26 0

File: 541.460.000n
C.G.

THE MEMPHIS DEPOT
TENNESSEE

ADMINISTRATIVE RECORD
COVER SHEET

AR File Number 26

26 1

File:
C.G. 541.460d
26

FINAL
PUMP TEST
WORK PLAN
FOR
DEFENSE DISTRIBUTION REGION CENTRAL
MEMPHIS, TENNESSEE

Contract No. DACA 87-90-D0030

PREPARED FOR

U.S. ARMY CORPS OF ENGINEERS
HUNTSVILLE DIVISION
Huntsville, Alabama

SUBMITTED BY

ENGINEERING-SCIENCE, INC.
St. Louis, Missouri

JULY 1992

SL016/67592/DDRC3

ES ENGINEERING-SCIENCE

ES
ENGINEERING-SCIENCE

425 Woods Mill Road South
Suite 150
Chesterfield, MO 63017
Telephone: (314) 576-7330
Fax: (314) 576-2702

27 July 1992

Commander
U.S. Army Corps of Engineers
Attention: CEHND-PM-EP (Skridulis)
106 Wynn Drive
Huntsville, AL 35805-1957

Subject: Final Pump Test Work Plan
Defense Distribution Region Central
Memphis, Tennessee
ES Project SL016.14
Contract No. DACA 87-90-D0030

Dear Mr. Skridulis:

Engineering-Science, Inc. (ES) is pleased to submit this Final Pump Test Work Plan for the DDRC project. This plan incorporates changes reflecting comments made by the USACE on 26 February 1992, by the USEPA, Region IV and by the Tennessee Department of Superfund. This work plan also reflects two modifications to the original scope of work.

We are enclosing replacements for the cover insert, the main body of the Work Plan and Appendix A. Appendix B was not altered and therefore is not being replaced. We look forward to receiving the approval to begin the field components of the Pump Test and Interim Remedial Measures Design.

If you have any questions, please call either of us at (314) 576-7330.

Yours truly,

ENGINEERING-SCIENCE, INC.

David E. Mizell, P.E.
Project Manager

Robert A. Mannebach, P.E.
Technical Director

Enclosure

FINAL
PUMP TEST
WORK PLAN
FOR
DEFENSE DISTRIBUTION REGION CENTRAL
MEMPHIS, TENNESSEE

Contract No. DACA 87-90-D0030

PREPARED FOR

U.S. ARMY CORPS OF ENGINEERS
HUNTSVILLE DIVISION
Huntsville, Alabama

SUBMITTED BY

ENGINEERING-SCIENCE, INC.
St. Louis, Missouri

JULY 1992

SL016/67592/DDRC3

FINAL
PUMP TEST
WORK PLAN
DEFENSE DISTRIBUTION REGION CENTRAL
MEMPHIS, TENNESSEE

Contract No. DACA 87-90-D0030

PREPARED FOR

U.S. ARMY CORPS OF ENGINEERS
HUNTSVILLE DIVISION
Huntsville, Alabama

SUBMITTED BY

ENGINEERING-SCIENCE, INC.
St. Louis, Missouri

Reviewed and approved:

Project Manager

Technical Director

Hydrogeology Technical Director

JULY 1992

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

1.0 INTRODUCTION

Defense Distribution Region Central (DDRC), formerly known as Defense Depot, Memphis, Tennessee (DDMT), is planning to install an interim ground water pumping and treatment system to control ground water contamination in the Dunn Field vicinity of the Depot. This contamination was discovered during a Remedial Investigation/Feasibility Study (RI/FS) which was completed for DDRC in 1990 (Law, 1990). While the extent of contamination is not fully known, DDRC has decided to install a pumping and treatment system to intercept ground water in the central part of the contaminated zone. This system, hereafter referred to as the Interim Remedial Measure (IRM), will provide ground water control in the area of highest contamination until the full extent of contamination is known and a permanent solution is developed.

This Pump Test Work Plan is part of a larger project which supplements the RI/FS previously done at DDRC. The RI/FS Follow-Up Work Plan is being prepared under separate cover, and is intended to further delineate ground water contaminants and further characterize potential contaminant sources within DDRC. Information collected during the RI/FS Follow-Up effort will be incorporated into the IRM effort to the maximum extent possible.

1.1 Purpose and Objectives

This Work Plan has been prepared to develop the technical specifications for the ground water pumping and treatment system. Engineering-Science, Inc. (ES), under a contract with the U.S. Army Corps of Engineers (USACE), Huntsville Division, will perform a pump test to characterize the ground water zone of interest, identify and evaluate pumping and treatment alternatives, and develop technical performance specifications for the system. ES will also prepare an Environmental Assessment for the IRM and prepare bid documents to support implementation of the IRM.

1.2 Technical Approach and Rationale

Engineering-Science, Inc. (ES) proposes to carry out data collection, technical evaluation, and engineering design activities as part of this effort. Task elements will be consistent with the National Contingency Plan (NCP) and the RCRA Corrective

Action Guidance for Interim Measures developed by the USEPA. Activities to be performed during this work are described as follows:

- Characterize the Zone of Ground Water Contamination - The Remedial Investigation (RI) identified volatile organic chemicals (VOCs) and metals in the upper-most water bearing zone beneath DDRC (known as the Fluvial Aquifer). ES will perform a pump test on this aquifer in the zone of contamination to define hydraulic properties of this formation.

- Establish Ground Water Cleanup Levels - ES will determine what levels of water treatment need to be achieved prior to discharge or release of extracted ground water. Tentative goals for the level of ground water cleanup will be established in consultation with the regulators and will be used to evaluate effectiveness of the interim pump and treat system.

- Develop Remedial Alternatives - ES will identify ground water pumping and treatment measures which should be considered for the IRM. Treatment technologies will include air stripping, carbon adsorption, and other physical and chemical methods. Ground water disposal alternatives will include reinjection, discharge to surface water, and disposal off-site (including the publicly-owned treatment works).

- Perform Detailed Analysis of Alternatives - Remedial alternatives will be evaluated and screened based on effectiveness, implementability and cost to compare the advantages and disadvantages of each. Since the IRM is a partial remedy, it may not be able to satisfy all requirements expected of a final remedy.

- Identify Preferred Remedy - The preferred alternative for ground water pumping and treatment will be identified and presented to the USACE and State and Federal regulators for consideration.

- Design Remedy - A Section C Work Statement will be developed for the USACE to use in soliciting bids on construction, installation, and startup of the IRM. A performance-based design will be presented to facilitate use of standard components throughout this system.

2.0 EXISTING ENVIRONMENT

The IRM is proposed for the Dunn Field vicinity of DDRC, which is the northern-most tract within the Depot (Figure 2-1). Information on soils and ground water beneath Dunn Field has been developed during the RI/FS (Law, 1990) and during other studies (AEHA, 1982). Figure 2-2 shows the location of existing monitoring wells in the Dunn Field vicinity. A study of regional characteristics of aquifers in the Memphis area (Smith and Ishak/Muhamad, 1989) also provides perspectives relevant to this study.

This chapter highlights relevant information from past studies which is useful in planning an IRM for contaminated ground water in the Dunn Field vicinity. Several references are made in this chapter to Figures in the Remedial Investigation (RI) report (Law, 1990). These figures are reproduced at the end of this chapter for the reader's convenience.

2.1 Site Geology

The Dunn Field area of DDRC is covered by loess deposits, which are underlain by the Fluvial Deposit, the Jackson Clay/Upper Claiborne Group, and the Memphis Sand. More information about these units is summarized below:

- Loess - Directly underlying the Dunn Field is loess, a semi-cohesive wind-blown deposit of silt, silty sand, and silty clay. It is about 20 feet thick in the Dunn Field vicinity and may occasionally reach 30 feet in thickness. Thin, discontinuous fine grained sand lenses may occur locally within the loess.

- Fluvial Deposit - Underlying the loess is the Fluvial Deposit. This unit consists of a top layer of silty clay, silty sand, or clayey sand; a clean, fine to medium-grained sand; and a basal gravelly sand. While the gravelly sand layer frequently occurs below the fine sand layer, some borings at DDRC exhibit additional fine sand layers below the gravelly sand. (See Figures 3-6 and 3-7 of the RI report on pages 2-9 and 2-10 in this chapter).

  The upper sand layers are orange color indicating an oxidation environment. The lower layers are very clean, tan to white sand. The

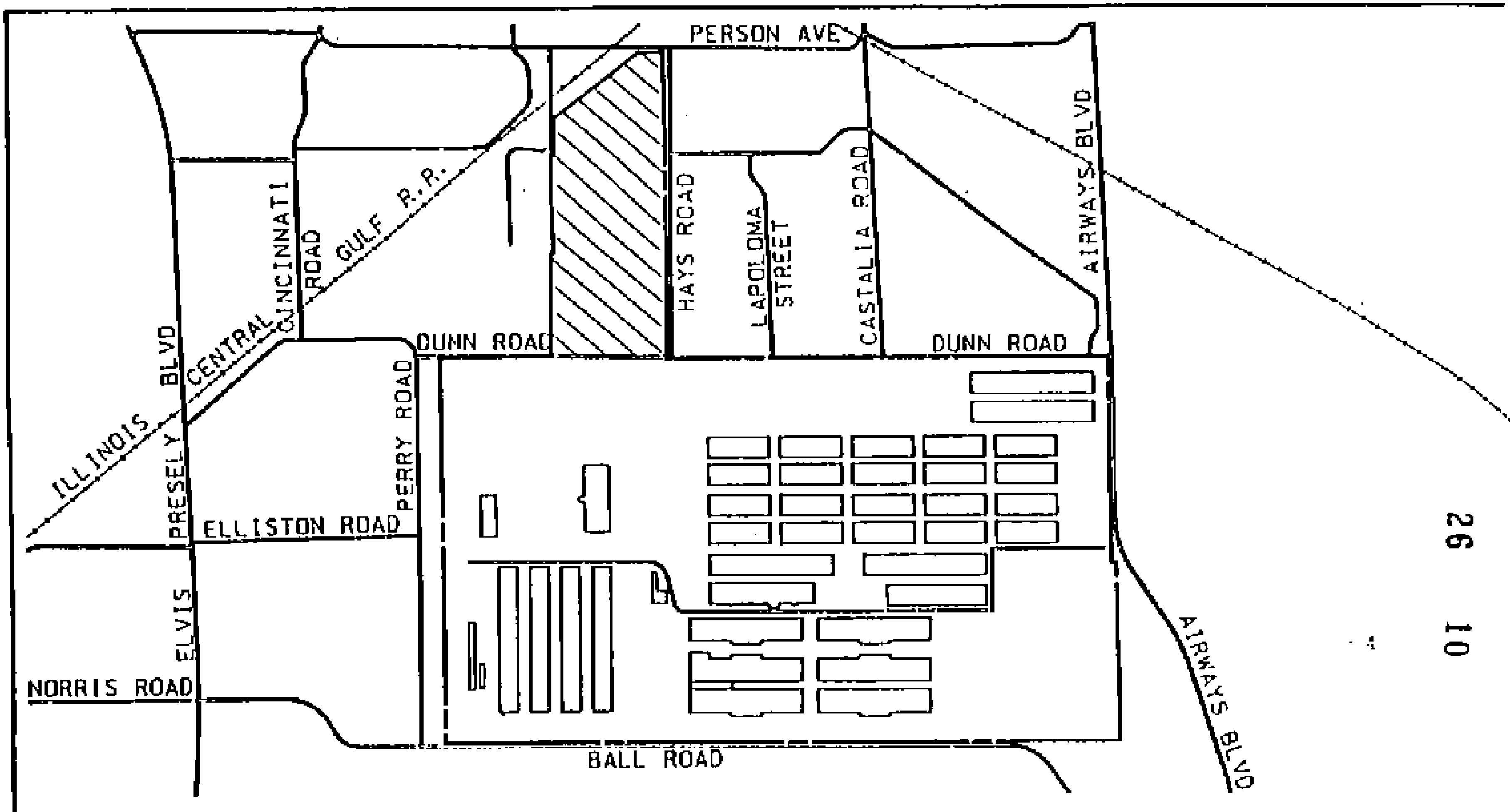


FIGURE 2-1:
DUNN FIELD LOCATION
DEFENSE DISTRIBUTION
REGION CENTRAL

DEFENSE DISTRIBUTION
REGION CENTRAL
MEMPHIS, TENNESSEE

DEFENSE LOGISTICS AGEN

ENGINEERING-SCIENCE
St. Louis, Missouri

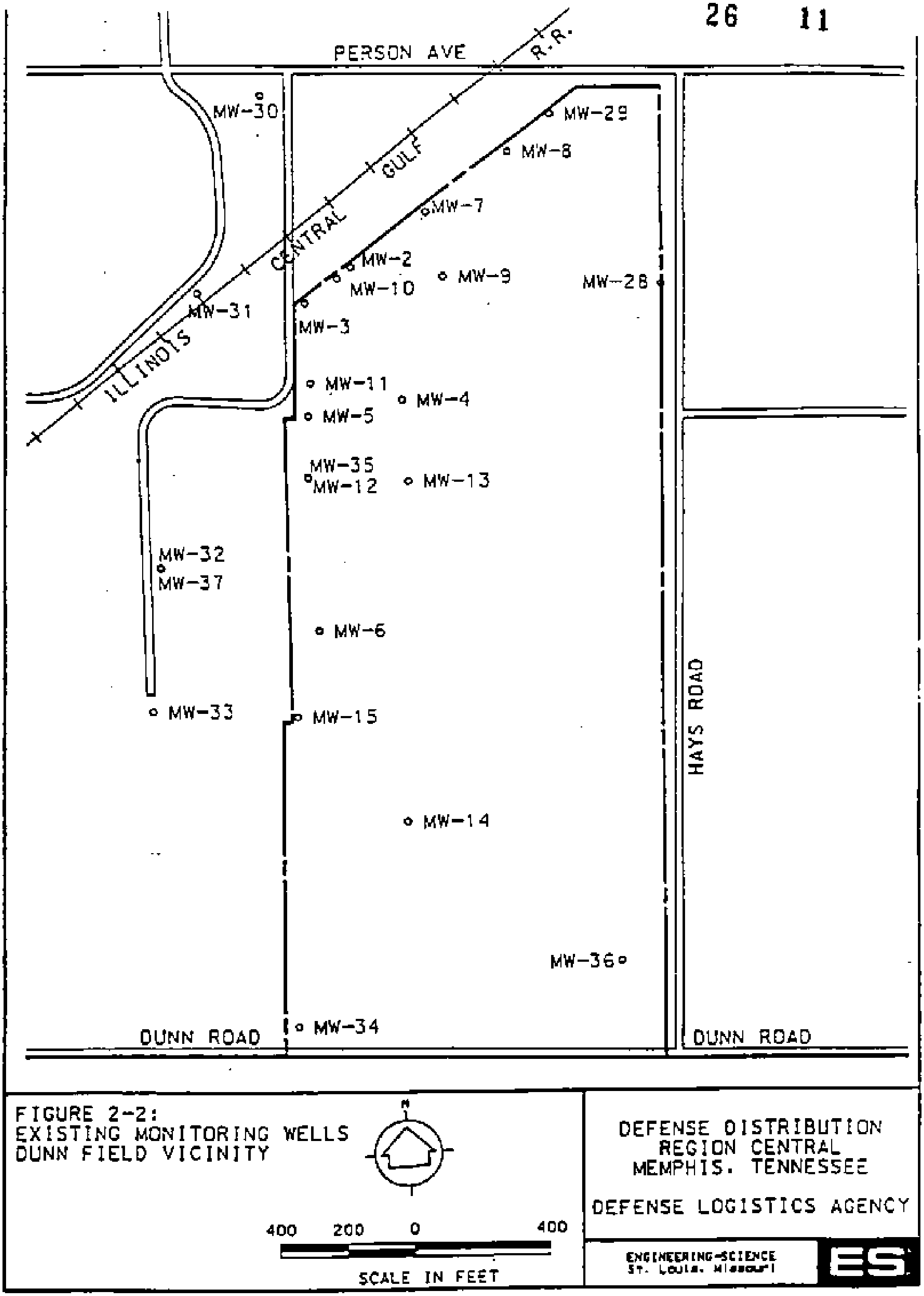


FIGURE 2-2:
EXISTING MONITORING WELLS
DUNN FIELD VICINITY

sand layers become coarser downwards into the gravelly sand. Gravel size ranges from pea-sized pebbles to baseball-size stones. The thickness of the Fluvial Deposit in Dunn Field ranges from 50 to 70 feet.

- Jackson Clay and Upper Claiborne Group - This unit is laterally persistent and fairly uniform in thickness, about 80 feet, throughout Dunn Field. This unit thins markedly in the area immediately south of Dunn Field. Windows in this unit have been documented in the Memphis area (Smith and Ishak/Muhamad, 1989). It is a stiff gray or orange plastic, lean to fat lignitic clay. The contact between the Jackson Clay and the upper, clay rich portion of the Claiborne Group is difficult to distinguish and is not of hydrologic significance. It forms a regional confining bed separating the Fluvial Deposit and the underlying Memphis Sand.

