp Lejeune, NC

COUNTY OF ORIGIN: Onslow

2. OWNER: Camp Lejeune

3. AGENT: Baker Environmental Inc.  
Airport Office Park - Bldg. 3  
420 Rouser Road  
Coraopolis, PA 15108

CONTACT: David Mamrose  
412-269-6000

4. FREIGHT: Bryson Industrial Services  
411 Burton Road  
Lexington, SC 29072

Wills Trucking Inc.  
2647 Shop Road  
Columbia, SC 29209

R&W Construction  
258 Richlands Hwy.  
Jacksonville, NC 28540

5. SOIL DESTINATION:

The McGill bioremediation facility  
at Delway, Sampson County

AFTER-HOURS EMERGENCY:

1-919-285-6291  
1-919-296-0395

DEM Permit #SR0600028

**Appendix B**  
**Site Sensitivity Evaluation**

---

Table 1  
**Site Sensitivity Evaluation (SSE)**  
 Site Characteristics Evaluation (Step 1)

| Characteristic                                                                                                              | Condition                                            | Rating |     |
|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|--------|-----|
| Grain Size*                                                                                                                 | Gravel                                               | 150    | 100 |
|                                                                                                                             | Sand                                                 | 100    |     |
|                                                                                                                             | Silt                                                 | 50     |     |
|                                                                                                                             | Clay                                                 | 0      |     |
|                                                                                                                             |                                                      |        |     |
| Are relict structures, sedimentary structures, and/or textures present in the zone of contamination and underlying "soils"? | Present and intersecting the water table.            | 10     | 0   |
|                                                                                                                             | Present but <u>not</u> intersecting the water table. | 5      |     |
|                                                                                                                             | None present.                                        | 0      |     |
|                                                                                                                             |                                                      |        |     |
| Distance from location of deepest contaminated soil** to water table.                                                       | 0 - 5 feet                                           | 20     | 20  |
|                                                                                                                             | (C, D & E sites only)                                | 20     |     |
|                                                                                                                             | 5 - 10 feet                                          | 10     |     |
|                                                                                                                             | >10 - 40 feet                                        | 0      |     |
|                                                                                                                             | > 40 feet                                            |        |     |
| Is the top of bedrock or transmissive indurated sediments located above the water table?                                    | Yes                                                  | 20     | 0   |
|                                                                                                                             | No                                                   | 0      |     |
| Artificial conduits present within the zone of contamination.                                                               | Present and intersecting the water table.            | 10     | 10  |
|                                                                                                                             | Present but <u>not</u> intersecting the water table. | 5      |     |
|                                                                                                                             | Not present.                                         | 0      |     |
|                                                                                                                             |                                                      |        |     |

**Total Site Characteristics Score:** 130

\* **Predominant** grain size based on Unified Soil Classification System or U.S. Dept. of Agriculture's Soil Classification Method.

\*\* (>10 ppm TPFH by Method 5030; >40 ppm TPFH by Method 3550; >250 ppm O&G by Method 9071)

## Site Sensitivity Evaluation (SSE)

Initial Cleanup Level  
(Step 2)

Final Cleanup Level  
(Step 3)

### EPA Method 5030 for Low Boiling Point Hydrocarbons such as Gasoline, Aviation Fuels, Gasohol

| Total Site Characteristics Score | Initial Cleanup Level TPFH (ppm) |                                  | Category A & B<br>(Multiply initial cleanup level by 1) | 1 x _____ = _____ ppm         | Final Cleanup Level |
|----------------------------------|----------------------------------|----------------------------------|---------------------------------------------------------|-------------------------------|---------------------|
| >150                             | ≤10                              | <b>Select Site Category*</b><br> | Category C & D<br>(Multiply initial cleanup level by 2) | 2 x <u>20</u> = <u>40</u> ppm |                     |
| 121-150                          | 20                               |                                  | Category E<br>(Multiply initial cleanup level by 3)     | 3 x _____ = _____ ppm         |                     |
| 91-120                           | 40                               |                                  |                                                         |                               |                     |
| 61-90                            | 60                               |                                  |                                                         |                               |                     |
| 31-60                            | 80                               |                                  |                                                         |                               |                     |
| 0-30                             | 100                              |                                  |                                                         |                               |                     |

### EPA Method 3550 for High Boiling Point Hydrocarbons such as Kerosene, Diesel, Varsol, Mineral Spirits, Naphtha

| Total Site Characteristics Score | Initial Cleanup Level TPFH (ppm) |                                  | Category A & B<br>(Multiply initial cleanup level by 1) | 1 x _____ = _____ ppm | Final Cleanup Level |
|----------------------------------|----------------------------------|----------------------------------|---------------------------------------------------------|-----------------------|---------------------|
| >150                             | ≤40                              | <b>Select Site Category*</b><br> | Category C & D<br>(Multiply initial cleanup level by 2) | 2 x _____ = _____ ppm |                     |
| 121-150                          | 80                               |                                  | Category E<br>(Multiply initial cleanup level by 3)     | 3 x _____ = _____ ppm |                     |
| 91-120                           | 160                              |                                  |                                                         |                       |                     |
| 61-90                            | 240                              |                                  |                                                         |                       |                     |
| 31-60                            | 320                              |                                  |                                                         |                       |                     |
| 0-30                             | 400                              |                                  |                                                         |                       |                     |

### EPA Method 9071 for Heavy Fuels - Oil & Grease (O&G) such as Fuel Oil #4, #5, #6, Motor Oil, Hydraulic Fluid

| Total Site Characteristics Score | Initial Cleanup Level O&G (ppm) |                                  | Category A & B<br>(Multiply initial cleanup level by 1) | 1 x _____ = _____ ppm | Final Cleanup Level |
|----------------------------------|---------------------------------|----------------------------------|---------------------------------------------------------|-----------------------|---------------------|
| >150                             | ≤250                            | <b>Select Site Category*</b><br> | Category C & D<br>(Multiply initial cleanup level by 2) | 2 x _____ = _____ ppm |                     |
| 121-150                          | 400                             |                                  | Category E<br>(Multiply initial cleanup level by 3)     | 3 x _____ = _____ ppm |                     |
| 91-120                           | 550                             |                                  |                                                         |                       |                     |
| 61-90                            | 700                             |                                  |                                                         |                       |                     |
| 31-60                            | 850                             |                                  |                                                         |                       |                     |
| 0-30                             | 1000                            |                                  |                                                         |                       |                     |

\* See Site Category Descriptions, Table 3

TABLE 3

SSE SITE CATEGORY DESCRIPTIONS

CATEGORY A (*Site meets any one of the criteria*)

1. Water supply well(s) contaminated and not served by accessible public water supply.
2. Vapors present in confined areas at explosive or health concern levels.
3. Treated surface water supply in violation of the safe drinking water standards.

CATEGORY B (*Site meets any one of the criteria*)

1. Water supply well(s) contaminated, but served by accessible public water supply.
2. Water supply well(s) within 1500 feet of site, but not contaminated and not served by accessible public water supply.
3. Vapors present in confined areas but not at explosive or health concern levels.

CATEGORY C (*Site meets both of the criteria*)

1. No known water supply well(s) contaminated.
2. Water supply well(s) greater than 1500 feet from site but not served by accessible public water supply.

CATEGORY D (*Site meets both of the criteria*)

1. No known water supply well(s) contaminated.
2. Water supply well(s) within 1500 feet of site but served by accessible public water supply.

CATEGORY E (*Site meets both of the criteria*)

1. No known water supply well(s) contaminated or within 1500 feet of site.
2. Area served by accessible public water supply.

## Appendix C

### Remediation Equipment

---



## SECTION 200 ON-SITE PLATFORM

### 200.1 DESCRIPTION

#### 200.11 Scope

Equipment to be furnished under this section shall include an Ejector Systems On-Site Platform, prefabricated ground water and soil remediation system with equipment as described elsewhere in this specification, securely mounted, piped, wired, ducted and tested at the factory. Provisions of Section 100, General Conditions shall apply.

#### 200.12 Functional Description

##### A. Platform

The dimensions of the platform are 8, 12 or 16 feet long x 8.5 feet wide x 9 feet high. The platform shall consist of a structural steel base on which major process equipment is mounted at the factory. The base structure shall be of 4 inch I-beam floor joists which are carried by 10 inch I-beams. It shall be capable of being shipped and off-loaded at the job site by fork lift or crane without damaging the equipment, inter-connecting pipe or electrical conduit. It shall be capable of functioning as a complete operating equipment package with or without the enclosure. Flooring shall be one inch thick plywood securely fastened to the platform.

##### B. Enclosure

In order to provide security and/or protection from the weather, the platform shall be provided with an enclosure. The enclosure shall be made up of 4 foot wide by 8 foot high insulated panels. Panels shall be faced inside and out with aluminum sheeting and be constructed such that they can be reversed and/or interchanged with any other panel. Insulation shall consist of 1-1/2 inches of urethane foam board with an R value of 10. In order to facilitate accessibility to all equipment on the platform, each and every panel shall be easily removable by one individual. Weight of an individual panel shall not exceed 55 lbs.

The roof shall be constructed of 1" aluminum extruded I-beams on 1 foot centers and covered with an aluminum skin. One and a half inches of urethane foam board with a R value of 10 shall insulate the roof. The roof shall be capable of carrying a 40 pound per square foot live load.

The integral roof shall be constructed with a structural steel frame mounted securely to the platform supporting the roof and its dead load and specified live load. The enclosure panels will be fastened to the roof. The frame shall be capable of withstanding a 20 pound per square foot wind load transferred by the enclosure panels.



## 200.2 PERFORMANCE AND DESIGN REQUIREMENTS

### 200.21 Platform and Enclosure

- A. Maximum width to any part shall not exceed 8 feet 6 inches and be of sufficient length to provide access for visual inspection of the operation and routine maintenance.
- B. Access shall be by way of a 2 foot 8 inch wide door hinged to swing outward. It shall not be necessary to remove a 4 foot x 8 inch wide panel to enter the enclosure.
- C. An explosion-proof electric heater with thermostat capable of a 12,000 btu output will be mounted and wired at the factory within the enclosure.
- D. An explosion-proof 100 watt light will be mounted on the ceiling.

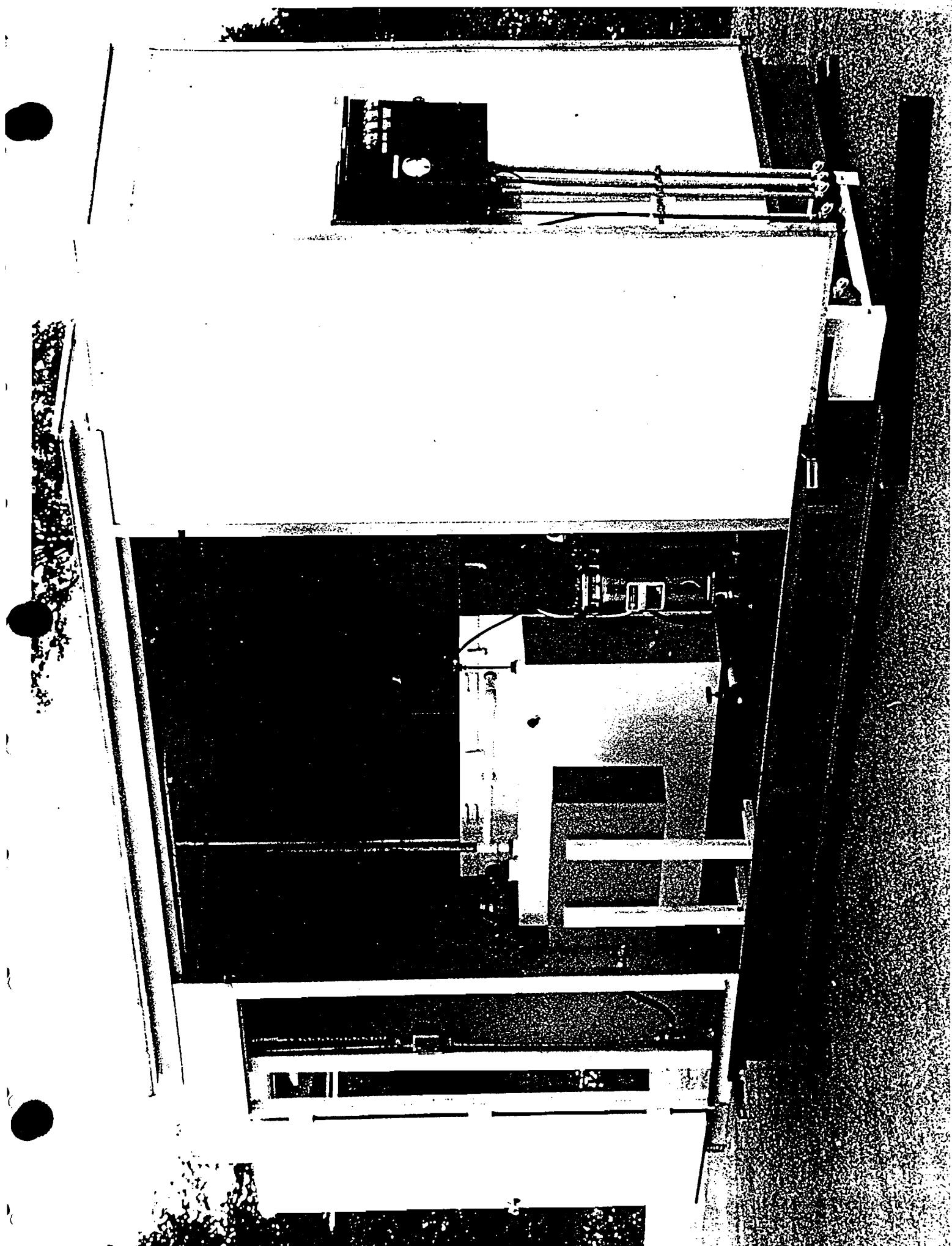
### 200.22 System Electrical

- A. All electrical components in the classified area including fittings, wiring, lights, thermostats, motors, etc. shall conform to the National Electrical Codes to meet the requirements for Class I, Division I, Group D.
- B. A motor control center housing starters and other control components shall be mounted in a NEMA 3R enclosure external to the platform enclosure. Circuit breakers shall be located in their own, separate 3R enclosure. These enclosures shall be mounted at the factory on a structural steel bracket attached to the platform in a fashion which will not inhibit removal of any platform enclosure panel. All interconnecting wiring from the panel to platform components shall be done at the factory. Tops of the electrical enclosures shall be at least 6 feet above the ground. Entry to the enclosures shall be possible either top or bottom.
- C. Service shall consist of one service drop or lateral. Main disconnect is to be rated suitable for service equipment where ground rod shall be installed per NEC 250-23. Other conditions may apply. Electrical conditions are \_\_\_phase 60 cycle \_\_\_volts \_\_\_wire.

### 200.23 Monitoring and Safety Devices

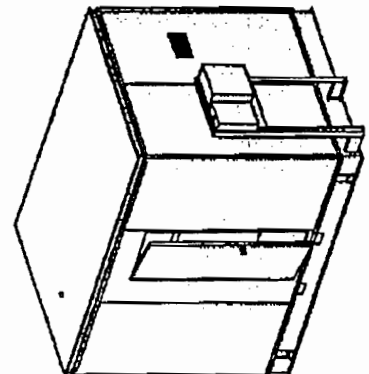
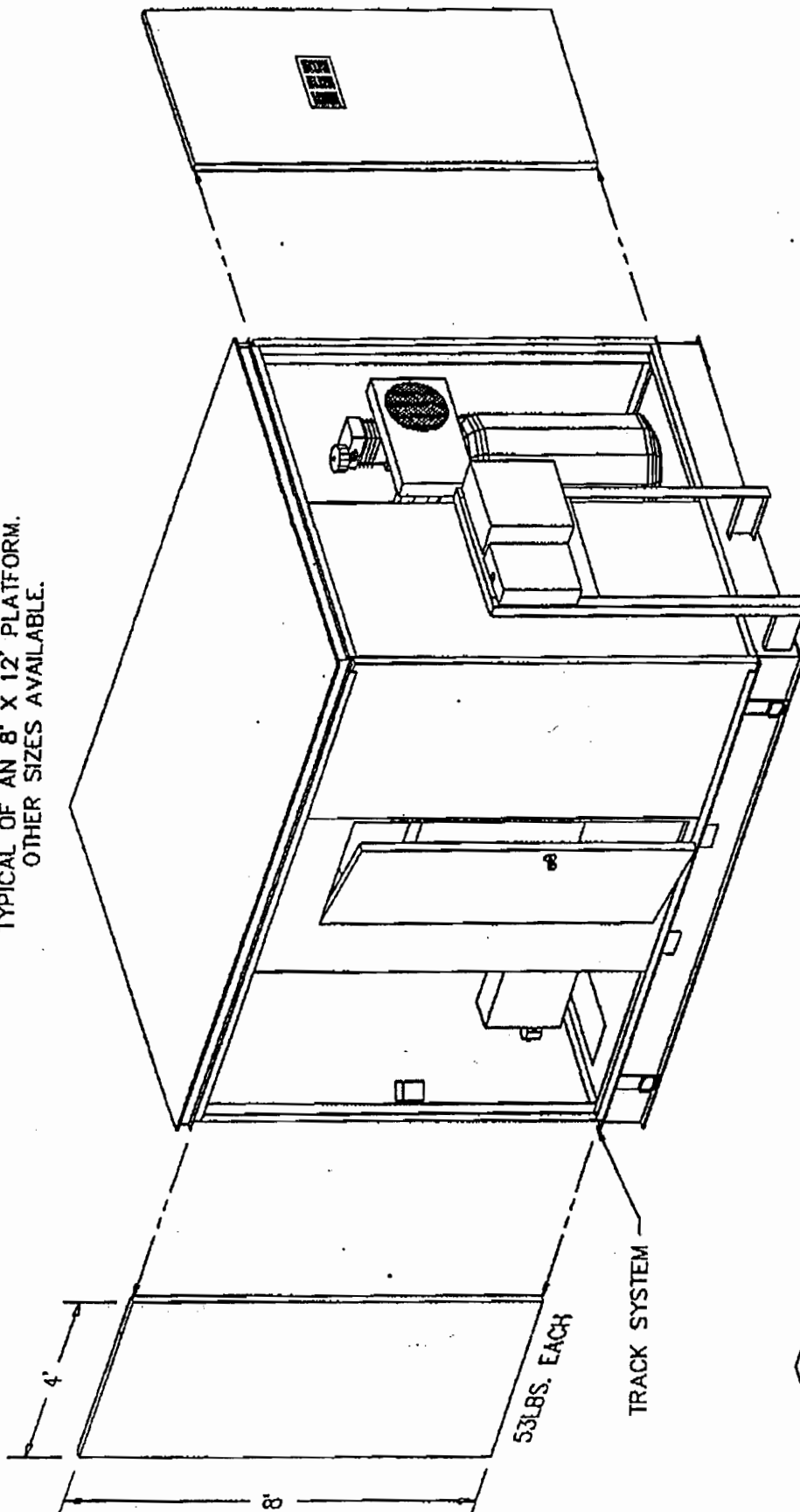
- A. Devices described elsewhere in the specifications used to detect abnormal operation and take shut down or notification functions shall be mounted, wired and integrated into the motor control center.
- B. These devices shall be "wet tested" at the factory prior to shipment.



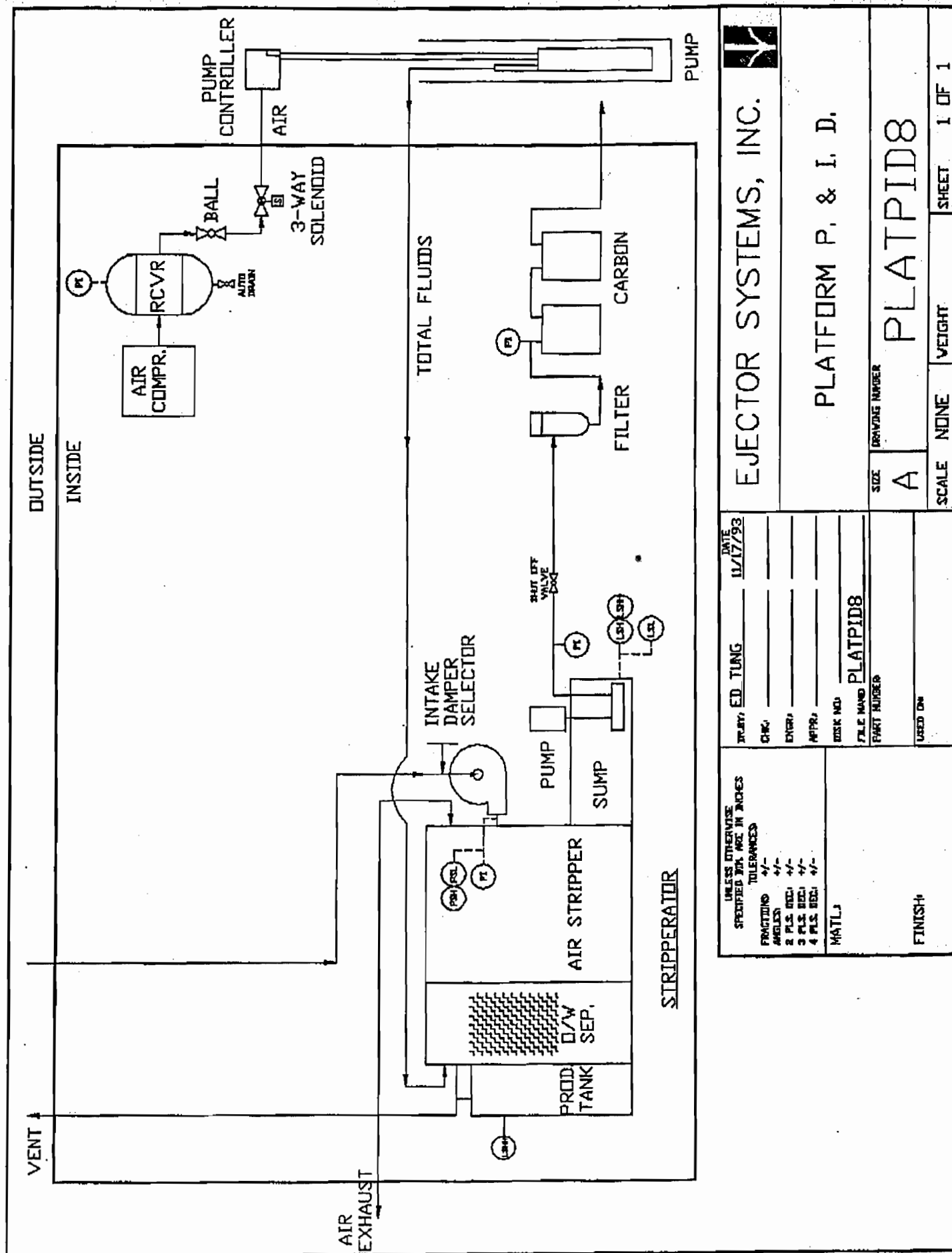




**EJECTOR SYSTEMS ON-SITE PLATFORM**  
 INSULATED, REMOVABLE WALL PANELS  
 TYPICAL OF AN 8' X 12' PLATFORM.  
 OTHER SIZES AVAILABLE.



04-12-94 D.B.  
 PLAT3.DWG



EJECTOR SYSTEMS, INC.

PLATFORM P, &amp; I. D.

PLATPID8

SIZE A

DRAWING NUMBER

SCALE NONE

WEIGHT

SHEET

1 OF 1

DATE 11/17/93

ED TUNG

CHK. \_\_\_\_\_

EXCH. \_\_\_\_\_

APPR. \_\_\_\_\_

DISK NO. \_\_\_\_\_

FILE NAME PLATPID8

PART NUMBER

USED ON

UNLESS OTHERWISE SPECIFIED DIMS ARE IN INCHES

TOLERANCES

FRACTIONS +/-

ANGLES +/-

3 PLS DEC +/-

3 PLS DEC +/-

4 PLS DEC +/-

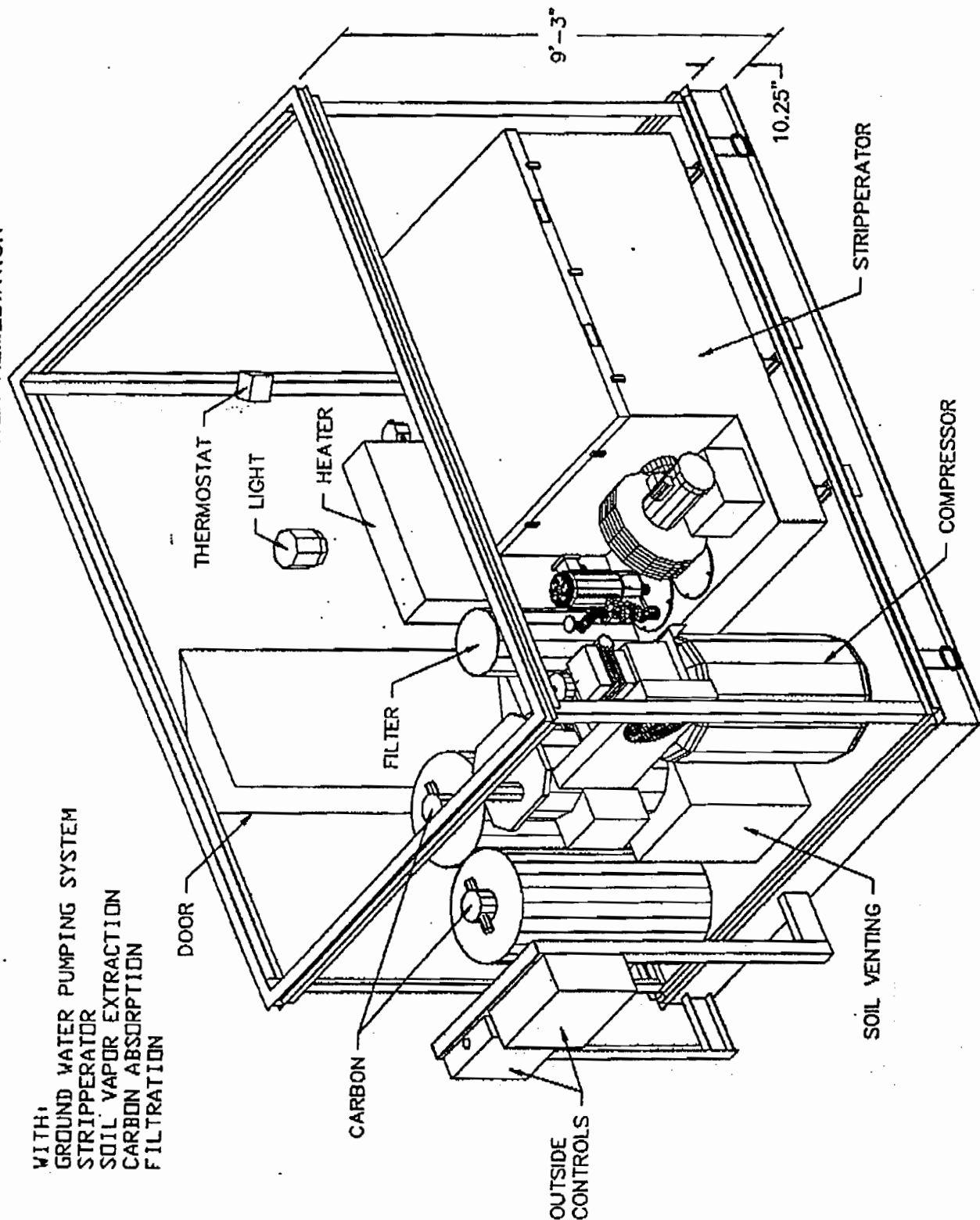
MATERIALS

FINISH

# **EJECTOR SYSTEMS ON-SITE PLATFORM**

0-10 OR 0-20 GPM PACKAGED GROUND WATER REMEDIATION

WITH:  
GROUND WATER PUMPING SYSTEM  
STRIPPERATOR  
SOIL VAPOR EXTRACTION  
CARBON ABSORPTION  
FILTRATION

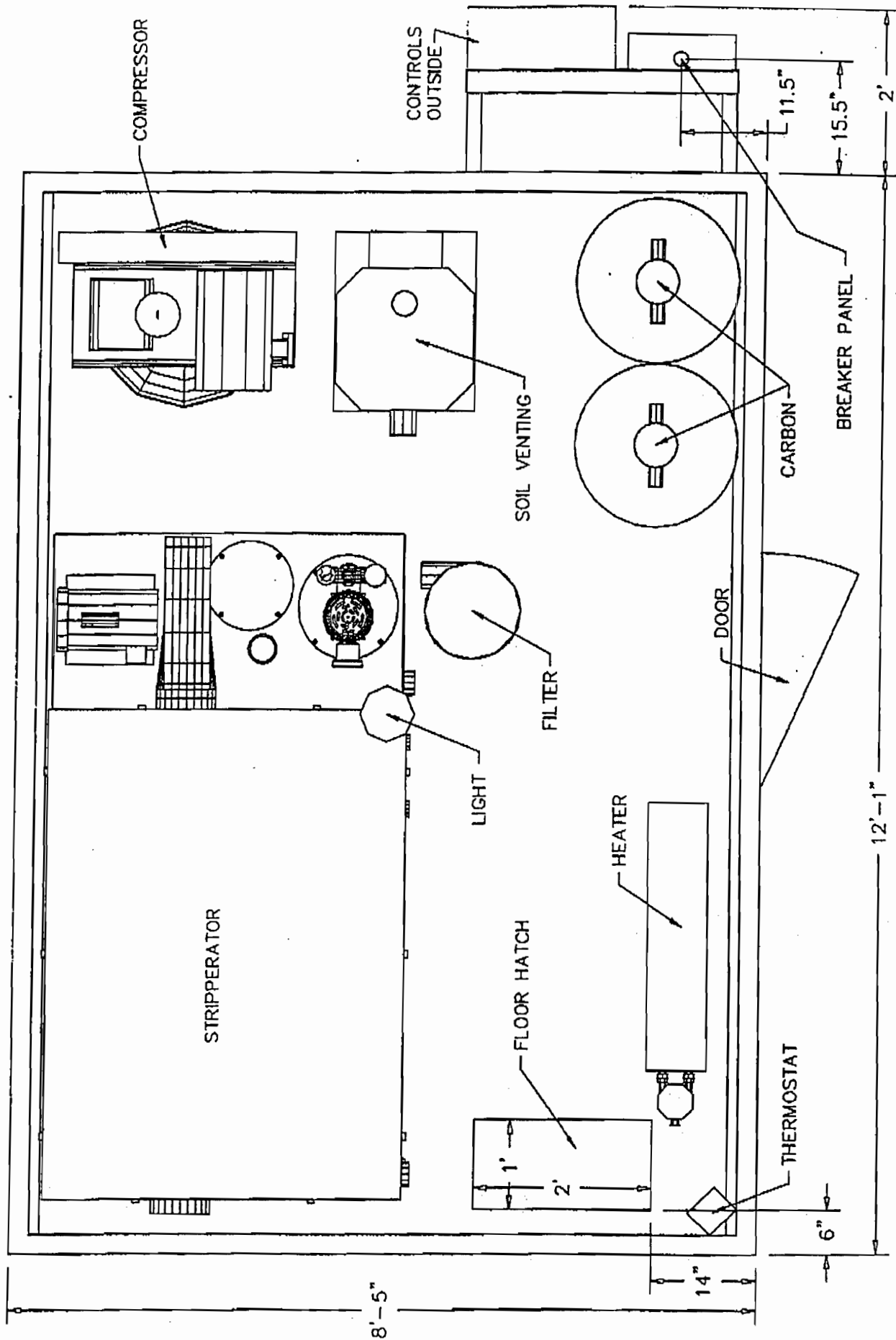


WITH:  
GROUND WATER PUMPING SYSTEM  
STRIPPER  
SOIL VAPOR EXTRACTION  
CARBON ABSORPTION  
FILTRATION

# **EJECTOR SYSTEMS ON-SITE PLATFORM**

0-10 OR 0-20 GPM PACKAGED GROUND WATER REMEDIATION

## **PLAN VIEW**





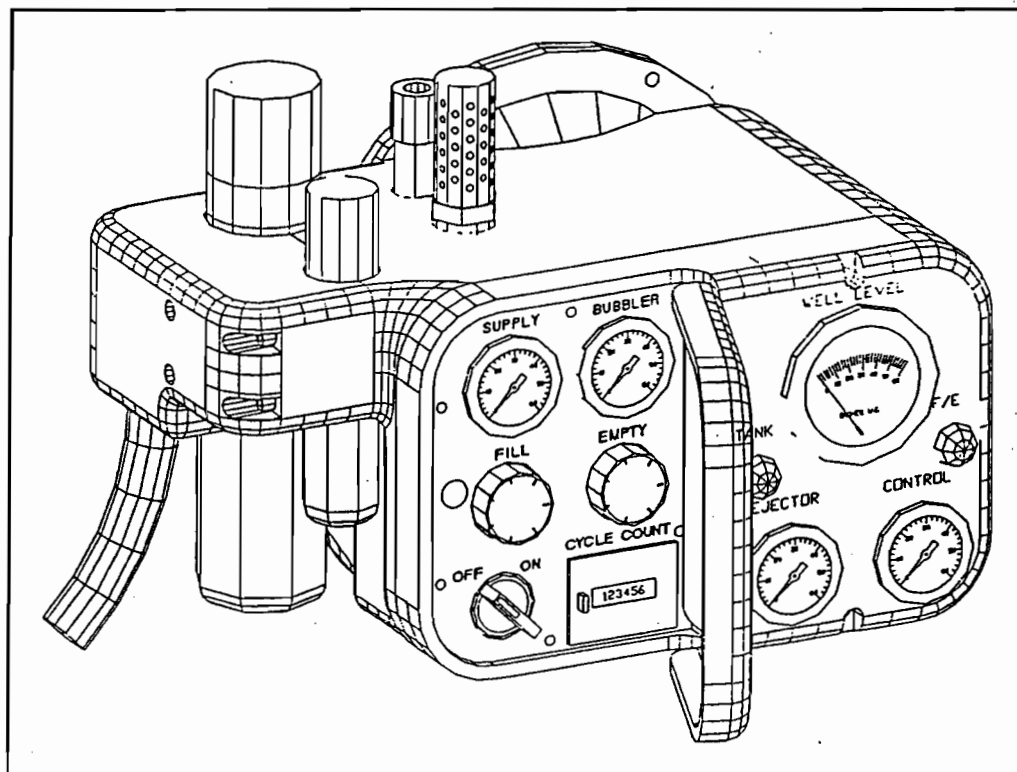
**EJECTOR SYSTEMS, INC.**

## **S2 SINGLE-WELL PUMPING SYSTEM**

**EJECTOR SYSTEMS, INC.  
910 NATIONAL AVENUE  
ADDISON, IL  
60101  
(708) 543-2214  
1-800-OIL-LEAK  
1/92**



Ejector Systems, Inc. presents the most advanced solution yet for groundwater remediation and leachate pumping. The same ingenuity that made ESI the first to use pneumatics for groundwater pumping is now combined with the new S2 single well controller to offer a vast number of options, yet remain amazingly economical.



**S2 SINGLE WELL CONTROLLER**

Product Only and Total Fluids pumps are both compatible with the new S2 controller. Ejector Systems, Inc.'s pumps are entirely pneumatic and have only two moving parts thereby reducing maintenance. In addition to leachate pumping, they can be used to pump lighter-than-water, phase-separated hydrocarbons, such as gasoline and fuel oils; heavier-than-water hydrocarbons, such as creosote or chlorinated solvents; or dissolved hydrocarbons only. Refer to the chart on page four for flow rate and air consumption.





**Some standard features on the new S2 single-well controller are:**

- The S2 system is totally submersible.
  - An extremely rugged 11" high x 14.5" wide x 10" deep casing encloses the S2 so it fits easily into a below grade box.
  - Water problems are virtually eliminated with the S2's **Pulsed Auto-Drain** which eliminates condensate in the compressed air system.
  - The **Manual Discharge** feature allows the pump to fire with the simple push of a button.
- 

**Dependent upon the specific site requirements, optional features are available:**

- To ensure accurate level control in sealed well applications with a vacuum, the **Differential Pressure** option is available.
- The **High Tank Shut-Off** option will shut down the pumping system in the event of a high level condition.
- A **Vacuum Fill Unit** which will apply a vacuum to the vent line during the fill cycle is available.
- Product recovery is maximized with the **Level Tracking** option which ensures that the inlet of the Product Only pump is always at the liquid surface of the well.