  The top of the Jackson Clay slopes toward the northwest and west beneath most of Dunn Field with a gradient of about one percent; however, the top surface slopes southwestward beneath the extreme southern portion of Dunn Field at a rate of about 7 percent. (See Figure 3-13 of the RI report on page 2-11 of this chapter).

- Memphis Sand - The Memphis Sand of the Claiborne Group is also called the 500-foot Sand because its center occurs generally at 500-foot below ground level (BGL). This unit ranges from 500 to 900 feet in thickness. At Dunn Field, the top of the Memphis Sand is at about 180 feet BGL along the western property line and at about 140 feet BGL along the eastern property line. (See Figures 3-6 and 3-7 of the RI report on pages 2-9 and 2-10 of this chapter). It is composed of thin bedded, white to brown or gray, very fine grained to gravelly, partially argillaceous and micaceous sand.

  Underneath the Memphis Sand is the Flour Island confining bed. This unit ranges from 150 to 300 feet in thickness.

2.2 Regional Hydrogeology

Water supply systems in the Memphis area depend heavily upon ground-water resources. The uppermost aquifer beneath Dunn Field is the Fluvial Aquifer, which is not used in the Memphis area for drinking water because of variable water quality, high hardness, and elevated iron concentrations. Furthermore, because the loess deposits allow infiltration and recharge to the Fluvial Aquifer, this unit is susceptible to contamination from the surface.

Beneath the Fluvial Aquifer lies the Memphis Sand Aquifer, which is the shallowest artesian aquifer in the area. The Memphis Sand Aquifer is heavily used for municipal water supplies in the Memphis area, supplying about 200 million gallons per day (MGD) to the City of Memphis and surrounding unincorporated areas. The Memphis Light, Gas and Water Division operates ten well fields in Shelby County, Tennessee, which extensively utilize the Memphis Sand. The closest of these is the Allen Well Field which is about 1 to 1.5 miles west of DDRC.

The Fort Pillow Sand Aquifer lies beneath the Memphis Sand and is not significant in this study because of its depth and because its hydraulic head is higher than the Memphis Sand stratum.

2.3 Site Hydrogeology

- Loess - The loess is not a water bearing zone. There is no evidence that it produces water to wells in the DDRC vicinity. The loess deposits permit recharge into underlying Fluvial Deposit during rainfall events.

  Seasonal perched ground water may occur within the loess. Monitoring well MW-2 is a well screened within the loess. It contains water following rainfall events but dries out afterward. The perched water table in northern Dunn Field is a fine sandy layer enclosed within the loess.

- Fluvial Deposit - The Fluvial Deposit forms the water table aquifer in the Dunn Field vicinity. The Fluvial Aquifer is about 15 to 20 feet thick beneath Dunn Field, and receives recharge from rainfall infiltration through overlying loess and lateral ground water inflow from the east. Discharge is toward the Mississippi River to the west and leakage is to the underlying Memphis Sand through the Jackson/Upper Claiborne confining bed.

  Ground water flow in January, 1990 was toward the west and southwest beneath Dunn Field (Figure 2-3). The estimated ground water flow velocity is 0.8 feet/day based on an average hydraulic conductivity of 7.6×10^{-3} ft/min and an assumed porosity of 0.26.

- Jackson Clay/Upper Caliborne Formation - This unit is a regional confining bed. As discussed before, it separates the Fluvial Deposit from the

26 14

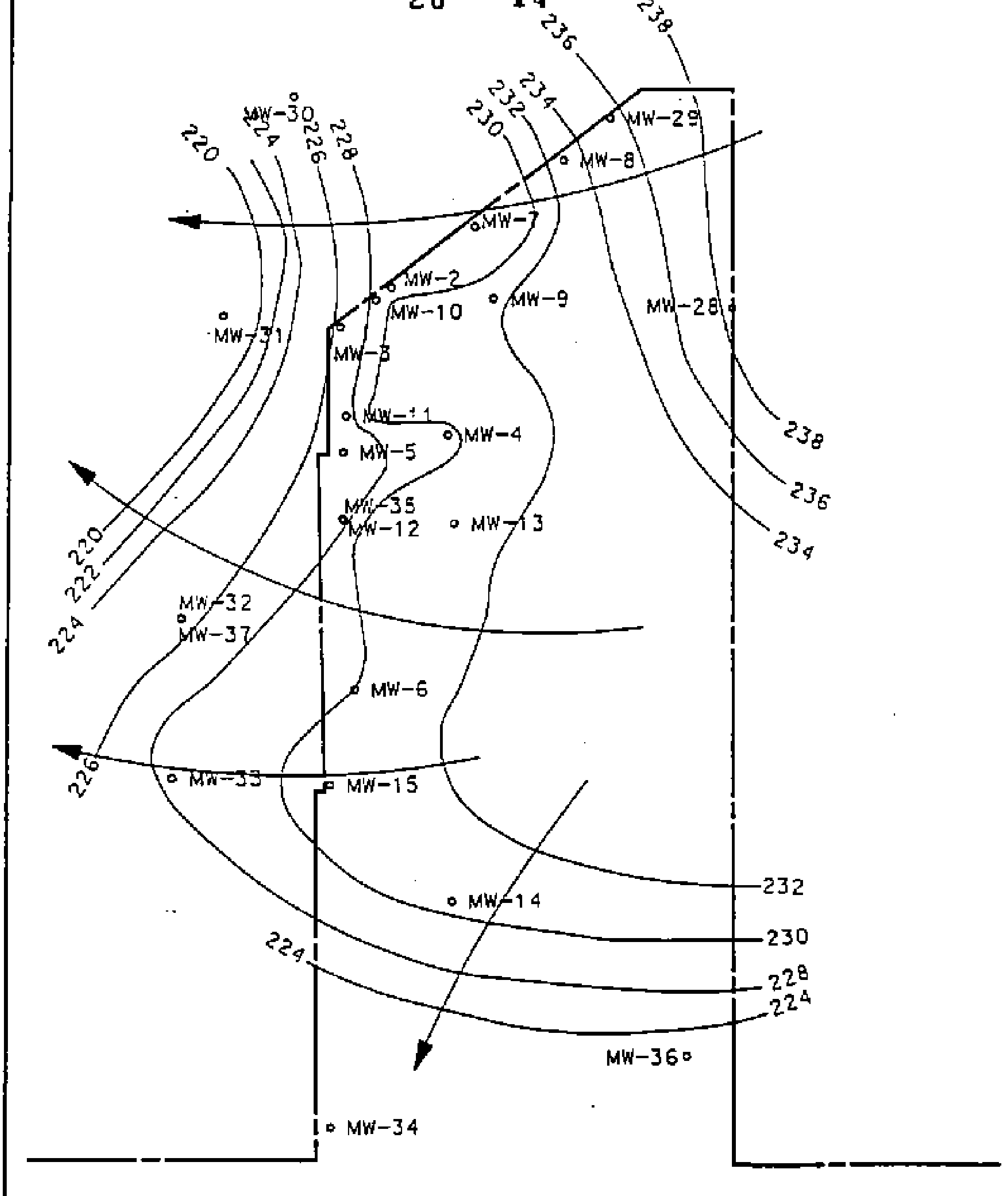


FIGURE 2-3:
GROUND WATER FLOW PATTERNS
DUNN FIELD VICINITY
JANUARY, 1990

SOURCE:
LAW ENVIRONMENTAL

400 200 0 400
SCALE IN FEET

DEFENSE DISTRIBUTION
REGION CENTRAL
MEMPHIS, TENNESSEE

DEFENSE LOGISTICS AGENCY

ENGINEERING-SCIENCE
St. Louis, Missouri

ES

Memphis Sand Aquifer. Due to erosional features, this unit is thinned at DDRC immediately south of Dunn Field. It is documented (Smith, and Ishak/Muhamad 1989) that some areas of the Memphis Sand are directly overlain by the Fluvial Deposit.

December 1989 measurements of MW-32 (Fluvial Aquifer) and MW-37 (Memphis Sand Aquifer) indicated that the water elevation of the Fluvial Aquifer was at 226 feet above Mean Sea Level (MSL), compared to the water level in the Memphis Sand of 143 feet MSL. The hydraulic head difference is about 83 feet.

- Memphis Sand - At DDRC, the top of Memphis Sand is approximately at 125 to 150 feet MSL. The base of this unit is about -750 feet MSL. Thus, the aquifer is about 900 feet thick and is under confined conditions. Recharge is from the outcrop area to the east and from leakage from the overlying Fluvial Deposit aquifer. Local discharge is the pumpage of Allen Well Field, located 1 to 2 miles to the west. Water levels in the two Memphis Sand wells installed during the RI/FS (Law, 1990) suggest a gradient toward the west.

2.4 Ground Water Chemistry

During the RI study, volatile organic chemicals (VOCs) and heavy metals were found in ground water beneath Dunn Field at levels exceeding the federal primary drinking water standards. Ground water samples were analyzed for the 129 priority pollutants excluding asbestos and cyanide.

- Volatile Organic Chemicals - Eleven volatile organic chemicals were detected in the Fluvial Aquifer. The plumes of tetrachloroethene; 1,1,2,2-tetrachlorothane; and 1,1-dichloroethene were illustrated in Figure 4-4 of the RI, page 2-12 of this chapter. Due to ground water flow and past hazardous waste disposal site locations, the plumes appear aligned with the north and west property lines. Well MW-30 is the northern boundary and MW-33 is the southern boundary of the plumes. The western boundary of these plumes is not delineated.

  Although the trichoroethene (TCE) plume was not illustrated in the 1990 RI report, it was detected at the highest concentrations of all the VOCs detected at Dunn Field. TCE was about 2 ug/l at MW-15 and 1500 ug/l at

MW-12 during the Phase I RI (April 1989). TCE was about the same concentration at MW-15 during Phase II RI (January 1990); however, it increased to 5100 ug/l at MW-12.

- Heavy Metals - Figure 4-5 of the RI, shown on page 2-13 of this chapter, presents the concentration contour maps of chromium and lead. These plumes cover a wider area than the organic plumes. There are two possible reasons for metal plumes wider than organic plumes. First, the VOCs are synthesized by man while heavy metals are contained in natural earth materials. An upgradient background well, MW-16, in the main facility at DDRC, detected these metals in the Fluvial Aquifer indicating they may not come from a source in Dunn Field. Second, both the dissolved and the suspended metals were analyzed. If only the dissolved phase was analyzed, the lead and chromium plumes may be smaller. However, all contaminants, dissolved or suspended, will need to be assessed and may be subject to remediation.

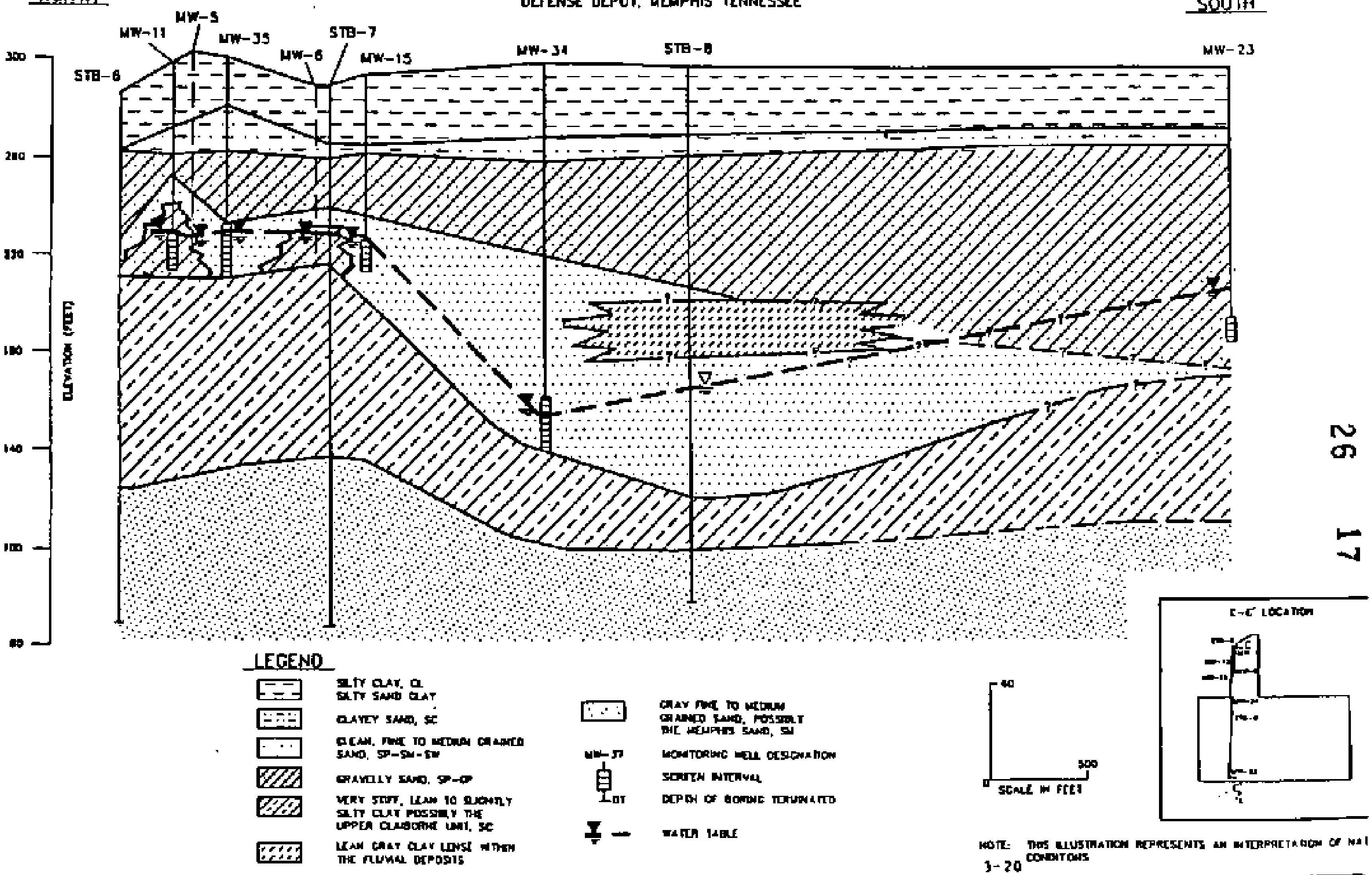
- Memphis Sand Aquifer - Two wells from the RI study are installed in the Memphis Sand. MW-36 is located at the southeast corner of Dunn Field and can be considered as an upgradient well. MW-37 is located west of Dunn Field (Figure 2-2) and is a downgradient well. These wells exhibited only low levels of metals. Acetone was detected in the water sample from MW-37 at a concentration of 3500 ug/l.

  Three wells (126, 127, and 128) of the Allen Well Field were closed due to VOCs contamination. The Memphis Light, Gas and Water Division is investigating the cause of the contamination but the source has not been identified. Other Allen Well Field wells located between these three wells and DDRC do not exhibit VOC contamination.

FIGURE 3-6

CROSS-SECTION C-C', NORTH TO SOUTH

DEFENSE DEPOT, MEMPHIS TENNESSEE



NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NA[illegible] CONDITIONS

3-20

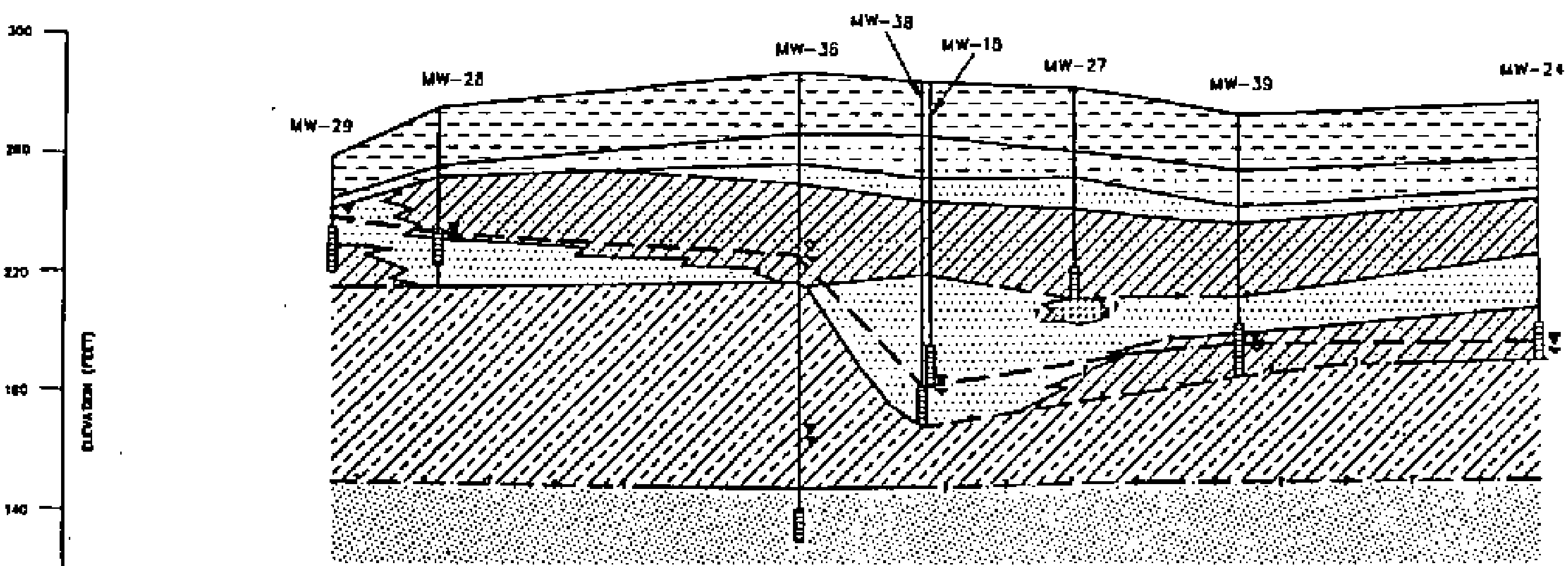
LAW ENVIRONMENTAL INC.
GOVERNMENT SERVICES DIVISION

26 17

FIGURE 3-7

CROSS-SECTION D-D', NORTH TO SOUTH

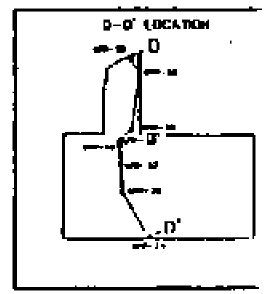
DEFENSE DEPOT, MEMPHIS TENNESSEE



LEGEND

- SILTY CLAY, CL SILTY SAND CLAY
- CLAYEY SAND, SC
- CLEAN, FINE TO MEDIUM GRAINED SAND, SP-SM-SW
- GRAVELLY SAND, SP-GP
- VERY STIFF, LEAN TO SLIGHTLY SILTY CLAY POSSIBLY THE UPPER CLAIBORNE UNIT, SC
- LEAN GRAY CLAY LENSE WITHIN THE FLUVIAL DEPOSITS
- GRAY FINE TO MEDIUM GRAINED SAND, POSSIBLY THE MEMPHIS SAND, SM
- MW-37 MONITORING WELL DESIGNATION
- SCREEN INTERVAL
- DEPTH OF BORING TERMINATED
- WATER TABLE

NOTE: THIS ILLUSTRATION REPRESENTS AN INTERPRETATION OF NATURAL CONDITIONS



LAW ENVIRONMENTAL INC. GOVERNMENT SERVICES DIVISION

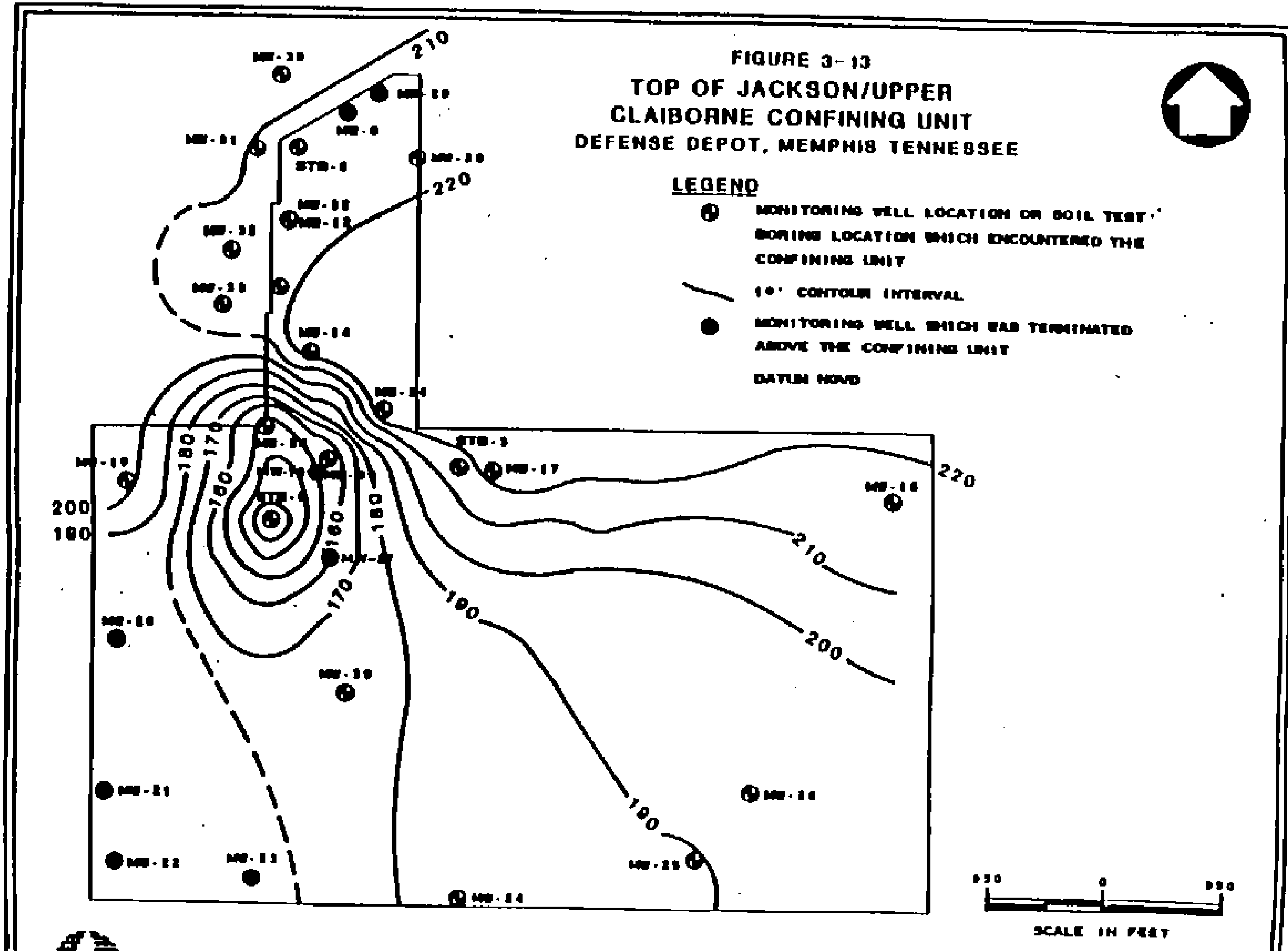


FIGURE 3-13
TOP OF JACKSON/UPPER
CLAIBORNE CONFINING UNIT
DEFENSE DEPOT, MEMPHIS TENNESSEE
LEGEND
MONITORING WELL LOCATION OR SOIL TEST BORING LOCATION WHICH ENCOUNTERED THE CONFINING UNIT
10' CONTOUR INTERVAL
MONITORING WELL WHICH WAS TERMINATED ABOVE THE CONFINING UNIT
DATUM NGVD
SCALE IN FEET
220
210
200
190
180
170
160

FIGURE 4-4
VOLATILE ORGANICS CONTAMINATION EXTENT IN FLUVIAL AQUIFER
DEFENSE DEPOT, MEMPHIS TENNESSEE

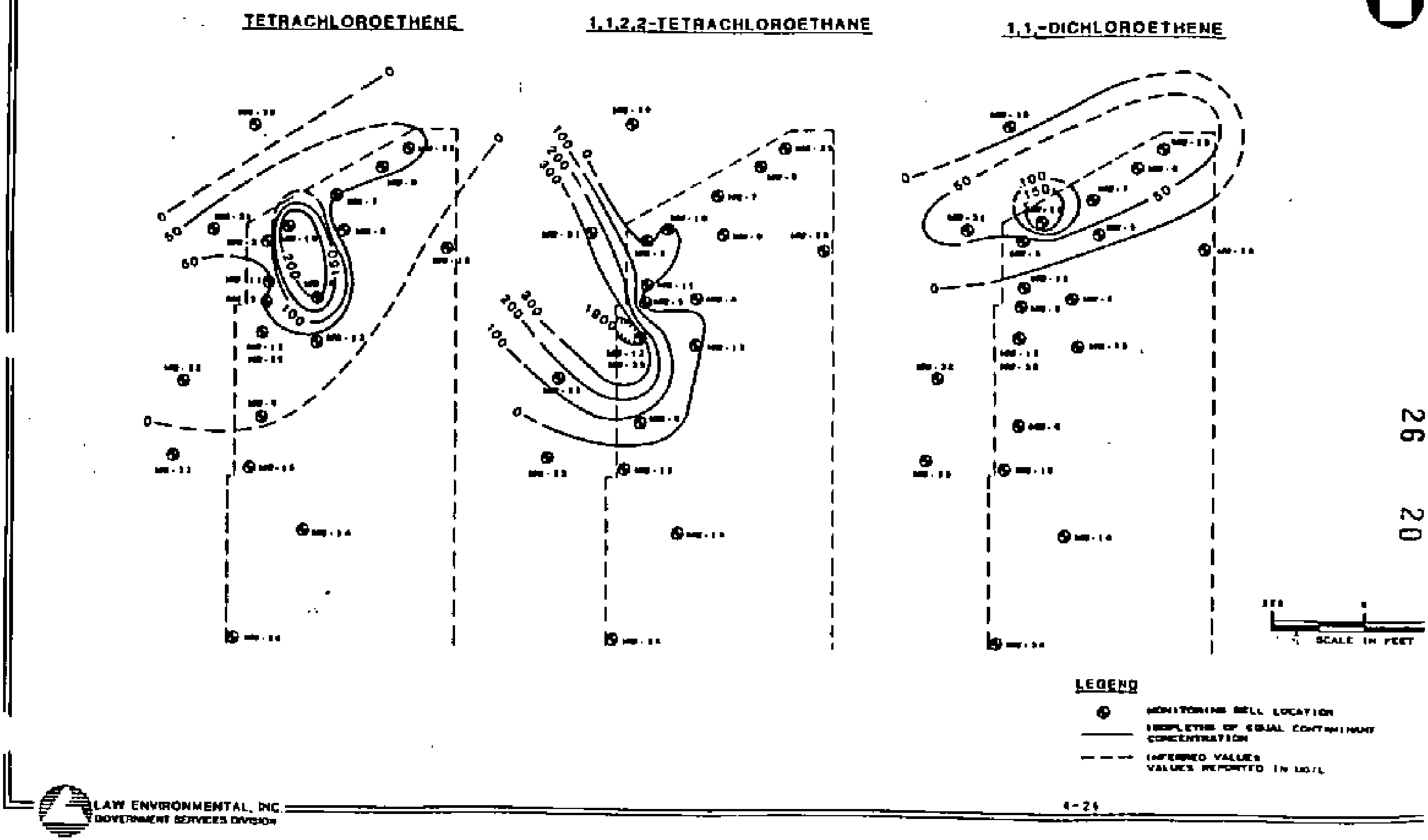
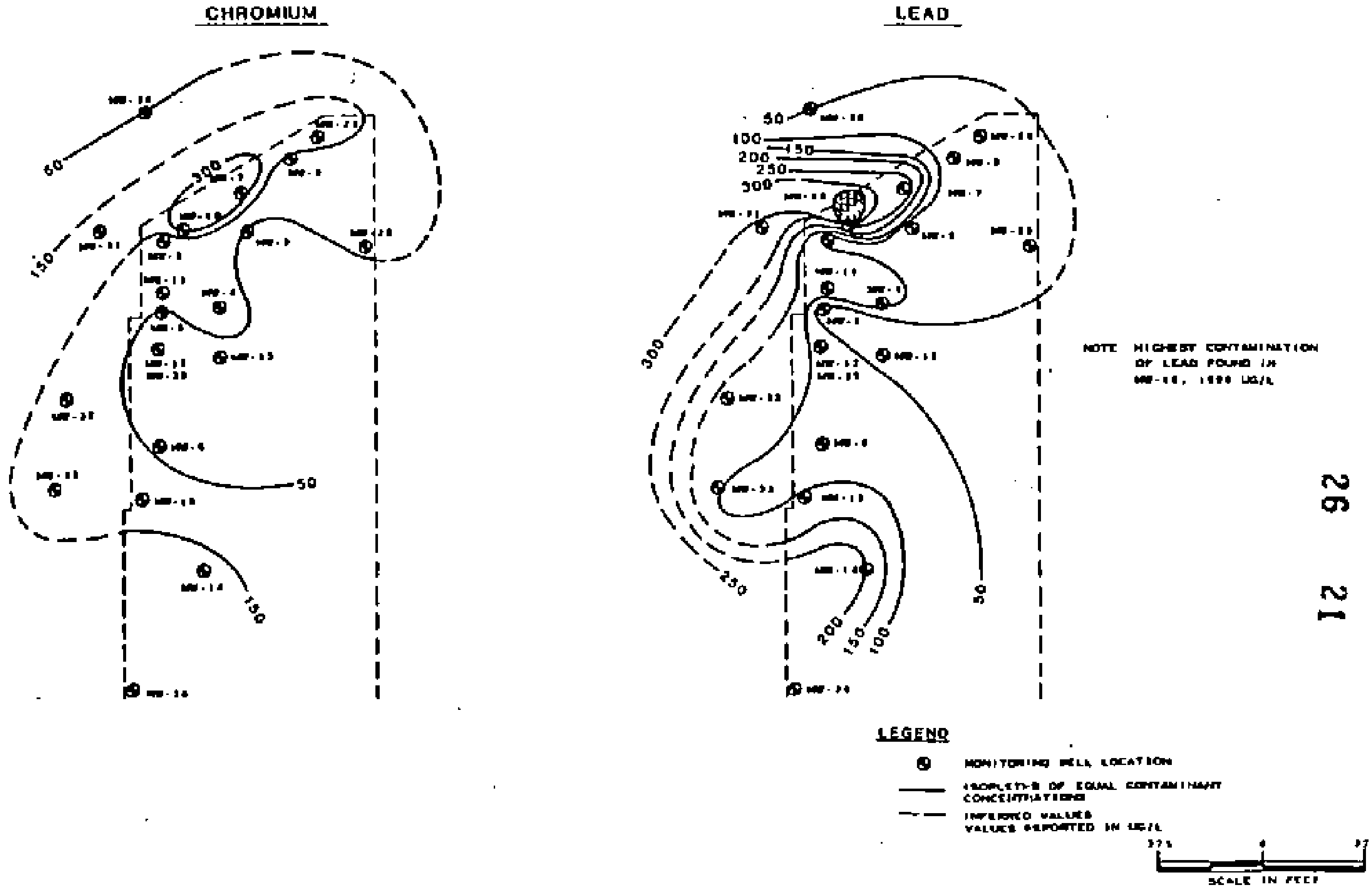


FIGURE 4-5
EXTENT OF ELEVATED METALS IN FLUVIAL AQUIFER
DUNN FIELD
DEFENSE DEPOT, MEMPHIS TENNESSEE



4-26

LAW ENVIRONMENTAL, INC.
GOVERNMENT SERVICES DIVISION

26 21

3.0 PUMPING TEST PLAN

A pumping test is planned for the Dunn Field area to characterize the Fluvial Aquifer for the design of a ground water pumping and treatment system. Specific objectives of the pumping test are to:

- estimate transmissivity
- estimate storativity
- estimate radius of influence
- estimate well specific capacity and efficiency
- estimate aquifer anisotropy, if any
- determine optimum pumping rate
- perform a time-series analysis of volatile organic vapors in headspace of samples from the pump test well
- determine non-contaminant chemistry pertaining to treatment system design

These parameters and the shapes of the contaminant plumes will be used to design a well field and assess the potential hydrogeologic impacts of this system. Several calculations were made to estimate the Fluvial Aquifer's response to pumping. Based on these calculations, the optimum pumping rate, well design, and location of the well could be estimated. These calculations were made following procedures in *Groundwater and Wells* (Driscoll, 1987).

3.1 Pumping Rate

The discharge rate for this pumping test was estimated using hydraulic conductivity measurements compiled during the RI/FS (Law, 1990) and other assumptions about the Fluvial Aquifer. Calculations were performed using the following assumptions:

- Hydraulic conductivity, $k = 7.6 \times 10^{-3}$ ft/min
  (based on the average hydraulic conductivity of the Fluvial Aquifer as mentioned in Section 2);
- Storage coefficient, $S = 0.26$
  (based on the average porosity of the sediments in the Fluvial Aquifer);
- Aquifer thickness = 20 feet.