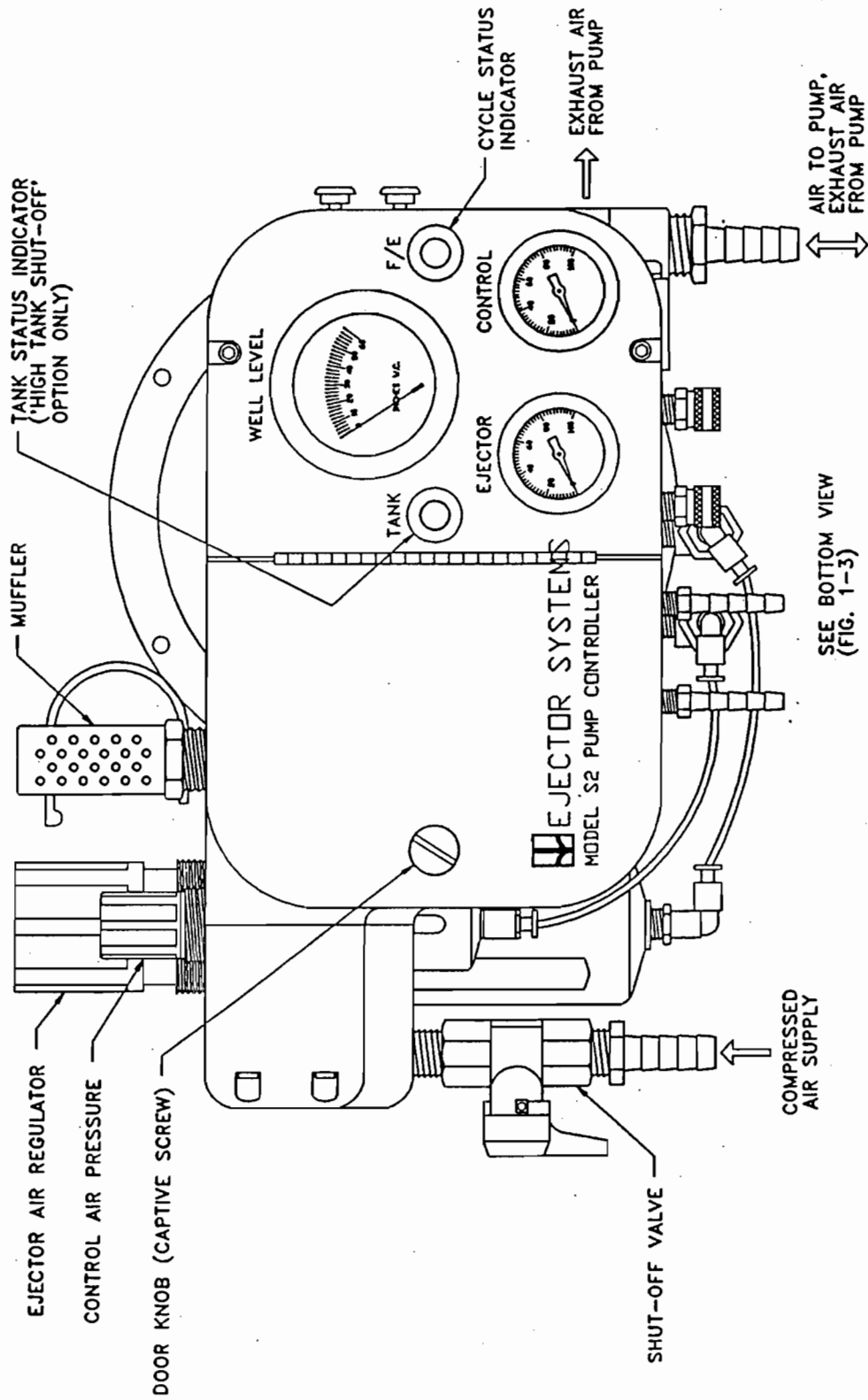
## MAXIMUM FLOW RATE AND APPROXIMATE AIR CONSUMPTION VS. EJECTOR DIAMETER AND LENGTH

Diameter of Ejector

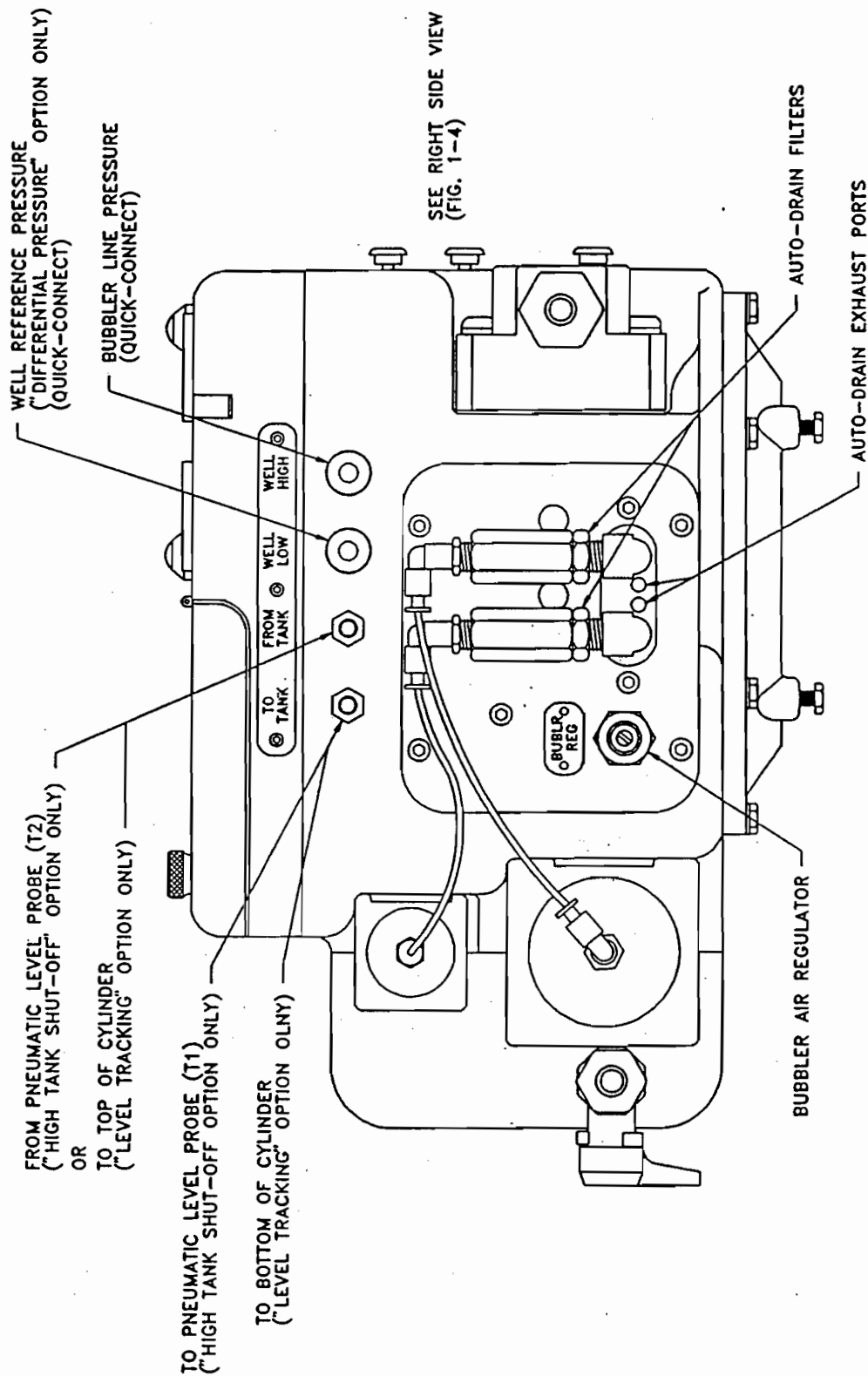
|          | 1.5<br>inches | 3<br>inches | 4<br>inches | 5<br>inches  | 6<br>inches   | 8<br>inches   |
|----------|---------------|-------------|-------------|--------------|---------------|---------------|
| 1.5 feet | 0.5<br>1.0    | 2.0<br>1.8  | 3.8<br>6.5  | 6.5<br>4.2   | 9.3<br>5.7    | 17.3<br>10.9  |
| 3 feet   | 1.0<br>1.2    | 4.1<br>2.9  | 7.5<br>4.8  | 12.9<br>8.6  | 18.6<br>11.7  | 34.5<br>21.5  |
| 4 feet   | 1.3<br>1.4    | 5.4<br>3.6  | 10.0<br>7.0 | 17.2<br>10.5 | 24.8<br>13.0  | 46.0<br>27.7  |
| 5 feet   | **<br>Special | 6.8<br>4.4  | 12.5<br>8.3 | 21.5<br>13.2 | 31.0<br>19.6  | 57.5<br>34.0  |
| 6 feet   | **<br>Special | 8.1<br>5.1  | 15.0<br>9.7 | 25.8<br>15.6 | **<br>Special | **<br>Special |

## Length of Ejector

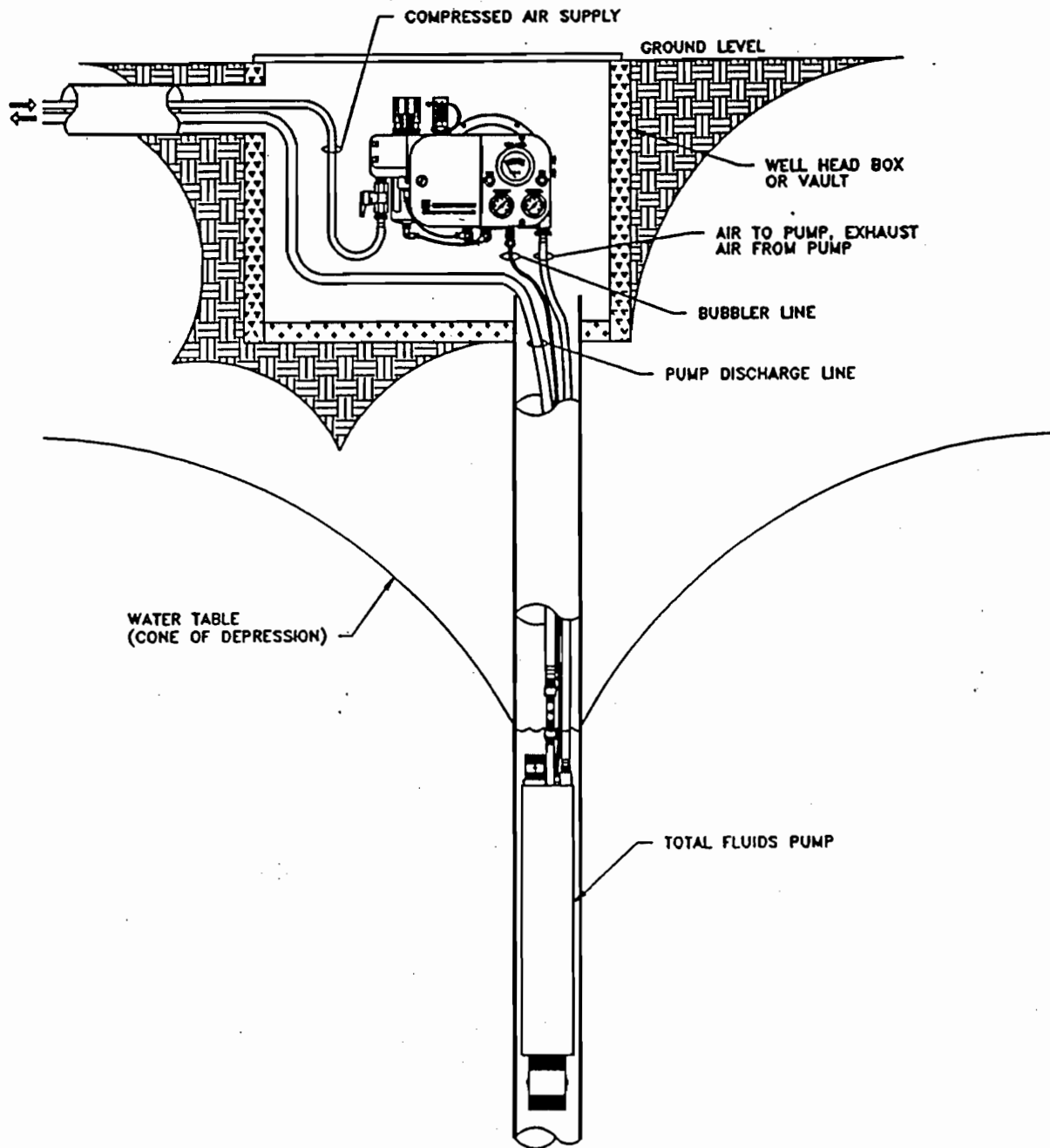
- Top number in each cell represents maximum flow rate at 5 cpm.
  - Bottom number represents approximate air consumption assuming 25 feet of 1/2 inch ID air line and 1 inch diameter discharge line.
- \*\*Special - These pumps must be special ordered.



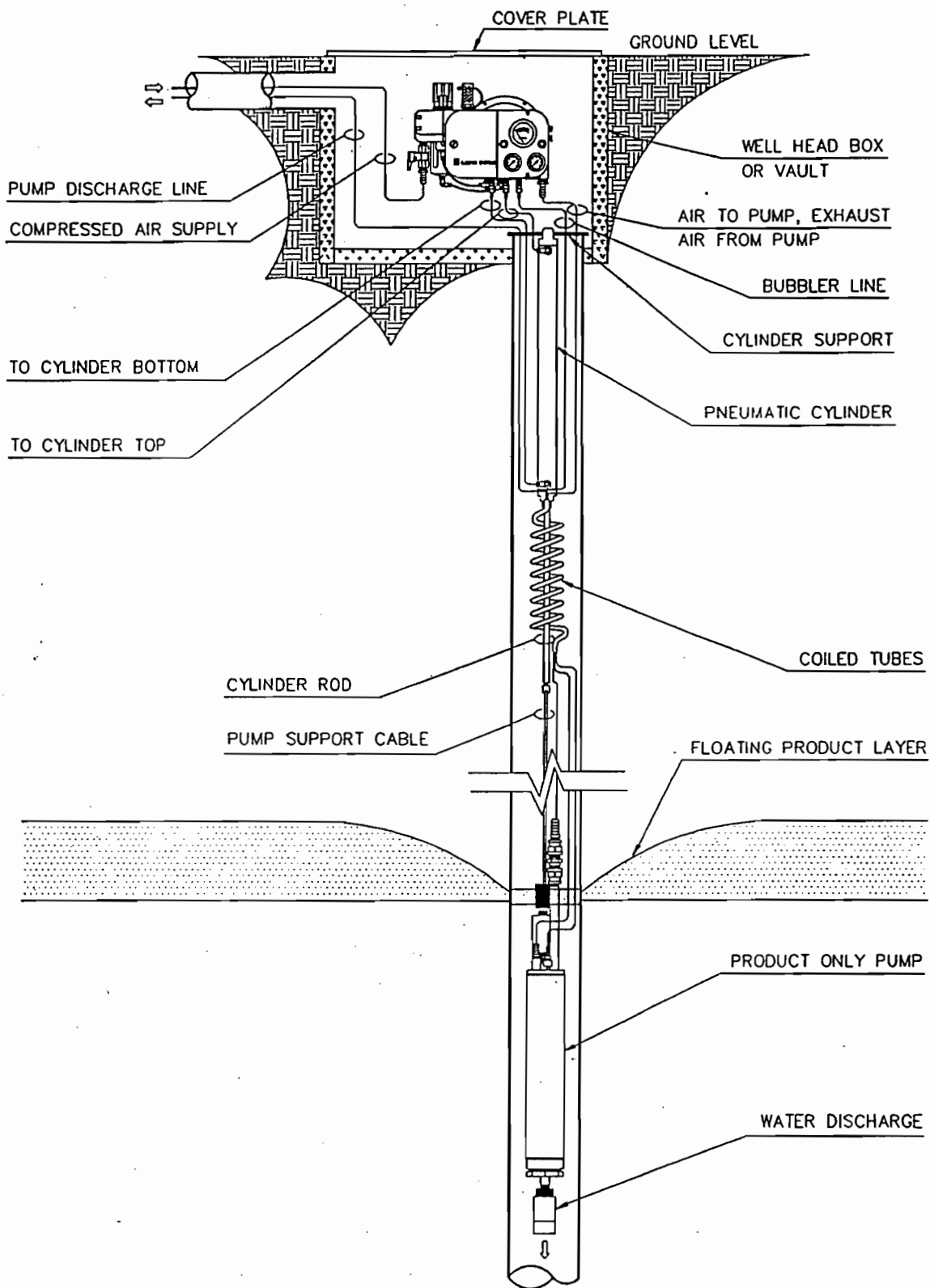
**FRONT VIEW**



## BOTTOM VIEW



## BELOW GRADE WELL HEAD ELEVATION



## S2 WITH OPTIONAL LEVEL TRACKING

## RECIPROCATING AIR COMPRESSORS

- MOST COMMONLY USED WITH ESI SYSTEMS
- PRODUCES HIGH PRESSURES (175 PSIG max), BUT LIMITED VOLUMES (100 SCFM max)
- CAN BE MADE EXPLOSION PROOF
- USUALLY OPERATED AT 50%-70% UTILIZATION
- ALWAYS USE COMPRESSORS WITH CAST IRON HEADS (NO ALUM.)
- DESIGNED FOR NON-CONTINUOUS OPERATION
- OVER SIZING THE COMPRESSOR HEADS WILL REDUCE THE RPM'S WHICH WILL DECREASE NOISE LEVEL AND INCREASE COMPRESSOR LIFE.

| SCFM   | * ACTUAL | PSIG(max) | H.P. | ** APPROX. MAX FLOW |
|--------|----------|-----------|------|---------------------|
| 1-7    | 11       | 125       | 3.0  | 7 GPM               |
| 8-15   | 18       | 125       | 5.0  | 13 GPM              |
| 15-25  | 27       | 125       | 7.5  | 19 GPM              |
| 25-35  | 35       | 125       | 10.0 | 25 GPM              |
| 35-50  | 55       | 125       | 15.0 | 39 GPM              |
| 50-70  | 70       | 125       | 20.0 | 49 GPM              |
| 70-85  | 88       | 125       | 25.0 | 62 GPM              |
| 85-100 | 105      | 125       | 30.0 | 74 GPM              |

### RECOMMENDED OPTIONS:

- AUTO START/STOP WITH OIL LEVEL SWITCH
- BELT GUARD
- MAGNETIC STARTER
- SINGLE PHASE IS ONLY AVAILABLE ON 3 AND 5 H.P.

\* REFERS TO AIR VOLUME OUTPUT THAT COMPRESSOR IS CAPABLE OF PRODUCING. HOWEVER, ALWAYS SIZE COMPRESSORS WITH A 50%-70% UTILIZATION FACTOR.

\*\* REFERS TO FLOW FOR A TOTAL FLUIDS SYSTEM WITH A MAXIMUM HEAD OF 50 FEET.

### ROTARY SCREW COMPRESSORS

- PRODUCES HIGH VOLUMES (2500 SCFM max), BUT LIMITED PRESSURE (125 PSIG max)
- CANNOT BE MADE EXPLOSION PROOF
- CAN BE OPERATED AT 100% UTILIZATION
- USUALLY 20%-30% MORE EXPENSIVE THAN RECIPROCATING COMPRESSORS
- PRODUCES LESS NOISE WHEN OPERATING THAN RECIPROCATING COMPS.
- POORLY SUITED FOR LOW DUTY CYCLES
- DESIGNED FOR CONTINUOUS USE DUTY

| SCFM    | * ACTUAL | PSIG(max) | H.P. | ** APPROX. MAX FLOW |
|---------|----------|-----------|------|---------------------|
| 20-34   | 34       | 125       | 10.0 | 34 GPM              |
| 34-56   | 56       | 125       | 15.0 | 56 GPM              |
| 57-78   | 78       | 125       | 20.0 | 78 GPM              |
| 78-92   | 92       | 125       | 25.0 | 92 GPM              |
| 92-120  | 120      | 125       | 25.0 | 120 GPM             |
| 120-125 | 125      | 125       | 30.0 | 125 GPM             |
| 125-162 | 162      | 125       | 40.0 | 162 GPM             |

### RECOMMENDED OPTIONS:

- MOTOR STARTER
- 10.0 H.P. AND GREATER ONLY AVAILABLE IN 3-PHASE

\* REFERS TO AIR VOLUME OUTPUT THAT COMPRESSOR IS CAPABLE OF PRODUCING. HOWEVER, ALWAYS SIZE COMPRESSORS WITH A 85%-95% UTILIZATION FACTOR.

\*\* REFERS TO FLOW FOR A TOTAL FLUIDS SYSTEM WITH A MAXIMUM HEAD OF 50 FEET.



## COOLERS AND DRYERS

### AIR COOLED AFTER COOLERS

- USE WITH BOTH RECIPROCATING  
AND ROTARY SCREW TYPE COMPRESSORS
- COOLS THE AIR FROM THE COMPRESSOR
- REQUIRED IF A DRYER IS BEING IMPLEMENTED
- VERY USEFUL IN HIGH HUMIDITY, HIGH TEMPERATURE CLIMATES
- INCREASES LIFE OF COMPRESSOR AND REDUCES MAINTENANCE  
REQUIREMENTS

### DRYERS

- USED TO ELIMINATE HUMIDITY IN COMPRESSOR AIR
- TWO TYPES (RECOMMEND USE OF REGENERATIVE)
  - 1.] REFRIGERATIVE
    - LOWERS D.P. TO 32 DEGREE F
    - FOR USE IN WARM AND HUMID CLIMATES
  - 2.] REGENERATIVE (USES DESICCANT)
    - LOWERS D.P. TO -40 DEGREES F
    - FOR USE IN EXTREMELY COLD CLIMATES
    - USES APPROXIMATELY 15% OF COMPRESSOR AIR VOLUME



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1-800-OIL-LEAK

## **EJECTOR SYSTEMS, INC. CORRUGATED PLATE INTERCEPTOR OIL/WATER SEPARATOR**

EJECTOR SYSTEMS, INC. has designed an oil/water separator specifically for groundwater remediation. The system is available in two configurations, 10 gpm and 25 gpm. Both systems have been designed to effectively remove 36 micron and larger oil droplets.

The units come standard with gasketed aluminum lids to allow easy removal of the coalescing pack, if required. The coalescing pack is constructed of hydrocarbon resistant polypropylene with plates spaced 1-1/2 inches apart at a 60 degree angle for maximum separation and minimum maintenance.

The 10 gpm and 25 gpm units are very similar in design. The only functional difference is the amount of corrugated plate interceptor pack utilized.

System parameters, 10 and 25 gpm:

|                           |                                                     |
|---------------------------|-----------------------------------------------------|
| Dimensions:               | 80-3/8 inches L x 46-3/8 inches W x 40-3/8 inches H |
| Total volume:             | 507 gallons                                         |
| Working volume:           | 412 gallons                                         |
| Product reservoir:        | 136 gallons                                         |
| Material of construction: | 3/16 inch hot rolled Carbon steel plate             |
| Influent and effluent:    | 3 inches FNPT                                       |
| Product effluent:         | 1-1/4 inch FNPT                                     |
| Type of separator:        | Baffles with coalescing pack                        |

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SECTION \_\_\_\_\_  
OIL/WATER SEPARATION SPECIFICATIONS

**PART 1 - GENERAL**

**1.01 DESCRIPTION**

**A. Scope**

1. The following oil/water separator shall be furnished and installed as shown on the contract drawings and described hereinafter. The oil/water separator system shall be manufactured by EJECTOR SYSTEMS, INC. and consist of:
  - a. Oil/water separator equipment, which includes, but is not limited to, base unit, lid, and coalescing packing. In order to assure a congruent oil/water separating system, the equipment as listed above shall be furnished by a single responsible supplier, that is established in the design and manufacture of oil/water separators for groundwater.
  - b. The oil/water separation system furnished under this section of the specifications shall be placed in a ventilated area that will not affect the performance of the system. All appurtenant components of the system not furnished by the system supplier, such as piping and fittings for influent and outlet water streams, piping and fittings for effluent product, concrete pads or foundations for system placement, and electrical controls and supplies not mentioned herein are the responsibilities of others.
2. The oil/water separator supplier shall provide the contractor adequate information on all aspects of the project as specified in these contract specifications and/or as shown on the contract drawings.



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## B. Functional Description

1. The requirements of the \_\_\_\_\_ groundwater remediation project are such that they mandate the use of a high performance, extremely flexible oil/water separating system. Therefore, in order to meet the performance requirements for the project, as specified hereinafter, it has been determined that the oil/water separating system shall incorporate, at a minimum, the following standard features:
  - a. Separation of lighter than water hydro-carbons shall be done through the use of a combination of baffles and a clog-resistant coalescing pack incorporated within the separation system.
  - b. Integral to the Oil/Water Separation System, an intermittent product overflow basin with a minimum volume of 136 gallons shall be included.
  - c. In conjunction with the baffle/packing network, the coalescing packing must be easily accessible so as to permit removal for cleaning.

## C. System Description

1. Flow into the separator will be through a 3 inch NPT fitting. Flow through the separating unit will be via gravity. Effluent from the separator will be through a 3 inch NPT fitting.
2. Within each unit, baffles set perpendicular to the flow shall be supplied for the following reasons:
  - 1] To dissipate inlet turbulence
  - 2] To congeal solids for easier removal
  - 3] To assist in oil/water separation
3. The unit shall incorporate a hydrocarbon resistant polypropylene corrugated plate interceptor for the means of separation.
4. Hydrocarbon that has been separated will exit the separating stage



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via an 1-1/4 inch FNPT fitting near the top of the separator and flow into the intermittent product overflow reservoir.

5. A site window shall be provided for viewing oil/water interface.

## 1.02 SUBMITTAL

### A. General

Submit all material pertaining to oil/water separating equipment furnished hereunder in the name of the separator supplier.

### B. Shop Drawings and Product Data

1. Complete layout drawings
2. Details and specifications for separator appurtenances

### C. Operation and Maintenance Manual

Submit a comprehensive and coordinated operation and maintenance manual which includes products furnished by the separator supplier.

### D. Submittal with Bid

Each bidder shall submit with his proposal or, the separator supplier shall submit to the Engineer at the time of opening bids the following:

1. Name, address, and telephone number of manufacturer.
2. Number of years experience in manufacturing oil/water separator systems of the type specified herein.
3. Number of oil/water separators of this type sold to date.
4. Name, address, and telephone number of at least three customers.
5. Evidence that the separating system will meet each of the performance and functional requirements.

### F. Submittal Pre-Bid

Each oil/water separator system supplier shall submit shop drawings and sufficient details to clearly define the equipment to be furnished and the total installation effort, including workmanship and materials that will be

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required to install the separating equipment as specified in this section. If the manufacturer's shop drawings require work, equipment, or materials beyond that called for in the Contract Documents, the Contractor shall bear the total costs (including redesign engineering) of such work, equipment or materials.

## PART 2

### 2.01 PERFORMANCE AND DESIGN REQUIREMENTS

#### A. Flow Rate and Influent Conditions to Oil/Water Separator

1. Total flow
2. Influent water temperature
3. Performance specification

The oil/water separating system specification is a performance type specification. In order to meet the intent of the specification and be suitable for the proposed application, the system shall be capable of meeting the following performance requirements:

- a. The oil/water separating system shall be capable of removing all lighter than water free-phase hydrocarbon. The system shall be designed to remove down to 36 micron droplets.
- b. Depending on the type of groundwater being separated, the following factors should not inhibit system operation nor quality of effluent stream.
  - i. High levels of suspended solids
  - ii. High levels of iron
  - iii. Build up of calcium deposits
  - iv. High levels of water hardness
  - v. High levels of dissolved solids

The acceptance of the oil/water separating system shall be based on the proven ability of the system to meet each of the performance criteria listed above. The Engineer will be the sole authority in reviewing the performance data, as submitted by the separator supplier in his bid

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submittal, and determining the acceptability of the proposed system to meet the performance requirements, as stated hereinfore, for the project. Refer to Substitution Clause in the INSTRUCTION TO THE BIDDERS for pre-bid requirements.

**B. Methods of Influent Feed**

Gravity flow or pumping are both acceptable methods of feeding the separating system. (Pumping equipment to be by others, unless specified.)

**C. Method of Effluent Draw-Off**

Gravity flow.

**D. Oil/water separating System Characteristics**

1. Type: Coalescing with clog-resistant corrugated plate interceptors and baffles
2. Working dimensions: 6.33' x 3.03' x 3.53'
3. Working volume: 507 gallons
4. Product reservoir volume: 136 gallons
5. System shall incorporate an integral, intermittent product overflow basin.
6. Provisions shall be available to allow for easy removal of coalescing pack for cleaning.

**2.02 MATERIALS OF CONSTRUCTION**

**A. Main Body of Separator**

Unit and baffles shall be constructed of 3/16 inch hot rolled Carbon steel plate. The entire unit shall be leak tested prior to shipment.

**B. Lid**

The separator lid shall implement a completely removable lid. Lid shall be constructed of 0.190 inch thick, anodized 5052 aluminum.

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### C. Coatings

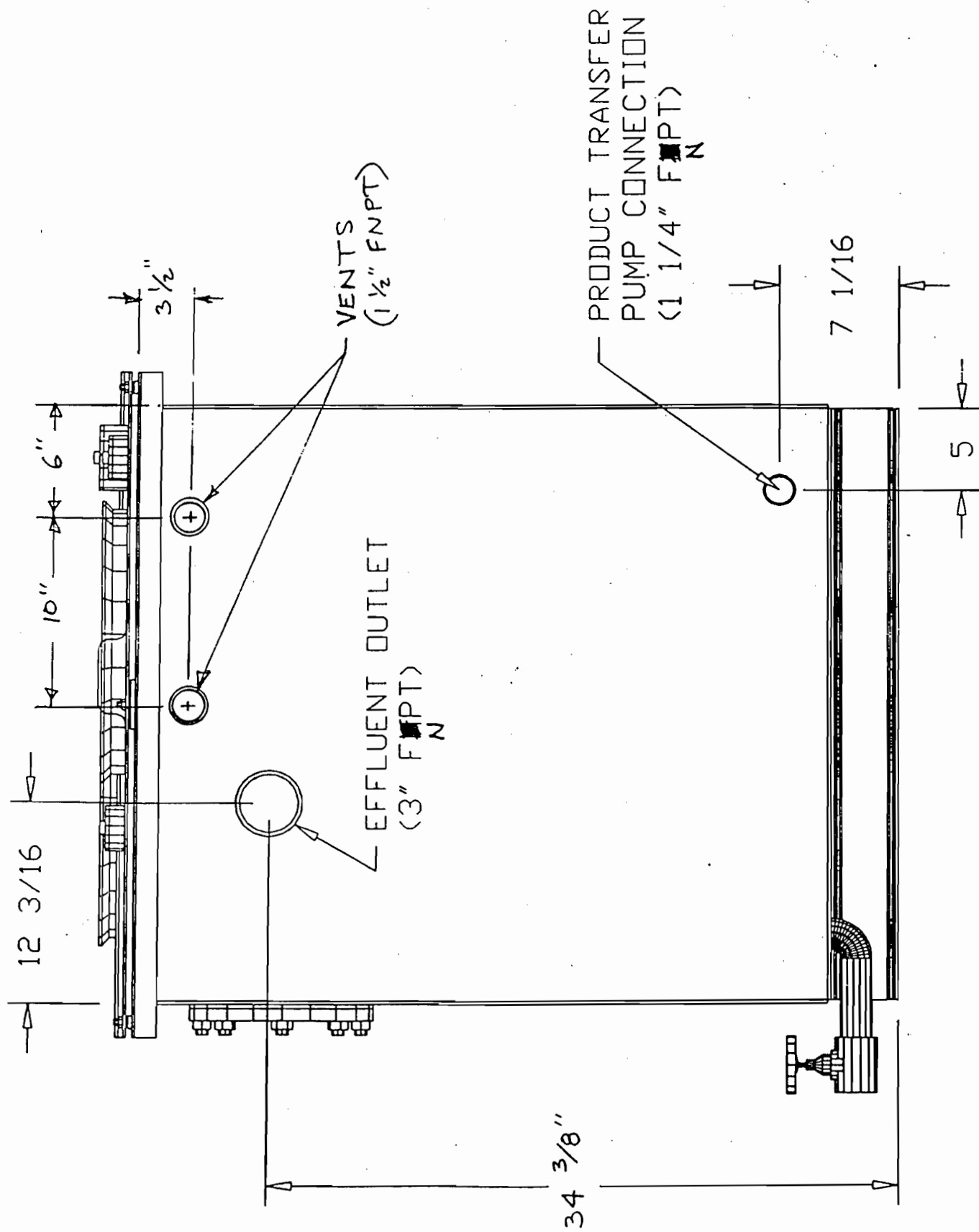
All internal separator components shall be coated with a modified, hydrocarbon resistant, epoxy coating and all external components shall be covered with an epoxy and polyurethane coating.

### D. Packing

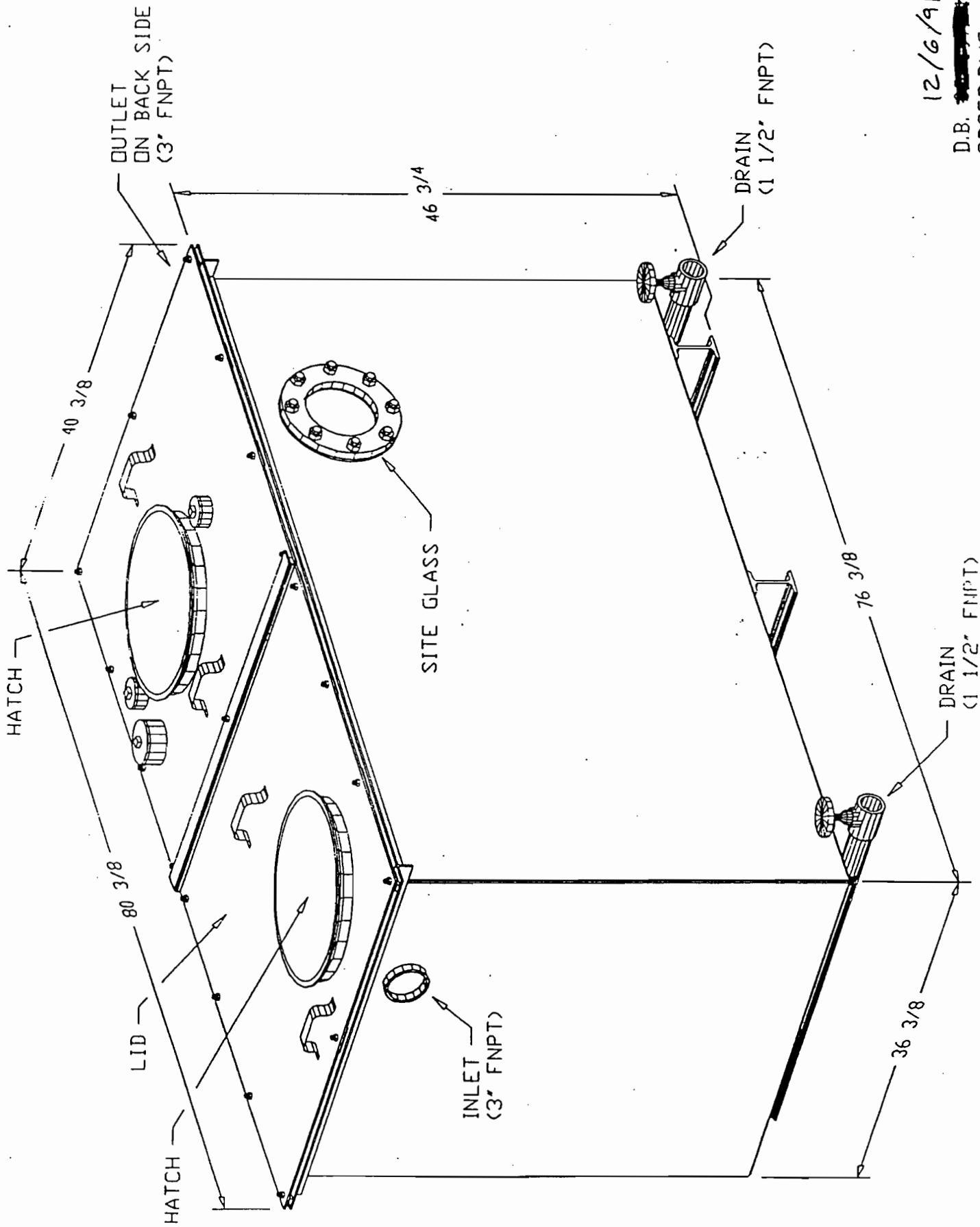
The oil/water separator corrugated plate interceptors shall be constructed of polypropylene. Spacing between plates shall be 1-1/2" which will allow for easy cleaning and less chance of clogging. Plates shall be at a 60 degree angle in reference to the bottom. A stainless steel cable shall be attached to the packing to assist in removal.



REAR VIEW



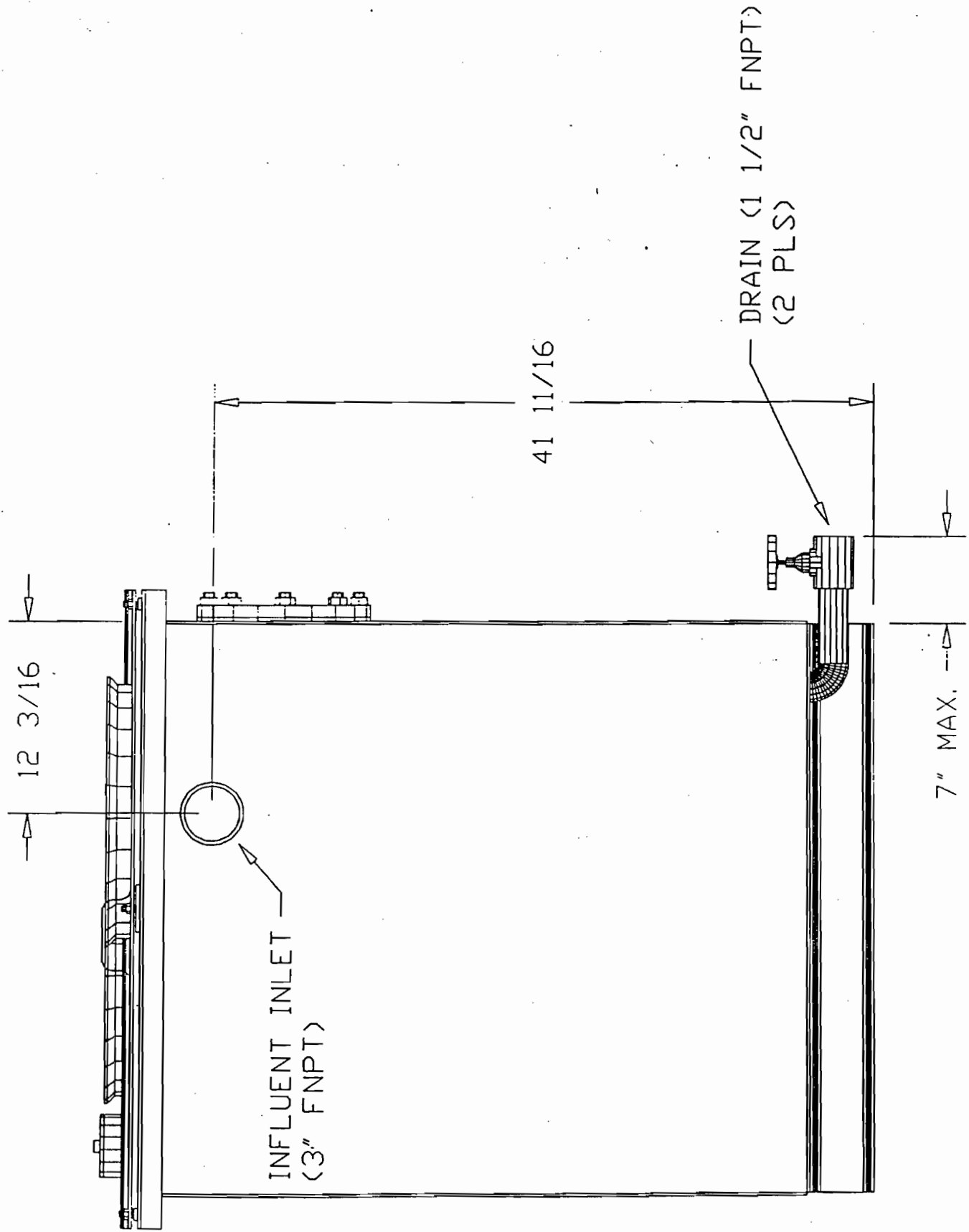
COALESCING SEPARATOR



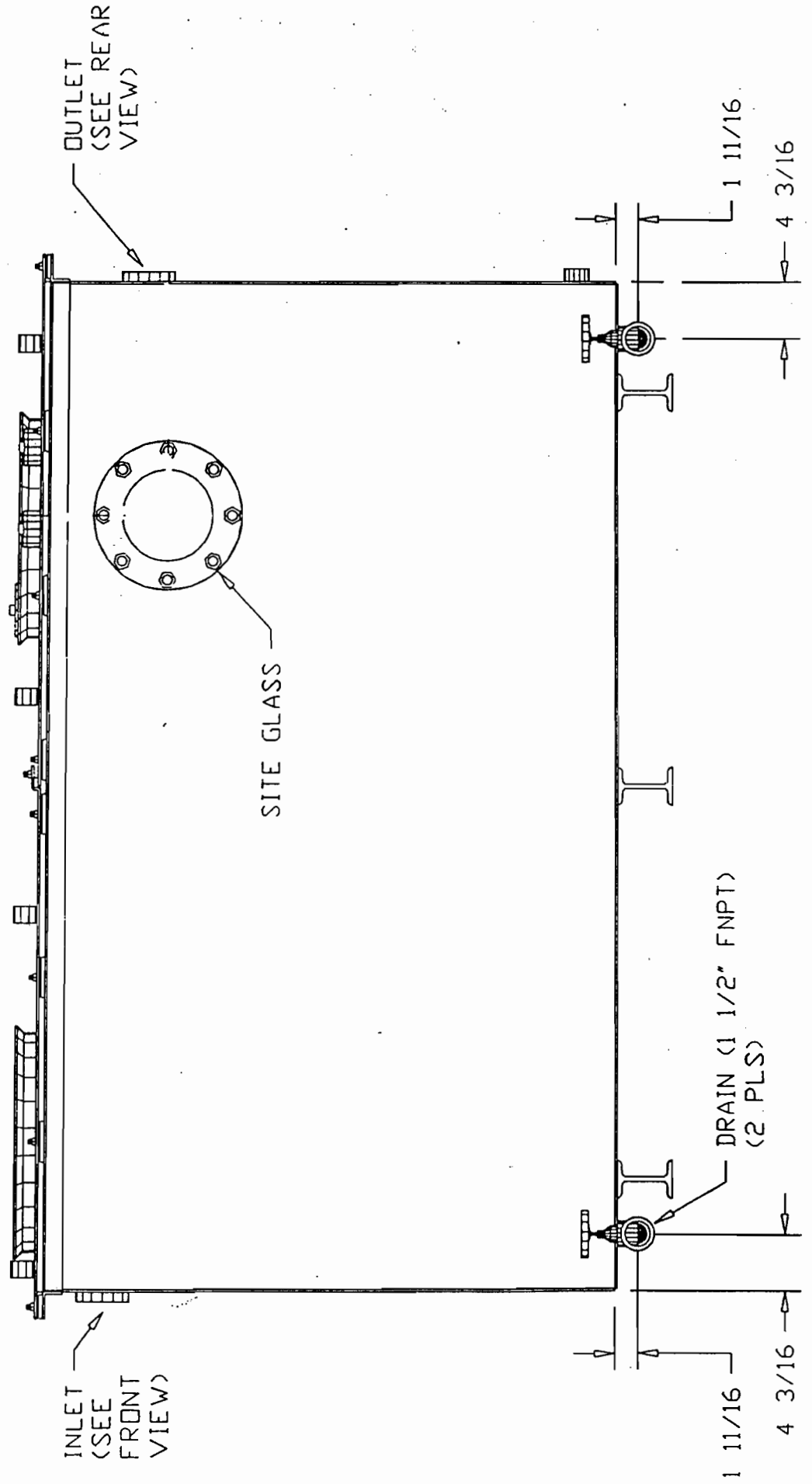
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D.B. ~~3DSEP.DWG~~  
3DSEP.DWG

FRONT VIEW



RIGHT SIDE VIEW



Ejector Systems Incorporated  
910 National Avenue, Addison, IL 60101-9812



## **STRIPPERATOR**

**process treatment unit for hydrocarbon contaminated water**

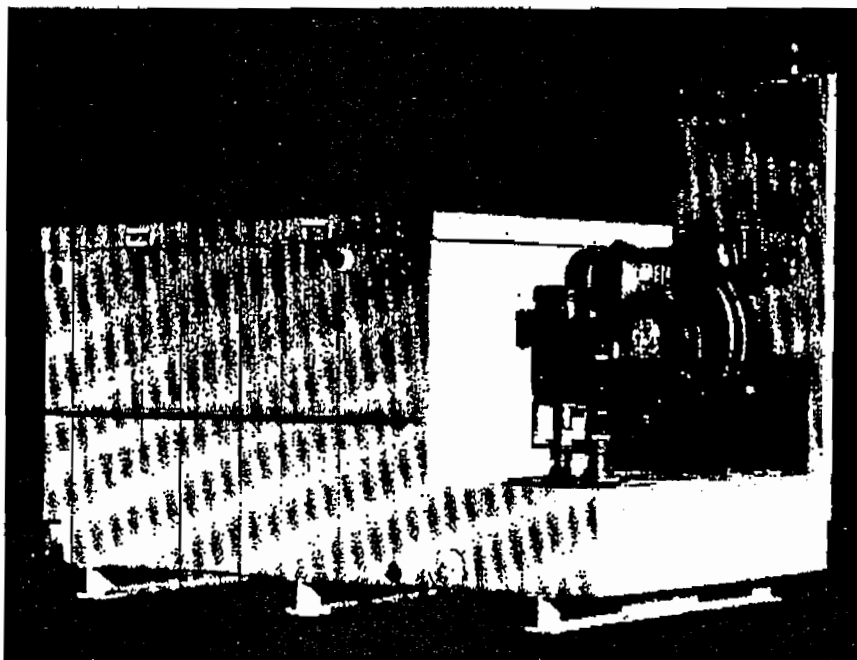
### **Standard Specifications:**

- 92" long x 50" wide x 65" high
- 11 gauge epoxy-coated carbon steel exterior
- Approximate Weight: 1,400 lbs.
- 185 gallon separator working capacity
- 60 micron droplet removal
- cast aluminum AMCA Type B spark-resistant blower
- influent 2 1/2" FNTF
- separated product 1 1/2" FNTF
- 3" FNTF effluent port
- effluent sump included
- 3 - 1 1/2" FNTF drain valves included
- 400 scfm blower

### **Options:**

- Blower motor starter
- TEFC 3/4 hp transfer pump
- TEFC 3/4 hp transfer pump controls
- Explosion-proof blower motor
- Explosion-proof blower motor starter
- Explosion-proof 3/4 hp transfer pump
- Explosion-proof 3/4 hp transfer pump controls
- High/low air switch
- High effluent switch

(Continued on back)



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**Principle of Operation**

The Stripperator is a complete process treatment unit for hydrocarbon-contaminated water. It integrates both a coalescing oil/water separator and Cascade low profile Air Stripper into one component. The unit will separate free product, coalesce suspended or colloidal hydrocarbons, settle solids and remove 99.99% of dissolved volatile organic compounds. The ESI STRIPPERATOR is available in 5 GPM (Model SA5), 10 GPM (Model SA10) and 20 GPM (Model SA20) configurations.

---

**Removal Data:**

| Flow   | Benzene | TCA    | MTBE |
|--------|---------|--------|------|
| 5 GPM  | .99995  | .99995 | .97  |
| 10 GPM | .9994   | .99995 | .90  |
| 20 GPM | .9994   | .99995 | .81  |

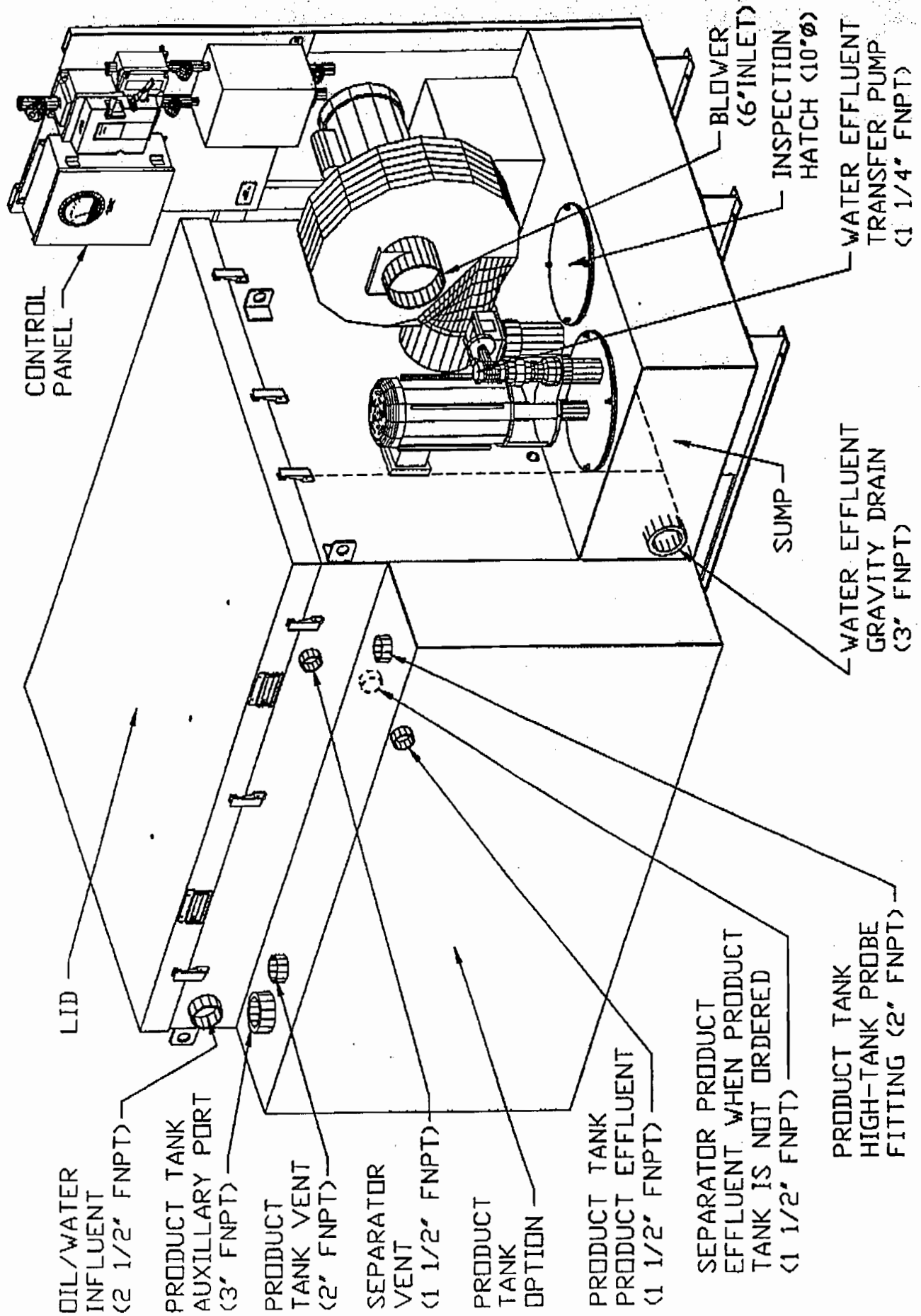
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**Feature**


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**Benefit**

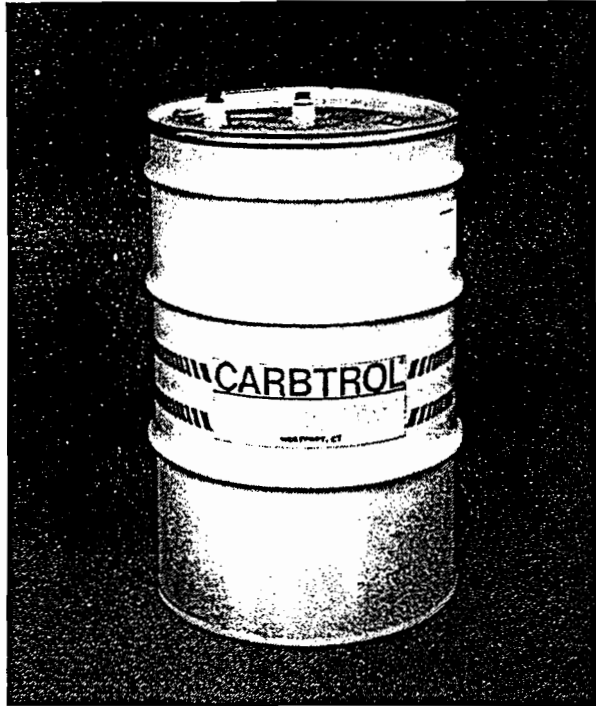
|                                                     |                                                                                              |
|-----------------------------------------------------|----------------------------------------------------------------------------------------------|
| Low profile                                         | - Unobtrusive and "out-of sight"                                                             |
| Small                                               | - Will fit through a standard double door, minimal space required                            |
| Integrated processes                                | - One unit process does not require extra tanks, pumps, piping, etc.                         |
| One piece lid with quick release adjustable latches | - Easy access to separator and air stripper as well as being simple to maintain              |
| Side mounted exhaust                                | - Allows for quick inspection and viewing of operation in progress without disturbing piping |
| Gravity flow                                        | - Eliminates re-pumping, sumps and controls                                                  |
| Fully gasketed                                      | - Leak-free indoor installation                                                              |
| Rubber isolated dynamically balanced blower         | - Minimal vibration                                                                          |

E.S.I. SA15 STRIPPER

# CARBOTROL®

## WATER PURIFICATION CANISTER 200 POUND ACTIVATED CARBON

### L-1



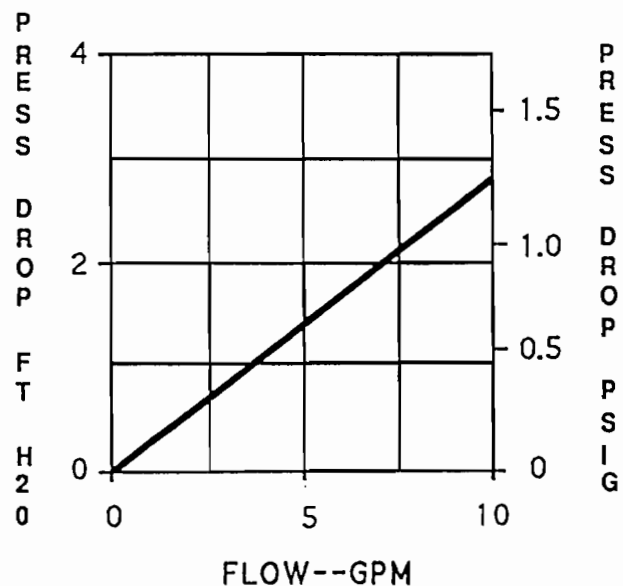
The CARBOTROL L-1 (liquid)  
Canister handles up to 10 gpm.

### FEATURES

- 200 pounds of high activity carbon.
- Large 1 1/4" internal piping. Low pressure drop allows operation of three canisters in series.
- Standard FPT couplings for easy installation - saves time and money.
- Special "no leak" lid gasket.
- Heavy duty steel drums, DOT 17C, suitable for shipment of spent hazardous carbon.
- Piping design eliminates channeling.

### SPECIFICATIONS

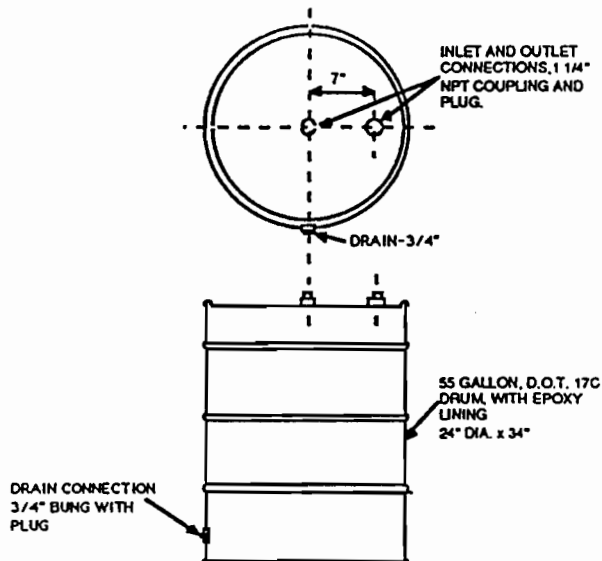
|                            |                                                                                                     |
|----------------------------|-----------------------------------------------------------------------------------------------------|
| DRUM                       | 24" Ø x 34" high,<br>mild steel, epoxy<br>phenolic internal<br>coating, with<br>polyethylene liner. |
| CARBON                     | 200 lbs.                                                                                            |
| SHIPPING WEIGHT            | 250 lbs.                                                                                            |
| INLET                      | 1 1/4" FPT, steel                                                                                   |
| OUTLET                     | 1 1/4" FPT, steel                                                                                   |
| INTERNAL PIPING            | 1 1/4" PVC                                                                                          |
| DRAIN                      | 3/4" bung                                                                                           |
| PRESSURE DROP              | 1.25 psi @ 10 gpm                                                                                   |
| MAX. OPERATING<br>PRESSURE | 10 psi                                                                                              |





## WATER PURIFICATION CANISTER 200 POUND ACTIVATED CARBON

L-1



### OPTIONS

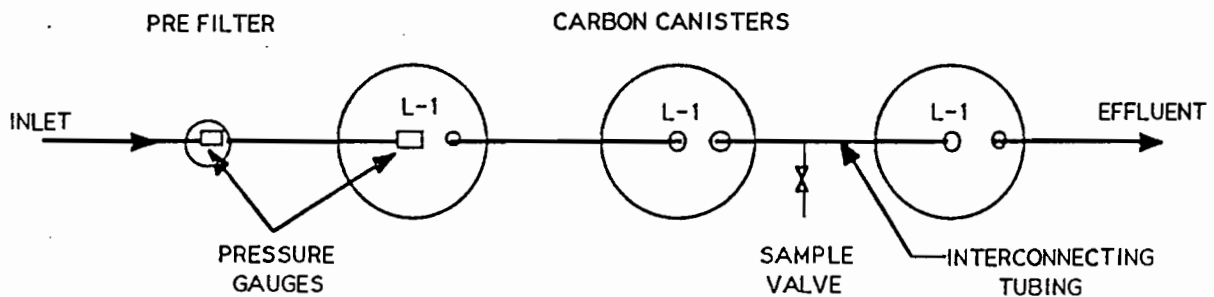
#### Interconnecting Piping Kit

Flexible 1 1/4" diameter PVC tubing with hose clamps. Includes inlet pressure gauge and intermediate sample valve.

#### Pre-filter For Suspended Solids Removal

Pre-filter consisting of a basket filter piped and mounted on support frame. Filter is of carbon steel construction.

**ARRANGEMENT** (3) L-1 Canisters in series for 10 gpm flow (contact time @ 10 gpm - 15 minutes)



### TYPICAL INSTALLATION



# CARBOTROL®

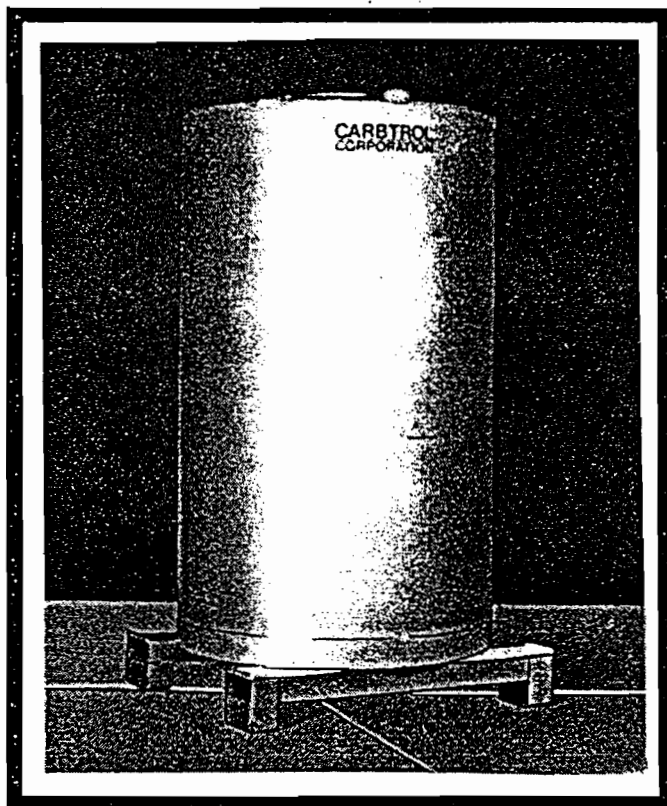
## WATER PURIFICATION ADSORBERS

1,000 LB. ACTIVATED CARBON

L-4

1,800 LB. ACTIVATED CARBON

L-5



### FEATURES

- Low pressure drop
  - L-4 0.25psi @ 25 gpm
  - L-5 1 psi @ 50 gpm
- Epoxy lined, mild steel construction.
- 2 1/2" dia. multiple pipe underdrain system.
- Fork lift fittings for easy handling.
- DOT rated. Acceptable for shipment of hazardous spent carbon.
- 9 psi max. operating pressure.
- High activity carbon.

### OPTIONS

- Plastisol, PVC lining.
- Interconnecting piping and fittings.
- Non transportable units.
- Air release valve.

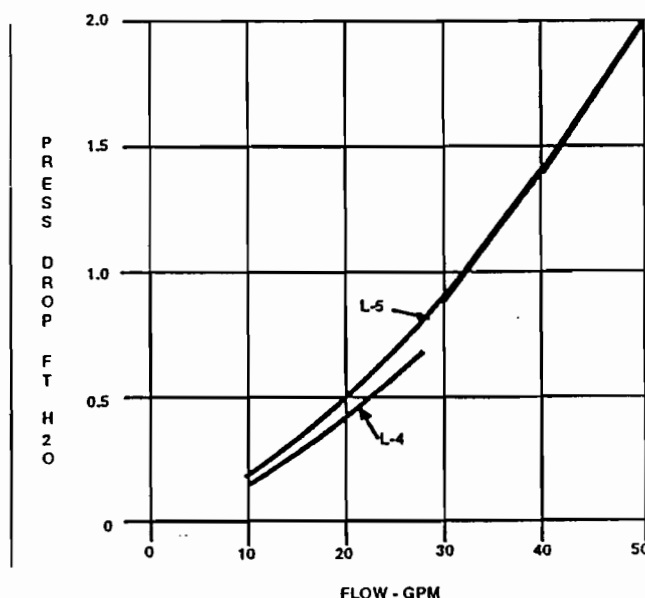
### SPECIFICATIONS

#### L-4

CARBON: 1,000 lbs  
DIMENSIONS: 45-1/2" Ø x 66-1/2" overall height  
SHIPPING WT: 1500 lbs. (Dry Carbon)  
2300 lbs. (Drained Carbon)

#### L-5

CARBON: 1,800 lbs.  
DIMENSIONS: 45-1/2" Ø x 90" overall height  
SHIPPING WT: 2400 lbs. (Dry Carbon)  
4200 lbs. (Drained Carbon)



# CARBOTROL®

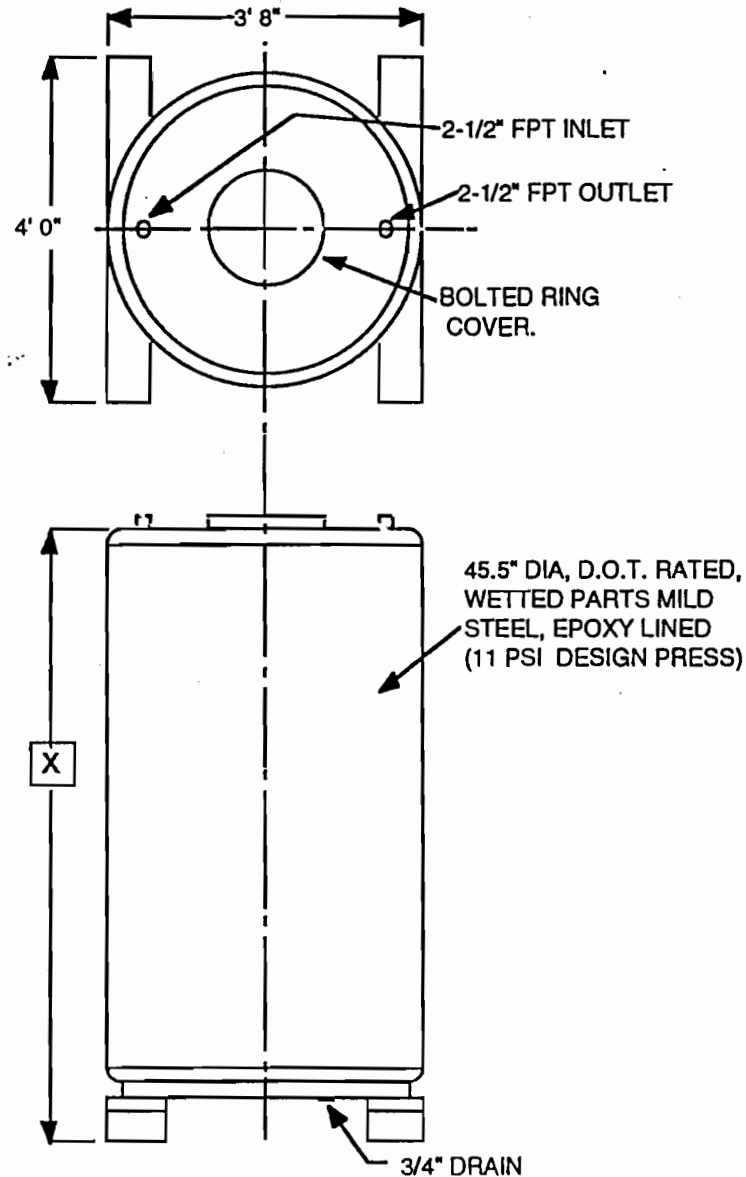
## WATER PURIFICATION ADSORBERS

1,000 LB. ACTIVATED CARBON

L-4

1,800 LB. ACTIVATED CARBON

L-5



| UNIT | DIM   | X |
|------|-------|---|
| L-4  | 5'-2" |   |
| L-5  | 7'-2" |   |

DIMENSIONS AND DETAILS SHOWN  
ARE FOR TRANSPORTABLE MODELS

**CARBOTROL®**  
CORPORATION

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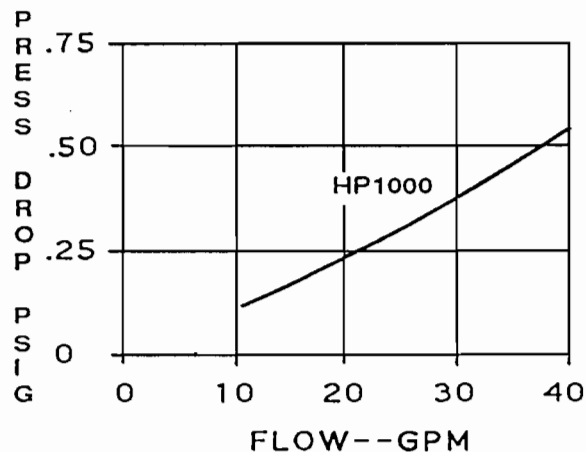
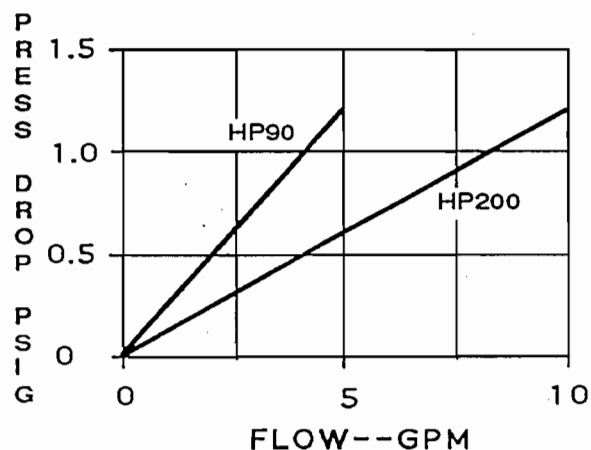
# CARBTROL®

## HIGH PRESSURE ACTIVATED CARBON WATER PURIFICATION SYSTEMS



### SIZES

| <u>MODEL</u> | <u>CARBON<br/>QUANTITY</u> | <u>FLOW<br/>CAPACITY</u> |
|--------------|----------------------------|--------------------------|
| HP-90        | 90 lbs.                    | 10 gpm                   |
| HP-200       | 200 lbs.                   | 10 gpm                   |
| HP-1000      | 1000 lbs.                  | 30 gpm                   |

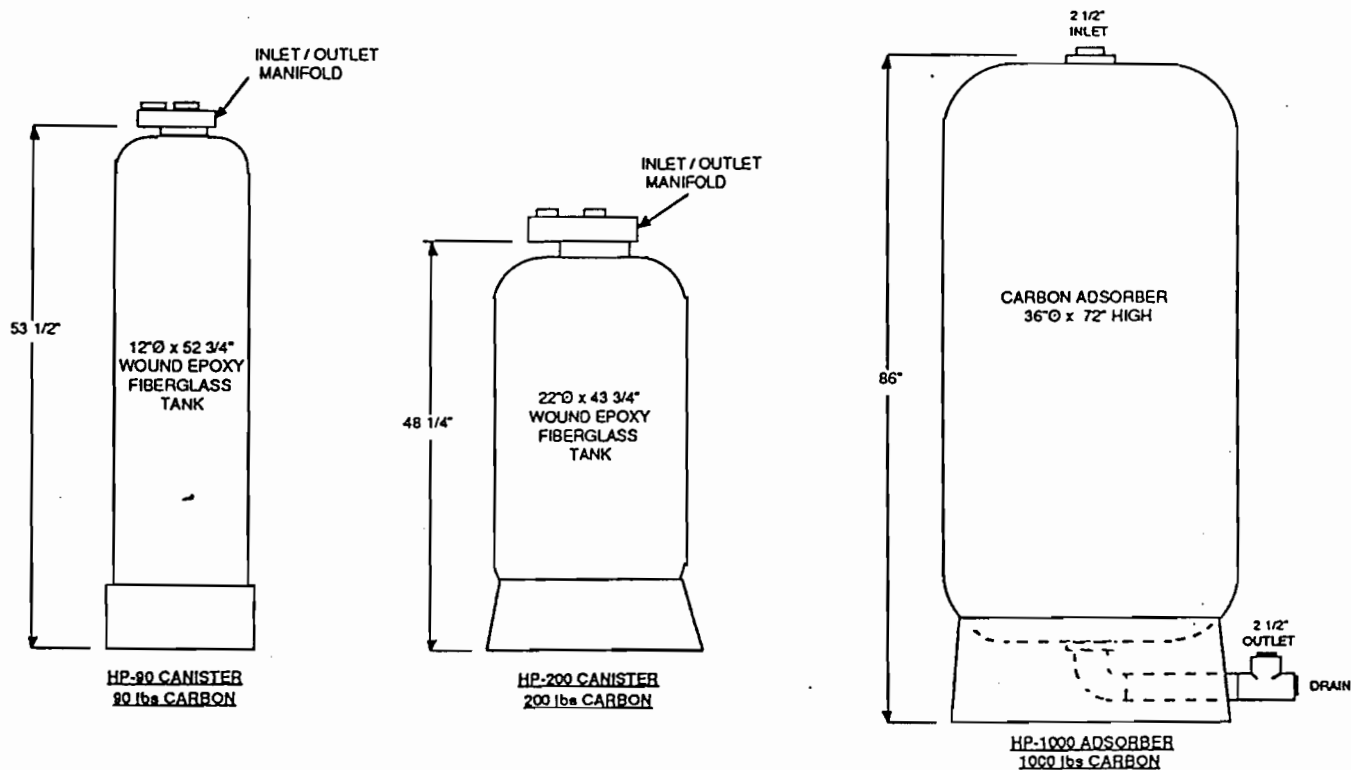


### FEATURES

- High activity liquid phase carbon.
- Operating pressure from 50-75 psi.
- Corrosion resistant wound/fiber glass/epoxy construction.
- ABS fittings, PVC internal piping.
- Standard FPT couplings for easy installation.
- Complete with support stand.

# CARBOTROL®

## HIGH PRESSURE ACTIVATED CARBON WATER PURIFICATION SYSTEMS



### SPECIFICATIONS

| <u>MODEL</u> | <u>DIAMETER/<br/>HEIGHT</u> | <u>CARBON<br/>WEIGHT</u> | <u>INLET/<br/>OUTLET</u> | <u>SHIPPING<br/>WEIGHT</u> |
|--------------|-----------------------------|--------------------------|--------------------------|----------------------------|
| HP-90        | 12"/54"                     | 90 lbs.                  | 1" FPT                   | 125 lbs.                   |
| HP-200       | 22"/48"                     | 200 lbs.                 | 1" FPT                   | 250 lbs.                   |
| HP-1000      | 36"/72"                     | 1000 lbs.                | 2 1/2" FPT               | 1750 lbs.                  |

**Appendix D**  
**Standard Operating Procedures**

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**SOP F102**  
**Soil and Rock Sample Acquisition**

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**SOIL AND ROCK SAMPLE ACQUISITION  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Rock Cores**
  - 5.2 Subsurface Soil Samples**
    - 5.2.1 Split-Barrel (Split-Spoon) Samples**
    - 5.2.2 Thin-Wall (Shelby Tube) Sampling**
    - 5.2.3 Bucket (Hand) Auger Sampling**
  - 5.3 Surface Soil Samples**
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**



## SOIL AND ROCK SAMPLE ACQUISITION

### 1.0 PURPOSE

The purpose of this procedure is to describe the handling of rock cores and subsurface soil samples collected during drilling operations. Surface soil sampling also is described.

### 2.0 SCOPE

The methods described in this SOP are applicable for the recovery of subsurface soil and rock samples acquired by coring operations or soil sampling techniques such as split-barrel sampling and thin-walled tube sampling. Procedures for the collection of surface soil samples also are discussed. This SOP does not discuss drilling techniques or well installation procedures. ASTM procedures for "Penetration Test and Split-Barrel Sampling of Soils," "Thin-Walled Tube Sampling of Soils," and "Diamond Core Drilling for Site Investigation" have been included as Attachments A through C, respectively.

### 3.0 DEFINITIONS

Thin-Walled Tube Sampler - A thin-walled metal tube (also called Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outer diameter (O.D.) and 18 to 54 inches length. A stationary piston device is included in the sampler to reduce sample disturbance and increase recovery.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into unconsolidated materials using a drive weight mounted on the drilling string. A standard split-spoon sampler (used for performing Standard Penetration Tests) is two inches O.D. and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively.

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes. Grab samples are associated with surface water,

groundwater, wastewater, waste, contaminated surfaces, soil, and sediment sampling. Grab samples are typically used to characterize the media at a particular instant in time.

Composite Samples - A sample collected over time that typically consists of a series of discrete samples which are combined or "composited". Two types of composite samples are listed below:

- Areal Composite: A sample collected from individual grab samples collected on an areal or cross-sectional basis. Areal composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include sediment composites from quarter-point sampling of streams and soil samples from grid points.
- Vertical Composite: A sample collected from individual grab samples collected from a vertical cross section. Vertical composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include vertical profiles of soil/sediment columns, lakes and estuaries.

#### 4.0 RESPONSIBILITIES

**Project Manager** - The Project Manager is responsible for ensuring that, where applicable, project-specific plans are in accordance with these procedures, or that other approved procedures are developed. Furthermore, the Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

**Drilling Inspector** - It is the responsibility of the drilling inspector to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The Drilling Inspector is responsible for the proper acquisition of rock cores and subsurface soil samples.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of samples.

## 5.0 PROCEDURES

Subsurface soil and rock samples are used to characterize the three-dimensional subsurface stratigraphy. This characterization can indicate the potential for migration of contaminants from various sites. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of subsurface soil samples. Where the remedial activities may include in-situ treatment, or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Surface soil samples serve to characterize the extent of surface contamination at various sites. These samples may be collected during initial site screening to determine gross contamination levels and levels of personal protection required as part of more intensive field sampling activities, to gather more detailed site data during design, or to determine the need for, or success of, cleanup actions.

Site construction activities may require that the engineering and physical properties of soil and rock be determined. Soil types, bearing strength, compressibility, permeability, plasticity, and moisture content are some of the geotechnical characteristics that may be determined by laboratory tests of soil samples. Rock quality, strength, stratigraphy, structure, etc. often are needed to design and construct deep foundations or remedial components.

### 5.1 Rock Cores

Once rock coring has been completed and the core recovered, the rock core must be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery, as well as the rock quality designation (RQD) (see SOP F101). If split-barrels are used, the core may be measured and classified in the split barrel after opening and then transferred to a core box.

Each core shall be described and classified on a Field Test Boring Record using a uniform system as presented in SOP F101. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of hydrated formations) or oxidation of the core, the core must be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores must be placed in the sequence of recovery in wooden or plastic core boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box. The core boxes should be constructed to accommodate at least 20 linear feet of core in rows of approximately five feet each and should be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened. Wood partitions shall be placed at the end of each core run and between rows. The depth from the surface of the boring to the top and bottom of the drill run and the run number shall be marked on the wooden partitions with indelible ink. The order of placing cores shall be the same in all core boxes. The top of each core obtained should be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, any empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data pertaining to the box's contents. At a minimum, the following information must be included:

- Project name
- Date
- CTO number
- Boring number
- Footage (depths)
- Run number(s)
- Recovery
- Rock Quality Designation (RQD)
- Box number (x of x)

It is also useful to draw a large diagram of the core in the box, on the inside of the box top. This

provides more room for elevations, run numbers, recoveries, comments, etc., than could be entered on the upper edges of partitions or spaces in the core box.

For easy retrieval when core boxes are stacked, the sides and ends of the box should also be labeled and include CTO number, boring number, top and bottom depths of core and box number.

Due to the weight of the core, a filled core box should always be handled by two people. Core boxes stored on site should be protected from the weather. The core boxes should be removed from the site in a careful manner as soon as possible. Exposure to extreme heat or cold should be avoided whenever possible.

## 5.2 Subsurface Soil Samples

This section discusses three methods for collecting subsurface soil samples: (1) split-spoon sampling; (2) shelby tube sampling; and, (3) bucket auger sampling. All three methods yield samples suitable for laboratory analysis. Copies of the ASTM procedures for split-spoon sampling and shelby-tube sampling are provided in Attachments A and B, respectively.

### 5.2.1 Split-Barrel (Split-Spoon) Sampling

The following procedures are to be used for split-spoon, geotechnical soil sampling:

1. Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation.
2. Side-discharge bits are permissible. A bottom-discharge bit should not be used. The process of jetting through the sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.
3. The two-inch O.D. split-barrel sampler should be driven with blows from a 140-pound hammer falling 30 inches in accordance with ASTM D1586-84, Standard Penetration Test.
4. Repeat this operation at intervals not longer than 5 feet in homogeneous strata, or as specified in the Sampling and Analysis Plan.
5. Record on the Field Test Boring Record or field logbook the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the

second and third six inches of penetration is termed the penetration resistance, N. If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of second and third six-inch increments will be used to calculate the penetration resistance. (Refusal of the SPT will be noted as 50 blows over an interval equal to or less than 6 inches; the interval driven will be noted with the blow count.)

6. Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Describe carefully the recovery (length), composition, structure, consistency, color, condition, etc. of the recovered soil according to SOP F101; then put into jars without ramming. Jars with samples not taken for chemical analysis should be sealed with wax, or hermetically sealed (using a teflon cap liner) to prevent evaporation of the soil moisture. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms (see SOP F302). Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area.
7. Split-spoon samplers shall be decontaminated after each use and prior to the initial use at a site according to SOP F501.

In addition to collecting soils for geotechnical purposes, split-spoon sampling can be employed to obtain samples for environmental analytical analysis. The following procedures are to be used for split-spoon, environmental soil sampling:

1. Follow sample collection procedures 1 through 6 as outlined in Section 5.2.1.
2. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should not be mixed. Further, sample containers for volatile organic compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.
3. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the Field Test Boring Record or field logbook. In addition, label, tag, and number the sample bottle(s).
4. Pack the samples for shipping (see SOP F300). Attach seal to the shipping package. Make sure that Chain-of-Custody Forms and Sample Request Forms are properly filled out and enclosed or attached (see SOP F301).
5. Decontaminate the split-spoon sample as described in SOP F501. Replace disposable latex gloves between sample stations to prevent cross-contaminating samples.

For obtaining composite soil samples (see Definitions), a slightly modified approach is employed. Each individual discrete soil sample from the desired sample interval will be placed into a stainless-steel, decontaminated bowl prior to filling the laboratory sample containers. Special care should be taken to cover the bowl between samples with aluminum foil to minimize volatilization. Immediately after obtaining soils from the desired sampling interval, the sample to be analyzed for Volatile Organic Compounds (VOCs) should be collected. Care should be taken to obtain a representative sampling of each sample interval. The remaining soils should be thoroughly mixed. Adequate mixing can be achieved by stirring in a circular fashion and occasionally turning the soils over. Once the remaining soils have been thoroughly combined, samples for analyses other than VOCs should be placed into the appropriate sampling containers.

#### 5.2.2 Thin-Wall (Shelby Tube) Sampling

When it is desired to take undisturbed samples of soil for physical laboratory testing, thin-walled seamless tube samplers (Shelby tubes) will be used. The following method applies:

1. Clean out the hole to the sampling elevation, being careful to minimize the chance for disturbance or contamination of the material to be sampled.
2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Any side discharge bits are permitted.
3. The sampler must be of a stationary piston-type, to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.
4. With the sampling tube resting on the bottom of the hole and the water level in the boring at the natural groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed further than the length provided for the soil sample. Allow a free space in the tube for cuttings and sludge.
5. After pushing the tube, the sample should sit 5 to 15 minutes prior to removal. Immediately before removal, the sample must be sheared by rotating the rods with a pipe wrench a minimum of two revolutions.
6. Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of

soil, from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape them into place and then dip the ends in wax to seal them.

7. Affix labels to the tubes and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and mark the end of the sample. Complete chain-of-custody and other required forms (see SOP F302). Do not allow tubes to freeze, and store the samples vertically (with the same orientation they had in the ground, i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.
8. From soil removed from the ends of the tube, make a careful description using the methods presented in SOP F101.
9. When thin-wall tube samplers are used to collect soil for certain chemical analyses, it may be necessary to avoid using wax, newspaper, or other fillers. The SAP for each site should address specific materials allowed dependent on analytes being tested.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dension or Pitcher cores can be used in conjunction with the tube samplers to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and, therefore, their use should be weighed against the increased cost and the need for an undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt should be made with a split-spoon sampler at the same depth so that at least one sample can be obtained for classification purposes.

### 5.2.3 Bucket (Hand) Auger Sampling

Hand augering is the most common manual method used to collect subsurface samples. Typically, 4-inch auger buckets with cutting heads are pushed and twisted into the ground and removed as the buckets are filled. The auger holes are advanced one bucket at a time. The practical depth of investigation using a hand auger is related to the material being sampled. In sands, augering is usually easily accomplished, but the depth of investigation is controlled by the depth at which sands begin to cave. At this point, auger holes usually begin to collapse and cannot practically be advanced to lower depths, and further samples, if required, must be collected using some type of pushed or driven device. Hand augering may



also become difficult in tight clays or cemented sands. At depths approaching 20 feet, torquing of hand auger extensions becomes so severe that in resistant materials, powered methods must be used if deeper samples are required.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a new bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of soil should be removed from the bucket to minimize the chances of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples as outlined in SOP F502.

In addition to hand augering, powered augers can be used to advance a boring for subsurface soil collection. However, this type of equipment is technically a sampling aid and not a sampling device, and 20 to 25 feet is the typical lower depth range for this equipment. It is used to advance a hole to the required sample depth, at which point a hand auger is usually used to collect the sample.

### 5.3 Surface Soil Samples

Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface. For loosely packed surface soils, stainless steel (organic analyses) or plastic (inorganic analyses) scoops or trowels, can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

1. Use a soil auger for deep samples (greater than 12 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collecting the sample.
2. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, chain-of-custody record, and other required forms.