The modified nonequilibrium equation of Cooper and Jacob (1946) was used to examine distance-drawdown relationships for the Fluvial Aquifer (see Appendix B). A discharge rate of 20 gallons per minute (gpm) was selected for initial evaluation. Two trial calculations were performed, one using hydraulic conductivities from monitor wells in the Dunn Field vicinity (Trial 1) and the other using hydraulic conductivities from all wells in the RI/FS into the Fluvial Aquifer (Trial 2). Trial 1 indicated drawdowns 10 feet from the pumping well of about 2.5 feet after 48 hours of pumping, while Trial 2 showed drawdowns around 5 feet. Drawdowns in the pumping well will exceed these numbers, and because the saturated thickness is estimated to be 20 feet, this 20 gpm appears to be a reasonable estimate in designing this pump test.

The Cooper and Jacob (1946) method, based on the Theis equation, was developed for confined aquifers. Since the pumping test will be conducted in an unconfined aquifer, the values obtained using this method can only be considered as a rough estimate. However, for the purpose of determining the optimum pumping rate and the resultant radius of influence, these results provide adequate estimations.

3.2 Location of Pumping Test Well and Observation Wells

Based on the above assumptions an estimated radius of influence was calculated following the procedures in *Groundwater and Wells* (Driscoll, 1987). This procedure uses drawdown values calculated from the Cooper and Jacob method; therefore the values obtained for the radius of influence must be considered approximate. Using the average hydraulic conductivity for all Fluvial Aquifer wells, and a pumping rate of 20 gpm for 48 hours, the radius of influence was graphically estimated in Appendix B as 60 feet. Drawdown in the pumping wells is estimated to be 13 feet. While the scope of work called for a minimum of 36 hours pumping, ES proposes to extend the pumping period to 48 hours if drawdown has not yet stabilized. Since pumping is occurring in an unconfined aquifer, a longer period of pumping may be needed to approach equilibrium conditions.

Based on a radius of influence of approximately 60 feet, ES proposes to locate the pumping well 20 feet northeast of MW-3 (Figure 3-1). This location, at the northwest corner of Dunn Field, meets the following criteria:

- located near several monitor wells which can be used for observation wells during the test;

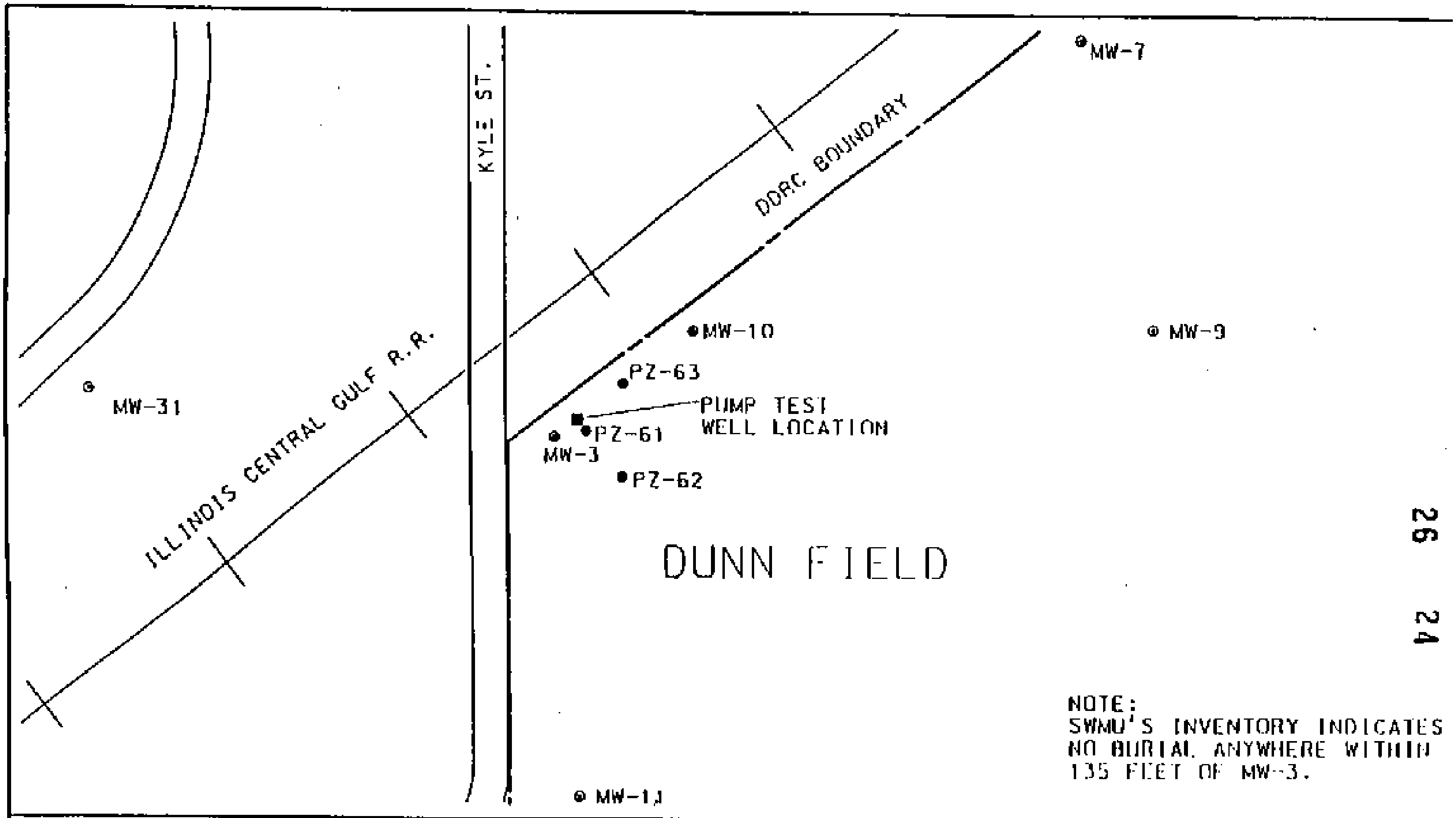


FIGURE 3-1:
PROPOSED PUMP TEST WELL
AND OBSERVATION
WELL LOCATIONS
DUNN FIELD VICINITY

DEFENSE DISTRIBUTION
REGION CENTRAL
MEMPHIS, TENNESSEE

DEFENSE LOGISTICS AGENCY

ENGINEERING-SCIENCE
St. Louis, Missouri

ES

- located near the downgradient edge of the known tetrachloroethene and 1,1 dichloroethane plumes;
- close to lead and chromium plumes detected during the RI/FS;
- average depth and thickness of Fluvial Aquifer in this vicinity; and
- suitable for use as a future extraction well.

ES proposes to conduct this pump test using one observation well and 3 piezometers within the estimated 60 foot radius of influence. MW-3, an existing monitor well, will be 20 feet to the southwest. Three new piezometers, PZ-61, 62, and 63 will be located southwest and northeast of the pump test well, as shown in Figure 3-1. These well numbers were selected to be compatible with the existing monitor well network.

PZ-61 is proposed ten feet southeast of the pumping well. PZ-61 will react first to pumping, and will provide distance-drawdown measurements close in to the pump test well. The small distance to the pumping well was chosen in order to obtain valuable data in the event that the radius of influence is smaller than was estimated in designing the test. There is no indication that stratification in the fluvial aquifer will restrict the vertical gradients that are common during pumping in an unconfined aquifer.

PZ-62 is proposed 40 feet southeast along the same axis as PZ-61. Given the uncertainties in hydraulic conductivity (see Trials 1 and 2 in Appendix B), a 40 foot distance will yield meaningful drawdown data regardless of the actual hydraulic conductivity. PZ-61 and 62 will provide data on time drawdown and distance drawdown relationships along the northwest-southeast axis from the pump test well. Both relationships will provide greater confidence in calculating the transmissivity and storage coefficient.

PZ-63 is proposed 40 feet northeast of the pump test well. PZ-63 and MW-3 will track drawdown along the northeast-southwest axis, and will reveal any differences in distance-drawdown relationships from the PZ 61-62 pair. Like PZ-62, PZ-63 is at a distance that will yield meaningful drawdown data regardless of hydraulic conductivity.

Water levels will be measured using a combination of data loggers equipped with pressure transducers and electric water level indicators. Pressure transducers will be used on the pumped well and on one of the piezometers, with other piezometers and monitoring wells being measured with an electric tape.

The three piezometers and MW3 will provide data from which a sound statistical basis for estimating transmissivity and storage coefficient characteristics in the Fluvial Aquifer beneath Dunn Field can be made. They will also provide empirical data on the shape of the capture zone in this vicinity.

Existing monitor wells outside of the estimated radius of influence will be used for observation wells during the pumping test. These wells include MW-7, MW-9, MW-10, MW-11, MW-30, and MW-31. Water level measurements in these outlying observation wells will be made on a less frequent basis than in the well and piezometers within the estimated radius of influence. The frequency of measurements in the wells beyond the estimated zone of influence will be determined in the field based upon the response of PZ2 and PZ3 to pumping and fluctuations noted in the wells being monitored. The frequency of monitoring will be no less than every two hours.

3.3 Pump Test Well Construction

The scope of work specifies that the pump test be constructed of 4-inch schedule 80 PVC casing and screen. The inside diameter of 4-inch schedule 80 PVC casing is 3.826 inches. Nominal 4-inch diameter submersible pumps are too large to fit into a well of this size. Therefore ES proposes to install a schedule 40 well screen and casing instead of schedule 80. Further information on the well installation program is presented below. Figure 3-2 is a construction diagram of the proposed pump test well.

3.3.1 Decontamination

Drill equipment used on-site will be inspected by the ES site geologist upon arrival to insure that the equipment has been thoroughly cleaned and decontaminated prior to arrival and that there are no fluids leaking from the equipment. A wooden framed decontamination fluid catch basin will be constructed and lined with heavy gauge plastic sheeting. The water collected in the catch basin will be transferred into an open-top settling basin. After particulates have settled from the water, the water will be treated using the activated carbon units that will be used to treat the pump test effluent. The water will then be discharged to a large capacity holding tank. The water treatment system will be described in detail in Section 3.5. Before drilling each well, the portion of the drill rig overhanging the borehole will be backed over the catch basin and pressure washed with laboratory-grade, phosphate-free detergent. The rig will then be pressure rinsed with tap water. Any foreign material not removed by the detergent pressure washing will be removed by wire brushing.

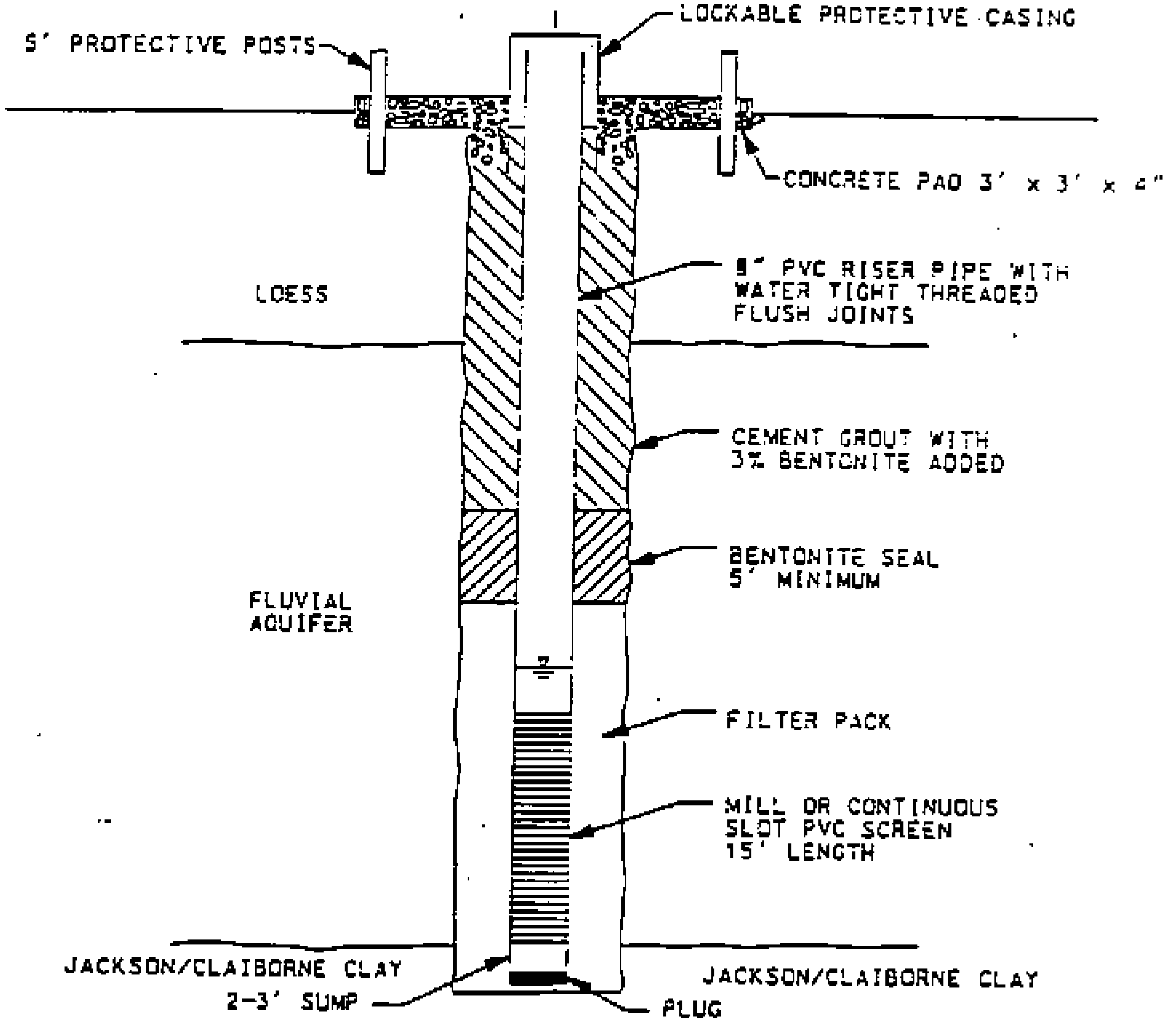


FIGURE 3-2
PUMP TEST WELL CONSTRUCTION
DUNN FIELD VICINITY

NOT TO SCALE

DEFENSE DISTRIBUTION
REGION CENTRAL
MEMPHIS, TENNESSEE

DEFENSE LOGISTICS AGENCY

ENGINEERING-SCIENCE
St. Louis, Missouri

ES

All down-hole drilling equipment that does not contact samples, including drill rods, tremie pipe and auger flights will be supported on racks within the catch basin and steam cleaned and rinsed as above. The support racks will be designed so as to protect the integrity of the plastic liner. Following the potable water rinse, the auger flights and drill rods will be rinsed with deionized water from a stainless steel pump sprayer.

Equipment that comes into contact with samples, including split-spoons, stainless steel bowls and spatulas will be decontaminated in the same manner as the auger flights and drill rods. The split-spoons, bowls and related equipment will then be rinsed twice with pesticide grade isopropanol and rinsed with organic-free water. The equipment will be allowed to air dry. Equipment contacting the samples will be wrapped in foil prior to transportation to the drill site. Other down-hole equipment will be placed on plastic sheeting and covered until use.

The PVC casing and screen will be delivered with specifications printed on the container rather than on the screen and pipe. These materials will be pre-cleaned and decontaminated by the supplier and will be shipped in individually sealed plastic wrappers. If the integrity of the seal is broken or is in doubt, the screen and riser will be decontaminated on site. The decontamination will consist of pressure washing with laboratory-grade, phosphate-free detergent, rinsing with tap water, rinsing twice with deionized water and air drying. The well materials will then be wrapped in plastic sheeting until use.

Sediment in the settling tank will be periodically removed and placed in drums. The well and soil boring numbers that had been completed since the last removal of sediment will be identified on the drum. The material in the drum will be considered potentially hazardous if any of the drums from the identified wells are considered potentially hazardous. The criteria for this designation is described in Section 3.3.2.

3.3.2 Well Drilling and Sampling

The borehole will be drilled to a depth necessary to penetrate into the top of the Jackson confining unit, but not extend more than 5 feet into that unit. The anticipated depth of the well is approximately 80-95 feet. The well is not to exceed 150 feet in depth. The pump test well will be drilled utilizing a 6½-inch ID hollow-stem auger. A split-spoon sample will be collected of the material that comprises the Fluvial Sand aquifer for a sieve analysis (ASTM C117 and C136). Observation wells will be drilled using 3½-inch ID or larger hollow-stem augers. Two soil samples will be collected from cuttings generated in the installation of the pump test well. Two samples will be collected of the cutting from each piezometer. These samples will be analyzed for volatile organic compounds, semi-volatiles (including chloroacetophenone), pesticides/PCB's, metals, mercury, thiodiglycol and mustard. Cuttings will be collected and stored in DOT approved containers. The depth interval of each drum will be listed on the container label and recorded in the site geologist's log for the well. In accordance with USEPA policy for investigatory-derived wastes (USEPA, 1991), the drums containing the cuttings will be staged at a site designated by the DDRC. Cuttings from the RI-Follow On will also be stored in this area. ES will make a recommendation as to whether the contents of each drum should be considered hazardous or non-hazardous based upon the results of the chemical analyses of sediment samples.

The State of Tennessee soil criteria guidelines will be used to evaluate whether a particular soil is potentially hazardous based upon organic contaminants. The RI/FS reported widespread occurrence of metals concentrations above the State of Tennessee soil criteria guidelines in both surface and sub-surface soils. A number of these samples were obtained from areas with no known source of metals contamination. Of particular concern are arsenic, chromium and lead. Soils will be considered potentially hazardous if the concentration of arsenic, chromium or lead exceeds 10 mg/kg. Although these thresholds are twice the State of Tennessee guidelines, they allow the disposal of cuttings that have concentrations of these compounds that are generally lower than the existing soils. If the analysis of the soil samples from nearby borings or wells indicate organic compounds exceeding the soil criteria guidelines then the drum(s) containing cuttings from that depth interval will be considered potentially hazardous.

3.3.3 Well Casing and Screen

The pump test well will be constructed of new 4-inch, schedule 40 polyvinyl chloride (PVC) casing and screen. PVC casing and screen will be free of ink markings to comply with requirements in the DDRC RCRA permit. Schedule 80 PVC is not necessary because the Fluvial Sand aquifer does not contain any cobbles or boulders that would crush the walls of the well. PVC was selected over stainless steel for the pump test well based on a number of factors. All existing wells at the site are constructed of PVC, thus this well would be consistent with the existing wells. The high productivity of the aquifer will result in rapid purging and a very short contact time between the sample and the well material. Furthermore, because this is intended to be an extraction well, the water in the well will be removed continually. PVC is not a potential source of the metals of concern in this study. Although there may be some adsorption/absorption of the organic compounds of concern, the fast purge rate should make the effect negligible.

All connections between sections of casing and screen will be threaded, flush and water tight. Solvents or glues will not be used. The well will consist of a 15-foot section of screen below the riser casing. Below the screen will be a 2 to 3 foot sump to collect any sediment which enters the well. A threaded PVC plug will be installed on the bottom of the sump. The bottom of the screen will be adjacent to the bottom of the Fluvial Aquifer. The casing and screen will be held in the center of the borehole by the hollow-stem augers. ES does not plan to use centralizers for this installation because they would increase the effective diameter of the casing from 4.50 inches to over 5 inches. This would make getting a tremie pipe into the remaining space in the auger extremely difficult.

The well will be constructed with a screen having an enhanced slot design. The screen will have approximately twice the open area of a similar sized section of mill slot screen. Entrance velocities will be less than 0.15 feet per second at the projected 20 GPM pumping rate even if drawdown reduces the effective screen length to as little as 5 feet.

The optimum slot size for the pumping test well was estimated using procedures outlined in Driscoll (1987). The sieve analysis of a sample from the saturated zone in MW-10 was used for this estimation. MW-10 was used because it is the nearest well with sieve analysis to the proposed pumping well location. A review of sieve analysis data from other samples collected from the Fluvial Aquifer indicate that this sample was representative of the Fluvial Aquifer in the Dunn Field area. Based upon this analysis a slot size of 0.020 to 0.030 inches is feasible for the pump test well. ES proposes to install well screen having a slot size of 0.020 inch. A sieve analysis (ASTM C117 and C136) will be conducted on a sample of the Fluvial Aquifer from the pump test well in order to confirm that the slot size is compatible with the aquifer material.

The three piezometers wells will be constructed of nominal 1-inch PVC flush-joint riser and screen. They will have a slot size of .020 inches with a screen length of 10 feet. The installation procedures for the observation wells will be the same as for the pump test well. The screens of the piezometers will be located in approximately the same horizon as the screen of the pump test well.

3.3.4 Annular Materials

A filter pack will be installed in the annulus of the pump test well and the piezometers next to the screen and extending up the annulus no less than two feet above the top of the screen. The filter pack will be placed in the well using a tremie pipe. The procedures outlined in Driscoll (1987, pg. 441) were used to establish a recommended filter pack grain size. The filter pack material will consist of a well graded, well rounded sand with a quartz content of no less than 90% and grains ranging in size from 0.040 inches to 0.070 inches.

A five-foot thick bentonite seal will be placed in the annulus above the filter sand. The seal will be composed of ¼-inch diameter bentonite pellets. The pellets will be placed using a tremie pipe. Potable water (5 to 10 gallons) will be used to hydrate the pellets after they are in place. The manufacturers recommendations for hydration time will be the minimum time that will elapse prior to grouting of the well. Bentonite Pel Plugs brand pellets are expected to be used. Polymer Drilling Systems of El Dorado, Arkansas manufactures this product and recommends a 30-minute wait between hydration and grouting for a 5-foot seal. To be conservative, grouting of the pump test well and piezometers will not begin for at least one hour after the pellets are hydrated.

The grout will consist of one 94-pound bag of portland cement with 3 to 5 percent bentonite added per 7½ gallons of potable water. The grout will be emplaced using a tremie pipe. The grout will be allowed to cure for at least 48 hours before development of the well is performed.

3.3.5 Well Protection

The top of the well and the three piezometers will be protected with a steel outer casing with locking cap. Three two-inch steel posts will be placed around the well. A three-foot by three-foot concrete pad with a thickness of at least 4 inches will be placed around the well. A survey marker identifying the well will be permanently attached to the concrete pad.

3.3.6 Well Development

The pump test well will be developed utilizing one or more of the following techniques: surging with a surge block, bailing, air lift pumping, or other pumping methods. If air lift pumping is utilized it will be performed with an eductor pipe system which prevents air from entering the screen, filter pack, or formation. A filter will be used to remove compressor oil from the air prior to use in the well. The development will be performed until the water is essentially clear of sediment, the temperature, pH and conductivity of the water has stabilized, five well volumes (including filter pack) have been removed and four hours have elapsed.

The small diameter of the piezometers precludes meaningful development of the piezometers. The combination of the sand formation and the installation through hollow stem augers minimizes the risk of a poor hydraulic connection between the well and the aquifer. Changes in the head in the aquifer will result in very low flows into and out of the piezometers. A one foot change in head will result in flow of 0.04 gallons of water through the ten foot long piezometer screen. At the expected rate of water level change, fluxes through the screen will be exceedingly small, and time lags in the response of the piezometer are not expected.

After completion of development, a water sample will be collected and placed in a clear container. A close-up, back-lit photograph will be taken of the sample as a record of the development of the well. All water produced as a part of the development process will be stored for processing through the granular activated carbon treatment system.

3.3.7 Pump Placement

Following the completion of the well, a submersible pump will be placed in the well to conduct the pumping test. The pump will be decontaminated using steam and detergent, followed by a tap water rinse prior to its installation and after its removal. The pump will be suspended in the lower 1/2 to 1/3 section of the screened interval. A valve will be placed on the discharge pipe to regulate the flow of water from the pump. A flow meter will be placed on the discharge pipe, following the valve, to measure the flow rates during the pumping test.

3.3.8 Well Installation Documentation

The site geologist will maintain complete records of the activities associated with the installation of the pump test well and the three piezometers. Well logs will be prepared for the pump test well and piezometers and will be submitted to the USACE within 10 days of the completion of the well. The log will contain, as a minimum, a lithologic description of the materials encountered and the depth and thickness of each unit, depth-to-static water level, total boring depth, lengths of casings and screens, specifications of all well materials, volumes of annular materials and method of placement, method and time period of well development, and disposition of well cuttings and development water.

3.4 Pumping Test Execution

The pump test will involve two phases of pumping. First, a step-drawdown test of ten hours duration will be conducted to determine the specific capacity and the well efficiency. The specific capacity is a measure of well yield per unit drawdown and is used to determine the optimum pumping rate for the second phase. The well efficiency shows the rate of yield reduction due to the well construction and should be used for extraction well design.

3.4.1 Step-Drawdown Test

A ten hour step-drawdown will be performed after the pumping well installation and development. Five steps are planned with each step consisting of constant pumping for one hour followed by recovery for one hour. Then, a higher pumping rate or step will be taken.

Data from the step-drawdown test will be used to select a suitable discharge rate for the constant-rate pump test. This data will provide both an empirical relationship between flow rate and drawdown (specific capacity) as well as quantitative data for evaluating the relative proportion of laminar and turbulent flow. As described in Driscoll (1987), drawdown can be expressed as the sum of a first-order (laminar) component and a second-order (turbulent) component:

$$S = BQ + CQ^2$$

Statistical analysis of the data will aid in estimating the magnitude of turbulent head losses at different flow rates. A flow rate will be selected to maximize drawdown while minimizing the influence of turbulent flow.

The initial, first step, pumping rate will be approximately 5 gpm, with four additional steps up to 25 gpm over the course of the test.

3.4.2 Constant-Discharge Pumping Test

The pumping test will be initiated the second day after the step-drawdown test.

Due to the thin saturated thickness of about 20 feet and the dewatering of the water table aquifer, the pump will be installed within the well screen and close to the bottom of the aquifer to achieve a maximum stress of the aquifer and maximize the cone of depression. The pumping duration will be a minimum of 36 continuous hours and if static drawdown conditions have not been achieved, ES may elect to extend the pumping period to 48 hours. Immediately after the pumping test, a 36 hour recovery test will follow. Data collected during the recovery period will be used in the evaluation of the geohydraulic parameters. The total time of the pump test and recovery test will be at least 72 hours.

Before the pumping test, water levels will be measured daily at the pumping well and observation wells selected in Section 3.1 in one well to determine the water level fluctuations and trends. A pressure transducer will be used in one well to record the water level for 24 hours before the start of the test. This will determine the diurnal effect. Periodic measurements of water levels will be made prior to the test in the pumping well and the three piezometers to establish water level trends.

Parameters to be measured during the pumping test are water levels in the pumping well, piezometers and observation wells, pH, specific conductance, temperature, and discharge rates. Frequency of measurement will be ten per time log cycle as recommended by the Bureau of Reclamation (1977).

Volatile organic chemicals (total) will be measured in the field using headspace methods and a HNu meter at two-hour intervals during the pumping period. This technique has been used by the USEPA in past projects as an informal, cost-effective technique for evaluating headspace VOC trends (Keely, 1987). If measurable levels are found they may indicate an increasing or decreasing trend of the VOCs in response to the pumping.

Over the course of the pump test, three ground water samples will be taken from a sampling port upstream of the discharge control valve and the 2,000 gallon equalization/settling tank. These samples will be taken 2 hours and 24 hours into the test, and in the last hour of pumping. These samples will be analyzed for volatile organics, B/N/As (including chloroacetophenone), pesticides/PCBs, metals, thiodiglycol (HPLC/electrochemical detector method), and agent mustard (EPA method 8140 extracted by EPA 3510). Further information on analytical methods, data management procedures, and quality control procedures is contained in the RI/FS Follow-On Work Plan (ES; November, 1991). At the end of the pumping, a water sample will be taken for analysis of conventional water quality parameters as follows:

- total suspended solids
- total dissolved solids
- organic carbon
- common cations and anions
- iron and magnesium
- biological oxygen demand
- hardness
- alkalinity

These parameters were not reported in the 1990 Remedial Investigation Final Report (USACE 1990), but are essential in the pretreatment technology evaluation. The scope of work did not include this sample collection or analysis, but ES proposes it to facilitate subsequent engineering evaluations.

3.5 Treatment/Disposal of Production Water

Water produced from the pump test will be released into a 2000 gallon equalizaton/settling tank (Figure 3-3). The purpose of this tank will be twofold. First, minimizing the flow variation to the treatment system will improve performance and reduce the size of the required treatment system. Secondly, the tank will provide a detention time sufficient for the settling of sediments which will also improve the performance of the treatment system as well as allow metals adsorbed to particles to be removed. The sediments will be drummed and managed with the drill cuttings. The water will be pumped at a constant rate from the equalization/settling tank to the activated carbon treatment units.

The treatment system will consist of two granular activated carbon (GAC) units (Figure 3-3). The flow through each adsorber will be pressure controlled allowing optimum contact to 200 pounds of GAC, which is capable of adsorbing 32 mg VOC per gram of GAC. The units will be connected in parallel to maintain an average contact time of 6 minutes. The GAC system will reduce any VOC encountered to below non-detectable levels and may achieve some reduction of heavy metal concentrations.

The discharge from the GAC units will be directed to a 70,000 gallon holding tank. Water from the well development, step-drawdown test and constant discharge pumping test will be stored in the holding tank. Three water samples will be collected from the holding tank after all water from the pump test has been processed through the GAC system to document treated water quality and to identify whether additional treatment would be required. The water samples will be collected from separate areas

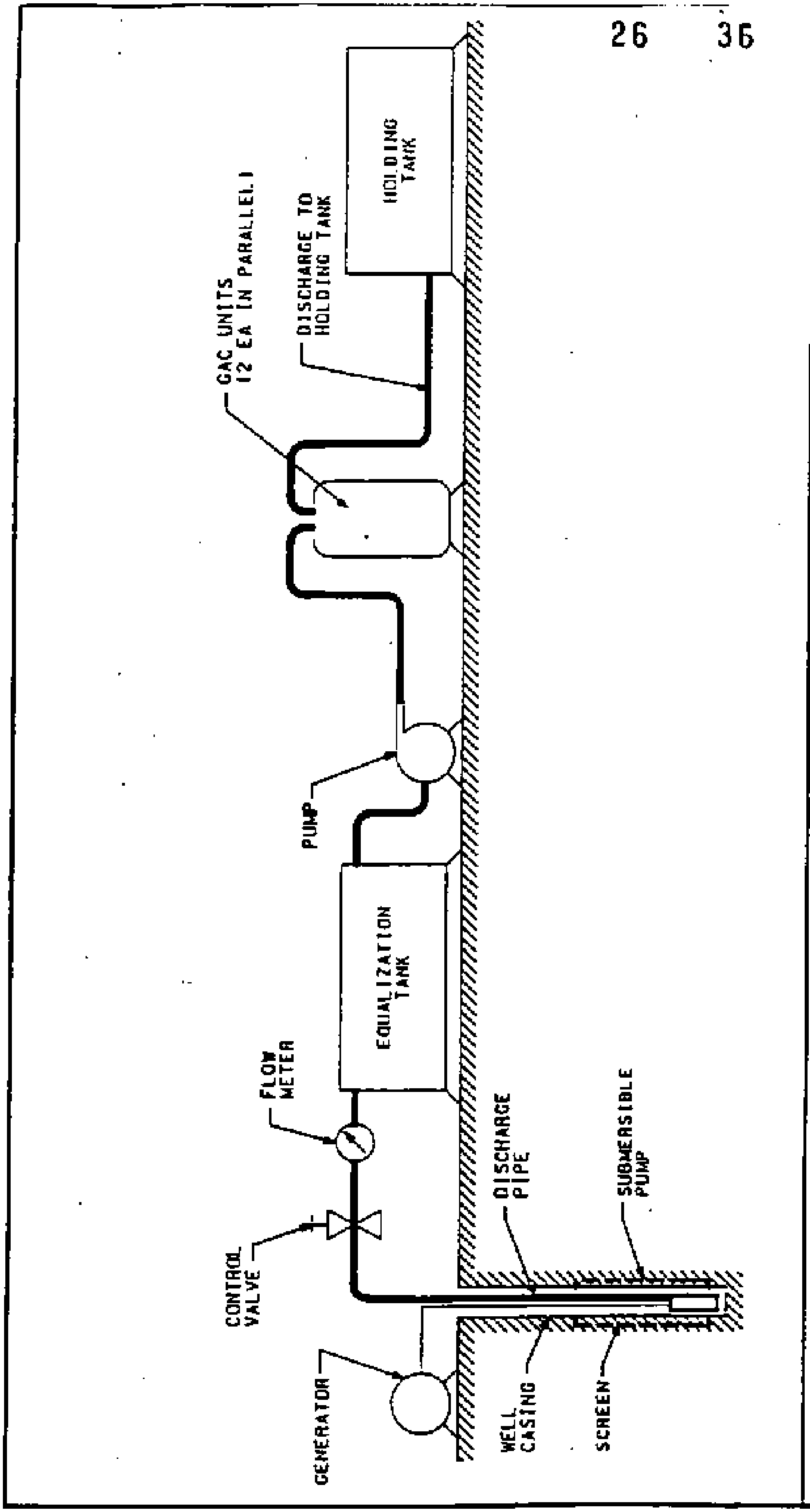


FIGURE 3-3:
PUMP TEST SET UP
DUNN FIELD VICINITY

DEFENSE DISTRIBUTION
REGION CENTRAL
MEMPHIS, TENNESSEE

DEFENSE LOGISTICS AGENCY

ES
ENGINEERING-SCIENCE
St. Louis, Missouri

of the tank using a bailer to obtain aliquots from all levels in the tank. The water samples will be analyzed for volatile organic compounds, semi-volatiles (including chlorocetophenone), pesticides and PCB's, metals, thiodiglycol and mustard.