3. Classify and record a description of the sample, as discussed in SOP F101. Descriptions for surface soil samples should be recorded in the field logbook; descriptions for soil samples collected with power or hand augers shall be recorded on a Field Test Boring Record.
4. Store the sampling utensil in a plastic bag until decontamination or disposal. Use a new or freshly-decontaminated sampling utensil for each sample taken.
5. Pack and ship as described in SOP F304.
6. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site or on a sketch in the field logbook.
7. When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles should be full) should be placed in a stainless steel bucket, mixed thoroughly using a stainless steel spatula or trowel, and a composite sample collected. In some cases, as delineated in project-specific sampling and analysis plans, laboratory compositing of the samples may be more appropriate than field compositing. Samples to be analyzed for parameters sensitive to volatilization should be composited and placed into the appropriate sample bottles immediately upon collection.

## 6.0 QUALITY ASSURANCE RECORDS

Where applicable, Field Test Boring Records and Test Boring Records will serve as the quality assurance records for subsurface soil samples, rock cores and near surface soil samples collected with a hand or power auger. Observations shall be recorded in the Field Logbook as described in SOP F303. Chain-of-Custody records shall be completed for samples collected for laboratory analysis as described in SOP F302.

## 7.0 REFERENCES

1. American Society for Testing and Materials, 1987. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-84, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
2. American Society for Testing and Materials, 1987. Standard Practice for Thin-Walled Tube Sampling of Soils. Method D1587-83, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

3. American Society for Testing and Materials, 1987. Standard Practice for Diamond Core Drilling for Site Investigation. Method D2113-83 (1987), Annual Book of Standards ASTM, Philadelphia, Pennsylvania.
4. U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

**ATTACHMENT A**

**ASTM D1586-84**

**STANDARD METHOD FOR PENETRATION TEST AND  
SPLIT-BARREL SAMPLING OF SOILS**



## Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils<sup>1</sup>

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.*

<sup>1</sup>NOTE—Editorial changes were made throughout October 1992.

### 1. Scope

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 2487 Test Method for Classification of Soils for Engineering Purposes<sup>2</sup>
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>2</sup>
- D 4220 Practices for Preserving and Transporting Soil Samples<sup>2</sup>
- D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems<sup>2</sup>

### 3. Terminology

#### 3.1 Descriptions of Terms Specific to This Standard

3.1.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the

hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *hammer*—that portion of the drive-weight assembly consisting of the  $140 \pm 2$  lb ( $63.5 \pm 1$  kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.1.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N-value*, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.9  $\Delta N$ —the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by  $360^\circ$  (see Fig. 1).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

### 4. Significance and Use

4.1 This test method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N-value*, and the engineering behavior of earthworks and foundations are available.

### 5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be

<sup>1</sup> This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Sept. 11, 1984. Published November 1984. Originally published as D 1586 - 58 T. Last previous edition D 1586 - 67 (1974).

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

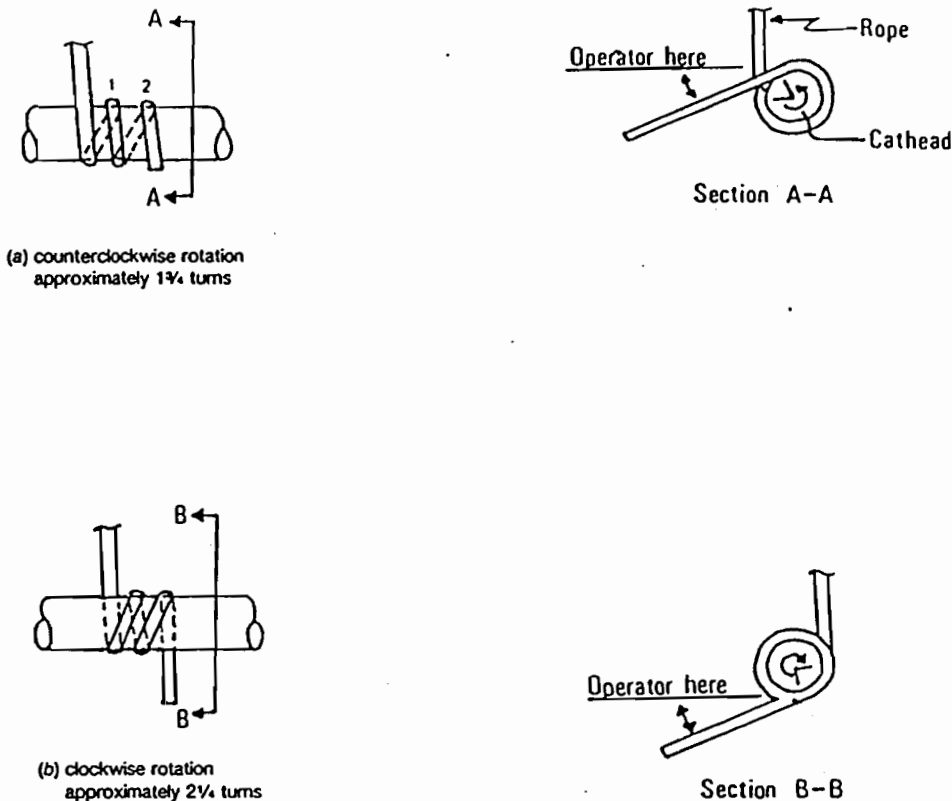


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead

suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1 1/8 in. (41.2 mm) and an inside diameter of 1 1/8 in. (28.5 mm)).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the *N*-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1 3/8 in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

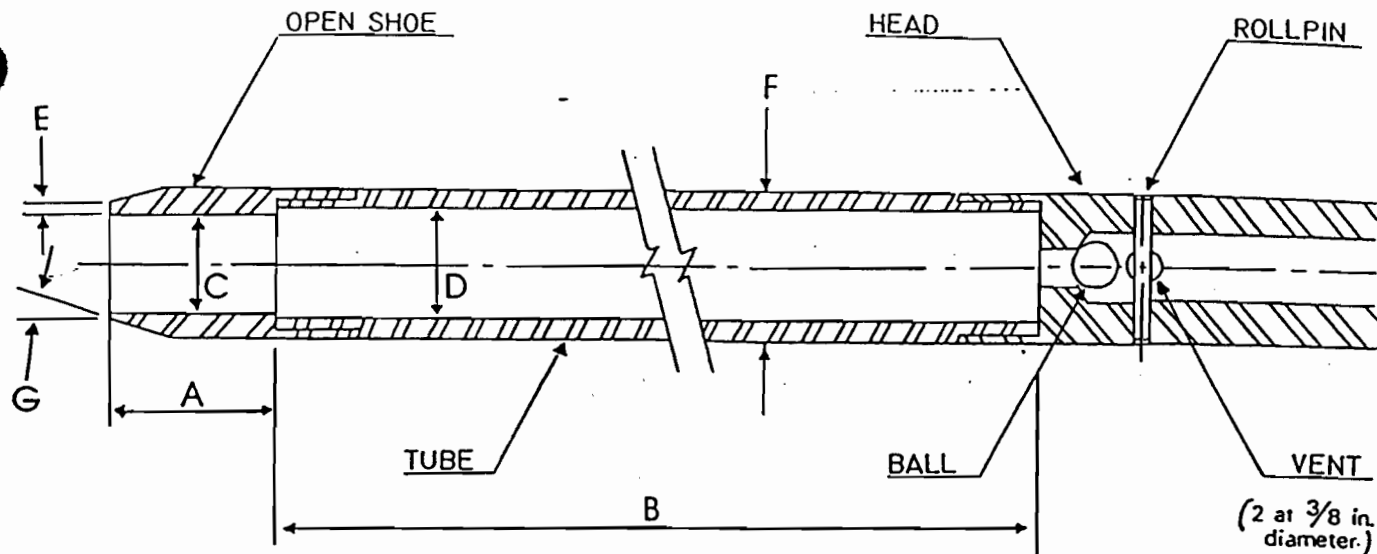
NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30 % when liners are used.

#### 5.4 Drive-Weight Assembly:

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of



- A = 1.0 to 2.0 in. (25 to 50 mm)  
 B = 18.0 to 30.0 in. (0.457 to 0.762 m)  
 C =  $1.375 \pm 0.005$  in. ( $34.93 \pm 0.13$  mm)  
 D =  $1.50 \pm 0.05 - 0.00$  in. ( $38.1 \pm 1.3 - 0.0$  mm)  
 E =  $0.10 \pm 0.02$  in. ( $2.54 \pm 0.25$  mm)  
 F =  $2.00 \pm 0.05 - 0.00$  in. ( $50.8 \pm 1.3 - 0.0$  mm)  
 G =  $16.0^\circ$  to  $23.0^\circ$

The  $1\frac{1}{2}$  in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

the sampler while re-engaging and lifting the hammer.

**5.5 Accessory Equipment**—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

## 6. Drilling Procedure

**6.1** The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 m) or less in homogeneous strata with test and sampling locations at every change of strata.

**6.2** Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

**6.2.1** Open-hole rotary drilling method.

**6.2.2** Continuous flight hollow-stem auger method.

**6.2.3** Wash boring method.

**6.2.4** Continuous flight solid auger method.

**6.3** Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing

may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

**6.4** The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

## 7. Sampling and Testing Procedure

**7.1** After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

**7.1.1** Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

**7.1.2** Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

**7.1.3** Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

**7.1.4** Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

**7.2** Drive the sampler with blows from the 140-lb (63.5-

kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "N-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop  $30 \pm 1.0$  in. ( $0.76 \text{ m} \pm 25 \text{ mm}$ ) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than  $2\frac{1}{4}$  rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either  $1\frac{1}{4}$  or  $2\frac{1}{4}$  rope turns, depending upon whether or not the rope comes off the top ( $1\frac{1}{4}$  turns) or the bottom ( $2\frac{1}{4}$  turns) of the cathead. It is generally known and accepted that  $2\frac{1}{4}$  or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent

stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

## 8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

- 8.1.1 Name and location of job,
- 8.1.2 Names of crew,
- 8.1.3 Type and make of drilling machine,
- 8.1.4 Weather conditions,
- 8.1.5 Date and time of start and finish of boring,
- 8.1.6 Boring number and location (station and coordinates, if available and applicable),
- 8.1.7 Surface elevation, if available,
- 8.1.8 Method of advancing and cleaning the boring,
- 8.1.9 Method of keeping boring open,
- 8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,
- 8.1.11 Location of strata changes,
- 8.1.12 Size of casing, depth of cased portion of boring,
- 8.1.13 Equipment and method of driving sampler,
- 8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),
- 8.1.15 Size, type, and section length of the sampling rods, and
- 8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

- 8.2.1 Sample depth and, if utilized, the sample number;
- 8.2.2 Description of soil,
- 8.2.3 Strata changes within sample,
- 8.2.4 Sampler penetration and recovery lengths, and
- 8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

## 9. Precision and Bias

9.1 *Precision*—A valid estimate of test precision has not been determined because it is too costly to conduct the necessary inter-laboratory (field) tests. Subcommittee D18.02 welcomes proposals to allow development of a valid precision statement.

9.2 *Bias*—Because there is no reference material for this test method, there can be no bias statement.

9.3 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.



9.5 The variability in  $N$ -values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting  $N$  on the basis of comparative energies. A method for energy measurement and  $N$ -value

adjustment is given in Test Method D 4633.

## 10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.*

**ATTACHMENT B**

**ASTM D1587-83**

**STANDARD PRACTICE FOR THIN-WALLED TUBE SAMPLING OF SOILS**



## Standard Practice for Thin-Walled Tube Sampling of Soils<sup>1</sup>

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

### 1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>2</sup>
- D 3550 Practice for Ring-Lined Barrel Sampling of Soils<sup>2</sup>
- D 4220 Practices for Preserving and Transporting Soil Samples<sup>2</sup>

### 3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

### 4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

### 5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For

hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio*, should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

### 6. Procedure

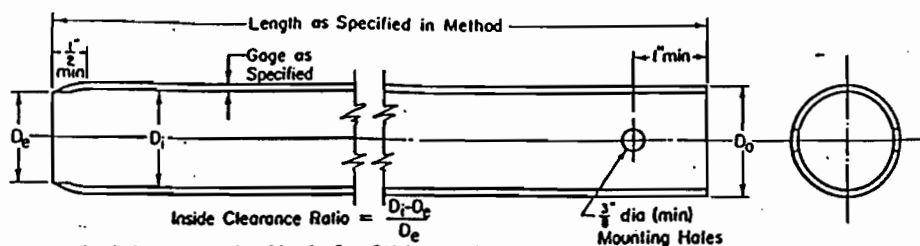
6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.



NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.

NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.

NOTE 3—Tube held with hardened screws.

NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for “undisturbed samples.” Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

| in. | mm    |
|-----|-------|
| ¾   | 6.77  |
| ½   | 12.7  |
| 1   | 25.4  |
| 2   | 50.8  |
| 3½  | 88.9  |
| 4   | 101.6 |

FIG. 1 Thin-Walled Tube for Sampling

TABLE 1 Suitable Thin-Walled Steel Sample Tubes<sup>a</sup>

|                    |       |       |       |
|--------------------|-------|-------|-------|
| Outside diameter:  |       |       |       |
| in.                | 2     | 3     | 5     |
| mm                 | 50.8  | 76.2  | 127   |
| Wall thickness:    |       |       |       |
| Bwg                | 18    | 16    | 11    |
| in.                | 0.049 | 0.065 | 0.120 |
| mm                 | 1.24  | 1.65  | 3.05  |
| Tube length:       |       |       |       |
| in.                | 36    | 36    | 54    |
| m                  | 0.91  | 0.91  | 1.45  |
| Clearance ratio, % | 1     | 1     | 1     |

<sup>a</sup> The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

| Nominal Tube Diameters from Table 1 <sup>a</sup> Tolerances, in. |          |          |          |  |
|------------------------------------------------------------------|----------|----------|----------|--|
| Size Outside Diameter                                            | 2        | 3        | 5        |  |
| Outside diameter                                                 | +0.007   | +0.010   | +0.015   |  |
|                                                                  | −0.000   | −0.000   | −0.000   |  |
| Inside diameter                                                  | +0.000   | +0.000   | +0.000   |  |
|                                                                  | −0.007   | −0.010   | −0.015   |  |
| Wall thickness                                                   | ±0.007   | ±0.010   | ±0.015   |  |
| Ovality                                                          | 0.015    | 0.020    | 0.030    |  |
| Straightness                                                     | 0.030/ft | 0.030/ft | 0.030/ft |  |

<sup>a</sup> Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.

possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed

5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a “driven sample.”

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

## 7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.

NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the

markings or labels are adequate to survive transportation and storage.

#### 6. Report

8.1 The appropriate information is required as follows:

- 8.1.1 Name and location of the project,
- 8.1.2 Boring number and precise location on project,
- 8.1.3 Surface elevation or reference to a datum,
- 8.1.4 Date and time of boring—start and finish,
- 8.1.5 Depth to top of sample and number of sample,
- 8.1.6 Description of sampler: size, type of metal, type of coating,
- 8.1.7 Method of sampler insertion: push or drive,

8.1.8 Method of drilling, size of hole, casing, and drilling fluid used,

8.1.9 Depth to groundwater level; date and time measured,

8.1.10 Any possible current or tidal effect on water level,

8.1.11 Soil description in accordance with Practice D 2488,

8.1.12 Length of sampler advance, and

8.1.13 Recovery: length of sample obtained.

#### 9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

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**ATTACHMENT C**

**ASTM D2113-83 (1987)**

**STANDARD PRACTICE FOR DIAMOND CORE DRILLING FOR  
SITE INVESTIGATION**



## Standard Practice for Diamond Core Drilling for Site Investigation<sup>1</sup>

This standard is issued under the fixed designation D 2113; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This practice describes equipment and procedures for diamond core drilling to secure core samples of rock and some soils that are too hard to sample by soil-sampling methods. This method is described in the context of obtaining data for foundation design and geotechnical engineering purposes rather than for mineral and mining exploration.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils<sup>2</sup>
- D 1587 Practice for Thin-Walled Tube Sampling of Soils<sup>2</sup>
- D 3550 Practice for Ring-Lined Barrel Sampling of Soils<sup>2</sup>

### 3. Significance and Use

3.1 This practice is used to obtain core specimens of superior quality that reflect the in-situ conditions of the material and structure and which are suitable for standard physical-properties tests and structural-integrity determination.

### 4. Apparatus

4.1 *Drilling Machine*, capable of providing rotation, feed, and retraction by hydraulic or mechanical means to the drill rods.

4.2 *Fluid Pump or Air Compressor*, capable of delivering sufficient volume and pressure for the diameter and depth of hole to be drilled.

4.3 *Core barrels*, as required:

4.3.1 *Single Tube Type, WG Design*, consisting of a hollow steel tube, with a head at one end threaded for drill rod, and a threaded connection for a reaming shell and core bit at the other end. A core lifter, or retainer located within the core bit is normal, but may be omitted at the discretion of the geologist or engineer.

4.3.2 *Double Tube, Swivel-Type, WG Design*—An assembly of two concentric steel tubes joined and supported at the upper end by means of a ball or roller-bearing swivel arranged to permit rotation of the outer tube without causing rotation of the inner tube. The upper end of the outer tube, or removable head, is threaded for drill rod. A threaded connection is provided on the lower end of the outer tube for

a reaming shell and core bit. A core lifter located within the core bit is normal but may be omitted at the discretion of the geologist or engineer.

4.3.3 *Double-Tube, Swivel-Type, WT Design*, is essentially the same as the double tube, swivel-type, WG design, except that the WT design has thinner tube walls, a reduced annular area between the tubes, and takes a larger core from the same diameter bore hole. The core lifter is located within the core bit.

4.3.4 *Double Tube, Swivel Type, WM Design*, is similar to the double tube, swivel-type, WG design, except that the inner tube is threaded at its lower end to receive a core lifter case that effectively extends the inner tube well into the core bit, thus minimizing exposure of the core to the drilling fluid. A core lifter is contained within the core lifter case on the inner tube.

4.3.5 *Double Tube Swivel-Type, Large-Diameter Design*, is similar to the double tube, swivel-type, WM design, with the addition of a ball valve, to control fluid flow, in all three available sizes and the addition of a sludge barrel, to catch heavy cuttings, on the two larger sizes. The large-diameter design double tube, swivel-type, core barrels are available in three core per hole sizes as follows: 2 1/4 in. (69.85 mm) by 3 1/2 in. (98.43 mm), 4 in. (101.6 mm) by 5 1/2 in. (139.7 mm), and 6 in. (152.4 mm) by 7 1/4 in. (196.85 mm). Their use is generally reserved for very detailed investigative work or where other methods do not yield adequate recovery.

4.3.6 *Double Tube, Swivel-Type, Retrievable Inner-Tube Method*, in which the core-laden inner-tube assembly is retrieved to the surface and an empty inner-tube assembly returned to the face of the borehole through the matching large-bore drill rods without need for withdrawal and replacement of the drill rods in the borehole. The inner-tube assembly consists of an inner tube with removable core lifter case and core lifter at one end and a removable inner-tube head, swivel bearing, suspension adjustment, and latching device with release mechanism on the opposite end. The inner-tube latching device locks into a complementary recess in the wall of the outer tube such that the outer tube may be rotated without causing rotation of the inner tube and such that the latch may be actuated and the inner-tube assembly transported by appropriate surface control. The outer tube is threaded for the matching, large-bore drill rod and internally configured to receive the inner-tube latching device at one end and threaded for a reaming shell and bit, or bit only, at the other end.

4.4 *Longitudinally Split Inner Tubes*—As opposed to conventional cylindrical inner tubes, allow inspection of, and access to, the core by simply removing one of the two halves. They are not standardized but are available for most core barrels including many of the retrievable inner-tube types.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

**4.5 Core Bits**—Core bits shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide slugs, or strips, hard-faced with various hard surfacing materials or furnished in saw-tooth form, all as appropriate to the formation being cored and with concurrence of the geologist or engineer. Bit matrix material, crown shape, water-way type, location and number of water ways, diamond size and carat weight, and bit facing materials shall be for general purpose use unless otherwise approved by the geologist or engineer. Nominal size of some bits is shown in Table 1.

**NOTE 1**—Size designation (letter symbols) used throughout the text in Tables 1, 2, and 3 are those standardized by the Diamond Core Drill Manufacturers' Assoc. (DCDMA). Inch dimensions in the tables have been rounded to the nearest hundredth of an inch.

**4.6 Reaming Shells**, shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide strips or slugs, hard faced with various types of hard surfacing materials, or furnished blank, all as appropriate to the formation being cored.

**4.7 Core Lifters**—Core lifters of the split-ring type, either plain or hard-faced, shall be furnished and maintained, along with core-lifter cases or inner-tube extensions or inner-tube shoes, in good condition. Basket or finger-type lifters, together with any necessary adapters, shall be on the job and available for use with each core barrel if so directed by the geologist or engineer.

#### 4.8 Casings:

**4.8.1 Drive Pipe or Drive Casing**, shall be standard weight (schedule 40), extra-heavy (schedule 80), double extra-heavy (schedule 160) pipe or W-design flush-joint casing as re-

quired by the nature of the overburden or the placement method. Drive pipe or W-design casing shall be of sufficient diameter to pass the largest core barrel to be used, and it shall be driven to bed rock or to firm seating at an elevation below water-sensitive formation. A hardened drive shoe is to be used as a cutting edge and thread protection device on the bottom of the drive pipe or casing. The drive shoe inside diameter shall be large enough to pass the tools intended for use, and the shoe and pipe or casing shall be free from burrs or obstructions.

**4.8.2 Casing**—When necessary to case through formations already penetrated by the borehole or when no drive casing has been set, auxiliary casing shall be provided to fit inside the borehole to allow use of the next smaller core barrel. Standard sizes of telescoping casing are shown in Table 2. Casing bits have an obstruction in their interior and will not pass the next smaller casing size. Use a casing shoe if additional telescoping is anticipated.

**4.8.3 Casing Liner**—Plastic pipe or sheet-metal pipe may be used to line an existing large-diameter casing. Liners, so used, should not be driven, and care should be taken to maintain true alignment throughout the length of the liner.

**4.8.4 Hollow Stem Auger**—Hollow stem auger may be used as casing for coring.

#### 4.9 Drill Rods:

**4.9.1 Drill Rods of Tubular Steel Construction** are normally used to transmit feed, rotation, and retraction forces from the drilling machine to the core barrel. Drill-rod sizes that are presently standardized are shown in Table 3.

**4.9.2 Large bore drill rods** used with retrievable inner-tube core barrels are not standardized. Drill rods used with retrievable inner-tube core barrels should be those manufactured by the core-barrel manufacturer specifically for the core barrel.

**4.9.3 Composite Drill Rods** are specifically constructed from two or more materials intended to provide specific properties such as light weight or electrical nonconductivity.

**4.9.4 Nonmagnetic Drill Rods** are manufactured of nonferrous materials such as aluminum or brass and are used primarily for hole survey work. Some nonmagnetic rods have left-hand threads in order to further their value in survey work. No standard exists for nonmagnetic rods.

**4.10 Auxiliary Equipment**, shall be furnished as required by the work and shall include: roller rock bits, drag bits, chopping bits, boulder busters, fishtail bits, pipe wrenches, core barrel wrenches, lubrication equipment, core boxes, and marking devices. Other recommended equipment includes:

TABLE 1 Core Bit Sizes

| Size Designation | Outside Diameter |       | Inside Diameter |       |
|------------------|------------------|-------|-----------------|-------|
|                  | in.              | mm    | in.             | mm    |
| RWT              | 1.16             | 29.5  | 0.375           | 18.7  |
| EWT              | 1.47             | 37.3  | 0.905           | 22.9  |
| EWG, EWM         | 1.47             | 37.3  | 0.845           | 21.4  |
| AWT              | 1.88             | 47.6  | 1.281           | 32.5  |
| AWG, AWM         | 1.88             | 47.6  | 1.185           | 30.0  |
| BWT              | 2.35             | 59.5  | 1.750           | 44.6  |
| BWG, BWM         | 2.35             | 59.5  | 1.655           | 42.0  |
| NWT              | 2.97             | 75.3  | 2.313           | 58.7  |
| NWG, NWM         | 2.97             | 75.3  | 2.155           | 54.7  |
| 2 3/4 x 3 1/4    | 3.84             | 97.5  | 2.69            | 68.3  |
| HWT              | 3.89             | 98.8  | 3.167           | 80.9  |
| HWG, ...         | 3.89             | 98.8  | 3.000           | 76.2  |
| 4 x 5 1/4        | 5.44             | 138.0 | 3.97            | 100.8 |
| 6 x 7 1/4        | 7.66             | 194.4 | 5.97            | 151.6 |

TABLE 2 Casing Sizes

| Size Designation | Outside Diameter |       | Inside Diameter |       | Threads per in. | Wt Ft Hole Drilled with Core Bit Size |
|------------------|------------------|-------|-----------------|-------|-----------------|---------------------------------------|
|                  | in.              | mm    | in.             | mm    |                 |                                       |
| RW               | 1.144            | 36.5  | 1.19            | 30.1  | 5               | EWG, EWG, EWM                         |
| EW               | 1.81             | 46.0  | 1.50            | 38.1  | 4               | AWT, AWG, AWM                         |
| AW               | 2.25             | 57.1  | 1.91            | 48.4  | 4               | BWT, BWG, BWM                         |
| BW               | 2.88             | 73.0  | 2.38            | 60.3  | 4               | NWT, NWG, NWM                         |
| NW               | 3.50             | 88.9  | 3.00            | 76.2  | 4               | HWT, HWG                              |
| HW               | 4.50             | 114.3 | 4.00            | 101.6 | 4               | 4 x 5 1/4                             |
| PW               | 5.50             | 139.7 | 5.00            | 127.0 | 3               | 6 x 7 1/4                             |
| SW               | 6.63             | 168.2 | 6.00            | 152.4 | 3               | 6 x 7 1/4                             |
| UW               | 7.63             | 193.6 | 7.00            | 177.8 | 2               | ...                                   |
| ZW               | 8.63             | 219.0 | 8.00            | 203.2 | 2               | ...                                   |



TABLE 3 Drill Rods

| Size Designation | Rod and Coupling Outside Diameter |      | Rod Inside Diameter |      | Coupling Bore, Threads |      |         |
|------------------|-----------------------------------|------|---------------------|------|------------------------|------|---------|
|                  | in.                               | mm   | in.                 | mm   | in.                    | mm   | per in. |
| RW               | 1.09                              | 27.7 | 0.72                | 18.2 | 0.41                   | 10.3 | 4       |
| EW               | 1.38                              | 34.9 | 1.00                | 25.4 | 0.44                   | 11.1 | 3       |
| AW               | 1.72                              | 43.6 | 1.34                | 34.1 | 0.63                   | 15.8 | 3       |
| BW               | 2.13                              | 53.9 | 1.75                | 44.4 | 0.75                   | 19.0 | 3       |
| NW               | 2.63                              | 66.6 | 2.25                | 57.1 | 1.38                   | 34.9 | 3       |
| HW               | 3.50                              | 88.9 | 3.06                | 77.7 | 2.38                   | 60.3 | 3       |

core splitter, rod wicking, pump-out tools or extruders, and hand sieve or strainer.

## 5. Transportation and Storage of Core Containers

5.1 *Core Boxes*, shall be constructed of wood or other durable material for the protection and storage of cores while enroute from the drill site to the laboratory or other processing point. All core boxes shall be provided with longitudinal separators and recovered cores shall be laid out as a book would read, from left to right and top to bottom, within the longitudinal separators. Spacer blocks or plugs shall be marked and inserted into the core column within the separators to indicate the beginning of each coring run. The beginning point of storage in each core box is the upper left-hand corner. The upper left-hand corner of a hinged core box is the left corner when the hinge is on the far side of the box and the box is right-side up. All hinged core boxes must be permanently marked on the outside to indicate the top and the bottom. All other core boxes must be permanently marked on the outside to indicate the top and the bottom and additionally, must be permanently marked internally to indicate the upper-left corner of the bottom with the letters UL or a splotch of red paint not less than 1 in.<sup>2</sup> Lid or cover fitting(s) for core boxes must be of such quality as to ensure against mix up of the core in the event of impact or upsetting of the core box during transportation.

5.2 Transportation of cores from the drill site to the laboratory or other processing point shall be in durable core boxes so padded or suspended as to be isolated from shock or impact transmitted to the transporter by rough terrain or careless operation.

5.3 Storage of cores, after initial testing or inspection at the laboratory or other processing point, may be in cardboard or similar less costly boxes provided all layout and marking requirements as specified in 5.1 are followed. Additional spacer blocks or plugs shall be added if necessary at time of storage to explain missing core. Cores shall be stored for a period of time specified by the engineer but should not normally be discarded prior to completion of the project for which they were taken.

## 6. Procedure

6.1 Use core-drilling procedures when formations are encountered that are too hard to be sampled by soil-sampling methods. A 1-in. (25.4-mm) or less penetration for 50 blows in accordance with Method D 1586 or other criteria established by the geologist or engineer, shall indicate that soil-sampling methods are not applicable.

6.1.1 Seat the casing on bedrock or in a firm formation to prevent raveling of the borehole and to prevent loss of

drilling fluid. Level the surface of the rock or hard formation at the bottom of the casing when necessary, using the appropriate bits. Casing may be omitted if the borehole will stand open without the casing.

6.1.2 Begin the core drilling using an N-size double-tube swivel-type core barrel or other size or type approved by the engineer. Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled in. Remove the core barrel from the hole and disassemble it as necessary to remove the core. Reassemble the core barrel and return it to the hole. Resume coring.

6.1.3 Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box as described in 5.1. Continue boxing core with appropriate markings, spacers, and blocks as described in 5.1. Wrap soft or friable cores or those which change materially upon drying in plastic film or seal in wax, or both, when such treatment is required by the engineer. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core which might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.

6.1.4 Stop the core drilling when soft materials are encountered that produce less than 50 % recovery. If necessary, secure samples of soft materials in accordance with the procedures described in Method D 1586, Practice D 1587, or Practice D 3550, or by any other method acceptable to the geologist or engineer. Resume diamond core drilling when refusal materials as described in 6.1 are again encountered.

6.2 Subsurface structure, including the dip of strata, the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described. Take special care to obtain and record information about these features. If conditions prevent the continued advance of the core drilling, the hole should be cemented and redrilled, or reamed and cased, or cased and advanced with the next smaller-size core barrel, as required by the geologist or engineer.

6.3 Drilling mud or grouting techniques must be approved by the geologist or engineer prior to their use in the borehole.

### 6.4 Compatibility of Equipment:

6.4.1 Whenever possible, core barrels and drill rods should be selected from the same letter-size designation to ensure maximum efficiency. See Tables 1 and 3.

6.4.2 Never use a combination of pump, drill rod, and core barrel that yields a clear-water up-hole velocity of less than 120 ft/min.

6.4.3 Never use a combination of air compressor, drill rod, and core barrel that yields a clear-air up-hole velocity of less than 3000 ft/min.

## 7. Boring Log

- 7.1 The boring log shall include the following:
  - 7.1.1 Project identification, boring number, location, date boring began, date boring completed, and driller's name.
  - 7.1.2 Elevation of the ground surface.
  - 7.1.3 Elevation of or depth to ground water and raising or lowering of level including the dates and the times measured.
  - 7.1.4 Elevations or depths at which drilling fluid return was lost.
  - 7.1.5 Size, type, and design of core barrel used. Size, type, and set of core bit and reaming shell used. Size, type, and length of all casing used. Description of any movements of the casing.
  - 7.1.6 Length of each core run and the length or percentage, or both, of the core recovered.
  - 7.1.7 Geologist's or engineer's description of the formation recovered in each run.
  - 7.1.8 Driller's description, if no engineer or geologist is present, of the formation recovered in each run.
  - 7.1.9 Subsurface structure description, including dip of strata and jointing, cavities, fissures, and any other observations made by the geologist or engineer that could yield information regarding the formation.

7.1.10 Depth, thickness, and apparent nature of the filling of each cavity or soft seam encountered, including opinions gained from the feel or appearance of the inside of the inner tube when core is lost. Record opinions as such.

7.1.11 Any change in the character of the drilling fluid or drilling fluid return.

7.1.12 Tidal and current information when the borehole is sufficiently close to a body of water to be affected.

7.1.13 Drilling time in minutes per foot and bit pressure in pound-force per square inch gage when applicable.

7.1.14 Notations of character of drilling, that is, soft, slow, easy, smooth, etc.

## 8. Precision and Bias

8.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

NOTE 2—Inclusion of the following tables and use of letter symbols in the foregoing text is not intended to limit the practice to use of DCDMA tools. The table and text references are included as a convenience to the user since the vast majority of tools in use do meet DCDMA dimensional standards. Similar equipment of approximately equal size on the metric standard system is acceptable unless otherwise stipulated by the engineer or geologist.

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**SOP F104**  
**Groundwater Sample Acquisition**

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**GROUNDWATER SAMPLE ACQUISITION  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Sampling, Monitoring, and Evaluation Equipment**
  - 5.2 Calculations of Well Volume**
  - 5.3 Evacuation of Static Water (Purging)**
    - 5.3.1 Evacuation Devices**
  - 5.4 Sampling**
    - 5.4.1 Sampling Methods**
    - 5.4.2 Sample Containers**
    - 5.4.3 Preservation of Samples and Sample Volume Requirements**
    - 5.4.4 Field Filtration**
    - 5.4.5 Handling and Transportation Samples**
    - 5.4.6 Sample Holding Times**
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## **GROUNDWATER SAMPLE ACQUISITION**

### **1.0 PURPOSE**

The purpose of this guideline is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

### **2.0 SCOPE**

This guideline provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

### **3.0 DEFINITIONS**

None.

### **4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

**Field Team Leader** - The Field Team Leader is responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, and documenting these in the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team

Leader and the Project Manager. The sampling personnel are responsible for the proper acquisition of groundwater samples.

## 5.0 PROCEDURES

To be useful and accurate, a groundwater sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to minimize any changes in water quality parameters.

The groundwater sampling program should be developed with reference to ASTM D4448-85A, Standard Guide for Sampling Groundwater Monitoring Wells (Attachment A). This reference is not intended as a monitoring plan or procedure for a specific application, but rather is a review of methods. Specific methods shall be stated in the Sampling and Analysis Plan (SAP).

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain largely isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach should be followed during sample withdrawal:

1. All monitoring wells shall be pumped or bailed prior to withdrawing a sample. Evacuation of three to five volumes is recommended for a representative sample.
2. Wells that can be pumped or bailed to dryness with the sampling equipment being used, shall be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of at least three well volumes of water is preferred; otherwise, a sample will be taken when enough water is available to fill the sample containers.

Stratification of contaminants may exist in the aquifer formation. This is from concentration gradients due to dispersion and diffusion processes in a homogeneous layer, and from

separation of flow streams by physical division (for example, around clay leases) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Pumping rates and volumes for non-production wells during sampling development should be moderate; pumping rates for production wells should be maintained at the rate normal for that well. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, thus result in the collection of a non-representative sample. Water produced during purging shall be collected, stored or treated and discharged as allowed. Disposition of purge water is usually site specific and must be addressed in the Sampling and Analysis Plan.

#### 5.1 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with EPA regulations for the appropriate contaminants and to the specific Quality Assurance Project Plan.

The following list is an example of the type of equipment that generally must be on hand when sampling groundwater wells:

1. Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, and appropriate packing cartons and filler, labels and chain-of-custody documents.
2. Field tools and instrumentation - Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; water-level indicator; and, where applicable, flow meter.
3. Pumps
  - a. Shallow-well pumps - Centrifugal, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing), as applicable.
  - b. Deep-well pumps - Submersible pump and electrical power generating unit, bladder pump with compressed air source, or air-lift apparatus, as applicable.
4. Tubing - Sample tubing such as teflon, polyethylene, polypropylene, or PVC. Tubing type shall be selected based on specific site requirements and must be chemically inert to the groundwater being sampled.
5. Other Sampling Equipment - Bailers, teflon-coated wire, stainless steel single strand wire, and polypropylene monofilament line (not acceptable in EPA Region I) with

tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.

6. Pails - Plastic, graduated.
7. Decontamination solutions - Decontamination materials are discussed in SOP F501 and F502.

Ideally, sample withdrawal equipment should be completely inert, economical, easily cleaned, sterilized, and reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well flushing and sample collection.

## 5.2 Calculations of Well Volume

Calculation of gallons/linear feet from a well

$$V = \pi r^2 h$$

Where: V = volume of standing water in well  
r = well radius  
h = feet of standing water in well

Table 5-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameter.

TABLE 5-1  
WELL VOLUMES

| Diameter of Casing<br>or Hole (in.) | Gallons per Foot<br>of Depth | Cubic Feet per Foot<br>of Depth |
|-------------------------------------|------------------------------|---------------------------------|
| 1                                   | 0.041                        | 0.0055                          |
| 2                                   | 0.163                        | 0.0218                          |
| 4                                   | 0.653                        | 0.0873                          |
| 6                                   | 1.469                        | 0.1963                          |
| 8                                   | 2.611                        | 0.3491                          |
| 10                                  | 4.080                        | 0.5454                          |

Notes:

1. Gallons per foot of depth will be multiplied by amount of standing water to obtain well volume quantity.
2. 1 gallon = 3.785 liters  
1 meter = 3.281 feet  
1 gallon water weighs 8.33 pounds = 3.785 kilograms  
1 liter water weighs 1 kilogram = 2.205 pounds  
1 gallon per foot of depth = 12.419 liters per foot of depth  
1 gallon per meter of depth = 12.419 x 10<sup>-3</sup> cubic meters per meter of depth



To insure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well pipe or casing. The volume can be easily calculated by the following method. Calculations shall be entered in the field logbook:

1. Obtain all available information on well construction (location, casing, screens, etc.).
2. Determine well or casing diameter.
3. Measure and record static water level (depth below ground level or top of casing reference point), using one of the methods described in Section 5.1 of SOP F202.
4. Determine the depth of the well (if not known from past records) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure.
5. Calculate number of linear feet of static water (total depth or length of well pipe or casing minus the depth to static water level).
6. Calculate the volume of water in the casing:

$$VW = \pi D^2 (TD - DW)$$

$$V_{gal} = VW \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = V_{gal} (\# \text{ Well Vol})$$

Where:

|                        |                                                                                           |
|------------------------|-------------------------------------------------------------------------------------------|
| $V_W$                  | = Volume of water in well in cubic feet (i.e., one well volume)                           |
| $\pi$                  | = pi, 3.14                                                                                |
| $D$                    | = Well diameter in feet (use $(D/12)$ if $D$ is in inches)                                |
| $TD$                   | = Total depth of well in feet (below ground surface or top of casing)                     |
| $DW$                   | = Depth to water in feet (below ground surface or top of casing)                          |
| $V_{gal}$              | = Volume of water in well in gallons                                                      |
| $V_{purge}$            | = Volume of water to be purged from well in gallons                                       |
| $\# \text{ Well Vol.}$ | = Number of well volumes of water to be purged from the well<br>(typically three to five) |

7. Determine the minimum number of gallons to be evacuated before sampling. (Note:  $V_{purge}$  should be rounded to the next highest whole gallon. For example, 7.2 gallons should be rounded to 8 gallons.)

### 5.3 Evacuation of Static Water (Purging)

The amount of flushing a well should receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce significant groundwater flow from a wide area. Generally, three to five well volumes are considered effective for purging a well.

An alternative method of purging a well, and one accepted in EPA Regions I and IV, is to purge a well continuously (usually using a low volume, low flow pump) while monitoring specific conductance, pH, and water temperature until the values stabilize. The well is considered properly purged when the values have stabilized.

The Project Manager shall define the objectives of the groundwater sampling program in the Sampling and Analysis Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

#### 5.3.1 Evacuation Devices

The following discussion is limited to those devices which are commonly used at hazardous waste sites. Note that all of these techniques involve equipment which is portable and readily available.

Bailers - Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line (e.g., Teflon-coated) is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Inexpensive.
- Minimal outgassing of volatile organics while the sample is in the bailer.
- Relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- Potentially excessively time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

Suction Pumps - There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (generally not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 10 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps will cause significant loss of dissolved gases, including volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

Gas-Lift Samples - This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift pumps are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics. An inert gas such as nitrogen is generally used as a gas source.

Submersible Pumps - Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed air or

electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for two-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- Potentially low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

#### 5.4 Sampling

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.
2. Brief description of area and waste characterization.
3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
4. Sampling equipment to be used.
5. Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these should be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
6. Sample preservation requirements.
7. Schedule.
8. List of team members.
9. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

#### 5.4.1 Sampling Methods

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNu or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well according to Section 5.2 of this SOP.
3. Lower purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (e.g., DOT-approved 55-gallon drum).
4. Measure the rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters.
5. Observe peristaltic pump intake for degassing "bubbles" and all pump discharge lines. If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. The preferred method for collecting volatile organic samples and the accepted method by EPA Regions I through IV is with a bailer.
6. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.
7. Record measurements of specific conductance, temperature, and pH during purging to ensure the groundwater stabilizes. Generally, these measurements are made after three, four, and five well volumes.
8. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling (this requires use of other than a "bucket-type" bailer). Purged water should be collected in a designated container and disposed of in an acceptable manner.
9. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
10. In the event that recovery time of the well is very slow (e.g., 24 hours), sample collection can be delayed until the following day. If the well has been bailed early in

the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.

11. Add preservative if required (see SOP F301). Label, tag, and number the sample bottle(s).
12. Purgeable organics vials (40 ml) should be completely filled to prevent volatilization and extreme caution should be exercised when filling a vial to avoid turbulence which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost, but air space in the bottle is eliminated. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure.
13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.
14. Pack the samples for shipping (see SOP F301). Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached (see SOP F302).
15. Decontaminate all equipment.

#### 5.4.2 Sample Containers

For most samples and analytical parameters, either glass or plastic containers are satisfactory. SOP F301 describes the required sampling containers for various analytes at various concentrations. Container requirements shall follow those given in NEESA 20.2-047B.

#### 5.4.3 Preservation of Samples and Sample Volume Requirements

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. SOP F301 describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Sample volume and preservation requirements shall follow those given in NEESA 20.2-047B.

#### **5.4.4 Field Filtration**

In general, preparation and preservation of water samples involve some form of filtration. All filtration must occur in the field immediately upon collection. The recommended method is through the use of a disposable in-line filtration module (0.45 micron filter) utilizing the pressure provided by the upstream pumping device for its operation.

In Region I, all inorganics are to be collected and preserved in the filtered form, including metals. In Region II, metals samples are to be collected and preserved unfiltered. In Regions III and IV, samples collected for metals analysis are also to be unfiltered. However, if metals analysis of monitoring wells is required, then both an unfiltered and filtered sample are to be collected, regardless of regulatory requirements. Filtration and preservation are to occur immediately in the field with the sample aliquot passing through a 0.45 micron filter. Samples for organic analyses shall never be filtered. Filters must be prerinsed with organic-free, deionized water.

#### **5.4.5 Handling and Transporting Samples**

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be double-bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged, and thus possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in SOP F301.

#### **5.4.6 Sample Holding Times**

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in NEESA 20.2-047B.

## 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method; volume of water purged prior to sampling; number of well volumes purged).
- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F302 describes the requirements for correctly completing a chain-of-custody form. Chain-of-custody forms (and sample analysis request forms) are considered quality assurance records.

## 7.0 REFERENCES

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.



**ATTACHMENT A**

**ASTM D4448-85A**

**STANDARD GUIDE FOR SAMPLING GROUNDWATER MONITORING WELLS**



## Standard Guide for Sampling Groundwater Monitoring Wells<sup>1</sup>

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices (1, 2).<sup>2</sup> The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.

2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary for sampling are increased. Therefore, the sampling objective must clearly be defined ahead of time. For example, to prepare equipment for sampling for mg/L (ppm) levels of Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample for  $\mu\text{g/L}$  (ppb) levels of a trace organic like benzene. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. No final Environmental Protection Agency (EPA) protocol is available for sampling of trace organics. A short guidance manual, (3) and an EPA document (4) concerning monitoring well sampling, including considerations for trace organics are available.

2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.

### 3. Significance and Use

3.1 The quality of groundwater has become an issue of national concern. Groundwater monitoring wells are one of

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D-34 on Waste Disposal and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

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<sup>2</sup> The boldface numbers in parentheses refer to a list of references at the end of this guide.

TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program

| Sample and Measurement                                    | Volume Required (mL) | Container P—Polyethylene G—Glass                       | Preservative                                                                                 | Maximum Holding Time                   |
|-----------------------------------------------------------|----------------------|--------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------------|
| Metals As/Ba/Cd/Cr/Fe Pb/Se/<br>Ag/Mn/Na                  | 1000–2000            | P/G (special acid cleaning)                            | high purity nitric acid to pH <2                                                             | 6 months                               |
| Mercury                                                   | 200–300              | P/G (special acid cleaning)                            | high purity nitric acid to pH <2<br>+0.05 %<br>K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> | 28 days                                |
| Radioactivity alpha/beta/radium                           | 4000                 | P/G (special acid cleaning)                            | high purity nitric acid to pH <2                                                             | 6 months                               |
| Phenolics                                                 | 500–1000             | G                                                      | cool, 4°C<br>H <sub>2</sub> SO <sub>4</sub> to<br>pH <2                                      | 28 days                                |
| Miscellaneous                                             | 1000–2000            | P                                                      | cool, 4°C                                                                                    | 28 days                                |
| Fluoride                                                  | 300–500              | P                                                      |                                                                                              | 28 days                                |
| Chloride                                                  | 50–200               | P/G                                                    |                                                                                              | 28 days                                |
| Sulfate                                                   | 100–500              | P/G                                                    |                                                                                              | 48 hours                               |
| Nitrate                                                   | 100–250              | P/G                                                    |                                                                                              | 6 h                                    |
| Coliform                                                  | 100                  | P/G                                                    |                                                                                              | on site/24 h                           |
| Conductivity                                              | 100                  | P/G                                                    |                                                                                              | on site/6 h                            |
| pH                                                        | 100                  | P/G                                                    |                                                                                              | 48 h                                   |
| Turbidity                                                 | 100                  | P/G                                                    |                                                                                              |                                        |
| Total organic carbon (TOC)                                | 25–100               | P/G                                                    | cool, 4°C or<br>cool, 4°C HCl<br>or H <sub>2</sub> SO <sub>4</sub> to<br>pH <2               | 24 h<br>28 days                        |
| Pesticides, herbicides and total<br>organic halogen (TOX) | 1000–4000            | G/TFE-fluoro-<br>carbon lined<br>cap solvent<br>rinsed | cool, 4°C                                                                                    | 7 days/extraction +30<br>days/analysis |
| Extractable organics                                      | 1000–2000            | G/TFE-fluoro-<br>carbon-lined<br>cap solvent<br>rinsed | cool, 4°C                                                                                    | 7 days/extraction +30<br>days/analysis |
| Organic purgeables<br>acrolein/acrylonitrile              | 25–120               | G/vial<br>TFE-fluorocar-<br>bon-lined sep-<br>tum      | cool, 4°C                                                                                    | 14 days<br>3 days                      |

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

#### 4. Well Flushing (Purging)

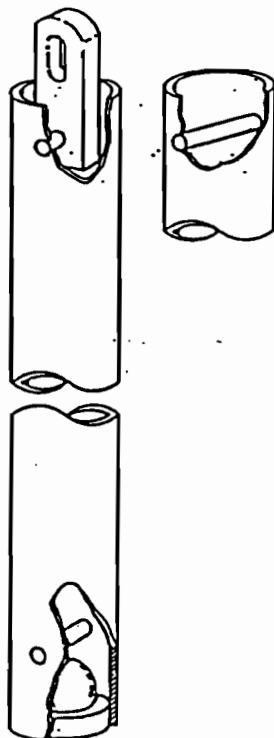
4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may

be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of samples with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Bailer

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

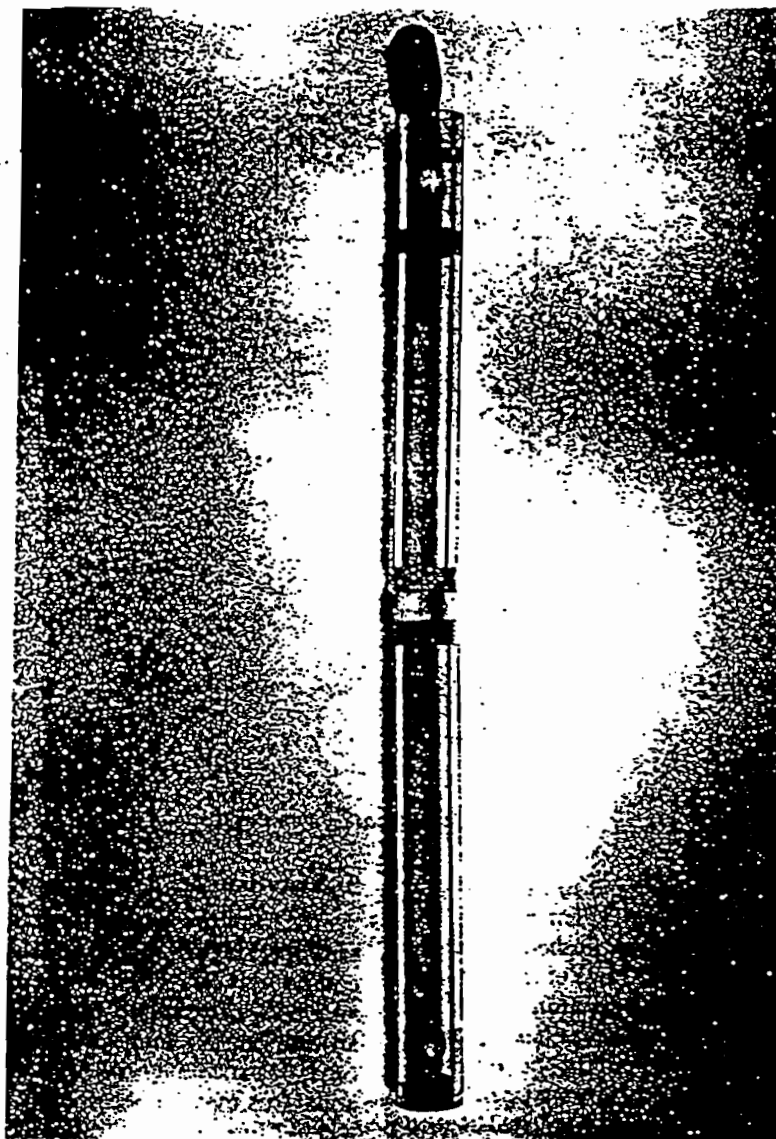
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

## 5. Materials and Manufacture

5.1 The choice of materials used in the construction of sampling devices should be based upon a knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic may be sufficient. In others, an all glass apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices used in sampling and storing samples for trace organics analysis ( $\mu\text{g/L}$  levels) must be constructed of glass or TFE-fluorocarbon resin, or both. One suggestion advanced by the EPA is that the monitoring well be constructed so that only TFE-fluorocarbon tubing be used in that portion of the sampling well that extends from a few feet above the water table to the bottom of the borehole. (3, 5) Although this type of well casing is now commercially available, PVC well casings are currently the most popular. If adhesives are avoided, PVC well casings are acceptable in many cases although their use may still lead to some problems if trace organics are of concern. At present, the type of background presented by PVC and interactions occurring between PVC and groundwater are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC casing. (9)

5.3 Since the most significant problem encountered in trace organics sampling, results from the use of PVC adhesives in monitoring well construction, threaded joints might avoid the problem (3, 5). Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Baller

groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

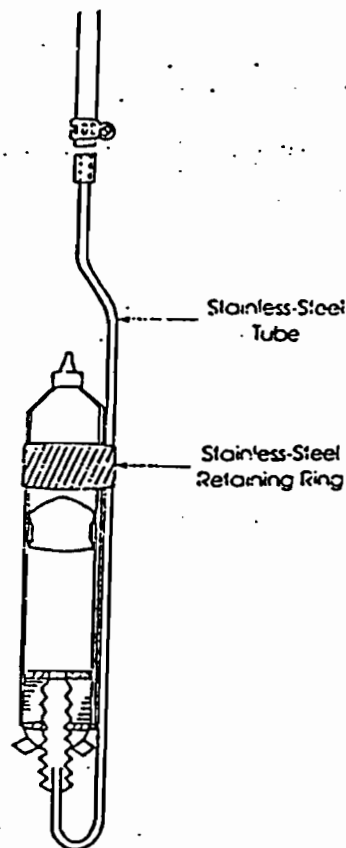
5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once

removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of course, glass sampling equipment must be handled carefully in the field. Stainless steel is strongly and easily machined to



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be non-plastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chem-

ical Society's committee on environmental improvement has published guidelines for data acquisition and data evaluation which should be useful in such environmental evaluation (10, 12).

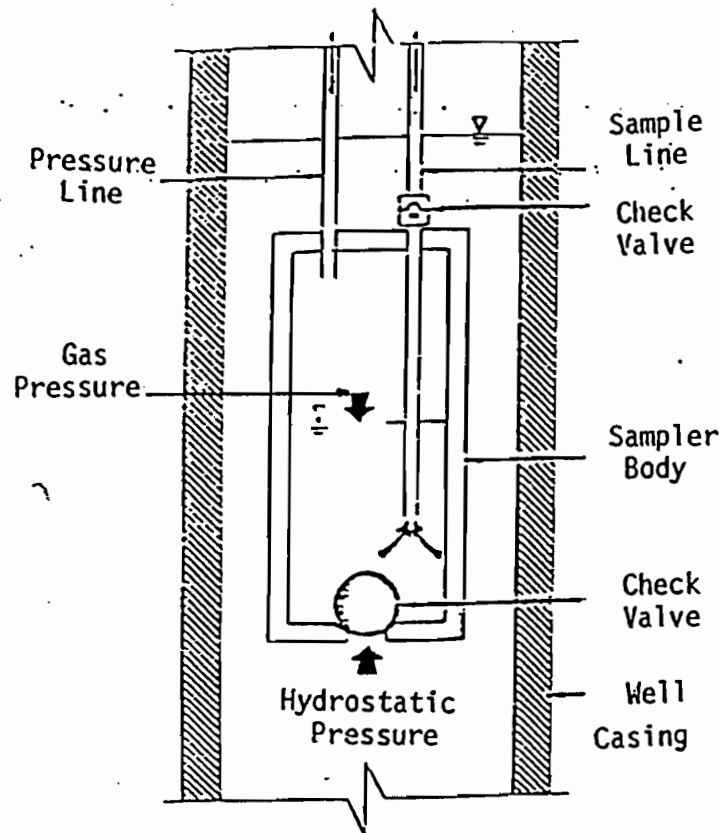
## 6. Sampling Equipment

6.1 There is a fairly large choice of equipment presently available for groundwater sampling from single screen wells and well clusters. The sampling devices can be categorized into the following eight basic types.

### 6.1.1 Down-Hole Collection Devices:

6.1.1.1 Bailers, messenger bailers, or thief samplers (11, 14) are examples of down-hole devices that probably provide valid samples once the well has been flushed. They are not practical for removal of large volumes of water. The devices can be constructed in various shapes and sizes from a variety of materials. They do not subject the sample to pressure extremes.

6.1.1.2 Bailers do expose part of the sample to the atmosphere during withdrawal. Bailers used for sampling of volatile organic compounds should have a sample cock or draft valve in or near the bottom of the sampler allowing withdrawal of a sample from the well below the exposed surface of the water or the first few inches of the sample should be discarded. Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. Down-hole devices are not very practical for use in deep



NOTE—Taken from Ref (5).

FIG. 4 The Principal of Gas Displacement Pumping

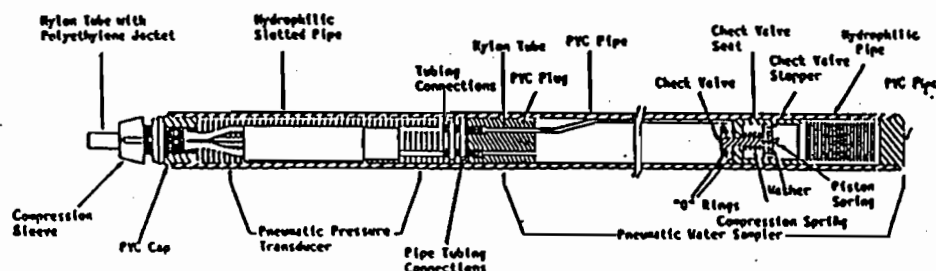
wells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for lowering and retrieval for deep sampling are the primary disadvantages.

6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A schematic of a single check valve unit is illustrated in Fig. 1. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon or PVC are the most common materials used for construction (15).

6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check

valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without any samples loss through the check valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container (14, 16).

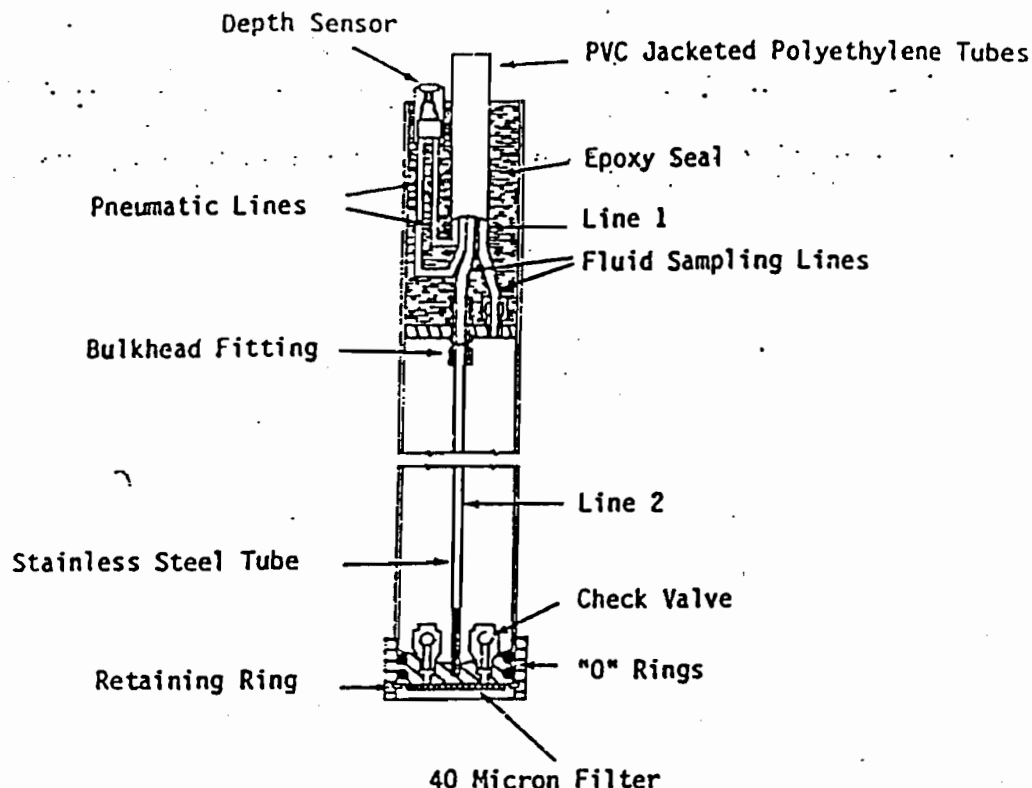
6.1.1.5 A double check valve bailer allows point source sampling at a specific depth (15, 17). An example is shown in Fig. 2. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes freely through the



NOTE—Taken from Ref (41).

FIG. 5 Pneumatic Water Sampler With Internal Transducer





NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). A simple and inexpensive pneumatic sampler was recently described by Gillham (20). The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number

of thief or messenger devices are available in various materials and shapes.

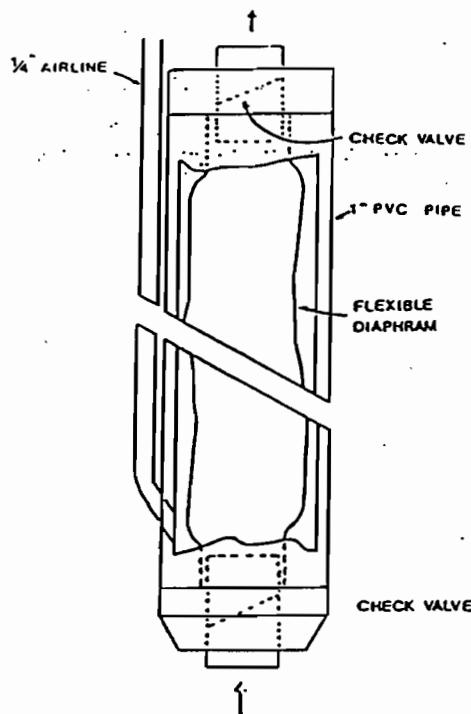
#### 6.1.2 Suction Lift Pumps:

6.1.2.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. Thus, if the surface of the water is more than about 25 ft below the pump, water may not be withdrawn. The theoretical suction limit is about 34 ft, but most suction pumps are capable of maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water through some sort of volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of common materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or even cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps are acceptable for purging of wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peristaltic pump. A peristaltic pump is a self-priming, low volume suction pump which consists of a rotor with ball bearing rollers (21). Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connected





NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton<sup>3</sup> for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or

mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

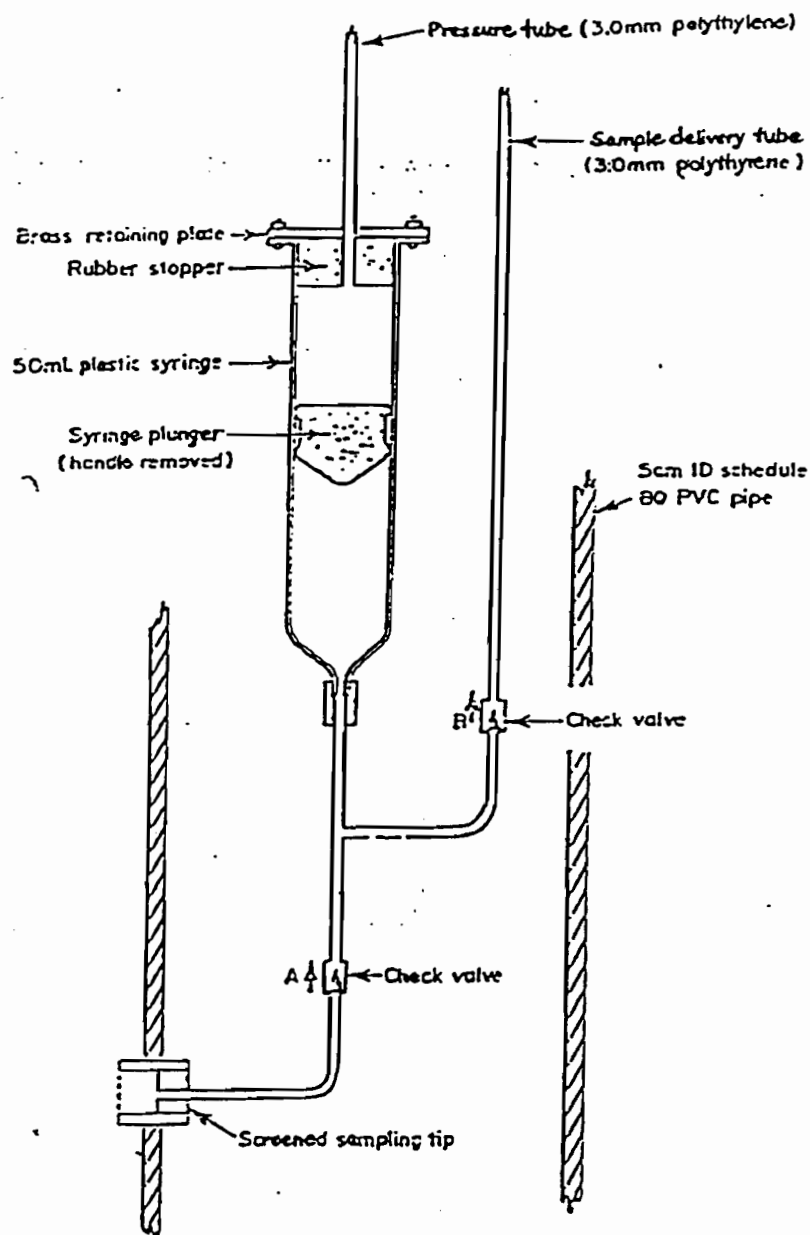
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE fluorocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

#### 6.1.3 Electric Submersible Pumps:

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

<sup>3</sup> Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (48).

FIG. 8 Positive Displacement Syringe Pump

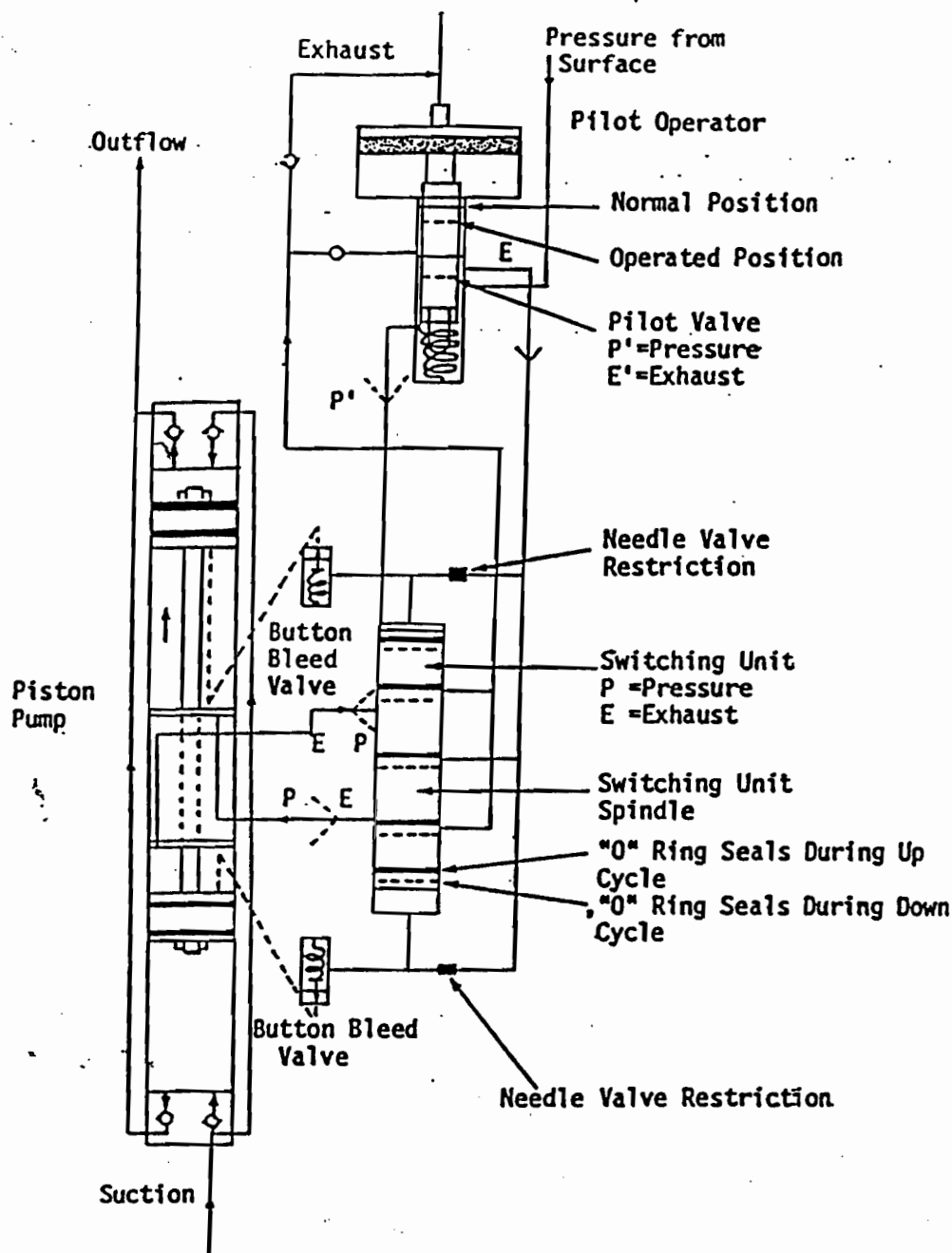
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

#### 6.1.4 Gas-Lift Pumps:

6.1.4.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water level (30, 31).

6.1.4.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (32). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (26). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.



NOTE—Taken from Ref (49).

FIG. 9 Gas Driven Piston Pump

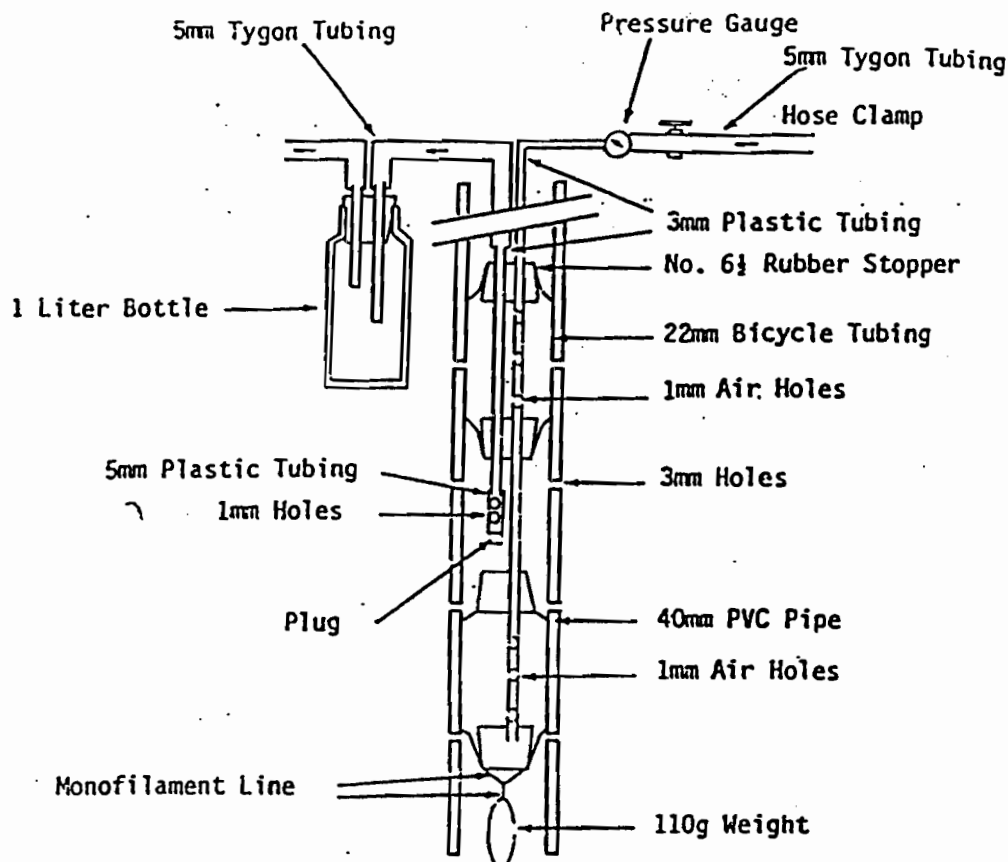
6.1.4.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, pressurized air bottles, and air compressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for volatile organics. The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb (8) uncovered difficulties in sampling for inorganics. These difficulties were attributed to changes in redox, pH,

and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

#### 6.1.5 Gas Displacement Pumps:

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig. 4. Water fills the chamber. A positive pressure is applied to the



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sampler in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sample with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

#### 6.1.6 Bladder Pumps:

6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materials are available (43, 44). Bladder materials include neoprene, rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.<sup>3</sup> A bladder made of TFE-fluorocarbon is also under development (45). Automated sampling systems have been developed to control the time between pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volumes required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.

#### 6.1.7 Gas Driven Piston Pumps:

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8 gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

#### 6.1.8 Packer Pump Arrangement:

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (48, 49, 50, 51). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (52).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

### 7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate

refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include a recording thermometer in the sample shipment to verify the maximum and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially pre-cleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (14, 53).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (13, 14, 50, 54, 55, 56). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (14). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-fluorocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days). For samples for solvent extractions (extractable organics-base neutrals, acids and

pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

NOTE—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other

parameters, the emphasis in groundwater monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 µm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include all metals, radioactivity parameters, total organic carbon, dissolved orthophosphate (if needed), and total dissolved phosphorous (if needed) (13, 14). If metals are to be analyzed, filter the sample prior to acid preservation. For TOC organics, the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well understood. However, if results of metal, TOC or other parameters that could be effected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit. All samples for organic analysis (and many other parameters), should arrive at the laboratory within one day after it is shipped and be maintained at about 4°C with wet ice. The best way to get them to the laboratory in good condition is to send them in sturdy insulated ice chests (coolers) equipped with bottle dividers. 24-h courier service is recommended, if personal delivery service is not practical.

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**SOP F201**  
**On-Site Water Quality Testing**

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**ON-SITE WATER QUALITY TESTING  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Measurement of pH
  - 5.2 Measurement of Specific Conductance/Salinity
  - 5.3 Measurement of Temperature
  - 5.4 Measurement of Dissolved Oxygen Concentration
  - 5.5 Turbidity (Secchi Disc)
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## ON-SITE WATER QUALITY TESTING (FIELD PARAMETERS)

### 1.0 PURPOSE

This SOP describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance (Sc)/Salinity
- Temperature (T)
- Dissolved Oxygen Concentration (DO)
- Turbidity (Secchi Disc)

The first three are the usual field parameters; dissolved oxygen may be used in particular applications according to project requirements.

### 2.0 SCOPE

These procedures are applicable for use in an on-site water quality monitoring program to be conducted during a Remedial Investigation or Site Investigation at a hazardous or nonhazardous site. The procedures and equipment described are applicable to nearly all aqueous samples, including potable well water, monitoring well water, surface water, leachate and drummed water, etc.

This procedure provides generic information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

### 3.0 DEFINITIONS

Conductance - A measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substances in the water. The units of measurement for conductance are the inverse of ohms, the unit commonly used to express resistance. Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only in the opposite direction due to the external source of applied voltage.

Galvanic Cell - An electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit.

Ohm - Standard unit of electrical resistance (R). A siemen or ohm is the standard unit of electrical conductance, the inverse of the ohm.

Oxidation - The process in which an atom or group of atoms loses electrons to achieve an increasing positive charge.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law,  $E = IR$ , where E is the potential difference, I is the current, and R is the resistance.

Secchi disc - A metal disc having four quadrants, two opposing ones painted black and the other two either white or unpainted. The Secchi disc is used to measure turbidity based on the depth of light penetration.

Turbidity - An optical property of water that causes light to be scattered or absorbed in the water, resulting in decrease in water transparency. It is a function of at least three variables: 1) dissolved chemicals, such as tannins, acids, or salts; 2) suspended particles, such as silt, clay, and organic matter; and, 3) density of microbial and planktonic life.

Salinity refers to the total amount of soluble salts in water, either naturally or added to the environment as pollutants.

#### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for determining which on-site water quality measurements shall be made, the data quality objectives (DQOs) for these measurements, and for ensuring that these measurements are made in accordance with project-specific plans.

Field Team Leader - The Field Team Leader is responsible for determining that these water quality measurement procedures are implemented in the field in accordance with this SOP, or in accordance with project-specific plans, and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures for collecting on-site water quality measurements including instrument calibration, quality control and recording of results, as well as care and maintenance of the instruments in the field.

#### 5.0 PROCEDURES

The following sections provide general procedures for collecting pH, specific conductance/salinity, temperature, dissolved oxygen concentration and turbidity measurements.

##### 5.1 Measurement of pH

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment, such as acid-base neutralization, water softening, and corrosion control, is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Measurements of pH also can be used to check the quality and corrosivity of soil and solid waste samples. However, these samples must be immersed in water prior to analysis; specific measurement techniques are not described here.

Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required; the pH meter is used when a more accurate measurement is needed. The response of a pH meter can be effected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In most cases, use of a pH meter will be required.

#### 5.1.1 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or alkalinity of the solution with the indicator compound on the paper. Depending on the indicator and the pH range of interest, a variety of different colors can be used. Typical indicators are weak acids or bases, or both. Process chemistry and molecular transformations leading to the color change are variable and complex.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on the establishment of a potential difference across a glass or other type of membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to hydrogen ion concentration can be generated and measured.

#### 5.1.2 Equipment

The following equipment and reagents are needed for taking pH measurements:

- Portable pH meter, or pH indicator paper, such as Mydrion or Alkacid, to cover the pH range 2 through 12.

- Laboratory-prepared buffer solutions of pH 4, 7 and 10, or other buffers which bracket the expected pH range.

### 5.1.3 Measurement Techniques for Field Determination of pH

#### 1. pH Meter

Standardization, calibration, and operation and maintenance shall be performed according to the manufacturers instructions. The following procedure is used for measuring pH with a pH meter:

- a. The batteries and instrument shall be checked and calibrated prior to initiation of the field effort.
- b. The accuracy of the buffer solutions used for field and laboratory calibration shall be checked. Buffer solutions need to be changed often due to degradation upon exposure to the atmosphere.
- c. Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.
- d. Make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
- e. Immerse the electrode(s) in a pH-7 buffer solution.
- f. Adjust the temperature compensator to the proper temperature (on models with automatic temperature adjustment, immerse the temperature probe into the buffer solution). It is best to maintain the buffer solution at or near expected sample temperature before calibration, if possible.
- g. Adjust the pH meter to read 7.0.

- h. Remove the electrode(s) from the buffer and rinse well with distilled-deionized water. Immerse the electrode(s) in pH-4 or 10 buffer solution (depending on the expected pH of the sample) and adjust the slope control to read the appropriate pH. For best results, the standardization and slope adjustments shall be repeated at least once.
- i. Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a chemical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.
- j. After adjusting the temperature compensator to the sample temperature, read and record the pH of the solution. The pH value shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature. All measurements shall be recorded in the Field Logbook.
- k. Upon completion of measurement and removal of the electrode from the sample, the electrode shall be thoroughly rinsed with deionized water.
- l. The electrode(s) shall remain immersed in deionized water when not in use.

The sample used for pH measurement shall never be saved for subsequent conductivity or chemical analysis. All pH electrodes leak small quantities of electrolytes (e.g., sodium or potassium chloride) into the solution. Precipitation of saturated electrolyte solution, especially at colder temperatures, or in cold water, may result in slow electrode response. Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted in the Field Logbook.

## 2. pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, or 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper.

### 5.2 Measurement of Specific Conductance/Salinity

Conductance provides a measure of dissolved ionic species in water and can be used to suggest the direction and extent of migration of contaminants in groundwater or surface water. Salinity refers to the total amount of soluble salts in water, either naturally or added to the environment as pollutants. One basic measure of salinity is the ability of water to conduct electric current, and, therefore, a measurement of specific conductance provides a measurement of salinity and the same instrument can be used. Salinity measurements are important in ecological field investigations because flora and fauna can be limited in their distribution based on the salinity of the sampled waters.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

It is important to obtain a specific conductance and salinity measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

#### 5.2.1 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, while the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases and salts (such as



hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell also may be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

#### 5.2.2 Equipment

A portable conductivity meter, probe and thermometer are needed for taking specific conductance and salinity measurements.

A variety of conductivity meters are available which also may be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment may be obtained to meet the specific requirements of the sampling program.

#### 5.2.3 Measurement Techniques for Specific Conductance/Salinity

Standardization, calibration, and operation and maintenance shall be performed according to manufacturers instructions. The steps involved in taking specific conductance and salinity measurements are listed below.

- Check batteries and calibrate instrument before going into the field.
- Calibrate the instrument daily when used. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.

- Immerse the electrode in the sample and measure the conductivity and salinity. If specified, adjust the temperature setting to the sample temperature.
- Read and record the results on the Calibration Form (in the absence of the Calibration Form, the Field Logbook will be used).
- If the meter does not compensate for temperature variations, the corrections given in Attachment A shall be applied.
- On some meters, specific conductivity and salinity measurements may need to be reported with the associated temperature measurement. If the conductivity and salinity has been corrected, the measurements shall be reported as "corrected to 25°C." (See Attachment A)

### 5.3 Measurement of Temperature

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field prior to sample collection. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

#### 5.3.1 Equipment

Temperature measurements may be taken with Thermistor, alcohol-toluene, mercury or bimetal thermometers. In addition, various meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature can be performed.

### 5.3.2 Measurement Techniques for Water Temperature

If a thermometer is used on a collected water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a Field Logbook to the nearest 0.5 or 0.1°C, depending on the measurement device used.

If a temperature meter or probe is to be used, the instrument shall be calibrated according to the manufacturer's recommendations with an approved thermometer.

### 5.4 Measurement of Dissolved Oxygen Concentration

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms, as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time, if the sample is not adequately preserved.

The method discussed here is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are suitable for highly polluted waters, because the probe is completely submersible. DO meters also are free from interference caused by color, turbidity, colloidal material or suspended matter.

#### 5.4.1 Principles of Equipment Operation

Dissolved oxygen probes normally are electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of higher nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH) occurs at the cathode surface. An electrical current is developed directly proportional to the rate of arrival of oxygen molecules at the cathode.

Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, but to leave the surface of the solution undisturbed.

Dissolved oxygen probes are relatively free of interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide which are not easily depolarized from the indicating electrode. If gaseous interference is suspected, it shall be noted in the Field Logbook and checked if possible. Temperature variations also can cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation normally is provided by the manufacturer. Attachment B presents variations of DO in water as a function of temperature and salinity.