Verbal authorization has been given from the City of Memphis to allow effluent from the GAC treatment system to be discharged into the sanitary sewers. The tentative approval was based on an estimated discharge of approximately 50,000 gallons of effluent over a 36 hour period. If pumping is extended to 48 hours, the discharge quantity increases to 65,000 gallons. The results of the analysis of the water in the holding tank will be presented to the Corps of Engineers, the USEPA and the City of Memphis along with recommendations as to further treatment that might be needed prior to discharge to the Memphis sanitary sewer. Upon approval from the USEPA and the City of Memphis, ES will discharge the treated water to the sanitary sewer. The location and timing of the discharge will be coordinated with the City of Memphis and DDRC installation authorities.

Decontamination of the treated water storage tank will consist of collecting the sediment and puddled water that remains in the tank following discharge to the sanitary sewer. Excess water will be discharged to the sewer as practical. Remaining water and sediment will be drummed and handled as cuttings. After the tank is decontaminated, approximately three to six inches of potable water will be added to the tank to stabilize the liner until the tank is again used in the RI/FS phase of the project.

3.6 Pumping Test Data Reduction

The pumping test data will be analyzed using Boulton's water table analytical method. This method is the best suited analytical method for use at DDRC. One of the assumptions of this method (and almost every other common analytical method) is that the aquifer is homogeneous and isotropic. The degree to which this assumption is met will be evaluated based upon the drawdown in equidistant observation wells in different directions. Another common assumption is that the pumping well is fully penetrating. The information available from the initial Remedial Investigation indicates that the saturated thickness of the Fluvial aquifer in MW-10 is 18 feet. The pump test well will have a screen length of 15 feet. Additionally the filter pack will extend a minimum of 2 feet above the top of the screen. The saturated thickness will decline with the drawdown induced by the pumping. For the purpose of this test, therefore, the pump test well will perform as a fully penetrating well.

In the very early and late stages of the response to pumping the Boulton equations are identical to the Theis equation and the Jacob approximation. These methods will be applied to the data in addition to the Boulton method. This will provide not only a check of the Boulton method but may also provide insight into the character of the Fluvial aquifer.

Water levels in the Fluvial aquifer will be monitored prior to the test to identify any long-term trend in water level and any tidal, diurnal or barometric effects on water levels. Barometer readings from the Memphis airport located two miles south of Dunn Field will be used for this purpose. Water level data will be adjusted to correct for any fluctuations due to these factors.

4.0 INTERIM REMEDIAL MEASURES DESIGN PLAN

Previous studies conducted at DDRC indicate that the ground water in the Fluvial aquifer may pose a potential health risk. The two factors contributing to this risk are the contaminants which were discovered and the uncertainty of the integrity of the confining unit. The purpose of the interim remedial measure (IRM) is to mitigate further migration of the primary region of volatile organics and heavy metal contaminants until the extent of the plume can be defined and final remediation can be implemented.

Completion of the IRM Design Plan will provide the rationale which will be used for developing technical specifications for a ground water pumping and treatment system which could be installed in the vicinity of Dunn Field at DDRC. The IRM Design Plan will consist of evaluation of the following areas.

4.1 Ground Water Cleanup Levels

Cleanup levels will be established for the discharge from the interim ground water treatment system and for the target residual ground water composition as a result of the interim treatment system. These required cleanup levels for volatile organics and metals will be developed in consultation with EPA, the State of Tennessee, and local regulators.

The discharge limits may be affected by the interval, duration, rate of discharge and ground water disposal option selected. The tentative goal for the level of residual ground water cleanup will be used to evaluate the effectiveness of the interim pump and treat system. Both of these cleanup levels must meet the approval of EPA, the State of Tennessee, local authorities, DDRC and the USACE.

4.2 Treated Ground Water Disposal Options

Disposal options for the effluent from the interim treatment system will be identified and evaluated. As a minimum the following options will be considered: reinjection into Fluvial aquifer, discharge into surface drains or storm drains, discharge into the sanitary sewer system for further treatment at the public owned treatment works, or transport off site for further treatment and/or ultimate disposal. In addition to the short-term effectiveness, the potential long-term effectiveness of each option will be evaluated. The options will be analyzed for feasibility based on the following evaluation criteria:

- Minimization of the potential for human and environmental exposure to contaminants;
- Compliance with ARARs;
- Compatibility with possible final remedial measures;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;
- Flowrate of discharge;
- Implementability;
- Cost;
- Regulatory acceptance.

4.3 Air Emission Evaluation

Air emissions resulting from ground water recovery operations, interim treatment system operations, and effluent disposal will be evaluated. Estimates for air emission loadings, concentrations, and flowrates from the facility will be made. These factors are dependent upon the interim treatment system and disposal options employed. The State of Tennessee and local authorities will be contacted for air emission guidelines and any associated permit considerations. The regulatory requirements will be used to determine if the anticipated air emissions will be allowed from the facility. If so, the feasibility of complying with the air emission standards will be evaluated based on technical and economic implementability.

4.4 Hydrogeologic Impact Assessment

Extraction and disposal of the contaminated and treated ground water may pose physical and chemical impacts to the aquifer itself and to the public health and the environment. To assist this task, a ground-water flow model such as MODFLOW or PLASM will be used to design well field layout, contaminant capture zone, volume of water to be extracted, and time frame of operation. Natural resources required and disposal impact will be evaluated. If disposal is by reinjection into the Fluvial Aquifer, the impact to the hydrogeologic system will be assessed by computer simulation.

Both MODFLOW and PLASM are finite difference ground water models. MODFLOW was developed by the US Geological Survey (McDonald and Harbaugh, 1984) and PLASM (Prickett and Lonnquist, 1971) by the Illinois State Water Survey.

Input data will be derived from the RI (Law, 1990), the pumping test discussed in Chapter 3 of this work plan, and any further findings derived from the RI/FS Follow-On activities.

4.5 Permit Requirements

The permits required for the interim remedial measure will be dependent upon the treatment system and disposal option employed. Inquiries will be made to federal, state, local, and DDRC installation authorities to determine the permits which will be required. The permit requirements for well construction, interim treatment system construction, operation, air emissions, and treated water discharge will be identified. Copies of the forms necessary to complete the required permits will be obtained from the responsible agency. The corresponding lead time for each permit preparation, review, and approval will be investigated and assessed. Any applicable fees associated with each permit will be determined.

4.6 Identification of Treatment Alternatives

Interim systems capable of mitigating ground water contaminant migration and treating water pumped from the Fluvial aquifer will be developed, evaluated, and recommended. The design data used to develop alternatives will be based on the pump test to be completed under this statement of work and the RI/FS (Law, 1990). The alternatives proposed in the RI/FS will be evaluated along with any other technologies based on short-term and long-term effectiveness, economics, technical feasibility, regulatory requirements, environmental impacts, operating period, and adequacy in satisfying the statutory determinations for interim actions. The following nine evaluation criteria, recommended by EPA guidance, will be used to screen each technology:

- Minimization of the potential for human and environmental exposure to contaminants;
- Compliance with ARARs;
- Compatibility with possible final remedial measures;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;
- Flowrate of discharge;
- Implementability;
- Cost;

- Regulatory acceptance.

Using these criteria, the advantages and disadvantages of each alternative will be discussed. A recommended interim treatment system will be presented for the preferred alternative. The selected remedy will be the alternative found to provide the best balance of tradeoffs among the evaluation criteria listed above. Rationale used for selection of the recommended option will consider site adaptation or designing a new facility, based on readily available "off-the-shelf" technologies. In addition, the system selected will be designed in a modular manner so that it can be easily transported within DDRC and removed once recovery activities are complete. The optimum locations for the placement of equipment associated with the recommended alternative will be discussed.

4.7 Cost Estimates

Cost estimates will be developed for each interim remedial measure evaluated. The cost estimates will include estimates of the various capital costs and annual operation and maintenance costs for the recommended design life of the facility. A unit price cost estimate for a convenient unit of treatment will be prepared for each alternative.

5.0 REPORT PREPARATION

Deliverables during this project shall conform to the specifications of the USACE, Huntsville Division. Four specific deliverables will be prepared as part of this study, as listed in Table 5-1. These deadlines are consistent with the schedule assumed in Chapter 7.0 of this Work Plan.

5.1 Pump Test Technical Memorandum

A technical memorandum will be prepared to address methods and procedures of data reduction and associated assumptions. Computations and raw data will be appendixed. The report will present:

- hydraulic conductivity
- transmissivity
- storativity
- well yield
- specific capacity
- radius of influence

5.2 Engineering Report

The Engineering Report will present all data, analysis, and recommendations and shall be arranged according to the following outline:

1.0 EXECUTIVE SUMMARY
2.0 SCOPE OF SERVICES
3.0 SITE CHARACTERIZATION
- 3.1 Site Location and History
- 3.2 Topography and Geology
- 3.3 Surface Water
- 3.4 Ground Water Hydrogeology
- 3.5 Summary of Previous Investigations

Table 5-1
List of Deliverables
Pump Test Work Plan

Description	Revised Delivery Deadline
Pump Test Technical Memorandum	16 Nov 92
Draft Engineering Report	18 Dec 92
Draft Environmental Assessment	18 Dec 92
Draft Section C Work Statement/ Technical Requirements	27 Jan 93

4.0 REMEDIAL ACTION OBJECTIVES AND CRITERIA
- 4.1 Applicable or Relevant and Appropriate Requirements
- 4.2 Ground Water
  - 4.2.1 Cleanup Levels
  - 4.2.2 Attainment Area

5.0 TREATMENT AND DISPOSAL ALTERNATIVES
- 5.1 Identify and Screen Technologies
- 5.2 Disposal/Treatment Alternatives for Ground Water
- 5.3 Comparative Analysis of Alternatives
  - 5.3.1 Criteria of Comparison
  - 5.3.2 Evaluation of Alternatives in meeting Criteria

6.0 HYDROGEOLOGIC IMPACTS

7.0 CONCLUSIONS AND RECOMMENDATIONS

8.0 REFERENCES

APPENDICES

5.3 Environmental Assessment

An environmental assessment document will be prepared for the signature of the Commander, DDRC. The assessment will address the decision to implement the approved interim ground water treatment facility at DDRC. A discussion of the environmental impacts and community concerns associated with the interim treatment facility will be addressed. The Environmental Assessment will be prepared in accordance with the National Environmental Policy Act (NEPA) and applicable State of Tennessee regulations.

5.4 Section C Work Statement/Technical Requirements

Based on the results of the preceding tasks, a "Section C Work Statement / Technical Requirements" for the approved IRM will be prepared. As a minimum, the Section C documents will contain details within each of the following sections:

1.0 BACKGROUND

2.0 OBJECTIVE

3.0 GENERAL REQUIREMENTS
- 3.1 Interim Remedial Measure Design
- 3.2 Interim Remedial Measure System Construction

Included in this submission will be a DD Form 1664, Data Item Description, and DD Form 1423, Contract Data Requirements List, which will provide a brief description and schedule for submittals required in the Service Contract.

6.0 SITE PERSONNEL

Mr. David E. Mizell, P.E., Principal Engineer, is the Project Manager for the DDRC project. Mr. Robert A. Mannebach, P.E., Senior Associate, is the Technical Director. Mr. John K. Yu, Ph.D., CGWP, is the Technical Director responsible for hydrogeology review on this project. Mr. Mizell, in his capacity as project manager, will be responsible for the technical, schedule, and budgetary objectives on this project, as well as the day-to-day coordination.

Mr. Lee Gorday, P.G., Hydrogeologist, will be responsible for overseeing installation and development of the pump test well. Ms. Susan V. Roberts, Senior Hydrogeologist, will serve as Pump Test Coordinator and be responsible for planning and implementing the pump test. Mr. Joe D. Bauer, Hydrogeologist, will serve on the Pump Test Field Team with Dr. Yu, Mr. Gorday, and Ms. Roberts.

Mr. Daniel Currence, P.E., Environmental Engineer, will be responsible for the activated carbon units used to pre-treat the pump test water prior to discharge. Mr. Currence will be responsible for procurement, installation, operation, and demobilization of these units.

All of these professionals will be responsible for preparation of the Engineering Report, Environmental Assessment Report, and the Section C Work Statement.

Resumes on these people follow this section.

Biographical Data 26 48

DAVID E. MIZELL, P.E.

Project Manager

EXPERIENCE SUMMARY

Seventeen years of environmental consulting experience with industrial and hazardous waste compliance at industrial facilities and uncontrolled waste sites. Managed waste site investigations, engineering feasibility studies, remedial permitting and design, and remedial action projects. Investigated plumes of petroleum products, metals, volatile organics, nitroaromatics, acids, and assorted other industrial materials.

EXPERIENCE RECORD

1990-Date — Engineering-Science, Inc., St. Louis, Missouri. Hazardous Waste Manager. Managed site assessments, site investigations, sampling and analysis for waste site characterizations. Oversight of underground storage tank removals and replacements for gasoline service station renovations, relinquishments, and new site acquisitions for a major petroleum marketer and a convenience store chain. Remedial design of vapor extraction pilot system at RCRA facility in Illinois. Remedial design of gravel water pumping and treatment systems and supervision of operation and maintenance activities.

1989-1990 — Heritage Remediation/Engineering, Inc., St. Louis, Missouri. Division Manager. Responsible for emergency response activities, industrial waste treatment operations, UST replacements, engineering studies, and environmental audits.

1980-1989 — Environmental Science and Engineering, Inc., St. Louis, Missouri. Chief Engineer. (1986-1989). Directed closure of RCRA lagoon facilities for two Missouri industries, and closure of a RCRA landfill in EPA Region VII. Directed groundwater investigations for a Missouri DNR at Valley Park TCE site. Managed groundwater pump and treatment operations for chlorinated solvents at Missouri manufacturing plant. Performed critical path scheduling evaluation of RI/FS program for Rocky Mountain Arsenal Contamination Cleanup using MS-Project and Primavera Project Planner software. Conducted operational and real estate transactional audits at six industrial facilities, railroad sites, and new development sites. Expert witness testimony for insurance carrier on petroleum spill cleanup. Directed groundwater remediation at rail fueling facility and gasoline service station.

Engineering Department Manager (1980-1986). Remedial investigation and installation of groundwater pump and treatment system for chlorinated solvents at Missouri manufacturing plant. Directed PCB site investigation for Union Electric Company at a fire control training facility. Managed cleanup of dry cleaning facility containing leaking underground storage tanks filled with spent solvents and sludge. Provided expert witness testimony following completion. Managed bioremediation project of watershed adjacent to Illinois railroad terminal. Managed site investigations at RCRA and Superfund sites in Missouri, Illinois, Indiana, Kentucky, Alabama, and Texas.

1974-1980 Envirodyne Engineers, Inc., St. Louis, Missouri. Project Engineer. managed survey of Weldon Spring Chemical Plant for U.S. Army. Coordinate the radiological, engineering, and environmental survey for uranium, and thorium residues in process equipment, building structures, and surrounding lands. Waste and wastewater management studies for various Midwest industries. Environmental impact statements for U.S. Army Corps of Engineers in Indiana, New York, Florida, and Mississippi. Site investigations at military installations in Missouri, Tennessee, and Wisconsin.

EDUCATION

B.S. in Astronomy, 1972, Case Western Reserve University, Cleveland, Ohio.

M.S. in Systems and Control Engineering, 1974, Case Western Reserve University, Cleveland, Ohio.

PROFESSIONAL AFFILIATIONS

American Society of Civil Engineers.
St. Louis Engineers Club.
Metropolitan St. Louis Engineering Guidance Council.

REGISTRATIONS

Registered Professional Engineer (Missouri, Illinois, Indiana, Kentucky, Minnesota, Nebraska, Kansas, and Arkansas).

PUBLICATIONS

"A Computer Simulation Model of Urban Runoff Pollution." M.S. Thesis, Case Western Reserve University (1974).

"A systems Approach to Recycling Hazardous Wastes" presented at the Resource and Investment Institute Seminar (April 1983).

"RCRA Ground Water Monitoring: Statistical Games or Honest Risk Assessment?" presented at AWRA-Illinois Section Annual Conference (April 1984).

"In-Situ Biological Decontamination of Hazardous Wastes Sites" presented at the Illinois EPA Hazardous Substances Technologies Seminar (April 1985).

"Strategies for Correcting Groundwater Pollution Problems" presented at the Missouri Waste Control Coalition Annual Conference (July 1987).

"Ground water Pollution Control" Session Moderator at Missouri Waste Control Coalition Annual Conference (July 1988).

Biographical Data

Robert A. Mannebach, P.E.

Environmental Engineer

EXPERIENCE SUMMARY

Fifteen years of environmental study and design experience. Direct responsibility for the study and design of municipal water treatment plants and distribution systems, municipal wastewater collection systems and treatment plants, hazardous waste treatment plants, industrial wastewater treatment plants, and stormwater conveyance systems across the United States.