#### 5.4.2 Equipment

The following, similar or equivalent, equipment is needed to measure dissolved oxygen concentration:

- YSI Model 56 dissolved oxygen monitor.
- Dissolved oxygen/temperature probe.
- Sufficient cable to allow the probe to contact the sample.

#### 5.4.3 Measurement Techniques for Dissolved Oxygen Determination

Probes differ as to specifics of use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure the dissolved oxygen concentration.

- Calibrate equipment and check batteries in the laboratory before going to the field.
- The probe shall be conditioned in a water sample for as long as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
- The instrument shall be calibrated in the field before each measurement or group of closely spaced measurements by placing the probe in a water sample of known dissolved oxygen concentration (i.e., determined by Winkler method) or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment B).
- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane, either by stirring the sample, or placing the probe in a flowing stream. Probes without stirrers which are placed in wells should be moved up and down.
- Record the dissolved oxygen content and temperature of the sample in a Field Logbook.
- Recalibrate the probe when the membrane is replaced, or following similar maintenance, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable, since sample handling is not involved. This, however, may not always be practical. Be sure to record whether the liquid was analyzed in-situ, or whether a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen solubilization and positive test interferences.

#### 5.5 Measurement of Turbidity Using a Secchi Disc

In combination with other parameters, turbidity can be a useful indicator of the likelihood of biological action in a water body. It can be used to determine the depth of light penetration of surface water and the distribution and intensity of photosynthesis in the body of water. Turbidity measurements shall be taken in-situ with a Secchi disc.

##### 5.5.1 Equipment

Turbidity measurements may be taken with a Secchi disc. In addition, turbidity may be measured using a colimeter or a spectrophotometer. These are ex-situ measurements conducted in a laboratory environment.

##### 5.5.2 Measurement Techniques for Turbidity

Observations must be made through a shaded area of water surface.

- Standard conditions for the use of the Secchi disc are: 1) clear sky; (2) sun directly overhead; 3) shaded, protected side of boat or under a sun shade; 4) minimal waves or ripples; and, 5) any departure from these conditions should be specifically stated on field sheets.
- Rope accurately graduated in meters with 0.1 meter graduations for the first meter and 0.5 meters thereafter.
- Observer's eye should be 1 meter above the surface of the water.
- Observations should be made during the middle of the day.
- Lower the disc into the water, noting the depth at which it disappears, then lift the disc and note the depth at which it reappears. The average of the two readings is

considered to be the limit of visibility and is recorded in a Field Logbook to the nearest 0.1 meter (first meter) or 0.5 meter, depending on the depth of visibility.

## 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records for on-site water quality management consists principally of observations and measurements recorded in the Field Logbook. Records of instrument calibration, malfunction, repair, etc., shall be maintained in an Equipment Logbook as described in the Navy CLEAN Contractor Quality Control Plan.

## 7.0 REFERENCES

American Public Health Association, 1980. Standard Methods for the Examination of Water and Wastewater, 15th Edition, APHA, Washington, D.C.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020.

U.S. Geological Survey, 1984. National Handbook of Recommended Methods for Water Data Acquisition, Chapter 5: Chemical and Physical Quality of Water and Sediment. U.S. Department of the Interior, Reston, Virginia.

**ATTACHMENT A**

**SPECIFIC CONDUCTANCE TEMPERATURE COMPENSATION**



## ATTACHMENT A

### SPECIFIC CONDUCTANCE TEMPERATURE COMPENSATION

| <u>Temperature (°C)</u> | <u>Multiplier*</u> | <u>Temperature (°C)</u> | <u>Multiplier*</u> |
|-------------------------|--------------------|-------------------------|--------------------|
| 5.0                     | 1.571              | 18.0                    | 1.147              |
| 5.5                     | 1.553              | 18.5                    | 1.133              |
| 6.0                     | 1.536              | 19.0                    | 1.121              |
| 6.5                     | 1.518              | 19.5                    | 1.110              |
| 7.0                     | 1.500              | 20.0                    | 1.100              |
| 7.5                     | 1.485              | 20.5                    | 1.088              |
| 8.0                     | 1.470              | 21.0                    | 1.077              |
| 8.5                     | 1.452              | 21.5                    | 1.067              |
| 9.0                     | 1.433              | 22.0                    | 1.058              |
| 9.5                     | 1.415              | 22.5                    | 1.048              |
| 10.0                    | 1.395              | 23.0                    | 1.038              |
| 10.5                    | 1.377              | 23.5                    | 1.029              |
| 11.0                    | 1.357              | 24.0                    | 1.019              |
| 11.5                    | 1.339              | 24.5                    | 1.010              |
| 12.0                    | 1.318              | 25.0                    | 1.000              |
| 12.5                    | 1.302              | 25.5                    | 0.990              |
| 13.0                    | 1.283              | 26.0                    | 0.980              |
| 13.5                    | 1.268              | 26.5                    | 0.970              |
| 14.0                    | 1.252              | 27.0                    | 0.960              |
| 14.5                    | 1.237              | 27.5                    | 0.950              |
| 15.0                    | 1.223              | 28.0                    | 0.940              |
| 15.5                    | 1.210              | 28.5                    | 0.930              |
| 16.0                    | 1.198              | 29.0                    | 0.920              |
| 16.5                    | 1.187              | 29.5                    | 0.910              |
| 17.0                    | 1.171              | 30.0                    | 0.900              |
| 17.5                    | 1.159              |                         |                    |

\* The multiplier corrects the specific conductivity reading from a given temperature to 25°C.

**ATTACHMENT B**

**VARIATION OF DISSOLVED OXYGEN CONCENTRATION  
IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY**

# ATTACHMENT B

## VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY

| Temperature<br>°C | Dissolved Oxygen mg/l           |       |        |        |        |                                |
|-------------------|---------------------------------|-------|--------|--------|--------|--------------------------------|
|                   | Chloride Concentration in Water |       |        |        |        | Difference/<br>100 mg chloride |
|                   | 0                               | 5,000 | 10,000 | 15,000 | 20,000 |                                |
| 0                 | 14.6                            | 13.8  | 13.0   | 12.1   | 11.3   | 0.017                          |
| 1                 | 14.2                            | 13.4  | 12.6   | 11.8   | 11.0   | 0.106                          |
| 2                 | 13.8                            | 13.1  | 12.3   | 11.5   | 10.8   | 0.015                          |
| 3                 | 13.5                            | 12.7  | 12.0   | 11.2   | 10.5   | 0.015                          |
| 4                 | 13.1                            | 12.4  | 11.7   | 11.0   | 10.3   | 0.014                          |
| 5                 | 12.8                            | 12.1  | 11.4   | 10.7   | 10.0   | 0.014                          |
| 6                 | 12.5                            | 11.8  | 11.1   | 10.5   | 9.8    | 0.014                          |
| 7                 | 12.2                            | 11.5  | 10.9   | 10.2   | 9.6    | 0.013                          |
| 8                 | 11.9                            | 11.2  | 10.6   | 10.0   | 9.4    | 0.013                          |
| 9                 | 11.6                            | 11.0  | 10.4   | 9.8    | 9.2    | 0.012                          |
| 10                | 11.3                            | 10.7  | 10.1   | 9.6    | 9.0    | 0.012                          |
| 11                | 11.1                            | 10.5  | 9.9    | 9.4    | 8.8    | 0.011                          |
| 12                | 10.8                            | 10.3  | 9.7    | 9.2    | 8.6    | 0.011                          |
| 13                | 10.6                            | 10.1  | 9.5    | 9.0    | 8.5    | 0.011                          |
| 14                | 10.4                            | 9.9   | 9.3    | 8.8    | 8.3    | 0.010                          |
| 15                | 10.2                            | 9.7   | 9.1    | 8.6    | 8.1    | 0.010                          |
| 16                | 10.0                            | 9.5   | 9.0    | 8.5    | 8.0    | 0.010                          |
| 17                | 9.7                             | 9.3   | 8.8    | 8.3    | 7.8    | 0.010                          |
| 18                | 9.5                             | 9.1   | 8.6    | 8.2    | 7.7    | 0.009                          |
| 19                | 9.4                             | 8.9   | 8.5    | 8.0    | 7.6    | 0.009                          |
| 20                | 9.2                             | 8.7   | 8.3    | 7.9    | 7.4    | 0.009                          |
| 21                | 9.0                             | 8.6   | 8.1    | 7.7    | 7.3    | 0.009                          |
| 22                | 8.8                             | 8.4   | 8.0    | 7.6    | 7.1    | 0.008                          |
| 23                | 8.7                             | 8.3   | 7.9    | 7.4    | 7.0    | 0.008                          |
| 24                | 8.5                             | 8.1   | 7.7    | 7.3    | 6.9    | 0.008                          |
| 25                | 8.4                             | 8.0   | 7.6    | 7.2    | 6.7    | 0.008                          |

**ATTACHMENT B**  
**(Continued)**  
**VARIATION OF DISSOLVED OXYGEN CONCENTRATION**  
**IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY**

| Temperature<br>°C | Dissolved Oxygen mg/l           |       |        |        |        |                                |
|-------------------|---------------------------------|-------|--------|--------|--------|--------------------------------|
|                   | Chloride Concentration in Water |       |        |        |        | Difference/<br>100 mg chloride |
|                   | 0                               | 5,000 | 10,000 | 15,000 | 20,000 |                                |
| 26                | 8.2                             | 7.8   | 7.4    | 7.0    | 6.6    | 0.008                          |
| 27                | 8.1                             | 7.7   | 7.3    | 6.9    | 6.5    | 0.008                          |
| 28                | 7.9                             | 7.5   | 7.1    | 6.8    | 6.4    | 0.008                          |
| 29                | 7.8                             | 7.4   | 7.0    | 6.6    | 6.3    | 0.008                          |
| 30                | 7.6                             | 7.3   | 6.9    | 6.5    | 6.1    | 0.008                          |

**Note:** In a chloride solution, conductivity can be roughly related to chloride concentration (and therefore used to correct measured D.O. concentration) using Attachment A.

**SOP F202**

**Water Level, Water-Product Level Measurements,  
and Well Depth Measurements**

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**WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND  
WELL DEPTH MEASUREMENTS  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Water Level Measurement
  - 5.2 Groundwater-Product Level Measurement
  - 5.3 Well Depth Measurements
  - 5.4 Decontamination of Measuring Devices
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## **WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS**

### **1.0 PURPOSE**

The purpose of this procedure is to describe the method of determining groundwater levels and product levels, if present, in groundwater monitoring wells and piezometers. This procedure also describes determining the depth of a well.

### **2.0 SCOPE**

The methods described in this SOP generally are applicable to the measurement of water levels, product levels, and well depths in monitoring wells and piezometers.

### **3.0 DEFINITIONS**

None.

### **4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed.

**Field Team Leader** - The Field Team Leader is responsible for ensuring that these procedures are implemented in the field, and for ensuring that personnel performing these activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the sampling personnel to follow these procedures or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of water level, water product level, and well depth measurements.

## 5.0 PROCEDURES

Calculations on water level and water-product level measurements collected from a monitoring well give an indication of:

- The horizontal hydraulic gradient (i.e., the direction of groundwater flow and the potential rate of movement [magnitude] in the horizontal plane).
- The vertical hydraulic gradient, if well nests are used (i.e., the direction of groundwater flow and the potential rate of movement in the vertical plane).
- Product thicknesses (either floating or sinking product).

This information, when combined with other site specific information such as hydraulic conductivity or transmissivity, extent of contamination, and product density, may be used to estimate contaminant movement or source areas, etc.

Well depth is one of the factors used to determine the zone that a well monitors. Well depth also is used in the calculation of purge volumes as discussed in SOP F104, Groundwater Sample Acquisition.

The following sections briefly discuss the procedures for measuring water levels, product levels, and well depth. For all of the procedures discussed, it is assumed that the measurement will be taken from the top of the PVC or stainless steel casing, and that horizontal and vertical control is available for each well through a site survey, such that measurements may be converted to elevations above Mean Sea Level (MSL) or some other consistent datum.

### 5.1 Water Level Measurement

Water levels in groundwater monitoring wells shall be measured from the top of the protective steel casing, unless otherwise specified in the project plans, using an electronic water level measuring device (water level indicator). Water levels are measured by lowering the probe into the well until the device indicates that water has been encountered, usually with either a constant buzz, or a light, or both. The location of the electric cord/tape against the measuring point on the top of the PVC or stainless steel casing is marked for surveys. The water level is recorded to the nearest foot (rounding down) using the graduated markings on the water level indicator cord. The water level then is measured off the cord/tape to the nearest 0.01 foot



using an engineers scale. The measurements are combined (feet plus hundredths of a foot) to yield a measurement of the depth to water below the top of the PVC or stainless steel casing. This measurement, when subtracted from the measuring point elevation, yields the water level elevation.

Groundwater levels shall always be measured to the nearest 0.01 foot. However, reporting of water level elevations depends on the accuracy of the vertical control (typically either 0.1 or 0.01 foot).

## 5.2 Groundwater-Product Level Measurements

The procedure for groundwater product level measurement is nearly identical to that for water level measurements. The only differences are the use of an interface probe that detects both product and water, and the indication signal given by the measurement device. Typically, encountering product in a monitoring well is indicated by a constant sound. When water is encountered, the signal becomes an alternating on/off beeping sound. This allows for the collection of measurements for both the top of the product layer in a well and the water/product interface.

The apparent water table elevation below the product level will be determined by subtracting the "depth to water" from the measuring point elevation. The corrected water table elevation will then be calculated using the following equation:

$$WTE_c = WTE_a + (\text{Free Product Thickness} \times 0.80)$$

Where:

- $WTE_c$  = Corrected water table elevation
- $WTE_a$  = Apparent water table elevation
- 0.80 = Average value for the density of petroleum hydrocarbons. Site-specific data will be used where available.

## 5.3 Well Depth Measurements

Well depths typically are measured using a weighted measuring tape. The tape is lowered down the well until resistance is no longer felt, indicating that the weight has touched the bottom of the well. The weight should be moved in an up and down motion a few times so that

obstructions, if present, may be bypassed. The slack in the tape then is collected until the tape is taut. The well depth measurement is read directly off of the measuring tape, at the top of the PVC or stainless steel casing, to the nearest 0.01-foot and recorded in the Field Logbook.

#### 5.4 Decontamination of Measuring Devices

Water level indicators, interface probes and weighted measuring tapes that come in contact with groundwater must be decontaminated using the following steps after use in each well:

- Rinse with potable water
- Rinse with deionized water
- Rinse with:
  - Methanol or acetone (EPA Region I)
  - Methanol or acetone (EPA Region II)
  - Methanol (EPA Region III)
  - Isopropanol (EPA Region IV)
- Rinse with deionized water

Portions of the water level indicators or other similar equipment that do not come into contact with groundwater, but may encounter incidental contact during use, need only undergo potable water and deionized water rinses.

#### 6.0 QUALITY ASSURANCE RECORDS

The Field Logbook shall serve as the quality assurance record for water, product level or well depth measurements.

#### 7.0 REFERENCE

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

**SOP F203**  
**Photoionization Detector (PID)**

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**PHOTOIONIZATION DETECTOR (PID)  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Calibration**
  - 5.2 Operation**
  - 5.3 Interferences and Potential Problems**
  - 5.4 Maintenance**
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## PHOTOIONIZATION DETECTOR (PID) HNu MODEL PI 101 and DL 101

### 1.0 PURPOSE

The purpose of this SOP is to provide general reference information for using the HNu Model PI 101 or DL 101 photoionization detector (PID), or an equivalent or similar instrument, in the field. Calibration and operation, along with field maintenance will be included in this SOP.

### 2.0 SCOPE

This procedure provides information on the field operation and general maintenance of the HNu (PID). Application of the information contained herein will ensure that this type of field monitoring equipment will be used properly. Review of the manufacturer's instruction manual is necessary for more complete information.

These procedures refer only to monitoring for health and safety. The methods are not directly applicable to surveillance of air quality for analytical purposes.

### 3.0 DEFINITIONS

Ionization Potential - In this case, a numeric equivalent that expresses the amount of energy needed to replace an electron with a photon. This energy is further defined in terms of electron volts (eV).

PID - Photoionization Detector

ppm - parts per million: parts of vapor or gas per million parts of air (directly proportional to calibration gas).

### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures

are developed. The Project Manager is responsible for selecting qualified individuals for the monitoring activities.

Project Health and Safety Officer (PHSO) - The Project Health and Safety Officer is responsible for developing a site-specific Health and Safety Plan (HASP) which specifies air monitoring requirements.

Field Team Leader - It is the responsibility of the Field Team Leader to implement these procedures in the field, and to ensure that the Field Investigation Personnel performing air monitoring activities, have been briefed and trained to execute these procedures before the start of site operations.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the specified air monitoring equipment is on site, calibrated, and used correctly by the Field Personnel. The SHSO will coordinate these activities with the Field Team Leader.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader/Site Health and Safety Officer. The Field Investigation Personnel are responsible for documenting all air monitoring results in both the Field Logbook and the daily Realtime Air Monitoring Log during each field investigation.

## 5.0 PROCEDURES

The HNu utilizes the principle of photoionization whereby contaminant molecules enter the ion chamber and electrons are displaced by ultraviolet photons producing positive ions. These displaced positive ions are in turn collected on a special electrode. As the positive ions collect on the electrode, they create an electrical current which is amplified and displayed on the meter as a concentration in parts per million (ppm).

The HNu is only effective for contaminants that have ionization potentials (IP) of less than or equal to the electron volt (eV) capacity of the lamp (i.e., methane, having an IP of 12.98 eV, will not be detected at a lamp potential of 11.7 eV). The standard lamp is 10.2 eV with optional lamps of 9.5 eV and 11.7 eV, respectively. For the PI 101 the span settings should be as

follows: 1.0 for 9.5 eV lamps; 9.8 for 10.2 eV lamps; and 5.0 for 11.7 eV lamps. During calibration, these span settings will be adjusted as necessary, using the span control knob.

The following subsections will discuss HNu calibration, operation, and maintenance. These sections, however, should not be used as a substitute for the manufacturer's instruction manual.

## 5.1 Calibration

For calibration purposes, the following items will be needed:

- \*Gas cylinder containing 95 to 100 parts per million (ppm) of isobutylene, balance in air.
- A 0.30 liters per minute regulator.
- Connector tubing.
- Screwdriver set.
- Calibration Gas Humidifier (for high humidity environments).
- Photoionization Detector (PID) Calibration Form.

\*Note: Do not rely on accuracy of rated cylinder concentration when content drops to <200 psi.

Prior to each use, make sure that the battery is fully charged, the ultraviolet lamp is working, and that the fan is operating and drawing air into the probe (fan operates at approximately 100-200 cc/minute for the PI 101 and 225 cc/minute for the DL 101). Procedures for completing these preliminary activities are given in the manufacturer's instruction manual.

### PI 101

To calibrate the HNu PI 101, the steps provided below should be followed. For an itemized description of the calibration process, refer to Section 3-5 in the manufacturer's instruction manual.

- Turn the function control switch to the standby position and zero the instrument by turning the zero adjustment knob to align the indicator needle with zero on the readout meter.
- Set the range on the HNu and allow the instrument to warm up a few minutes before calibrating. Choices for range are 0-20, 0-200, and 0-2,000 ppm, respectively. Range choice must take into account the concentration of the calibration gas. If you have to zero the instrument in the desired range, record background if present.

- Calibrate the HNu PID to benzene equivalents using a concentration of 100 ppm isobutylene as the calibration gas. For example, if you are using the 10.2 eV probe, your range should be set on the 0-200 scale, and calibrated to 55 ppm (i.e., adjust span so that the instrument reads 55 units with 100 ppm isobutylene connected). Using the 11.7 eV probe the PID should read 65 units with 100 ppm of isobutylene.
- Attach tubing to the regulator (use the Calibration Gas Humidifier in high humidity environments).
- Attach the free end of the tubing to the probe and turn on the calibration gas.
- If the reading on the meter is not  $\pm 5$  percent of the concentration of the calibration gas, adjust the span setting knob until the meter reads accordingly. If after adjusting the span setting knob the readout meter is still not responding, refer to the manufacturer's instruction manual. Also, when the HNu is calibrated it should respond to a minimum of 90 percent of the concentration of the calibration gas within three seconds after introduction of that gas. If proper calibration cannot be obtained, internal calibration may be required. Note, only qualified personnel should perform internal calibrations.
- Record the calibration on the "Photoionization Detector (PID) Calibration Form".

#### DL 101

To calibrate the HNu DL 101, the steps provided below should be followed. For an itemized description of the calibration process, refer to Section 4.4 in the manufacturer's instruction manual.

- Press and release the POWER button on the keypad and wait for the screen to stabilize then press the CALIBRATE key until "Calibrate?" appears. At this point press the ENTER key until "Elec\_Zero? Yes" appears on the screen in which case you will press the ENTER key, again, to confirm the electronic zero.
- The display will now read "CE/ENT/EXIT Conc = \_\_\_\_ ppm" which requires the concentration of the calibration gas (noted on the side of the calibration gas bottle) to be entered on the keypad. The display will prompt you to "Attach gas to probe and /ENTER/" so attach tubing to probe (use the calibration gas humidifier in high humidity environments), open valve, and press ENTER key. Press ENTER again when "Press ENTER when Ready: xxx ppm" appears on screen. This will cause "Calibrating...Please Wait" to appear on screen.

Note: This calibration is effective when the instrument is in the Survey Mode, which is the default mode. For calibrations other the one described, or if proper calibration cannot be obtained, refer to the manufacturer's instruction manual.



- For calibrations using an alternate gas or span values, refer to Section 4.5 of the manufacturer's instruction manual.
- Record the calibration on the "Photoionization Detector (PID) Calibration Form" which accompanies each HNu.

## 5.2 Operation

### PI 101

Note: IMPORTANT - The HNu should be "zeroed" in a fresh air environment if at all possible. If there is a background concentration, it must be documented and then zeroed out.

- Prior to each use of the HNu, check that the battery is fully charged by turning the dial to BATT and making sure that it is within range. Also make sure that the ultraviolet lamp and the fan are working properly.
- Select your desired range. HNu ranges consists of a 0-20, 0-200, and 0-2,000 ppm, respectively. Consult with the Field Team Leader for more information when choosing the appropriate range, however, in most instances the range will be set initially at 0-20.
- When HNu is used intermittently, turn knob to STANDBY to help in extending the life of the UV lamp when operating in a low humidity environment. Otherwise, leave the knob set to the range desired so that the UV lamp will "burn off" any accumulated moisture.

Note: When using the PI 101 HNu, make sure that the probe does not contact water or soil during sampling. This will cause erroneous readings and will possibly damage the instrument.

### DL 101

The DL 101 is designed to default to the survey mode when initially powered up, therefore once the calibration has been completed, the instrument is ready to go. Within the survey mode several options are available, briefly these options include:

- (1) The Site Function

The Site function assigns a number to a site that is being analyzed. Press the Site Key on the keypad to enter a specific site number, or press the gray button on the rear of the probe to increment a site number.

## (2) Logging Data

The Log function stores data in memory. To log data, press the Log key on the keypad or the Log button on the back of the probe. "Log" will appear in the upper right corner of the display when activated and disappears when not activated. To turn logging off, press either the Log key on the keypad or the red Log button on the rear of the probe.

- The DL 101 allows for the interchanging of different voltage lamps, however, refer to the manufacturer's instructions before attempting to change the lamp.
- The DL 101 also offers three other modes of operation, the Hazardous Waste Mode, the Industrial Hygiene Mode, and the Leak Detection Mode. Each of these modes increases the range of capabilities for this instrument which is covered in detail in the manufacturer's instruction manual.

Note: When using the DL 101 HNu, make sure that the probe does not contact water or soil during sampling. This will cause erroneous readings and will possibly damage the instrument.

## 5.3 Interferences and Potential Problems

A number of factors can affect the response of the PI 101 HNu and DL 101 HNu.

- High humidity can cause lamp fogging and decreased sensitivity. This can be significant when soil moisture levels are high, or when monitoring a soil gas well that is accessible to groundwater.
- High concentrations of methane can cause a downscale deflection of the meter.
- High and low temperature, electrical fields, FM radio transmission, and naturally occurring compounds, such as terpenes in wooded areas, will also affect instrument response.

## 5.4 Maintenance

The best way to keep an HNu operating properly is to keep it as clean as possible. HNu's should be decontaminated and wiped down after each use.

#### Corrective Maintenance

- The ultraviolet lamp should be periodically cleaned using a special compound supplied by HNu Systems, Inc. for the 10.2 eV lamp, and a chlorinated solvent such as 1,1,1-trichloroethane for the 11.7eV lamp. Consult the manufacturer's instruction manual for specific cleaning instructions.
- The ionization chamber can be periodically cleaned with methyl alcohol and a swab.

Note: UV lamp and ion chamber cleaning is accomplished by following the procedures outlined in Section 5.2, however, this should only be performed by trained personnel.

- Documenting the HNu's observed symptoms and then referring to the manufacturer's instruction manual section on troubleshooting (Section 6.0) also can be employed. If this does not work, the Field Team Leader should be consulted for an appropriate course of action.

Repair and Warranty Repair - HNu's have different warranties for different parts, so documenting the problem and sending it into the manufacturer assists in expediting repair time and obtaining appropriate warranty service.

#### 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the Field Logbook.

- Identification - Site name, location, CTO number, activity monitored, (surface water sampling, soil sampling, etc.) serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the HNu meter had wide range fluctuations during air monitoring activities).

## **7.0 REFERENCES**

HNu Systems, Inc. Instruction Manual. Model PI 101, 1986.

HNu Systems, Inc. Operator's Manual. Model DL 101, 1991.

**SOP F204**  
**Flame Ionization Detector (FID)**

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**FLAME IONIZATION DETECTOR (FID)  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Calibration
  - 5.2 Operation
  - 5.3 Maintenance
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

## FLAME IONIZATION DETECTOR (FID) FOXBORO OVA 128

### 1.0 PURPOSE

The purpose of this procedure is to provide general reference information for using the Foxboro OVA 128, Flame Ionization Detector (FID) or an equivalent or substitute device, in the field. Calibration, operation, and field maintenance will be included in this SOP.

### 2.0 SCOPE

This procedure provides information on the field operation and general maintenance of the Foxboro OVA 128 (FID). Application of the information contained herein will ensure that this type of field monitoring equipment will be properly operated. Review of the manufacturer's operating manual is a necessity for more detailed descriptions and operating information.

These procedures refer only to monitoring for health and safety. The methods are not directly applicable to surveillance of air quality for analytical purposes.

### 3.0 DEFINITIONS

FID - Flame Ionization Detector

ppm - parts per million: parts of vapor or gas per million parts of air (directly proportional to calibration gas).

### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures where applicable, or that other approved procedures are developed. The Project Manager is responsible for selecting qualified individuals for the monitoring activities.

Project Health and Safety Officer (PHSO) - The Project Health and Safety Officer is responsible for developing a site-specific Health and Safety Plan (HASP) which specifies air monitoring requirements.

Field Team Leader - It is the responsibility of the Field Team Leader to implement these procedures in the field, and to ensure that the Field Investigation Personnel performing air monitoring activities have been briefed and trained to execute these procedures before the start of site operations.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the specified air monitoring equipment is on site, calibrated, and used correctly by the Field Personnel. The SHSO will coordinate these activities with the Field Team Leader.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader/Site Health and Safety Officer.. The Field Investigation Personnel are responsible for documenting all air monitoring results in both the Field Logbook during each field investigation.

## 5.0 PROCEDURES

The OVA 128 utilizes the principle of flame ionization whereby contaminant molecules enter the detector chamber and are exposed to a hydrogen flame which ionizes the organic vapors. As the vapors are burned they leave positively-charged carbon-containing ions. These positive ions are driven by an electric field to a collecting electrode. As the positive ions collect on the electrode, a current is created. This current corresponds to the collection rate of the positive ions. The current is then measured with a linear electrometer preamplifier which produces a signal proportional to the ionization current. This signal is then amplified by a signal conditioning amplifier and sent to the readout assembly and the strip chart recorder (when attached) in parts per million (ppm). The FID responds to virtually all organic compounds, that is, compounds that contain carbon-hydrogen or carbon-carbon bonds. The OVA can operate in two modes:

Survey Mode: During normal survey mode operation, a sample is drawn into the probe and transmitted to the detector chamber by an internal pumping system. When the sample



reaches the FID it is ionized as described above and the resulting signal is translated to the meter as a direct reading concentration for total organic vapors; or recorded as a quantifiable peak on a strip chart. The meter display is an integral part of the probe/readout assembly and has a scale graduation from 0-10 which can be set to read 0-10, 0-100, or 0-1000 ppm on the x1, x10, or x100 scales, respectively.

Gas Chromatography Mode: Gas Chromatography (GC) is a technique for separating components of a sample and qualitatively and quantitatively identifying them. The sample to be separated is injected into a column packed with an inert solid. As the carrier gas (hydrogen) forces the sample through the column, the separated components of the sample are retained on the column for different periods of time. This is possible when using the OVA128 GC Model. Only qualified personnel are permitted to use this model.

The OVA 128 is an intrinsically safe organic vapor monitor, but it cannot be used in atmospheres that are oxygen deficient and it is unable to detect inorganic compounds, including poisonous atmospheres.

Caution must be used when filling the hydrogen tank to maintain safe operating pressures and temperatures. Only prepurified or zero grade hydrogen will be used.

The following subsections will discuss calibration, operation and maintenance of the OVA 128. These sections, however, should not be used as a substitute for the manufacturer's operating manual.

## 5.1 Calibration

Primary calibration involves internal adjustments and should only be done by the manufacturer or an authorized equipment technician.

The following items will be needed for secondary calibration of the OVA 128:

- Calibration gas (usually methane but can be contaminant specific).
- Gas regulator.
- Tedlar bag (usually two to three liter capacity).

- Tubing.
- Screw driver set.
- Flame Ionization Detector (FID) Calibration Form.

Prior to each use, make sure that the battery is fully charged (a minimum of 7.5 on the x1 scale), the pump is working, there is a sufficient supply of hydrogen gas in the tank (approximately 150-200 psi per hour of usage), and the igniter is working (refer to operating manual). After moving the PUMP switch to the ON position, then place the instrument panel in the vertical position and check the sample flow rate indicator. The normal range is 1.5 to 2.0 units. If less, filters may need to be changed, or the battery may need further charging or replacement.

Points to follow for "Single Sample Calibration:"

- For methane calibration in the 90 to 100 ppm range, set scale to x10 and gas select control to 300.
- Use calibration adjustment knob to "zero" the meter.
- Introduce methane sample of known concentration from Tedlar Bag and adjust gas select knob so that meter reading equals sample concentration. Withdraw methane sample, allow meter reading to stabilize and repeat. Discontinue calibration when meter reaction to sample introduction is consistent.
- If there is a problem with calibration, consult the manufacturer's operating manual or an experienced technician.
- Refer to manufacturer's operating manual for additional information.

Since the Foxboro OVA 128 uses flame ionization, it has a broad application in terms of which organic contaminants it can ionize. Care must be taken to document background readings before zeroing the instruments. Note: the OVA 128 hydrogen flame ionization detector is more sensitive to hydrocarbons than any other class of organic compounds.

## 5.2 Operation

Review of the Startup Procedure Chapter of the manufacturer's operating manual (page 7), is critical prior to actual field operation.

Points to follow for startup of the OVA 128:

- After the OVA is assembled check that the battery level is sufficient for operation. At a minimum, a reading of 7.5 on the x1 scale should provide four hours of operation.
- Turn instrument switch on and allow a minimum of a five minute warmup before turning pump on.
- Turn the pump switch on.
- Ensure that an air-tight seal exists from the probe back to the instrument by placing your thumb over the end of the probe. Cover the probe long enough to shut the pump down (approximately 5-10 seconds). If the pump does not shut down, check all fittings and connections from the probe assembly back to the instrument. An air-tight seal is very important for obtaining an accurate reading. Readings obtained without an air-tight seal are diluted and not indicative of contaminants present.
- Use calibrate adjust knob to set meter to predetermined level for activating audible alarm (if desired).
- Set to x1 scale and adjust meter reading to zero.
- Open hydrogen tank valve to be certain that there is enough hydrogen in the tank for operation approximately 1.5 to 2 full turns. The OVA will use approximately 150 psi/hour. Then open the hydrogen supply valve approximately 1.5 to 2 full turns noting that the reading should be within the range of 8 to 12 psi.

Note: Use the hydrogen filling hose supplied by the manufacturer, and hydrogen tank with a rated pressure that does not exceed the capacity of the fill line.

- After approximately one minute depress the igniter button until the hydrogen has been ignited (needle on readout assembly should deflect to full-scale). **DO NOT HOLD THE IGNITER BUTTON IN FOR MORE THAN FIVE SECONDS.** If hydrogen does not light, wait two minutes and try again. If it still does not light, consult manufacturer's operating manual.

Note: Hydrogen gas will not ignite if battery is too low.

- The instrument is now ready for calibration, if required.

Once the Foxboro OVA 128 has been running and stabilized for 15 minutes, it is ready for "Survey Mode" procedures. Set the calibrate switch to the desired range and the Foxboro OVA 128 is now ready for field operation.

Note: Care must be taken when operating the Foxboro OVA 128. Special areas of concern are the probe assembly and the analyzer. Do not stick the probe in water or soil; this will give erroneous readings and could possibly damage the pump. The analyzer unit must be kept clean and away from physical hazards, and the exhaust free from obstructions.

For shutdown and refueling, follow manufacturer's recommend procedures.

### 5.3 Maintenance

Preventive maintenance consists of keeping the Foxboro OVA 128 as clean as possible. The Foxboro OVA 128 must be decontaminated and wiped down with a damp cloth after each use.

The other type of maintenance is the manufacturer's scheduled maintenance which consists of the following:

- Check particle filters on a monthly basis.
- Check quad rings on a monthly basis or as needed.
- Clean burner chamber on a quarterly basis or as needed.
- Primary calibration and factory check on an annual basis or when non-operational.
- Secondary calibration on a daily or weekly basis depending on usage.

### 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the Field Logbook.

- Identification - Site name, location, CTO number, activity monitored, (surface water sampling, soil sampling, etc.), serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the Foxboro OVA 128 meter had wide range fluctuations during air monitoring activities).

### 7.0 REFERENCES

Foxboro Model OVA 128 Century Organic Vapor Analyzer Instruction Manual, 1985.

**SOP F301**  
**Sample Preservation and Handling**

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**SAMPLE PRESERVATION AND HANDLING  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Sample Containers**
  - 5.2 Preservation Techniques**
  - 5.3 Sample Holding Times**
- 6.0 SAMPLE HANDLING AND TRANSPORTATION**
- 7.0 REFERENCES**

## SAMPLE PRESERVATION AND HANDLING

### 1.0 PURPOSE

This SOP describes the appropriate containers for samples of particular matrices, and the steps necessary to preserve those samples when shipped off site for chemical analysis. It also identifies the qualifications for individuals responsible for the transportation of hazardous materials and samples and the regulations set forth by the Department of Transportation regarding the same.

### 2.0 SCOPE

Some chemicals react with sample containers made of certain materials; for example, trace metals adsorb more strongly to glass than to plastic, while many organic chemicals may dissolve various types of plastic containers. It is therefore critical to select the correct container in order to maintain the integrity of the sample prior to analysis.

Many water and soil samples are unstable and may change in chemical character during shipment. Therefore, preservation of the sample may be necessary when the time interval between field collection and laboratory analysis is long enough to produce changes in either the concentration or the physical condition of the constituent(s). While complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that may occur after the sample is collected.

Preservation techniques are usually limited to pH control, chemical addition(s), and refrigeration/freezing. Their purposes are to (1) retard biological activity, (2) retard hydrolysis of chemical compounds/complexes, (3) reduce constituent volatility, and (4) reduce adsorption effects.

Sample container and preservation requirements for the CLEAN Program are referenced in NEESA 20.2-047B and are provided in Attachment A of this SOP. Note that sample container requirements (i.e., volumes) may vary by laboratory.

The Department of Transportation, Code of Federal Regulations (CFR) Title 49 establishes regulations for all materials offered for transportation. The transportation of environmental

samples for analysis is regulated by Code of Federal Regulations Title 40 (Protection of the Environment), along with 49 CFR Part 172 Subpart H. The transportation of chemicals used as preservatives and samples identified as hazardous (as defined by 49 CFR Part 171.8) are regulated by 49 CFR Part 172.

### 3.0 DEFINITIONS

HCl - Hydrochloric Acid  
H<sub>2</sub>SO<sub>4</sub> - Sulfuric Acid  
HNO<sub>3</sub> - Nitric Acid  
NaOH - Sodium Hydroxide

Normality (N) - Concentration of a solution expressed as equivalents per liter, where an equivalent is the amount of a substance containing one mole of replaceable hydrogen or its equivalent. Thus, a one molar solution of HCl, containing one mole of H, is "one-normal," while a one molar solution of H<sub>2</sub>SO<sub>4</sub> containing two moles of H, is "two-normal."

### 4.0 RESPONSIBILITIES

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is also responsible for proper certification of individuals responsible for transportation of samples of hazardous substances.

**Field Team Leader** - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures. The Field Team Leader is responsible to ensure all samples and/or hazardous substances are properly identified, labeled, and packaged prior to transportation.

**Sampling Personnel** - It is the responsibility of the field sampling personnel to initiate sample preservation and handling. It is also the responsibility of the field sampling personnel to understand and adhere to the requirements for proper transportation of samples and/or hazardous substances.



## 5.0 PROCEDURES

The following procedures discuss sample containerization and preservation techniques that are to be followed when collecting environmental samples for laboratory analysis.

### 5.1 Sample Containers

For most samples and analytical parameters either glass or plastic containers are satisfactory. In general, if the analyte(s) to be measured is organic in nature, the container shall be made of glass. If the analyte(s) is inorganic, then the container shall be plastic. Containers shall be kept out of direct sunlight (to minimize biological or photo-oxidation/photolysis of constituents) until they reach the analytical laboratory. The sample container shall have approximately five to ten percent air space ("ullage") to allow for expansion/vaporization if the sample is heated during transport (one liter of water at 4°C expands by 15 milliliters if heated to 130°F/55°C); however, head space for volatile organic analyses shall be omitted.

The analytical laboratory shall provide sample containers that have been certified clean according to USEPA procedures. Shipping containers for samples, consisting of sturdy ice chests, are to be provided by the laboratory.

Once opened, the sample container must be used at once for storage of a particular sample. Unused, but opened, containers are to be considered contaminated and must be discarded. Because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused containers which appear contaminated upon receipt, or which are found to have loose caps or missing liners (if required for the container) shall be discarded.

General sample container, preservative, and holding time requirements are listed in Attachment A.

### 5.2 Preservation Techniques

The preservation techniques to be used for various analytes are listed in Attachment A. Reagents required for sample preservation will either be added to the sample containers by

the laboratory prior to their shipment to the field or added in the field using laboratory supplied preservatives. In general, aqueous samples of low concentration organics (or soil samples of low or medium concentration organics) are cooled to 4°C. Medium concentration aqueous samples and high hazard organic samples are not preserved. Low concentration aqueous samples for metals are acidified with HNO<sub>3</sub>, while medium concentration and high hazard aqueous metal samples are not preserved. Low or medium concentration soil samples for metals are cooled to 4°C, while high hazard samples are not preserved. Unless documented otherwise in the project plans, all samples shall be considered low concentration. All samples preserved with chemicals shall be clearly identified by indicating on the sample label that the sample is preserved.

### 5.3 Sample Holding Times

The elapsed time between sample collection and initiation of laboratory analyses must be within a prescribed time frame for each individual analysis to be performed. Sample holding times for routine sample collection are provided in Attachment A.

## 6.0 SAMPLE HANDLING AND TRANSPORTATION

After collection, the outside of all sample containers will be wiped clean with a damp paper towel; however sample handling should be minimized. Personnel should use extreme care to ensure that samples are not contaminated. If samples are placed in an ice chest, personnel should ensure that melted ice cannot cause sample containers to become submerged, as this may result in sample cross-contamination. Sealable plastic bags, (zipper-type bags), should be used when glass sample containers are placed in ice chests to prevent cross-contamination, if breakage should occur.

Samples may be hand delivered to the laboratory or they may be shipped by common carrier. Relevant regulations for the storage and shipping of samples are contained in 40 CFR 261.4(d). Parallel state regulations may also be relevant. Shipment of dangerous goods by air cargo is also regulated by the United Nations/International Civil Aviation Organization (UN/ICAO). The Dangerous Goods Regulations promulgated by the International Air Transport Association (IATA) meet or exceed DOT and UN/ICAO requirements and should be used for shipment of dangerous goods via air cargo. Standard procedure for shipping environmental samples are given in Attachment B.

## 7.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater. 15th Edition. APHA, Washington, D.C.

USEPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

USEPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. USEPA EMSL, Cincinnati, Ohio.

USEPA, Region IV, 1991. Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual. Athens, Georgia.

Protection of the Environment, Code of Federal Regulation, Title 40, Parts 260 to 299.

Transportation, Code of Federal Regulation, Title 49, Parts 100 to 177.

**ATTACHMENT A**

**REQUIRED CONTAINER, PRESERVATION TECHNIQUES  
AND HOLDING TIMES**

# ATTACHMENT A

## REQUIRED CONTAINERS, PRESERVATIVE TECHNIQUES AND HOLDING TIMES

| Parameter                 | EPA Document SW-846 (3rd Ed.)                                                              |                                                                                        |                                        |                                        | Contract Laboratory Protocol                                                               |                                                                                        |                                         |                                        |
|---------------------------|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------|----------------------------------------|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-----------------------------------------|----------------------------------------|
|                           | Container                                                                                  | Preservative                                                                           | Holding Time <sup>(1)</sup>            |                                        | Container                                                                                  | Preservative                                                                           | Holding Time <sup>(2)</sup>             |                                        |
|                           |                                                                                            |                                                                                        | Soil                                   | Water                                  |                                                                                            |                                                                                        | Soil                                    | Water                                  |
| Volatiles by GC/MS and GC | Water - 40 mL glass vial with Teflon-lined septa<br><br>Soil-glass with Teflon-lined septa | Cool to 4°C                                                                            | 14 days                                | 14 days                                | Water - 40 mL glass vial with Teflon-lined septa<br><br>Soil-glass with Teflon-lined septa | Conc. HCl<br>Cool to 4°C                                                               | 10 days                                 | 10 days                                |
| PCB/Pesticides            | G, Teflon-lined lid                                                                        | Cool to 4°C                                                                            | Extract within 7 days, analyze 40 days | Extract within 7 days, analyze 40 days | G, Teflon-lined lid                                                                        | Cool to 4°C                                                                            | Extract within 10 days, analyze 40 days | Extract within 5 days, analyze 40 days |
| Extractable Organics      | G, Teflon-lined lid                                                                        | Cool to 4°C                                                                            | Extract within 7 days, analyze 40 days | Extract within 7 days, analyze 40 days | G, Teflon-lined lid                                                                        | Cool to 4°C                                                                            | Extract within 10 days, analyze 40 days | Extract within 5 days, analyze 40 days |
| Metals <sup>(3)</sup>     | P, G                                                                                       | HNO <sub>3</sub> to pH < 2                                                             | 6 months                               | 6 months                               | P, G                                                                                       | HNO <sub>3</sub> to pH < 2                                                             | 180 days                                | 180 days                               |
| Mercury                   | P, G                                                                                       | HNO <sub>3</sub> to pH < 2                                                             | 28 days                                | 28 days                                | P, G                                                                                       | HNO <sub>3</sub> to pH < 2                                                             | 26 days                                 | 26 days                                |
| Cyanide                   | P, G                                                                                       | NaOH to pH > 12<br>Cool to 4°C<br>Add 0.6 g ascorbic acid if residual chlorine present | 14 days                                | 14 days                                | P, G                                                                                       | NaOH to pH > 12<br>Cool to 4°C<br>Add 0.6 g ascorbic acid if residual chlorine present | 14 days                                 | 14 days                                |
| Chromium (Hexavalent)     | P, G                                                                                       | HNO <sub>3</sub> to pH < 2                                                             | 24 hrs.                                | 24 hrs.                                | P, G                                                                                       | HNO <sub>3</sub> to pH < 2                                                             | 24 hrs.                                 | 24 hrs.                                |

(1) From date of sample collection in field.

(2) From date of sample receipt at laboratory.

(3) Dissolved metals (liquid) must be field filtered prior to preservation.

Note: Check with laboratory for specific volume requirements.

**ATTACHMENT B**

**SAMPLE SHIPPING PROCEDURES**

## ATTACHMENT B

### SAMPLE SHIPPING PROCEDURES

#### Introduction

Samples collected during field investigations or in response to a hazardous materials incident must be classified by the project leader, prior to shipping by air, as either environmental or hazardous substances. The guidance for complying with U.S. DOT regulations in shipping environmental laboratory samples is given in the "National Guidance Package for Compliance with Department of Transportation Regulations in the Shipment of Environmental Laboratory Samples."

Pertinent regulations for the shipping of environmental samples is given in 40 CFR 261.4(d). Samples collected from process wastewater streams, drums, bulk storage tanks, soil, sediment, or water samples from areas suspected of being highly contaminated may require shipment as dangerous goods/hazardous substance. Regulations for packing, marking, labeling, and shipping of dangerous goods by air transport are promulgated by the United Nations International Civil Aviation Organization (UN/ICAO), which is equivalent to IATA.

Individuals responsible for transportation of environmental samples or dangerous goods/hazardous substances must be tested and certified by their employer. This is required by 49 CFR Part 172 Subpart H Docket HM-126 to assure the required qualifications for individuals offering materials for transportation.

Environmental samples shall be packed prior to shipment by commercial air carrier using the following procedures:

1. Select a sturdy cooler in good repair. Secure and tape the drain plug (inside and outside) with fiber or duct tape. Line the cooler with a large heavy duty plastic bag. This practice keeps the inside of the cooler clean and minimizes cleanup at the laboratory after samples are removed.
2. Allow sufficient headspace (ullage) in all bottles (except VOAs) to compensate for any pressure and temperature changes (approximately 10 percent of the volume of the container).

3. Be sure the lids on all bottles are tight (will not leak). In many regions custody seals are also applied to sample container lids. The reason for this practice is two-fold: to maintain integrity of samples and keep lid on the container should the lid loosen during shipment. Check with the appropriate regional procedures prior to field work. In many cases, the laboratory manager of the analytical lot to be used on a particular project can also provide this information.
4. It is good practice to wrap all glass containers in bubblewrap prior to placing in plastic bags.
5. Place all bottles in separate and appropriately sized polyethylene bags and seal the bags with tape (preferably plastic electrical tape, unless the bag is a zipper-type bag). Up to three VOA bottles, separately wrapped in bubblewrap, may be packed in one plastic bag.
6. Optionally, place three to six VOA vials in a quart metal can and then fill the can with vermiculite.
7. Place two to four inches of vermiculite (ground corn cob, or other inert packing material) in the bottom of the cooler and then place the bottles and cans in the cooler with sufficient space to allow for the addition of more vermiculite between the bottles and cans.
8. Put frozen "blue ice" (or ice that has been placed in properly sealed, double-bagged, heavy duty polyethylene bags) on top of and between the samples. Fill all remaining space between the bottles or cans with packing material. Fold and securely fasten the top of the large garbage bag with tape (preferably electrical or duct).
9. Place the Chain-of-Custody Record and the Request for Analysis Form (if applicable) into a plastic bag, tape the bag to the inner side of the cooler lid, and then close the cooler and securely tape (preferably with fiber tape) the top of the cooler unit. Wrap the tape three to four times around each side of the cooler unit. Chain-of-custody seals should be affixed to the top and sides of the cooler within the securing tape so that the cooler cannot be opened without breaking the seal.
10. Each cooler (if multiple coolers) should have its own Chain-of-Custody Record reflecting the samples shipped in that cooler.
11. Label according to 40 CFR 261.4(d). The shipping containers should be marked "THIS END UP," and arrow labels which indicate the proper upward position of the container should be affixed to the container. A label containing the name and address of the shipper and laboratory shall be placed on the outside of the container. It is good practice to secure this label with clear plastic tape to prevent removal during shipment by blurring of important information should the label become wet. The commercial carrier is not required to sign the COC record as long as the custody seals remain intact and the COC record stays in the cooler. The only other documentation required is the completed airbill, which is secured to the top of the shipping container. Please note several coolers/shipping containers may be shipped under one airbill. However, each cooler must be labeled as "Cooler 1 of 3, Cooler 2 of 3, etc.", prior to shipping. Additionally it is good practice to label each COC form to correspond to each cooler (i.e., 1 of 3, 2 of 3, etc.).



5. Place all bottles in separate and appropriately sized polyethylene bags and seal the bags with tape (preferably plastic electrical tape, unless the bag is a zipper-type bag). Up to three VOA bottles, separately wrapped in bubblewrap, may be packed in one plastic bag.
6. Optionally, place three to six VOA vials in a quart metal can and then fill the can with vermiculite.
7. Place two to four inches of vermiculite (ground corn cob, or other inert packing material) in the bottom of the cooler and then place the bottles and cans in the cooler with sufficient space to allow for the addition of more vermiculite between the bottles and cans.
8. Put frozen "blue ice" (or ice that has been placed in properly sealed, double-bagged, heavy duty polyethylene bags) on top of and between the samples. Fill all remaining space between the bottles or cans with packing material. Fold and securely fasten the top of the large garbage bag with tape (preferably electrical or duct).
9. Place the Chain-of-Custody Record and the Request for Analysis Form (if applicable) into a plastic bag, tape the bag to the inner side of the cooler lid, and then close the cooler and securely tape (preferably with fiber tape) the top of the cooler unit. Wrap the tape three to four times around each side of the cooler unit. Chain-of-custody seals should be affixed to the top and sides of the cooler within the securing tape so that the cooler cannot be opened without breaking the seal.
10. Each cooler (if multiple coolers) should have its own Chain-of-Custody Record reflecting the samples shipped in that cooler.
11. Label according to 40 CFR 261.4(d). The shipping containers should be marked "THIS END UP," and arrow labels which indicate the proper upward position of the container should be affixed to the container. A label containing the name and address of the shipper and laboratory shall be placed on the outside of the container. It is good practice to secure this label with clear plastic tape to prevent removal during shipment by blurring of important information should the label become wet. The commercial carrier is not required to sign the COC record as long as the custody seals remain intact and the COC record stays in the cooler. The only other documentation required is the completed airbill, which is secured to the top of the shipping container. Please note several coolers/shipping containers may be shipped under one airbill. However, each cooler must be labeled as "Cooler 1 of 3, Cooler 2 of 3, etc.", prior to shipping. Additionally it is good practice to label each COC form to correspond to each cooler (i.e., 1 of 3, 2 of 3, etc.).

**SOP F302**  
**Chain-of-Custody**

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CHAIN-OF-CUSTODY  
TABLE OF CONTENTS

- 1.0 PURPOSE
- 2.0 SCOPE
- 3.0 DEFINITIONS
- 4.0 RESPONSIBILITIES
- 5.0 PROCEDURES
  - 5.1 Sample Identification
  - 5.2 Chain-of-Custody Procedures
- 6.0 QUALITY ASSURANCE RECORDS
- 7.0 REFERENCES

## CHAIN-OF-CUSTODY

### 1.0 PURPOSE

The purpose of this SOP is to provide information on chain-of-custody procedures to be used under the CLEAN Program.

### 2.0 SCOPE

This procedure describes the steps necessary for transferring samples through the use of Chain-of-Custody Records. A Chain-of-Custody Record is required, without exception, for the tracking and recording of samples collected for on-site or off-site analysis (chemical or geotechnical) during program activities (except wellhead samples taken for measurement of field parameters, SOP F101). Use of the Chain-of-Custody Record Form creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis. This procedure identifies the necessary custody records and describes their completion. This procedure does not take precedence over region-specific or site-specific requirements for chain-of-custody.

### 3.0 DEFINITIONS

Chain-of-Custody Record Form - A Chain-of-Custody Record Form is a printed two-part form that accompanies a sample or group of samples as custody of the sample(s) is transferred from one custodian to another custodian. One copy of the form must be retained in the project file.

Custodian - The person responsible for the custody of samples at a particular time, until custody is transferred to another person (and so documented), who then becomes custodian. A sample is under one's custody if:

- It is in one's actual possession.
- It is in one's view, after being in one's physical possession.
- It was in one's physical possession and then he/she locked it up to prevent tampering.
- It is in a designated and identified secure area.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the point and time that it was collected.

#### 4.0 RESPONSIBILITIES

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is responsible for ensuring that chain-of-custody procedures are implemented. The Project Manager also is responsible for determining that custody procedures have been met by the analytical laboratory.

**Field Team Leader** - The Field Team Leader is responsible for determining that chain-of-custody procedures are implemented up to and including release to the shipper or laboratory. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the field sampling personnel to initiate chain-of-custody procedures, and maintain custody of samples until they are relinquished to another custodian, the sample shipper, or to a common carrier.

#### 5.0 PROCEDURES

The term "chain-of-custody" refers to procedures which ensure that evidence presented in a court of law is valid. The chain-of-custody procedures track the evidence from the time and place it is first obtained to the courtroom, as well as providing security for the evidence as it is moved and/or passed from the custody of one individual to another.

Chain-of-custody procedures, recordkeeping, and documentation are an important part of the management control of samples. Regulatory agencies must be able to provide the chain-of-possession and custody of any samples that are offered for evidence, or that form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

## 5.1 Sample Identification

The method of identification of a sample depends on the type of measurement or analysis performed. When in-situ measurements are made, the data are recorded directly in bound logbooks or other field data records with identifying information.

Information which shall be recorded in the field logbook, when in-situ measurements or samples for laboratory analysis are collected, includes:

- Field Sampler(s);
- CTO Number;
- Project Sample Number;
- Sample location or sampling station number;
- Date and time of sample collection and/or measurement;
- Field observations;
- Equipment used to collect samples and measurements; and,
- Calibration data for equipment used.

Measurements and observations shall be recorded using waterproof ink.

### 5.1.1 Sample Label

Samples, other than in-situ measurements, are removed and transported from the sample location to a laboratory or other location for analysis. Before removal, however, a sample is often divided into portions, depending upon the analyses to be performed. Each portion is preserved in accordance with the Sampling and Analysis Plan. Each sample container is identified by a sample label (see Attachment A). Sample labels are provided, along with sample containers, by the analytical laboratory. The information recorded on the sample label includes:

- Project - Contract Task Order (CTO) Number.
- Station Location - The unique sample number identifying this sample.
- Date - A six-digit number indicating the day, month, and year of sample collection (e.g., 12/21/85).
- Time - A four-digit number indicating the 24-hour time of collection (for example: 0954 is 9:54 am., and 1629 is 4:29 p.m.).
- Medium - Water, soil, sediment, sludge, waste, etc.

- Sample Type - Grab or composite.
- Preservation - Type and quantity of preservation added.
- Analysis - VOA, BNAs, PCBs, pesticides, metals, cyanide, other.
- Sampled By - Printed name of the sampler.
- Remarks - Any pertinent additional information.

Using only the work assignment number of the sample label maintains the anonymity of sites. This may be necessary, even to the extent of preventing the laboratory performing the analysis from knowing the identity of the site (e.g., if the laboratory is part of an organization that has performed previous work on the site).

## 5.2 Chain-of-Custody Procedures

After collection, separation, identification, and preservation, the sample is maintained under chain-of-custody procedures until it is in the custody of the analytical laboratory and has been stored or disposed.

### 5.2.1 Field Custody Procedures

- Samples are collected as described in the site Sampling and Analysis Plan. Care must be taken to record precisely the sample location and to ensure that the sample number on the label matches the Chain-of-Custody Record exactly.
- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.
- When photographs are taken of the sampling as part of the documentation procedure, the name of the photographer, date, time, site location, and site description are entered sequentially in the site logbook as photos are taken. Once developed, the photographic prints shall be serially numbered, corresponding to the logbook descriptions; photographs will be stored in the project files. It is good practice to identify sample locations in photographs by including an easily read sign with the appropriate sample/location number.
- Sample labels shall be completed for each sample, using waterproof ink unless prohibited by weather conditions, e.g., a logbook notation would explain that a pencil was used to fill out the sample label if the pen would not function in freezing weather.

### 5.2.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. A Chain-of-Custody Record Form example is shown in Attachment B. When transferring the possession of samples, the individual(s) relinquishing and receiving will sign, date, and note the time on the Record. This Record documents sample custody transfer from the sampler, often through another person, to the analyst in the laboratory. The Chain-of-Custody Record is filled out as given below.

- Enter header information (CTO number, samplers, and project name).
- Enter sample specific information (sample number, media, sample analysis required and analytical method grab or composite, number and type of sample containers, and date/time sample was collected).
- Sign, date, and enter the time under "Relinquished by" entry.
- Have the person receiving the sample sign the "Received by" entry. If shipping samples by a common carrier, print the carrier to be used in this space (i.e., Federal Express).
- If a carrier is used, enter the airbill number under "Remarks," in the bottom right corner;
- Place the original (top, signed copy) of the Chain-of-Custody Record Form in a plastic zipper-type bag or other appropriate sample shipping package. Retain the copy with field records.
- Sign and date the custody seal, a 1- by 3-inch white paper label with black lettering and an adhesive backing. Attachment C is an example of a custody seal. The custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field. Custody seals shall be provided by the analytical laboratory.
- Place the seal across the shipping container opening so that it would be broken if the container was to be opened.
- Complete other carrier-required shipping papers.

The custody record is completed using waterproof ink. Any corrections are made by drawing a line through and initialing and dating the change, then entering the correct information. Erasures are not permitted.

Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the shipping container (enclosed with other



documentation in a plastic zipper-type bag). As long as custody forms are sealed inside the shipping container and the custody seals are intact, commercial carriers are not required to sign the custody form.

The laboratory representative who accepts the incoming sample shipment signs and dates the Chain-of-Custody Record, completing the sample transfer process. It is then the laboratory's responsibility to maintain internal logbooks and custody records throughout sample preparation and analysis.

## 6.0 QUALITY ASSURANCE RECORDS

Once samples have been packaged and shipped, the COC copy and airbill receipt becomes part of the Quality Assurance Record.

## 7.0 REFERENCES

1. USEPA. User's Guide to the Contract Laboratory Program. Office of Emergency and Remedial Response, Washington, D.C. (EPA/540/P-91/002), January 1991.

**ATTACHMENT A**

**EXAMPLE SAMPLE LABEL**

ATTACHMENT A

EXAMPLE SAMPLE LABEL

|                                                                        |                                                                                                     |
|------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| <b>Baker</b>                                                           | Baker Environmental Inc.<br>Airport Office Park, Bldg. 3<br>420 Rouser Road<br>Coraopolis, PA 15108 |
| Project: <u>19026-SRN</u>                                              | CTO No.: <u>0026</u>                                                                                |
| Sample Description: <u>Groundwater</u>                                 |                                                                                                     |
| Date: <u>09/17/92</u>                                                  | Sampler: <u>ABC</u>                                                                                 |
| Time: <u>0944</u>                                                      |                                                                                                     |
| Analysis: <u>TAL Metals (CAP)</u> Preservation: <u>HNO<sub>3</sub></u> |                                                                                                     |
| Project Sample No.: <u>CAX-GW-04</u>                                   |                                                                                                     |

Note: Typically, sample labels are provided by the analytical laboratory and may be used instead of the above. However, samplers should make sure all pertinent information can be affixed to the label used.

**ATTACHMENT B**

**EXAMPLE CHAIN-OF-CUSTODY RECORD**

**Baker Environmental, Inc.**  
420 Rouser Road, AOP Building 3, Coraopolis, PA 15108

[illegible]

**ATTACHMENT C**

**EXAMPLE CUSTODY SEAL**

**ATTACHMENT C**

**EXAMPLE CUSTODY SEAL**

|                                                                           |                                                                           |
|---------------------------------------------------------------------------|---------------------------------------------------------------------------|
| <b>Baker</b> _____<br>Date<br>_____<br>Signature<br>_____<br>CUSTODY SEAL | <b>Baker</b> _____<br>Date<br>_____<br>Signature<br>_____<br>CUSTODY SEAL |
|---------------------------------------------------------------------------|---------------------------------------------------------------------------|

**SOP F304**  
**QA/QC Samples**

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**QUALITY CONTROL SAMPLES  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Trip Blanks
  - 5.2 Equipment Rinsates
  - 5.3 Field Blanks
  - 5.4 Duplicates
  - 5.5 MS/MSD
- 6.0 SAMPLE HANDLING AND TRANSPORTATION**
- 7.0 REFERENCES**

## QUALITY CONTROL SAMPLES

### 1.0 PURPOSE

The SOP describes the type and quantity of Quality Control (QC) samples to be collected for most field sampling operations.

### 2.0 SCOPE

QC samples are those samples (usually collected in the field) that are sent to the laboratory along with the environmental samples in order to evaluate site conditions and laboratory precision and accuracy. Evaluation of the results from the QC samples allows for the quality of the data to be assessed. There are five different type of QC samples: trip blanks, equipment rinsate blanks, field blanks, duplicates and matrix spike/matrix spike duplicate (MS/MSD) samples. The first three types of QC samples are used to assess field conditions during sampling and/or transport of the environmental samples. The latter two types of QC samples are used by the laboratory to help assess precision and accuracy. (The laboratory also has other internal samples and procedures to assess precision and accuracy.)

Depending on the NEESA Level of data quality required by the project, different amounts of QC samples are collected. These are described in detail below.

### 3.0 DEFINITIONS

Trip Blank - Trip blanks are 40-ml volatile organic analysis (VOA) vials of ASTM Type II water that are filled at the laboratory, transported to the sampling site, and returned to the laboratory with environmental VOA samples. Trip blanks are not opened in the field.

Equipment Rinsates - Equipment rinsates are samples of ASTM Type II water (provided by the laboratory) passed over decontaminated sampling equipment. They are used as a measure of the effectiveness of the decontamination procedure. The rinsate is analyzed for the same parameters as the environmental samples collected from the piece of equipment.

Field Blanks - Field blanks are samples of source water used for decontamination and steam cleaning. At a minimum there is one sample collected for each source of water used per

sampling event. The field blank is analyzed for all the parameters tested during the sampling event.

Duplicates - Duplicates are collected to help assess laboratory reproducibility (precision). Solid matrix samples are homogenized before being split, except for VOAs, which are not homogenized because of potential volatile loss. Liquid matrix samples are collected simultaneously. For both solid and liquid matrices, double the normal volume is required. The same analyses are completed on the duplicate as on the environmental sample.

MS/MSD - MS/MSD samples are used by the laboratory (but collected in the field) to help determine both precision and accuracy of analysis. For liquid matrices, triple the volume of sample is required (that is, one volume for the environmental sample, one volume for the MS sample, and one volume for the MSD sample). For solid matrices, additional volume is usually not required (although this will depend upon the laboratory).

#### 4.0 RESPONSIBILITIES

The Project Manager is responsible for estimating the number of QC samples required for any sampling event. The procedures for determining the number is described in Section 5.0 below. The Field Team Leader is responsible for making sure that the sampling team(s) are collecting the required number of QC samples. The Field Team member(s) are responsible for understanding the rationale and methods for QC sample collection and for coordinating QC sample collection as appropriate.

#### 5.0 PROCEDURES

The procedures for QC sample collection and the frequency at which each type of sample should be collected is described below.

##### 5.1 Trip Blanks

Trip blanks (one pair of 40 ml vials) are sent to the laboratory in each cooler which contains samples for volatile organic analyses. The trip blank should also be kept in the field, with the volatile samples, during the period of sample collection. Analyses of the trip blank will ensure that the sample containers were not contaminated prior to the assessment or during transport.

## 5.2 Equipment Rinsates

Equipment rinsates are collected by pouring analyte-free water (provided by the laboratory) over decontaminated sampling equipment and collecting the rinsate. These are collected at a frequency of once per day and are analyzed for the same parameters as are the samples collected from that equipment. If two (or more) different types of equipment are used to collect samples in the same day (say by two field teams, one collecting soil samples from split spoons and one collecting groundwater from bailers), then two separate rinsate samples may be collected. The rinsate blank is used to qualify data.

## 5.3 Field Blanks

One field blank per source of water used for decontamination per sampling event is collected for all the parameters analyzed during that sampling event. In general, two field blanks are collected - one from the potable water source used for steam cleaning and one from distilled water purchased at a local store for use in general decontamination. The field blank is collected by opening up the water source and pouring the water directly into the appropriate sample bottles. Analysis of the sample will indicate whether contamination was introduced into the samples during the collection process.

## 5.4 Duplicates

Field duplicates are collected at a frequency of 10% for levels C and D analyses, and at 5% for level E analyses. The samples are split as described above and in other SOPs related to sample collection procedures. The number of duplicates to collect is determined as follows: 1-10 environmental samples, 1 duplicate; 11-20 environmental samples, 2 duplicates; 21-30 environmental samples, 3 duplicates, etc. Field duplicates are primarily used to check the precision and consistency of the sampling procedures used.

## 5.5 MS/MSD

MS/MSD samples are collected in the same manner as for a duplicate sample, except that triple the volume is required for analysis (for liquids). Generally no additional volume is required by the laboratory for solid samples (CHECK WITH THE LAB). The frequency of

collection is 1 MS/MSD pair for each 20 environmental samples collected of similar matrix (e.g. groundwater, surface water, soil). The number of MS/MSD samples to collect is determined as follows: 1-20 environmental samples, 1 MS/MSD pair; 21-40 environmental samples, 2 MS/MSD pairs, etc. NEESA requires that one field duplicate be collected at the same location as the MS/MSD pair.

## 6.0 SAMPLE HANDLING AND TRANSPORTATION

Records of collection of QC samples are kept in the field logbooks and on the Chain-of-Custody forms. Evaluation of the results from the QC samples is performed by the laboratory and through data validation for the MS/MSD samples. Results of the other QC samples are compared to analytical results from the sampling event to determine if any field procedures, or sample transportation/handling may have adversely affected the concentrations found in the environmental samples.

## 7.0 REFERENCES

Hazardous Waste Remedial Actions Program, 1990. Requirements for Quality Control of Analytical Data. DOE/HWP-65/R1, US Department of Energy, Oak Ridge, Tennessee.

Naval Energy and Environmental Support Activity, 1998. Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program. NEESA 20.2-047B, Port Hueneme, California.

USEPA, 1988. User's Guide to the Contract Laboratory Program. 9240.0-1, Office of Emergency and Remedial Response, Washington, D.C.

USEPA, 1990. Quality Assurance/Quality Control Guidance for Removal Activities - Sampling QA/QC Plan and Data Validation Procedures (Interim Final). EPA/540/G-90/004, Office of Emergency and Remedial Response, Washington, D.C.

**SOP F502**  
**Decontamination of Sampling and**  
**Monitoring Equipment**

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**DECONTAMINATION OF SAMPLING AND  
MONITORING EQUIPMENT**

**TABLE OF CONTENTS**

|            |                                               |
|------------|-----------------------------------------------|
| <b>1.0</b> | <b>PURPOSE</b>                                |
| <b>2.0</b> | <b>SCOPE</b>                                  |
| <b>3.0</b> | <b>DEFINITIONS</b>                            |
| <b>4.0</b> | <b>RESPONSIBILITIES</b>                       |
| <b>5.0</b> | <b>PROCEDURES</b>                             |
| 5.1        | Sampling Equipment Decontamination Procedures |
| 5.2        | Field Analytical Equipment Decontamination    |
| <b>6.0</b> | <b>QUALITY ASSURANCE RECORDS</b>              |
| <b>7.0</b> | <b>REFERENCES</b>                             |

## DECONTAMINATION OF SAMPLING AND MONITORING EQUIPMENT

### 1.0 PURPOSE

The purpose of this SOP is to provide a general methodology and protocol, and to reference information for the proper decontamination of field chemical sampling and analytical equipment.

### 2.0 SCOPE

This procedure applies to all field sampling equipment including, but not limited to, split-barrel soil samplers (split-spoons), bailers, beakers, trowels, filtering apparatus, and pumps. This procedure should be consulted when decontamination procedures are being developed as part of project-specific plans. Additionally, current USEPA regional procedures and decontamination guidance as well as state guidance should be reviewed.

### 3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

### 4.0 RESPONSIBILITIES

**Project Manager** - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

**Field Team Leader** - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring field personnel performing decontamination activities have been briefed and trained to execute these procedures.



Sampling Personnel - It is the responsibility of field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader.

## 5.0 PROCEDURES

In order to ensure that chemical analysis results reflect actual concentrations present at sampling locations, sampling equipment must be properly decontaminated prior to the field effort, during the sampling program (i.e., between sampling locations) and at the conclusion of the sampling program. This will minimize the potential for cross-contamination between sampling locations and the transfer of contamination off site.

Preferably, sampling equipment should be dedicated to a given sampling location. If this is not possible, equipment must be decontaminated between sampling locations. Sampling personnel also must use disposable gloves and change them between sampling locations.

### 5.1 Sampling Equipment Decontamination Procedures

Soil and sediment sampling equipment including, but not limited to trowels, beakers, dredges, etc., shall be decontaminated using the following USEPA Region procedures.

The following sections summarize decontamination procedures for USEPA Regions I through IV for overall comparison. Each region should be contacted prior to initiation of sampling activities to assure that the most recent, accepted decontamination procedures are used.

#### USEPA Region I

Prior to use, all sampling equipment should be carefully cleaned using the following procedure:

1. A dilute hydrochloric acid rinse
2. Deionized water rinse
3. Methanol or acetone rinse; and,
4. Distilled, organic-free water rinse.

For badly contaminated equipment, a hot water detergent wash may be needed prior to the rinse procedure. Additionally, a hexane rinse also may be needed, prior to the final distilled water rinse, when sampling for low-level organic pollutants.

### USEPA Region II

Prior to use, all sampling equipment will be decontaminated using the following procedure:

1. Low-phosphate detergent wash (i.e., Alconox or Liquinox)
2. Tap water rinse
3. 10 percent nitric acid solution rinse
4. Tap water rinse
5. Methanol followed by a hexane or an acetone rinse
6. Analyte-free deionized water rinse
7. Air dry
8. Wrap in aluminum foil, shiny side out, for storage or transport

If the samples will not be analyzed for metals, then steps 3 and 4 may be omitted; if samples will not be analyzed for organics, then step 5 may be omitted. All solvents must be pesticide-grade.

### USEPA Region III

Prior to use, all sampling equipment will be decontaminated using the following procedure:

1. Potable water rinse
2. Alconox or Liquinox detergent wash
3. Scrubbing, as necessary
4. Potable water rinse
5. 10 percent nitric acid rinse
6. Distilled-deionized water rinse
7. Methanol or hexane rinse
8. Distilled-deionized water rinse
9. Air dry

### USEPA Region IV

The general decontamination procedure for Region IV is similar to that for Regions II and III. However, there may be some specialized procedures applicable to certain types of field equipment such as equipment used for the collection of samples for analysis of trace organic compounds, automatic wastewater sampling equipment, sampling tubing, and miscellaneous

equipment (i.e., pumps, hand augers, etc.). The most current version is "Standard Operating Procedures and Quality Assurance Manual," USEPA Region IV, Environmental Services Division, Environmental Compliance Branch (see Appendix B in February 1, 1991 version).

## 5.2 Field Analytical Equipment Decontamination

Field analytical equipment which may come in direct contact with the sample or sample media, including, but not limited to water level meters, water/product level meters, pH or specific ion probes, specific conductivity probes, thermometers, and/or borehole geophysical probes must be decontaminated before and after use, according to the procedures outlined in Section 5.1, unless manufacturers instructions indicate otherwise. Probes that contact water samples not used for laboratory analyses may be rinsed with distilled water. Probes which make no direct contact (e.g. HNu or OVA probes) will be wiped clean with clean paper towels or an alcohol-saturated cloth.

## 6.0 QUALITY ASSURANCE RECORDS

Decontamination procedures are monitored through the collection of equipment rinsate samples and field blanks. Collection of these samples shall be specified in the project-specific Sampling and Analysis and Quality Assurance Plans following the requirements of NEESA 20.2-047B. Documentation recorded in the field logbook also shall serve as a quality assurance record.

## 7.0 REFERENCES

NEESA 20.2-047B. Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program. Naval Energy and Environmental Support Activity. Port Hueneme, CA. June 1988.

U. S. EPA Office of Waste Program Enforcement. RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD). OSWER Directive 9950.1. 1986.

U. S. EPA. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA Environmental Services Division, Athens, Georgia. 1991.

Micham, J. T., R. Bellandi, E. C. Tift, Jr. "Equipment Decontamination Procedures for Ground Water and Vadose Zone Monitoring Programs: Status and Prospects." in Ground Water Monitoring Review. Spring 1989.

**Appendix E**  
**Model Results**

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## **SOLUTE SLUG2D MODEL**

### **Introduction**

The SLUG2D (version 2.03) analytical model for solute transport in groundwater was used to evaluate the migration of contamination in the vicinity of Building AS-4151. This model is part of the Solute program package by M. S. Beljin for the International Groundwater Modeling Center, Golden, Colorado, and was used to compute the two-dimensional distribution of benzene in the shallow water-bearing zone through time.

The Solute model package includes eight analytical models, providing a variety of initial conditions (ie. source areal extent, type of release, and areal extent of the aquifer) and site-specific aquifer conditions (ie. groundwater velocity, porosity, and dispersivity). Some of these models also take into account solute-specific geochemical behavior such as adsorption and decay. SLUG2D was selected based on its similarity in source and sink geometry, boundary conditions, and initial solute conditions.

The SLUG2D simulation of the fate and transport problem is based on the generalized advection-dispersion equation by Wilson and Miller (1978) as outlined in Beljin (1991).

Several assumptions of the model include:

- Steady and uniform flow in a porous, confined aquifer.
- The aquifer is homogeneous, isotropic, infinite in areal extent, and constant in thickness.
- The source is a fully penetrating solute injection well.
- The solute is distributed instantaneously into the entire aquifer thickness beneath the source.
- Injection is of short duration in relation to transport time.
- Recharge rates are negligible in relation to the uniform regional flow rate.

Since these assumptions simplify present site conditions, and several site- and solute-specific parameters require estimation, this model provides an order-of-magnitude estimate of the variation of solute concentrations with time and distance.

### **Model Parameters**

Input parameters required by the SLUG2D model include geometry of the aquifer/water-bearing system and the source area, quantity of release, site-specific aquifer characteristics, and solute-specific characteristics. Specific input data for the SLUG2D model include groundwater flow velocity, aquifer thickness, porosity, lateral and longitudinal dispersivity, source configuration, source strength, and elapsed time since release.

A 500- by 500-foot grid was overlain on the site normal to groundwater flow direction. The origin (source area) of the contamination approximates the location of the pipeline. The source was modeled by a 25- by 150-foot area (the approximate area parallel to the pipeline that will not be excavated). The water-bearing zone thickness is estimated to be 13 feet, based on data obtained during the site investigation. It is noted that the depth and thickness of the water-bearing zone are simplified in this model. An additional simplification is the assumption that the entire water-bearing zone consists of a fine-grained sand. Therefore, the water-bearing zone parameters are considered a worst case scenario.

Since the contaminant sources have been, or will be, removed, the SLUG2D model was used to estimate the movement of the contamination with time. The model assumes a conservative (worst case) scenario. Model parameters, including the concentrations in the surrounding monitoring wells, were used to calibrate the models.

The models were then used to calculate the concentrations of benzene at specific distances from the source for time periods of 0.5, 1, 5, 10, and 25 years.

Table 1 provides a summary of the input parameters used in the naphthalene models. Porosity and velocity values were based on results of the site assessment. Dispersivity values were based on published data (USEPA, 1985). The remaining parameter is contaminant-specific, and discussed in the following section.

**Table 1**  
**Solute SLUG2D Input Parameters for the**  
**for the Naphthalene Models**

| Input Parameters                        | Parameter Value                |
|-----------------------------------------|--------------------------------|
| Porosity ( $N_e, \theta$ ) <sup>1</sup> | 34 %                           |
| Velocity (V)                            | 0.004 ft/day                   |
| Dispersivity (D)                        | $D_L = 500$ ft; $D_T = 167$ ft |
| Source Concentration ( $Q_c$ )          | 0.0079 lbs                     |

<sup>1</sup> - Based on boring logs, effective porosity ( $N_e$ ) and total porosity are estimated as the same.

*Source Concentration (lbs/day):* The source concentration was estimated using the following equation:

$$Q_c = C * V_u * T \quad (1)$$

Where:

- $Q_c$  = source concentration (lbs)
- $C$  = estimated concentration of dissolved naphthalene (mg/L)
- $V_u$  = unit flow through the source area (ft<sup>3</sup>/day)
- $T$  = duration of release (days)

This formula includes the unit groundwater flow through the source area. It was calculated with the equation:

$$V_u = V * W * b \quad (2)$$

Where:

- $V_u$  = unit flow through the source area (ft<sup>3</sup>/day)
- $V$  = groundwater flow velocity (ft/day)
- $W$  = width of the source area (feet)
- $b$  = aquifer thickness (feet)

The data used in this equation was based on information obtained during the site assessment ( $V = 0.004$  ft/day and  $b = 13$  feet). The average width of the source area, based on the grid used in the model, is 25 feet. Therefore, the unit flow rate is 1.3 ft<sup>3</sup>/day (36.8 L/day).

The model was used to simulate the transport of naphthalene leached from the remaining contaminated soils. An estimated groundwater naphthalene concentration was calculated based on the water soluble components of JP-5, listed on Table 3-2. The estimated naphthalene concentration, 0.1349 mg/L (calculated from the maximum TPH concentration in the zone of soil contamination that will remain on site) and an elapsed time of two years was used to calculate the source concentration. This is the amount of time that the remediation system is estimated to be in operation. Although groundwater contaminated by the downgradient soils may be captured during the remediation activities, this model assumes that it will not be captured, as a conservative

(worst case) assumption. Based on these values, a source concentration of 0.0079 lbs was calculated.

### **Model Runs**

Using the estimated parameters, an initial run was conducted. Since this model estimates the migration of naphthalene once remediation activities have ceased, there are no analytical data available to compare with the model results. However, sensitivity tests identified  $D$  and  $Q_c$  as the most sensitive parameters. The model was used to approximate concentrations for the periods 0.5, 1, 5, 10, and 25 years.