EXPERIENCE RECORD

1984 to Present

Engineering Science, Inc. Senior Associate/Office Manager. (1989-Date). Responsible for the management of the ES St. Louis, Missouri Office. This office conducts projects in underground storage tank assessments/remediations, industrial/hazardous waste, municipal wastewater treatment, water treatment, stormwater conveyance and environmental studies. Clientele include industries, water/wastewater authorities, municipalities and the United States Government (EPA and DOD).

Technical Manager of Design (1988-Date). Responsible for overview of all ES design projects in the eastern United States. Activities include reviewing projects, providing technical support, insuring compliance with the ES Quality Assurance Policy and assisting offices in marketing/selling, project planning and project management.

Design and Municipal Studies Department Manager (1986-1989). Responsible for all Department activities in the ES Fairfax, Virginia office including marketing, staffing, project review and quality control. Department design projects include a 180 mgd municipal wastewater treatment filtration facility, a 1700 WTPD sludge conveying, stabilization and storage facility, and a 5 mgd water treatment plant with a 10,000 foot, 12 inch water main and a 500 gpm contaminated groundwater treatment plant. Department study projects include an Alternate Use Plan for a 60 mgd wastewater treatment plant and a Sludge Management Plan for a 72 mgd wastewater treatment plant. Initiated TRE Studies group for ES, including staffing and project team organization.

Design Phase Manager (1984-1986). Responsible for the design of a $100 million, 18 mgd expansion to an existing 36 mgd municipal advanced wastewater treatment plant. Plant included bar screens, primary sedimentation, an activated sludge system, filtration, twin 60-inch river outfalls, sludge thickening, a filter press system for sludge dewatering and a sludge incineration system.

1983 to 1984	Brown & Caldwell, Atlanta, Georgia. Project Manager. Responsible for preparing preliminary design reports and final design documents for 6 mgd expansion to an existing 6 mgd municipal advanced wastewater treatment plant. Plant included bar screens, primary sedimentation, a two-stage nitrification activated sludge system, filtration and a sludge dissolved air flotation system.
1978 to 1983	Engineering-Science, Inc. Design Department Manager. (1982-1983) Responsible for design activities in the ES Atlanta, Georgia office including project review quality control. Department projects include the expansion of several municipal and industrial wastewater treatment plants.
	Project Manager (1979-1983). Responsible for several environmental studies including a military guidance manual on state-of-the-art oil/wastewater separation technology, a wastewater treatability study for candy manufacturer, and an investigative study evaluating a rotating biological contractor system failure at a 6 mgd wastewater treatment plant. Responsible for several wastewater treatment plant design projects including a new 400 gpm plant treating metal finishing wastewater at an Army ammunition plant, a new 200 gpm plant treating contaminated groundwater, a modification and expansion of a 350 gpm plant treating pharmaceutical wastewater and a modification of a 10 mgd municipal wastewater treatment plant.
1976 to 1978	Greeley & Hansen, Chicago, Illinois. Project Engineer. Developed conceptual design reports on site layout, feed systems, clarification, sludge thickening and sludge dewatering for a new chemical 50 mgd municipal water treatment plant. Prepared final design documents for the clarification system, the sludge thickening system and the 44 dry ton per day sludge dewatering system for the water treatment plant.

EDUCATION

B.S. in Civil Engineering, 1975, University of Missouri, Columbia, Missouri

M.S. in Sanitary Engineering, 1976, University of Missouri, Columbia, Missouri

PROFESSIONAL AFFILIATIONS

Registered Professional Engineer (Missouri No. E-24012, Illinois No. 062-045526, Georgia No. 12168, Florida No. 30161, Virginia No. 16073, Tennessee No. 22883, Kentucky No. 17333)

American Society of Civil Engineers

American Water Works Association

Water Pollution Control Federation

ROBERT A. MANNEBACH, P.E.
Environmental Engineer
Page 3

PUBLICATIONS

"The Effects of Inorganic Carbon and Temperature on Algal Growth Kinetics", M.S. thesis, University of Missouri, 1976.

"Quantifying Algal Carbon Uptake Kinetics", presented at the 50th Annual Water Pollution Control Federation Conference, October 1977 (coauthors: D.E. Bruen and J.T. Novak).

"Munitions Manufacturing Wastewater Treatment - A Grass Roots Facility Case History", Proceedings of the Purdue Industrial Waste Conference, May 1982 (Coauthors: M.R. Hockenbury and W.M. Reilly).

Standard Handbook of Environmental Engineering, McGraw-Hill Publishing company, 1990, Contributing Author to Chapter 1, Environmental Engineering.

"Application of the EPA Municipal TRE Protocol: Case Examples", presented at the 62nd Annual Missouri Water Pollution Control Association, February 1991 (Coauthors: J. Botts and T. Morris).

Biographical Data

JOHN K. YU, Ph.D., C.G.W.P.

Hydrologist

EXPERIENCE SUMMARY

Dr. Yu has over 17 years of consulting experience in surface and subsurface contamination hydrology, covering thirty-two states, Guam, and Taiwan. His hands-on experience in design, instrumentation, and data collection and reduction enables him to provide guidance and troubleshooting on various hydrologic programs. As a hydrologist, he has served projects concerned with energy development for coal and uranium, landfills, hazardous waste treatment facilities, minerals, subdivisions, water supply, acid mine drainage, gasoline and chemical spills, coal and nuclear generating stations, interceptor dewatering, wastewater treatment lagoons, urban runoff, and many others. He has assisted clients in meeting the requirements of NEPA, CEQA, CWA, SMCRA, CERCLA, RCRA, and SDWA.

EXPERIENCE RECORD

1991-Date — Engineering-Science, Inc., Austin, Texas. Hydrologist, manager of hydrogeology department. Provides technical direction and guidance on hydrogeological investigations for the Austin office. Projects include site investigation and work plan for uncontrolled hazardous waste disposal sites throughout Texas for the Texas Water Commission, and for an industrial site with lead and sulfate contamination of shallow groundwater in Dallas, Texas; storm water NPDES permits; a hydrogeologic study for the Department of Energy's Pantex Plant RCRA closure; and pumping tests for groundwater operable unit at Defense Depot, Memphis, Tennessee. Manages and monitors the hydrogeology department.

1990-1991 — Roy F. Weston, Inc., Woodland Hills, California. Technical director, hydrology. Provided quality assurance for contamination hydrogeology for western region, covering Denver, Seattle, Albuquerque, Walnut Creek, and Los Angeles. Major projects were a solvent-contaminated site in Burbank, California; a groundwater contamination and subsidence of an apartment complex built on old oil sludge disposal site near Seal Beach, California; the Harbor Island Superfund site, Seattle, Washington; the Bureau of Land Management Superfund landfill in northern New Mexico; and the DOE Mound, Ohio, groundwater investigation for the Environmental Restoration Program. Acted as task manager for the hydrogeologic investigation of a $3 million Superfund landfill in Monterey Park, California. Established seminar program and trained engineers and scientists in contamination hydrogeology.

1984-1990 — Air Force Occupational and Environmental Health Laboratory, Brooks AFB, Texas. Chief, Environmental Restoration Branch. Contract and technical management for studies and control of hazardous material disposal sites of the Air Force Installation Restoration Program, and 5-year, $500 million program. Supervised sixteen scientists and engineers. Performed field work and negotiated with regulatory agencies throughout the United States and Guam. Conducted surface water and groundwater supply study for Shemya AFB, Attu Island, Alaska.

1982-1984 Soil Exploration Company, St. Paul, Minnesota. **Project manager, senior hydrogeologist.** Directed surface and subsurface water studies of landfill, sewer dewatering, gas stations, plating, semiconductor, glass lens grinding, PCB, chemical spills, arsenic disposal sites, POTW lagoons, and nuclear power plants. Projects located in Minnesota, Iowa, North Dakota, and Wisconsin.

1981-1982 Morrison-Knudson Company, Boise, Idaho. **Senior hydrologist.** Finished hydrologic study and impact assessment for various mines in Idaho, Washington, Montana, Wyoming, and Texas.

1980-1981 Tera Corporation, Berkeley, California. **Senior geohydrologist.** Performed surface and subsurface hydrologic investigations for oil field disposal siting, coal generating station, hazardous waste treatment plant, lignite mine dewatering, and power plant site selection. Project sites were in Texas, Louisiana, California, and Washington.

1978-1980 VTN Consolidated, Inc., Irvine, California. **Senior hydrologist.** Performed hydrologic studies for environmental impact assessment and baseline data collection for projects in California, Hawaii, Idaho, Alaska, Texas, Nevada, and Colorado. Key projects were assessment of surface and groundwater availability for thirteen known geothermal resource areas in California and Hawaii; hydrological baseline study for U.S. Borax molybdenum mine at Thompson Creek, Idaho; Trabaco Canyon sand and gravel operation impact in Orange County, California; uranium mine hydrogeologic baseline study and EIS in northern Nevada; Heber geothermal power plant EIR, Imperial County, California; uranium mine hydrologic study for permit extension in Karne County, Texas; 208 urban runoff study for Southern California Association of Governments; oil shale hydrologic baseline studies in Utah and Colorado.

1971-1978 University of Arizona, Tucson. **Research associate/graduate research associate/graduate research assistant.** Participate in several hydrologic research projects including a $1 million surface coal mining environmental monitoring and reclamation study in northeastern Arizona, gold mine tailing reclamation near Prescott, Arizona, and the lower Colorado River stream flow data reconstruction using dendrohydrology.

1969-1971 Taiwan Sugar Corporation, Huewei General Mill, Taiwan. **Irrigation engineer.** Supervised water use, groundwater monitoring and irrigation network design and construction for sugar cane plantations in coastal plain and hills of west central Taiwan.

1968-1969 Second lieutenant, CCK, Taiwan, Republic of China. Platoon leader, instructor, and assistant company commander in an infantry training camp.

EDUCATION

B.S., soil and water, Taiwan Chung Hsing University, 1968.

M.S., hydrology, University of Arizona, 1974.

Ph.D., hydrology, University of Arizona, 1977.

Professional Affiliations

Certified Ground Water Professional 197, September 1986
American Geophysical Union, Hydrology Section
Association of Ground Water Scientists and Engineers

Honors

Letter of appreciation from LtC Paul T. Foxworthy, dean, School of Civil Engineering and Services, Wright-Patterson AFB, Ohio, March 1990.

Civilian Employee of the Year, U.S. Air Force Occupational and Environmental Health Laboratory, January 1989.

Supervisor of the Year, finalist, San Antonio Federal Executive Association, May 1988.

Letter of appreciation from Brig. Gen. Rufus M. Dehart, U.S. Air Force, MC Command Surgeon, HQ TAC, Langley AFB, Virginia, September 1985.

Who's Who in the Midwest, 1981.

Publications

Yu, J.K., 1991, "Indomitable Practices in Ground Water Contamination Studies – *cum grano salis*." Submitted to *Ground Water Monitoring Review* for fall issue.

Yu, J.K., et al., 1990, "Surface Water and Ground-Water TCE Interaction at Air Force Installations Within Denver Basin, Colorado, and Suisan Fairfield Basin, California." Presented at the annual meeting of The Association of Ground Water Scientists and Engineers, September 25-27, 1990, Anaheim, California.

Baladi, E., and J.K. Yu, 1990, "SARA Mandated Timelines May Force Less than Cost-Effective Cleanup of CERCLA Sites at DOD Facilities." Presented at the Air and Waste Management Association annual convention, Pittsburgh, Pennsylvania, September 1990.

Yu, J.K., 1989, "Reply to the preceding discussion by Arthur J. Gordon, Sr., of "Should We Use a Well Foot (Sediment Trap) in Monitoring Wells?" *Ground Water Monitoring Review*, 9(4):83-85, Fall 1989.

Draft final interim monitoring guidance document for Installation Restoration Program, co-author and editor. Technical Services Division, U.S. Air Force Occupational and Environmental Health Laboratory, Brooks AFB, Texas, May 1989.

Handbook to Support the Installation Restoration Program (IRP) Statements of Work for Remedial Investigations/Feasibility Studies (RI/FS), version 3.0; co-author. U.S. Air Force Occupational and Environmental Health Laboratory, Human Systems Division (AFSC), Brooks AFB, Texas, May 1989.

"Should we use well foot (sediment trap) or not?" *Ground Water Monitoring Review*, spring 1989.

Yu, J.K, T. Shangraw, D. Michaud, and T. Murphy. "Verification of the utility of a Photovac chromatograph for conduct of soil gas surveys." Presented at the Second National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, Las Vegas, Nevada, May 1988.

Yu, J.K., and R.C. Wooten. "Ground water pollution potential of Air Force installation on glacial, alluvial, and basalt deposits of the Northwest – Washington, Oregon, and Idaho." *Proceedings of the NWWA Focus Conference on Northwestern Ground Water Issues*. National Water Well Association, Portland, Oregon, May 1987.

Yu, J.K., G.R. New, and R.C. Wooten. "Hydrogeologists and data acquisition for aquifer modeling: *Quo vadis?*" Southern Regional Ground Water Conference, San Antonio, Texas, September 1985.

Yu, J.K. "Landfill and the high-yield wells of the Eau Claire-Mount Simon aquifer – a Wisconsin case study." Presented at the 13th Annual Rocky Mountain Groundwater Conference, Great Falls, Montana, April 1984.

Yu, J.K. "Geohydraulic considerations of well field design for aquifer restoration." *6th Annual Conference of Applied Research Practice on Municipal and Industrial Waste*, University of Wisconsin, September 1983.

Yu, J.K. *Manual of Aquifer Test Procedures*, January 1983.

Yu, J.K., et al. "Geohydrologic considerations of coal pile effluents at the coal terminal of the Port of Vancouver, Washington." SME-AIME Fall Meeting, Honolulu, Hawaii, September 1982.

Yu, J.K., and M.M. Fogel. "The development of a combined water quality index." *Water Resources Bulletin*, 14(5), 1978.

Yu, J.K. "The fallacy of increasing rainfall and streamflow by planting trees." *Journal of Soil and Water Conservation*, Taiwan, 8:1-6, 1975.

Yu, J.K. "The utilization of tree-ring data to predict hydrologic properties of semi-arid watersheds near Tucson, Arizona." M.S. thesis, University of Arizona, 1974.

Yu, J.K. "Tree-ring hydrology." *Journal of Soil and Water Conservation*, Taiwan, 5:19-24, December 1972.

Biographical Data

Lee L. Gorday, P.G.

Hydrogeologist

EXPERIENCE SUMMARY

Ten years of experience in characterizing groundwater flow and quality in varying hydrogeologic systems and ranging from site-specific to regional in scope. Responsible for all aspects of projects from conceptualization to report preparation.

EXPERIENCE RECORD

1991 to Present — Engineering Science, Inc. **Senior Geologist.** Responsible for the hydrogeologic characterization and delineation of extent of contamination at hazardous waste sites, design of monitor well networks and preparation of landfill permit applications. Reviewed adequacy of existing monitor well networks and designed additions as required in settings including multi-layered sediments, karst, glacial and regolith overlying impermeable bedrock. Supervised the installation of monitor wells and soil borings at RCRA sites in Alabama. Conducted an investigation of the borrow area of a landfill in Kentucky. Evaluated extent of contamination from fuel spills and landfills in Kansas and Michigan.

1982 to 1991 — Georgia Geologic Survey Branch, Environmental Protection Division. **Principal Hydrogeologist.** (1986-1991). Principal investigator in regional and local hydrogeologic studies. Activities included project conceptualization and management, construction and calibration of groundwater flow models, aquifer testing, evaluation of groundwater quality and availability, report preparation, evaluation of groundwater contamination, and geophysical logging. **Senior Hydrogeologist.** (1982-1986). Lead investigator in hydrogeological studies. Activities include planning and conducting hydrogeological investigations, preparation of project reports, assessing extent of contamination and threat to public drinking-water supplies from contamination from hazardous waste sites, review groundwater withdrawal permit requests, and installation and plugging of wells.

EDUCATION

M.A. in Geology, May 1982, University of Missouri, Columbia, Missouri

B.A. in Geology, June 1979, University of South Florida

Geology Field Camp, June-July 1979, Emory University

PROFESSIONAL AFFILIATIONS

Professional Geologist, State of Georgia, Number 634

Professional Geologist, State of Tennessee, Number TN1271

Association of Groundwater Scientists and Engineers

Georgia Groundwater Association

PUBLICATIONS

"The Hydrogeology of the Gulf Trough/Apalachicola Embayment Area, Georgia", Georgia Geologic Survey Bulletin 94, 1990. (Coauthor: M.F. Kellam).

"The Hydrogeology of Lamar County, Georgia", Georgia Survey Information Circular 80, 1989.

"The Hydrogeology of the Coastal Plain Strata of Richmond and Northern Burke Counties", Georgia Geologic Survey Information Circular 61, 1985.