### **Results**

The results from the 0.5-year model indicate that low levels (maximum of 0.0114 mg/L) of naphthalene will migrate 25 feet from the source. The maximum distance estimated by the model is 75 feet, with a concentration of 0.0004 mg/L. Successive models indicate that the naphthalene will naturally degrade, with respect to time. The 25-year model estimate that the maximum naphthalene concentration at the site will be 0.0012 mg/L, 75 feet downgradient of the source.



```
*****
*                                     *
*               PLUME2D               *
*                                     *
*   INTERNATIONAL GROUND WATER MODELING CENTER   *
*   GOLDEN, COLORADO - DELFT, NETHERLANDS        *
*                                     *
*               S O L U T E   version 2.03        *
*                                     *
*   ANALYTICAL MODELS FOR SOLUTE TRANSPORT        *
*                                     *
*****
```

PROJECT..... = AS-4151  
USER NAME..... = KAT  
DATE..... = 07-28-1994  
DATA FILE..... = B:HALFYR.270

## INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .004 [ft/d]  
AQUIFER THICKNESS..... = 13 [ft]  
POROSITY..... = .34  
LONGITUDINAL DISPERSIVITY..... = 500 [ft]  
LATERAL DISPERSIVITY..... = 167 [ft]  
NUMBER OF POINT SOURCES..... = 6

## SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 175 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 182.5 [d]

## SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 200 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 182.5 [d]

## SOURCE NO. 3

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 225 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 182.5 [d]

## SOURCE NO. 4

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 250 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 182.5 [d]

## SOURCE NO. 5

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 275 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 182.5 [d]

## SOURCE NO. 6

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 300 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 182.5 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
DISTANCE INCREMENT DELX..... = 25 [ft]  
DISTANCE INCREMENT DELY..... = 25 [ft]  
NUMBER OF NODES IN X-DIRECTION.... = 20  
NUMBER OF NODES IN Y-DIRECTION.... = 20

## CONCENTRATION C [mg/l]

| ROW\COLUMN |             | 1       | 2      | 3      | 4      | 5      |
|------------|-------------|---------|--------|--------|--------|--------|
|            |             | [ft]    |        |        |        |        |
|            |             | 0.00    | 25.00  | 50.00  | 75.00  | 100.00 |
| 1          | 0.00 [ft]   | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00 [ft]  | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00 [ft]  | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00 [ft]  | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5          | 100.00 [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6          | 125.00 [ft] | 0.0001  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7          | 150.00 [ft] | 0.0031  | 0.0021 | 0.0006 | 0.0001 | 0.0000 |
| 8          | 175.00 [ft] | -0.9969 | 0.0094 | 0.0027 | 0.0003 | 0.0000 |
| 9          | 200.00 [ft] | -0.9969 | 0.0114 | 0.0032 | 0.0004 | 0.0000 |
| 10         | 225.00 [ft] | -0.9969 | 0.0114 | 0.0032 | 0.0004 | 0.0000 |
| 11         | 250.00 [ft] | -0.9969 | 0.0114 | 0.0032 | 0.0004 | 0.0000 |
| 12         | 275.00 [ft] | -0.9970 | 0.0114 | 0.0032 | 0.0004 | 0.0000 |
| 13         | 300.00 [ft] | -1.0000 | 0.0094 | 0.0027 | 0.0003 | 0.0000 |
| 14         | 325.00 [ft] | 0.0031  | 0.0021 | 0.0006 | 0.0001 | 0.0000 |
| 15         | 350.00 [ft] | 0.0001  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16         | 375.00 [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17         | 400.00 [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18         | 425.00 [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |             | 6      | 7      | 8      | 9      | 10     |
|------------|-------------|--------|--------|--------|--------|--------|
|            |             | [ft]   |        |        |        |        |
|            |             | 125.00 | 150.00 | 175.00 | 200.00 | 225.00 |
| 1          | 0.00 [ft]   | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00 [ft]  | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00 [ft]  | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00 [ft]  | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5          | 100.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6          | 125.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7          | 150.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8          | 175.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9          | 200.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10         | 225.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11         | 250.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12         | 275.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13         | 300.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14         | 325.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15         | 350.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16         | 375.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17         | 400.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18         | 425.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |            | 11     | 12     | 13     | 14     | 15     |
|------------|------------|--------|--------|--------|--------|--------|
|            |            | [ft]   |        |        |        |        |
|            |            | 250.00 | 275.00 | 300.00 | 325.00 | 350.00 |
| 1          | 0.00 [ft]  | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00 [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

|    |        |      |        |        |        |        |        |
|----|--------|------|--------|--------|--------|--------|--------|
| 3  | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4  | 75.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5  | 100.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6  | 125.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7  | 150.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8  | 175.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9  | 200.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | 225.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 250.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12 | 275.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13 | 300.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14 | 325.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15 | 350.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16 | 375.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17 | 400.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18 | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19 | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20 | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |        |      | 16     | 17     | 18     | 19     | 20     |
|------------|--------|------|--------|--------|--------|--------|--------|
| [ft]       |        |      | 375.00 | 400.00 | 425.00 | 450.00 | 475.00 |
| 1          | 0.00   | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5          | 100.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6          | 125.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7          | 150.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8          | 175.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9          | 200.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10         | 225.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11         | 250.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12         | 275.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13         | 300.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14         | 325.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15         | 350.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16         | 375.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17         | 400.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18         | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

```
*****
*                                     *
*               PLUME2D               *
*                                     *
*   INTERNATIONAL GROUND WATER MODELING CENTER   *
*   GOLDEN, COLORADO - DELFT, NETHERLANDS        *
*                                     *
*               S O L U T E   version 2.03        *
*                                     *
*   ANALYTICAL MODELS FOR SOLUTE TRANSPORT        *
*                                     *
*****
```

PROJECT..... = AS-4151  
USER NAME..... = KAT  
DATE..... = 07-28-1994  
DATA FILE..... = B:YR1.270

## INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .004 [ft/d]  
AQUIFER THICKNESS..... = 13 [ft]  
POROSITY..... = .34  
LONGITUDINAL DISPERSIVITY..... = 500 [ft]  
LATERAL DISPERSIVITY..... = 167 [ft]  
NUMBER OF POINT SOURCES..... = 6

## SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 175 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 365 [d]

## SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 200 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 365 [d]

## SOURCE NO. 3

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 225 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 365 [d]

## SOURCE NO. 4

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 250 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 365 [d]

## SOURCE NO. 5

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 275 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 365 [d]

## SOURCE NO. 6

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 300 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 365 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
DISTANCE INCREMENT DELX..... = 25 [ft]  
DISTANCE INCREMENT DELY..... = 25 [ft]  
NUMBER OF NODES IN X-DIRECTION.... = 20  
NUMBER OF NODES IN Y-DIRECTION.... = 20

## CONCENTRATION C [mg/l]

| ROW\COLUMN |        |      | 1       | 2      | 3      | 4      | 5      |
|------------|--------|------|---------|--------|--------|--------|--------|
|            |        |      | 0.00    | 25.00  | 50.00  | 75.00  | 100.00 |
|            |        |      | [ft]    |        |        |        |        |
| 1          | 0.00   | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00  | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5          | 100.00 | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6          | 125.00 | [ft] | 0.0004  | 0.0004 | 0.0002 | 0.0001 | 0.0000 |
| 7          | 150.00 | [ft] | 0.0033  | 0.0027 | 0.0015 | 0.0005 | 0.0001 |
| 8          | 175.00 | [ft] | -0.9967 | 0.0073 | 0.0039 | 0.0014 | 0.0003 |
| 9          | 200.00 | [ft] | -0.9967 | 0.0096 | 0.0052 | 0.0018 | 0.0004 |
| 10         | 225.00 | [ft] | -0.9967 | 0.0100 | 0.0054 | 0.0019 | 0.0004 |
| 11         | 250.00 | [ft] | -0.9967 | 0.0100 | 0.0054 | 0.0019 | 0.0004 |
| 12         | 275.00 | [ft] | -0.9971 | 0.0096 | 0.0052 | 0.0018 | 0.0004 |
| 13         | 300.00 | [ft] | -1.0000 | 0.0073 | 0.0039 | 0.0014 | 0.0003 |
| 14         | 325.00 | [ft] | 0.0033  | 0.0027 | 0.0015 | 0.0005 | 0.0001 |
| 15         | 350.00 | [ft] | 0.0004  | 0.0004 | 0.0002 | 0.0001 | 0.0000 |
| 16         | 375.00 | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17         | 400.00 | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18         | 425.00 | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |        |      | 6      | 7      | 8      | 9      | 10     |
|------------|--------|------|--------|--------|--------|--------|--------|
|            |        |      | 125.00 | 150.00 | 175.00 | 200.00 | 225.00 |
|            |        |      | [ft]   |        |        |        |        |
| 1          | 0.00   | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5          | 100.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6          | 125.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7          | 150.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8          | 175.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9          | 200.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10         | 225.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11         | 250.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12         | 275.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13         | 300.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14         | 325.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15         | 350.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16         | 375.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17         | 400.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18         | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |       |      | 11     | 12     | 13     | 14     | 15     |
|------------|-------|------|--------|--------|--------|--------|--------|
|            |       |      | 250.00 | 275.00 | 300.00 | 325.00 | 350.00 |
|            |       |      | [ft]   |        |        |        |        |
| 1          | 0.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

|    |        |      |        |        |        |        |        |
|----|--------|------|--------|--------|--------|--------|--------|
| 3  | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4  | 75.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5  | 100.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6  | 125.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7  | 150.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8  | 175.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9  | 200.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | 225.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 250.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12 | 275.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13 | 300.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14 | 325.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15 | 350.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16 | 375.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17 | 400.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18 | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19 | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20 | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |        |      | 16     | 17     | 18     | 19     | 20     |
|------------|--------|------|--------|--------|--------|--------|--------|
| [ft]       |        |      | 375.00 | 400.00 | 425.00 | 450.00 | 475.00 |
| 1          | 0.00   | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5          | 100.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6          | 125.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7          | 150.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8          | 175.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9          | 200.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10         | 225.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11         | 250.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12         | 275.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13         | 300.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14         | 325.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15         | 350.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16         | 375.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17         | 400.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18         | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |



```
*****
*                                     *
*               PLUME2D               *
*                                     *
*   INTERNATIONAL GROUND WATER MODELING CENTER   *
*   GOLDEN, COLORADO - DELFT, NETHERLANDS        *
*                                     *
*               S O L U T E   version 2.03        *
*                                     *
*   ANALYTICAL MODELS FOR SOLUTE TRANSPORT        *
*                                     *
*****
```

PROJECT..... = AS-4151  
USER NAME..... = KAT  
DATE..... = 07-28-1994  
DATA FILE..... = B:YR5.270

## INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .004 [ft/d]  
AQUIFER THICKNESS..... = 13 [ft]  
POROSITY..... = .34  
LONGITUDINAL DISPERSIVITY..... = 500 [ft]  
LATERAL DISPERSIVITY..... = 167 [ft]  
NUMBER OF POINT SOURCES..... = 6

## SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 175 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 1825 [d]

## SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 200 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 1825 [d]

## SOURCE NO. 3

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 225 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 1825 [d]

## SOURCE NO. 4

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 250 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 1825 [d]

## SOURCE NO. 5

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 275 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.990000000000001D-03 [lb]  
ELAPSED TIME..... = 1825 [d]

## SOURCE NO. 6

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 300 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 1825 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
DISTANCE INCREMENT DELX..... = 25 [ft]  
DISTANCE INCREMENT DELY..... = 25 [ft]  
NUMBER OF NODES IN X-DIRECTION.... = 20  
NUMBER OF NODES IN Y-DIRECTION.... = 20

## CONCENTRATION C [mg/l]

| ROW\COLUMN |        |      | 1       | 2      | 3      | 4      | 5      |
|------------|--------|------|---------|--------|--------|--------|--------|
|            |        |      | 0.00    | 25.00  | 50.00  | 75.00  | 100.00 |
| [ft]       |        |      |         |        |        |        |        |
| 1          | 0.00   | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] | 0.0001  | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| 4          | 75.00  | [ft] | 0.0002  | 0.0002 | 0.0002 | 0.0001 | 0.0001 |
| 5          | 100.00 | [ft] | 0.0005  | 0.0005 | 0.0005 | 0.0004 | 0.0003 |
| 6          | 125.00 | [ft] | 0.0012  | 0.0012 | 0.0011 | 0.0009 | 0.0007 |
| 7          | 150.00 | [ft] | 0.0021  | 0.0021 | 0.0019 | 0.0016 | 0.0012 |
| 8          | 175.00 | [ft] | -0.9979 | 0.0032 | 0.0029 | 0.0024 | 0.0018 |
| 9          | 200.00 | [ft] | -0.9979 | 0.0041 | 0.0037 | 0.0030 | 0.0023 |
| 10         | 225.00 | [ft] | -0.9980 | 0.0046 | 0.0041 | 0.0034 | 0.0026 |
| 11         | 250.00 | [ft] | -0.9984 | 0.0046 | 0.0041 | 0.0034 | 0.0026 |
| 12         | 275.00 | [ft] | -0.9990 | 0.0041 | 0.0037 | 0.0030 | 0.0023 |
| 13         | 300.00 | [ft] | -1.0000 | 0.0032 | 0.0029 | 0.0024 | 0.0018 |
| 14         | 325.00 | [ft] | 0.0021  | 0.0021 | 0.0019 | 0.0016 | 0.0012 |
| 15         | 350.00 | [ft] | 0.0012  | 0.0012 | 0.0011 | 0.0009 | 0.0007 |
| 16         | 375.00 | [ft] | 0.0005  | 0.0005 | 0.0005 | 0.0004 | 0.0003 |
| 17         | 400.00 | [ft] | 0.0002  | 0.0002 | 0.0002 | 0.0001 | 0.0001 |
| 18         | 425.00 | [ft] | 0.0001  | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| 19         | 450.00 | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] | 0.0000  | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |        |      | 6      | 7      | 8      | 9      | 10     |
|------------|--------|------|--------|--------|--------|--------|--------|
|            |        |      | 125.00 | 150.00 | 175.00 | 200.00 | 225.00 |
| [ft]       |        |      |        |        |        |        |        |
| 1          | 0.00   | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00  | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5          | 100.00 | [ft] | 0.0002 | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| 6          | 125.00 | [ft] | 0.0005 | 0.0003 | 0.0002 | 0.0001 | 0.0000 |
| 7          | 150.00 | [ft] | 0.0008 | 0.0005 | 0.0003 | 0.0002 | 0.0001 |
| 8          | 175.00 | [ft] | 0.0013 | 0.0008 | 0.0005 | 0.0003 | 0.0001 |
| 9          | 200.00 | [ft] | 0.0016 | 0.0010 | 0.0006 | 0.0003 | 0.0002 |
| 10         | 225.00 | [ft] | 0.0018 | 0.0012 | 0.0007 | 0.0004 | 0.0002 |
| 11         | 250.00 | [ft] | 0.0018 | 0.0012 | 0.0007 | 0.0004 | 0.0002 |
| 12         | 275.00 | [ft] | 0.0016 | 0.0010 | 0.0006 | 0.0003 | 0.0002 |
| 13         | 300.00 | [ft] | 0.0013 | 0.0008 | 0.0005 | 0.0003 | 0.0001 |
| 14         | 325.00 | [ft] | 0.0008 | 0.0005 | 0.0003 | 0.0002 | 0.0001 |
| 15         | 350.00 | [ft] | 0.0005 | 0.0003 | 0.0002 | 0.0001 | 0.0000 |
| 16         | 375.00 | [ft] | 0.0002 | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| 17         | 400.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18         | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |       |      | 11     | 12     | 13     | 14     | 15     |
|------------|-------|------|--------|--------|--------|--------|--------|
|            |       |      | 250.00 | 275.00 | 300.00 | 325.00 | 350.00 |
| [ft]       |       |      |        |        |        |        |        |
| 1          | 0.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

|    |        |      |        |        |        |        |        |
|----|--------|------|--------|--------|--------|--------|--------|
| 3  | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4  | 75.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5  | 100.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6  | 125.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7  | 150.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8  | 175.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9  | 200.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | 225.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 250.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12 | 275.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13 | 300.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14 | 325.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15 | 350.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16 | 375.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17 | 400.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18 | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19 | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20 | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |        |      | 16     | 17     | 18     | 19     | 20     |
|------------|--------|------|--------|--------|--------|--------|--------|
| [ft]       |        |      | 375.00 | 400.00 | 425.00 | 450.00 | 475.00 |
| 1          | 0.00   | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5          | 100.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6          | 125.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7          | 150.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8          | 175.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9          | 200.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10         | 225.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11         | 250.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12         | 275.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13         | 300.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14         | 325.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15         | 350.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16         | 375.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17         | 400.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18         | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

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*****
*                                     *
*               PLUME2D               *
*                                     *
*   INTERNATIONAL GROUND WATER MODELING CENTER   *
*   GOLDEN, COLORADO - DELFT, NETHERLANDS        *
*                                     *
*               S O L U T E   version 2.03        *
*                                     *
*   ANALYTICAL MODELS FOR SOLUTE TRANSPORT        *
*                                     *
*****
```

PROJECT..... = AS-4151  
USER NAME..... = KAT  
DATE..... = 07-28-1994  
DATA FILE..... = B:YR10.270

## INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .004 [ft/d]  
AQUIFER THICKNESS..... = 13 [ft]  
POROSITY..... = .34  
LONGITUDINAL DISPERSIVITY..... = 500 [ft]  
LATERAL DISPERSIVITY..... = 167 [ft]  
NUMBER OF POINT SOURCES..... = 6

## SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 175 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 3650 [d]

## SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 200 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 3650 [d]

## SOURCE NO. 3

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 225 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 3650 [d]

## SOURCE NO. 4

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 250 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 3650 [d]

## SOURCE NO. 5

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 275 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 3650 [d]

## SOURCE NO. 6

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 300 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 3650 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
DISTANCE INCREMENT DELX..... = 25 [ft]  
DISTANCE INCREMENT DELY..... = 25 [ft]  
NUMBER OF NODES IN X-DIRECTION.... = 20  
NUMBER OF NODES IN Y-DIRECTION.... = 20

## CONCENTRATION C [mg/l]

| ROW\COLUMN |        |      | 1    | 2       | 3      | 4      | 5      |
|------------|--------|------|------|---------|--------|--------|--------|
|            |        |      | [ft] |         |        |        |        |
|            |        |      |      | 0.00    | 25.00  | 50.00  | 75.00  |
|            |        |      |      |         |        |        | 100.00 |
| 1          | 0.00   | [ft] |      | 0.0000  | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] |      | 0.0001  | 0.0001 | 0.0001 | 0.0001 |
| 3          | 50.00  | [ft] |      | 0.0002  | 0.0002 | 0.0002 | 0.0002 |
| 4          | 75.00  | [ft] |      | 0.0004  | 0.0004 | 0.0004 | 0.0003 |
| 5          | 100.00 | [ft] |      | 0.0007  | 0.0007 | 0.0007 | 0.0006 |
| 6          | 125.00 | [ft] |      | 0.0011  | 0.0011 | 0.0011 | 0.0010 |
| 7          | 150.00 | [ft] |      | 0.0016  | 0.0016 | 0.0015 | 0.0014 |
| 8          | 175.00 | [ft] |      | -0.9985 | 0.0021 | 0.0020 | 0.0018 |
| 9          | 200.00 | [ft] |      | -0.9986 | 0.0025 | 0.0024 | 0.0022 |
| 10         | 225.00 | [ft] |      | -0.9988 | 0.0027 | 0.0026 | 0.0024 |
| 11         | 250.00 | [ft] |      | -0.9991 | 0.0027 | 0.0026 | 0.0024 |
| 12         | 275.00 | [ft] |      | -0.9995 | 0.0025 | 0.0024 | 0.0022 |
| 13         | 300.00 | [ft] |      | -1.0000 | 0.0021 | 0.0020 | 0.0018 |
| 14         | 325.00 | [ft] |      | 0.0016  | 0.0016 | 0.0015 | 0.0014 |
| 15         | 350.00 | [ft] |      | 0.0011  | 0.0011 | 0.0011 | 0.0010 |
| 16         | 375.00 | [ft] |      | 0.0007  | 0.0007 | 0.0007 | 0.0006 |
| 17         | 400.00 | [ft] |      | 0.0004  | 0.0004 | 0.0004 | 0.0003 |
| 18         | 425.00 | [ft] |      | 0.0002  | 0.0002 | 0.0002 | 0.0002 |
| 19         | 450.00 | [ft] |      | 0.0001  | 0.0001 | 0.0001 | 0.0001 |
| 20         | 475.00 | [ft] |      | 0.0000  | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |        |      | 6    | 7      | 8      | 9      | 10     |
|------------|--------|------|------|--------|--------|--------|--------|
|            |        |      | [ft] |        |        |        |        |
|            |        |      |      | 125.00 | 150.00 | 175.00 | 200.00 |
|            |        |      |      |        |        |        | 225.00 |
| 1          | 0.00   | [ft] |      | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] |      | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] |      | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 4          | 75.00  | [ft] |      | 0.0003 | 0.0002 | 0.0002 | 0.0001 |
| 5          | 100.00 | [ft] |      | 0.0005 | 0.0004 | 0.0003 | 0.0002 |
| 6          | 125.00 | [ft] |      | 0.0007 | 0.0006 | 0.0005 | 0.0003 |
| 7          | 150.00 | [ft] |      | 0.0011 | 0.0009 | 0.0007 | 0.0005 |
| 8          | 175.00 | [ft] |      | 0.0014 | 0.0011 | 0.0009 | 0.0006 |
| 9          | 200.00 | [ft] |      | 0.0016 | 0.0013 | 0.0010 | 0.0008 |
| 10         | 225.00 | [ft] |      | 0.0018 | 0.0015 | 0.0011 | 0.0008 |
| 11         | 250.00 | [ft] |      | 0.0018 | 0.0015 | 0.0011 | 0.0008 |
| 12         | 275.00 | [ft] |      | 0.0016 | 0.0013 | 0.0010 | 0.0008 |
| 13         | 300.00 | [ft] |      | 0.0014 | 0.0011 | 0.0009 | 0.0006 |
| 14         | 325.00 | [ft] |      | 0.0011 | 0.0009 | 0.0007 | 0.0005 |
| 15         | 350.00 | [ft] |      | 0.0007 | 0.0006 | 0.0005 | 0.0003 |
| 16         | 375.00 | [ft] |      | 0.0005 | 0.0004 | 0.0003 | 0.0002 |
| 17         | 400.00 | [ft] |      | 0.0003 | 0.0002 | 0.0002 | 0.0001 |
| 18         | 425.00 | [ft] |      | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 19         | 450.00 | [ft] |      | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] |      | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |       |      | 11   | 12     | 13     | 14     | 15     |
|------------|-------|------|------|--------|--------|--------|--------|
|            |       |      | [ft] |        |        |        |        |
|            |       |      |      | 250.00 | 275.00 | 300.00 | 325.00 |
|            |       |      |      |        |        |        | 350.00 |
| 1          | 0.00  | [ft] |      | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00 | [ft] |      | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

|    |        |      |        |        |        |        |        |
|----|--------|------|--------|--------|--------|--------|--------|
| 3  | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4  | 75.00  | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5  | 100.00 | [ft] | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| 6  | 125.00 | [ft] | 0.0002 | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| 7  | 150.00 | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0000 |
| 8  | 175.00 | [ft] | 0.0003 | 0.0002 | 0.0001 | 0.0001 | 0.0000 |
| 9  | 200.00 | [ft] | 0.0004 | 0.0002 | 0.0002 | 0.0001 | 0.0001 |
| 10 | 225.00 | [ft] | 0.0004 | 0.0003 | 0.0002 | 0.0001 | 0.0001 |
| 11 | 250.00 | [ft] | 0.0004 | 0.0003 | 0.0002 | 0.0001 | 0.0001 |
| 12 | 275.00 | [ft] | 0.0004 | 0.0002 | 0.0002 | 0.0001 | 0.0001 |
| 13 | 300.00 | [ft] | 0.0003 | 0.0002 | 0.0001 | 0.0001 | 0.0000 |
| 14 | 325.00 | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0000 |
| 15 | 350.00 | [ft] | 0.0002 | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| 16 | 375.00 | [ft] | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| 17 | 400.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18 | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19 | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20 | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| ROW\COLUMN |        |      | 16     | 17     | 18     | 19     | 20     |
|------------|--------|------|--------|--------|--------|--------|--------|
|            | [ft]   |      | 375.00 | 400.00 | 425.00 | 450.00 | 475.00 |
| 1          | 0.00   | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00  | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5          | 100.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6          | 125.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7          | 150.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8          | 175.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9          | 200.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10         | 225.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11         | 250.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 12         | 275.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 13         | 300.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 14         | 325.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 15         | 350.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 16         | 375.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17         | 400.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18         | 425.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |



```

*****
*                                     *
*                               PLUME2D                               *
*                                     *
*   INTERNATIONAL GROUND WATER MODELING CENTER                     *
*   GOLDEN, COLORADO - DELFT, NETHERLANDS                           *
*                                     *
*   S O L U T E   version 2.03                                       *
*                                     *
*   ANALYTICAL MODELS FOR SOLUTE TRANSPORT                           *
*                                     *
*****

```

PROJECT..... = AS-4151  
 USER NAME..... = KAT  
 DATE..... = 07-28-1994  
 DATA FILE..... = B:YR25.270

## INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .004 [ft/d]  
 AQUIFER THICKNESS..... = 13 [ft]  
 POROSITY..... = .34  
 LONGITUDINAL DISPERSIVITY..... = 500 [ft]  
 LATERAL DISPERSIVITY..... = 167 [ft]  
 NUMBER OF POINT SOURCES..... = 6

## SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
 Y-COORDINATE OF THE SOURCE..... = 175 [ft]  
 TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
 ELAPSED TIME..... = 9125 [d]

## SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
 Y-COORDINATE OF THE SOURCE..... = 200 [ft]  
 TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
 ELAPSED TIME..... = 9125 [d]

## SOURCE NO. 3

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
 Y-COORDINATE OF THE SOURCE..... = 225 [ft]  
 TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
 ELAPSED TIME..... = 9125 [d]

## SOURCE NO. 4

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
 Y-COORDINATE OF THE SOURCE..... = 250 [ft]  
 TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
 ELAPSED TIME..... = 9125 [d]

## SOURCE NO. 5

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
 Y-COORDINATE OF THE SOURCE..... = 275 [ft]  
 TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
 ELAPSED TIME..... = 9125 [d]

## SOURCE NO. 6

X-COORDINATE OF THE SOURCE..... = 0 [ft]  
Y-COORDINATE OF THE SOURCE..... = 300 [ft]  
TOTAL SOLUTE MASS INJECTED..... = 7.9900000000000001D-03 [lb]  
ELAPSED TIME..... = 9125 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
Y-COORDINATE OF GRID ORIGIN..... = 0 [ft]  
DISTANCE INCREMENT DELX..... = 25 [ft]  
DISTANCE INCREMENT DELY..... = 25 [ft]  
NUMBER OF NODES IN X-DIRECTION.... = 20  
NUMBER OF NODES IN Y-DIRECTION.... = 20

## CONCENTRATION C [mg/l]

| ROW\COLUMN |        |      | 1       | 2      | 3      | 4      | 5      |
|------------|--------|------|---------|--------|--------|--------|--------|
| [ft]       |        |      | 0.00    | 25.00  | 50.00  | 75.00  | 100.00 |
| 1          | 0.00   | [ft] | 0.0002  | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| 2          | 25.00  | [ft] | 0.0002  | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| 3          | 50.00  | [ft] | 0.0003  | 0.0004 | 0.0003 | 0.0003 | 0.0003 |
| 4          | 75.00  | [ft] | 0.0005  | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| 5          | 100.00 | [ft] | 0.0006  | 0.0006 | 0.0006 | 0.0006 | 0.0006 |
| 6          | 125.00 | [ft] | 0.0008  | 0.0008 | 0.0008 | 0.0008 | 0.0007 |
| 7          | 150.00 | [ft] | 0.0009  | 0.0009 | 0.0009 | 0.0009 | 0.0009 |
| 8          | 175.00 | [ft] | -0.9992 | 0.0011 | 0.0011 | 0.0010 | 0.0010 |
| 9          | 200.00 | [ft] | -0.9993 | 0.0012 | 0.0012 | 0.0011 | 0.0011 |
| 10         | 225.00 | [ft] | -0.9994 | 0.0012 | 0.0012 | 0.0012 | 0.0011 |
| 11         | 250.00 | [ft] | -0.9996 | 0.0012 | 0.0012 | 0.0012 | 0.0011 |
| 12         | 275.00 | [ft] | -0.9998 | 0.0012 | 0.0012 | 0.0011 | 0.0011 |
| 13         | 300.00 | [ft] | -1.0000 | 0.0011 | 0.0011 | 0.0010 | 0.0010 |
| 14         | 325.00 | [ft] | 0.0009  | 0.0009 | 0.0009 | 0.0009 | 0.0009 |
| 15         | 350.00 | [ft] | 0.0008  | 0.0008 | 0.0008 | 0.0008 | 0.0007 |
| 16         | 375.00 | [ft] | 0.0006  | 0.0006 | 0.0006 | 0.0006 | 0.0006 |
| 17         | 400.00 | [ft] | 0.0005  | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| 18         | 425.00 | [ft] | 0.0003  | 0.0004 | 0.0003 | 0.0003 | 0.0003 |
| 19         | 450.00 | [ft] | 0.0002  | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| 20         | 475.00 | [ft] | 0.0002  | 0.0002 | 0.0002 | 0.0002 | 0.0002 |

| ROW\COLUMN |        |      | 6      | 7      | 8      | 9      | 10     |
|------------|--------|------|--------|--------|--------|--------|--------|
| [ft]       |        |      | 125.00 | 150.00 | 175.00 | 200.00 | 225.00 |
| 1          | 0.00   | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 2          | 25.00  | [ft] | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| 3          | 50.00  | [ft] | 0.0003 | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| 4          | 75.00  | [ft] | 0.0004 | 0.0004 | 0.0004 | 0.0003 | 0.0003 |
| 5          | 100.00 | [ft] | 0.0006 | 0.0005 | 0.0005 | 0.0004 | 0.0004 |
| 6          | 125.00 | [ft] | 0.0007 | 0.0007 | 0.0006 | 0.0005 | 0.0005 |
| 7          | 150.00 | [ft] | 0.0008 | 0.0008 | 0.0007 | 0.0006 | 0.0006 |
| 8          | 175.00 | [ft] | 0.0010 | 0.0009 | 0.0008 | 0.0007 | 0.0007 |
| 9          | 200.00 | [ft] | 0.0010 | 0.0010 | 0.0009 | 0.0008 | 0.0007 |
| 10         | 225.00 | [ft] | 0.0011 | 0.0010 | 0.0009 | 0.0008 | 0.0007 |
| 11         | 250.00 | [ft] | 0.0011 | 0.0010 | 0.0009 | 0.0008 | 0.0007 |
| 12         | 275.00 | [ft] | 0.0010 | 0.0010 | 0.0009 | 0.0008 | 0.0007 |
| 13         | 300.00 | [ft] | 0.0010 | 0.0009 | 0.0008 | 0.0007 | 0.0007 |
| 14         | 325.00 | [ft] | 0.0008 | 0.0008 | 0.0007 | 0.0006 | 0.0006 |
| 15         | 350.00 | [ft] | 0.0007 | 0.0007 | 0.0006 | 0.0005 | 0.0005 |
| 16         | 375.00 | [ft] | 0.0006 | 0.0005 | 0.0005 | 0.0004 | 0.0004 |
| 17         | 400.00 | [ft] | 0.0004 | 0.0004 | 0.0004 | 0.0003 | 0.0003 |
| 18         | 425.00 | [ft] | 0.0003 | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| 19         | 450.00 | [ft] | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| 20         | 475.00 | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |

| ROW\COLUMN |       |      | 11     | 12     | 13     | 14     | 15     |
|------------|-------|------|--------|--------|--------|--------|--------|
|            |       | [ft] | 250.00 | 275.00 | 300.00 | 325.00 | 350.00 |
| 1          | 0.00  | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0000 |
| 2          | 25.00 | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |

|    |        |      |        |        |        |        |        |
|----|--------|------|--------|--------|--------|--------|--------|
| 3  | 50.00  | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0001 |
| 4  | 75.00  | [ft] | 0.0003 | 0.0002 | 0.0002 | 0.0002 | 0.0001 |
| 5  | 100.00 | [ft] | 0.0003 | 0.0003 | 0.0002 | 0.0002 | 0.0002 |
| 6  | 125.00 | [ft] | 0.0004 | 0.0004 | 0.0003 | 0.0002 | 0.0002 |
| 7  | 150.00 | [ft] | 0.0005 | 0.0004 | 0.0004 | 0.0003 | 0.0002 |
| 8  | 175.00 | [ft] | 0.0006 | 0.0005 | 0.0004 | 0.0003 | 0.0003 |
| 9  | 200.00 | [ft] | 0.0006 | 0.0005 | 0.0004 | 0.0004 | 0.0003 |
| 10 | 225.00 | [ft] | 0.0006 | 0.0006 | 0.0005 | 0.0004 | 0.0003 |
| 11 | 250.00 | [ft] | 0.0006 | 0.0006 | 0.0005 | 0.0004 | 0.0003 |
| 12 | 275.00 | [ft] | 0.0006 | 0.0005 | 0.0004 | 0.0004 | 0.0003 |
| 13 | 300.00 | [ft] | 0.0006 | 0.0005 | 0.0004 | 0.0003 | 0.0003 |
| 14 | 325.00 | [ft] | 0.0005 | 0.0004 | 0.0004 | 0.0003 | 0.0002 |
| 15 | 350.00 | [ft] | 0.0004 | 0.0004 | 0.0003 | 0.0002 | 0.0002 |
| 16 | 375.00 | [ft] | 0.0003 | 0.0003 | 0.0002 | 0.0002 | 0.0002 |
| 17 | 400.00 | [ft] | 0.0003 | 0.0002 | 0.0002 | 0.0002 | 0.0001 |
| 18 | 425.00 | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0001 |
| 19 | 450.00 | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 20 | 475.00 | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0000 |

| ROW\COLUMN |        |      | 16     | 17     | 18     | 19     | 20     |
|------------|--------|------|--------|--------|--------|--------|--------|
| [ft]       |        |      | 375.00 | 400.00 | 425.00 | 450.00 | 475.00 |
| 1          | 0.00   | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2          | 25.00  | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3          | 50.00  | [ft] | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| 4          | 75.00  | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| 5          | 100.00 | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0000 |
| 6          | 125.00 | [ft] | 0.0002 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 7          | 150.00 | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0001 |
| 8          | 175.00 | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0001 |
| 9          | 200.00 | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0001 |
| 10         | 225.00 | [ft] | 0.0003 | 0.0002 | 0.0002 | 0.0001 | 0.0001 |
| 11         | 250.00 | [ft] | 0.0003 | 0.0002 | 0.0002 | 0.0001 | 0.0001 |
| 12         | 275.00 | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0001 |
| 13         | 300.00 | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0001 |
| 14         | 325.00 | [ft] | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0001 |
| 15         | 350.00 | [ft] | 0.0002 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 16         | 375.00 | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0000 |
| 17         | 400.00 | [ft] | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| 18         | 425.00 | [ft] | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| 19         | 450.00 | [ft] | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 20         | 475.00 | [ft] | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

**Appendix F**  
**Cost Estimate**

---

PROJECT LOCATION: MCB Camp Lejeune, Jacksonville, NC  
PROJECT NAME: Building AS-4151  
CONTRACT NUMBER: CTO- 270

CAP RAC ESTIMATE

TASK I. Mobilization and Site Preparation

|                                              |          |
|----------------------------------------------|----------|
| 1) Pre-Construction Submittals               | \$14,452 |
| 2) Equipment Mobilization                    | \$995    |
| 3) Personnel Mobilization and Demobilization | \$8,680  |
| 4) Setup/Construct Temporary Facilities      | \$10,678 |

Assumptions:

- Equipment rented from local companies. Long distance mobilization costs not included.
- One 8-hr day each for mobilization and demobilization.
- Two technicians 4 hrs each to set up trailer.
- Two technicians, 1 equipment operator and utility tractor 16 hrs each to set up decontamination and lay down areas.
- Decontamination area is 20' x 20' with geotextile liner, 6" PVC pipe for curb containment, and gravel to anchor textile.
- Lay-down area is 60' x 30' w/geotextile liner, 6" gravel.
- Two technicians, 1 equipment operator and utility tractor 8 hrs. each to set up temporary soil staging area.
- Soil storage area is 40' x 30' with geotextile liner and strawbales for berm.
- 40 additional bails of straw will keep geotextile in place.
- A 30' x 30' chain link fence around remediation equipment building will have two 10' wide double swing doors.

|              |          |
|--------------|----------|
| TASK I Total | \$34,805 |
|--------------|----------|

TASK II. Excavation and Disposal of Soil, Cleaning and Removal of Abandoned Pipeline

|                                                 |          |
|-------------------------------------------------|----------|
| 1) Soil Removal and Disposal                    | \$20,590 |
| 2) Confirmation Sampling                        | \$4,922  |
| 3) Abandoned Fuel Pipeline Cleaning and Removal | \$26,070 |

Assumptions:

- Estimated 230 cyds of soil to be excavated.
- Hauling costs (\$23/cyd) based on 35 miles (one way) haul.
- Disposal costs based on actual rate (\$28/ton) from McGill Environmental.
- 1.73 tons/cy conversion factor for sandy soil.
- Well abandonment, if required, is not included.
- Pipeline cleaning/removal includes installation of cleaning and decon fluid recovery equipment.
- 5,000 gal tanker: mob = \$1,000; rental = 30 days @ \$75/day; cleaning = \$300; total = \$3550
- Pipeline cleaning - 5,000 LF; Means 026-108-0140 & 0160 \$2.36/LF for 4" dia. and \$6.10/LF for 24" dia; use \$3/lf
- 200 LF abandoned pipeline removal in the vicinity of the excavation.

|               |          |
|---------------|----------|
| TASK II Total | \$51,582 |
|---------------|----------|

TASK III: Recovery Trench Installation

|                                         |         |
|-----------------------------------------|---------|
| 1) Traffic Control Requirements         | \$800   |
| 2) Trench Construction                  | \$6,936 |
| 3) Recovery Well Installation - 2 wells | \$6,070 |

Assumptions:

- Recovery wells will be installed during installation of the trench.
- Excavation/trench backfill - 1/2 drainage stone, 1/2 clean soil.

- Reseeding includes excavation, recovery trench, infiltration gallery, product piping, contractor areas.

|                |          |
|----------------|----------|
| TASK III Total | \$13,806 |
|----------------|----------|

#### Task IV: Pipe Subsurface Trenching

|                             |         |
|-----------------------------|---------|
| 1) Trench Installation      | \$827   |
| 2) Trench Construction      | \$6,045 |
| 3) Discharge to Storm Sewer | \$2,393 |

Assumptions:

- 75 LF of new trench must be installed for product piping; remainder of product piping (15 LF) in trench area.
- 90 LF of 2-inch PVC pipe will be used to contain product piping and air pipeline.
- Discharge sewer line connects to nearby existing storm sewer manhole/catch basin; does not cross road.
- 15 LF of new trench must be installed to infiltration gallery.
- 4-inch PVC pipe will be used for discharge line and infiltration gallery header line (15 LF + 24 LF).
- 2-inch PVC pipe will be used for infiltration gallery distribution lines (16 lines x 21 LF each).

|               |         |
|---------------|---------|
| TASK IV Total | \$9,265 |
|---------------|---------|

#### TASK V: Remediation System

|                                                            |          |
|------------------------------------------------------------|----------|
| 1) Groundwater Recovery System - Packaged Treatment System | \$50,866 |
|------------------------------------------------------------|----------|

Treatment system includes:

- Insulated Equipment Building (building is pre-wired)
- ESI Stripperator, Includes:
  - Oil/water Separator (268 gal operating capacity)
  - Air Stripper (two tray low profile with 30 gpm capacity)
  - Integral Effluent Sump (60 gal capacity)
  - Suspended Solids Bag Filter (5 sq ft surface area, 180 gpm flow capacity)
  - Liquid Phase Carbon Adsorbers (two 350 lb drums connected in series)
  - Compressed Air System (10 hp, 38 cfm @ 100 PSI)
  - High Level Shut-off System
- Total Fluids Pumping System (includes pumps, controls, down hole hoses and support cables)

|                                           |          |
|-------------------------------------------|----------|
| 2) Additional Construction Costs          | \$14,190 |
| 3) Demobilization Upon Project Completion | \$4,525  |
| 4) Post-Construction Submittals           | \$4,500  |

Assumptions:

- Remediation equipment based on flow rates of 20 gallons per minute.
- Treated groundwater to be discharged to storm sewer.
- Additional equipment to treat vapors discharged to the atmosphere will not be required.
- Price based on vendor quote from Ejector Systems, Inc., of Chicago, IL.
- Assume 30' x 30' x 6" gravel pad with geomembrane liner for equipment building foundation.

|              |          |
|--------------|----------|
| TASK V Total | \$74,081 |
|--------------|----------|

#### TASK VI: System Operation and Monitoring

|                       |          |
|-----------------------|----------|
| 1). Maintenance       | \$25,920 |
| 2). System Monitoring | \$30,708 |
| 3). Reporting         | \$18,600 |

Assumptions:

- Two years of operational monitoring and one year of post monitoring will be required.
- Monthly monitoring will be performed at same time as system maintenance.

- Additional time will be required for quarterly groundwater sampling.
- Monthly monitoring and maintenance activities to be performed by a local firm.
- Monthly and quarterly reports shall include description of system operations, fluid level measurements, sampling results, and figures depicting fluid measurements and analytical results.
- Yearly reports shall provide fourth quarter data and summarize previous three quarters.

|               |                 |
|---------------|-----------------|
| TASK VI Total | <u>\$75,228</u> |
|---------------|-----------------|

TASK VII: Distributive Costs

|                                                     |          |
|-----------------------------------------------------|----------|
| 1). Management Functions                            | \$27,560 |
| 2). Temporary Construction Facilities and Utilities | \$645    |
| 3). Project Travel Costs                            | \$20,927 |
| 4). Personnel Protection Equipment                  | \$1,880  |

|                |                 |
|----------------|-----------------|
| TASK VII Total | <u>\$51,012</u> |
|----------------|-----------------|

TOTAL ESTIMATED COST

|                                                     |                  |
|-----------------------------------------------------|------------------|
| TASK I. Mobilization and Site Preparation           | \$34,805         |
| TASK II. Excavation and Disposal of Soil Mound Area | \$51,582         |
| TASK III: Recovery Trench Installation              | \$13,806         |
| TASK IV: Shallow subsurface Trenching               | \$9,265          |
| TASK V: Remediation System                          | \$74,081         |
| TASK VI: System Operation and Monitoring            | \$75,228         |
| TASK VII: Distributive Costs                        | <u>\$51,012</u>  |
|                                                     | <u>\$309,779</u> |

Notes:

- Design costs not included; assumed that design completed under separate contract.
- Cost estimates based on Means Sitework and Landscape Cost Data (1994) or vendor quotes.
- Remediation equipment costs based on estimates provided by Ejector Systems, Inc.