"Proceedings: A Conference on the Water Resources of Georgia and Adjacent Areas", Georgia Geologic Survey Bulletin 99, 1984. (Edited with R. Arora).

"The Hydrogeology of Alluvial Aquifers in or Bordering the Dissected Till Plains", Unpublished M.A. Thesis, University of Missouri, Columbia, 1982.

SPECIAL TRAINING AND CLEARANCES

Completed 40-hour health and safety training for work at hazardous waste site and 8-hour supervisory training in compliance with OSHA regulations.

Biographical Data

DANIEL W. CURRENCE, P.E.

Environmental Engineer

EXPERIENCE SUMMARY

Responsible for tasks assigned in the development of a work plan for an interim remedial measure and a RI/FS follow-on study at a hazardous waste site. Researched biodegradation of pentachlorophenol. Four years as a Navy Civil Engineer Corps Officer provided experience at managing U.S. Navy construction contracts, project documentation, facilities engineering, budget programming, and supervising technical personnel.

EXPERIENCE RECORD

1991-Present — Environmental Engineer, Engineering Science, Inc. St. Louis, Missouri. Responsible for assigned environmental engineering related tasks on hazardous waste remediation projects. Specific assignments include initial site assessment, sampling program planning, and design of a ground water treatment system for an interim remedial measure and a RI/FS follow-on work plan.

1990-1991 — Graduate Assistant, University of Missouri-Columbia. Conducted research funded by EPA on biodegradation of pentachlorophenol by mixted culture bacteria in an aqueous phase media. Taught Engineering Graphics course to undergraduate students .

1988-1990 — Director of Facilities Engineering, Naval Supply Center, Charleston, South Carolina. Responsible for supervising nine personnel and utilizing a $2 million annual budget to maintain a $145 million physical plant consisting of approximately 60 structures. Responsible for all aspects of a $35 million major repair and construction program including planning, 1391 documentation, and administration. Directed a one year, $8 million effort to repair damages caused by hurricane which hit Charleston in 1989.

1986-1988 — Assistant Resident Officer in Charge of Construction, Naval Base, Charleston, South Carolina. Administered Department of Defense contracts for construction and repairs valued at over $9 million. Responsible for contract interpretation quality assurance, change order negotiations, schedule coordination, final acceptance, and payment approval.

EDUCATION

B.S. in Civil Engineering, 1986, University of Missouri, Columbia, Missouri

M.S. in Environmental Engineering, 1991, University of Missouri, Columbia, Missouri

PROFESSION AFFILIATIONS

Registered Professional Engineer (Missouri No. EN 024767)

SPECIAL TRAINING AND CLEARANCES

Completed 40-hour health and safety training for work at hazardous waste site and 8-hour supervisory training in compliance with OSHA regulations.

Biographical Data

SUSAN V. ROBERTS

Senior Hydrogeologist

EXPERIENCE SUMMARY

Managed environmental and hazardous waste remediations, feasibility studies, and investigations involving soil and groundwater contamination by petroleum hydrocarbons, chlorinated solvents, metals, and pesticides. Project experience includes work at government installations and RCRA- and UST-related sites utilizing groundwater flow modeling, geostatistical assessment, design, aquifer testing, and conventional field techniques of borehole logging, soil and water sampling, and soil-gas testing. Computer modeling experience with MODFLOW to predict aquifer flow conditions as calibrated by pump test results. Management experience in staff training, report preparation and evaluation, and regulatory liaison.

EXPERIENCE RECORD

1991-Date Engineering-Science, Austin, Texas. Senior hydrogeologist. Currently managing UST assessment and compliance program. Involved with aquifer test and groundwater modeling of shallow aquifer at government installation site. Field team co-leader for McConnell AFB remedial investigation of twelve sites involving team mobilization, data management, and field work using drilling, well installation, sampling, and geophysical surveys as foundation for site-specific remediation. Prepared work plan for $6 million project involving removal, assessment, and soil remediation of forty USTs at Kelly AFB, Texas.

1990-1991 EnecoTech, Inc., Austin, Texas. Project hydrogeologist. Worked at environmental consulting firm as project manager of UST- and RCRA-related projects, including UST closure, site assessments, and remediations with regard to petroleum hydrocarbons and pesticides/herbicides in soil and groundwater.

1988-1990 GeoResearch, Los Angeles, California. Project hydrogeologist. Managed soil and groundwater RI/FS projects pertaining to petroleum hydrocarbons, chlorinated solvents, and metals. Experience in geostatistical design, groundwater flow computer modeling, aquifer tests, evaluation of remedial alternatives and costs, vapor extraction feasibility, and field work using soil/groundwater/soil-gas testing. Responsible for project client/regulatory liaison.

1987 Independent contractor to Mobil Oil, Bakersfield, California. Geologic consultant. Participated in field exploration of a potential oil field in northern California. Used structural and stratigraphic data to determine potential for development in onshore/offshore basin.

1985-1988 University of Southern California, Los Angeles, California. Research/teaching assistant. Performed fission-track dating research to produce age calculations with statistical verification of various geologic province types. Taught oceanography laboratory.

EDUCATION

B.S., geology/geochemistry, The University of Texas at Austin, 1985

M.S., geology (emphasis on geochronology), University of Southern California in Los Angeles, 1988

PROFESSIONAL AFFILIATIONS

NWWA
Geological Society of America

PUBLICATIONS

Roberts, S.V., and Burbank, D.W., "Uplift and Thermal History of the Teton Range Defined by Apatite Fission-Track Dating, Northwestern Wyoming," Earth and Planetary Science Letters (in review; submitted May 1991).

Biographical Data

JOE D. BAUER

Hydrologist

EXPERIENCE SUMMARY

Involved with hydrogeologic investigations at hazardous waste sites during the past year. Experience includes groundwater contamination studies, aquifer testing, groundwater and soil sampling, supervision of monitor well installation, and environmental site assessments.

EXPERIENCE RECORD

1988-Date Engineering-Science, Inc., Austin, Texas. Hydrologist and project manager. Field team leader. RCRA surface impoundment closure and groundwater studies for a Department of Energy facility. Recently supervised the installation of 36 monitor wells at a hazardous waste landfill in south Texas. Performed pumping and slug tests. Assisted in the construction of monitor wells for a remedial investigation at McConnell Air Force Base, Kansas. Performed site inspections on pesticide sites for the Texas Water Commission PA/SI project. Performed underground storage tank investigations. Interpretation of aquifer testing and resistivity survey data for hazardous waste sites.

EDUCATION

B.S., hydrology, Tarleton State University, 1988

PROFESSIONAL AFFILIATIONS

Association of Groundwater Scientists and Engineers, Division of National Water Well Association

7.0 SCHEDULE

The installation of the pump test well and piezometers is expected to begin around 17 August 1992, assuming approval of this Work Plan by 7 August 1992. The review of this plan will be performed by Mr. David Skridulis of the USACE, Huntsville Division; Mr. Randy Wilson of DDRC; and by regulatory personnel with the State of Tennessee and the USEPA-Region IV.

Mobilization and setup of the activated carbon units, along with advance preparations for the pump test are expected to occur during the week beginning 31 August 1992. The pump test itself is planned for the week of 14 September 1992.

Reduction of pump test data and preparation of the pump test technical memorandum is planned by 16 November 1992.

The Draft Engineering Report and Draft Environmental Assessment Report will be assembled by 18 December 1992. Assuming that review is completed by 15 January 1993, Draft Final versions of these reports will be prepared by 1 February 1993. Following comments on these reports by DDRC and USACE, Huntsville Division, Final Reports will be issued by 24 February 1993.

The Draft Section C Work Statement will be prepared by 27 January 1993, followed by review by the USACE, Huntsville Division. The Final Section C Work Statement will be submitted by 24 February 1993, the same deadline as for the Engineering and Environmental Assessment Reports.

8.0 SITE HEALTH AND SAFETY PLAN

The Health and Safety Plan for the Pump Test well construction and Pump Test execution is presented as a separate document and enclosed as Appendix A.

9.0 REFERENCES

Driscoll, F.G., *Groundwater and Wells*, second edition, 1986.

Keely, J.F., *The Use of Models In Managing Ground-Water Protection Programs*, EPA/600/8-87/003, January 1987.

Law Environmental, Inc., Government Services Division, *Final Feasibility Study Report Defense Depot Memphis, Tenneessee*, September, 1990.

Law Environmental, Inc., Government Services Division, *Remedial Investigation Final Report Defense Depot Memphis, Tenneessee*, August, 1990.

McDonald, M.G., and A.W. Harbaugh, *A Modular Three-Dimensional Finite Difference Ground-Water Flow Model*, US Geological Survey, open file report 83-875, 1984.

Prickett, T.A., and C.G. Lonnquist, *Selected Digital Computer Techniques for Groundwater Resource Evaluation*, Bulletin 55, Illinois State Water Survey, 1971.

Smith, J.W., and Z. Ishak-Muhamad, *Memphis Light, Gas, and Water Department Water System Contingency Study*, Memphis State University, December, 1989.

US Army Toxic and Hazardous Materials Agency, *Geotechnical Requirements for Drilling, Monitor Wells, Data Acquisition, and Reports*, March 1987.

US Bureau of Reclamation, *Ground Water Manual*, 1977

US EPA, *Handbook Remedial Action at Waste Disposal Sites (revised)*, EPA/626/G-85/006, October 1985.

US EPA, *Superfund Remedial Design and Remedial Action Guidance (revised)*, OSWER Directive 9355.0-4A, PB88-107529, June 1986.

US EPA, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final*, EPA/540/G-89/004, October 1988.

US EPA, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*, EPA/540/G-88/003, December 1988.

US EPA, *40 CFR 300 National Oil and Hazardous Substances Pollution Contingency Plan, Final Rule. Federal* Register 55(46):8665-8865, 8 March 1990.

US EPA, *Management of Investigatory-Derived Wastes*, OW9345.3-O2FS, May 1991.

APPENDIX A

26 67

HEALTH AND SAFETY PLAN

FOR
DEFENSE DISTRIBUTION REGION CENTRAL
MEMPHIS, TENNESSEE

PREPARED BY

ENGINEERING-SCIENCE, INC.
425 Woods Mill Road South
Suite 150
Chesterfield, Missouri

REVIEWED AND APPROVED BY:

David E. Mizell	7-27-92	Scott E. Bowden, CIH	7-26-92
Project Manager	Date	Project Health and Safety Officer	Date

SL016/67359133/DDRC3

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

APPENDIX A

SITE HEALTH AND SAFETY PLAN

1.0 PURPOSE AND POLICY

The purpose of this plan is to identify the health and safety policies, practices and procedures to be followed during the initial site investigation at Defense Distribution Region Central, Memphis, Tennessee. In addition, this plan assigns responsibilities, establishes standard operating procedures, and provides for contingencies that may arise while operations are conducted. The provisions of this plan are equally applicable to Engineering-Science (ES) personnel. Subcontractors shall have Health and Safety Plans for work at DDRC.

A site description and scope of work summary for the project are provided in Section 2. Section 3 presents the project team organization, personnel responsibilities, and lines of authority. Site-specific training and medical monitoring requirements are contained in Section 4. Section 5 presents a safety and health risk analysis. Section 6 contains the site emergency response plan, a list of emergency contacts and a narrative for the route from the facility to the nearest hospital. Site-specific requirements for levels of protection are included in Section 7, and air monitoring procedures are provided in Section 8. Site control measures, including designation of site work zones, is contained in Section 9, Section 10 provides detailed site-specific decontamination procedures, and Section 11 outlines air monitoring use and calibration procedures. Attachment 1 is a Plan Acceptance form to be filled out by all personnel working at the site.

2.0 SITE DESCRIPTION AND SCOPE OF WORK

2.1 Background

Site Name:	Defense Distribution, Region Central Memphis, Tennessee
Site Contact:	Randy Wilson, Environmental Coordinator
Site Contact Phone Number:	(901) 775-6969
USACE Contact:	David Skridulis
USACE Contact Phone Number:	(205) 955-5143

2.2 SITE HISTORY AND DESCRIPTION

The Defense Distribution, Region Central (DDRC) is located on 642 acres within the City of Memphis, Shelby County, Tennessee. DDRC is operated by the Defense Logistics Agency (DLA) as a distribution and stockpile center serving Department of Defense facilities of all service branches throughout the central United States. Use of this site dates back to 1942. In previous times, normal procedure was to dispose of items in damaged containers, off-grade products, surplus materials or otherwise unwanted or unneeded items in trenches in Dunn Field. This practice has led to soil, ground-water, and surface-water being contaminated by materials that are now considered hazardous waste. Localized areas of contamination have been identified on the main portion of the post as the result of spills and local operations.

2.3 Scope of Work

Field tasks to be performed at DDRC include the following in the Interim Remedial Measures (IRM) phase:

- Test Well Construction
- Aquifer Test Execution
- Surveying

Field tasks to be performed as a part of the RI/FS follow-up include:

- Geophysical Surveying
- Stratigraphic Test Boring
- Monitor Well Drilling and Installation
- Surveying
- Performing *In-Situ* Permeability Tests
- Surface-Soil Sampling
- Ground-Water Sampling
- Surface-Water Sampling

3.0 PROJECT TEAM ORGANIZATION

The project team assigned to the DDRC site, their responsibilities, and lines of authority are outlined below.

Senior level management for the project will be provided by Mr. Robert A. Mannebach, Senior Associate, who will be responsible for enforcing the requirements of the project Health and Safety Plan. Mr. Scott E. Rowden is the Project Health and Safety Officer and will be responsible for administering, updating and revising the project Health and Safety Plan, as necessary. He will perform periodic field audits to ensure that the provisions of the Health and Safety Plan are being enforced. Mr. Rowden will also provide technical assistance to the Site Safety Manager and ensure that accident reports are submitted.

The Site Safety Manager will be responsible for assuring that the day-to-day project activities are performed in strict conformance with the project Health and Safety Plan. The Site Safety Manager is to be independent of the Project Manager and has the authority to stop work on the site if actions or conditions are judged unsafe or not in conformance with the Health and Safety Plan. The Site Safety Manager will periodically inspect protective clothing and equipment, confirm each project team member's suitability for work, conduct the daily safety meetings, coordinate emergency medical care and report any health and safety deficiencies identified to the Project Manager. The person designated to be the Site Safety Manager will be determined based on the nature of the activities currently underway at the site.

All field team members are responsible for reading and conforming to the project Health and Safety Plan. No employee shall perform a project activity that he or she believes may endanger his or her health and safety or the health and safety of others.

Visitors to the work site must check in and out with the Site Safety Manager. If visitors desire entrance to the area of active work at the site, they must wear the appropriate personal protective equipment for the activities underway and have received the OSHA 40-hour training discussed in 4.1 below. Furthermore, they must read this health and safety plan and sign an acceptance form indicating that they will abide by the work rules outlined in this plan.

4.0 EMPLOYEE TRAINING AND MEDICAL SURVEILLANCE REQUIREMENTS

4.1 Training

ES personnel and subcontractors are required to receive 40-hours of initial health and safety training in hazardous waste operations (29 CFR Part 1910.120 [e]) and be current with required refresher training prior to participating in this project. All ES personnel engaged in site supervisory positions will have completed the 8-hour

OSHA supervisory training.

The Site Safety Manager is responsible for developing and conducting a site-specific training program for on-site personnel. This training should encompass the following topics:

- Name of personnel responsible for site safety and health.
- Safety, health and other hazards at the site.
- Proper use of personal protective equipment.
- Work practices by which the employee can minimize risk from hazards.
- Safe use of engineering controls and equipment on the site.
- Acute effects of compounds at the site.
- Decontamination procedures.

Site training must be documented by use of attendance list. No personnel will be permitted to work without first receiving training.

Daily safety briefing will be conducted by the Site Safety Manager prior to each days activities. The daily safety briefing will include notification of the location of the phone to be used in the event of an emergency, the location of sanitary facilities and other information that may be unique to that day's operations.

4.2 Medical Surveillance

The Occupational Safety and Health Administration (29 CFR Part 1910.120 [f]) requires all personnel engaged in operations involving hazardous material to be enrolled in a medical surveillance program.

ES utilizes the services of licensed, local physicians to provide medical surveillance of employees at the various ES offices. Site personnel receive a complete physical at least once per year. More frequent monitoring is conducted as needed based upon potential exposures and individual medical history.

5.0 SAFETY AND HEALTH RISK ANALYSIS

5.1 Chemical Hazards

The products of primary concern at this jobsite are wide range of halogenated volatiles, non-halogenated volatiles, non-halogenated semi-volatiles, heavy metals and pesticides.

The properties of these chemicals are summarized in Table 5.1. If other compounds are discovered at this site, the Health and Safety Plan shall be amended, pertinent information about the compounds shall be provided in Table 5.1, and an appropriate risk analysis of the compound's hazards shall be communicated to the on-site employees.

Lead has been noted as a contaminant in soils at the site. The maximum concentration noted in the soils was 11 mg/Kg. In order to reach the PEL for lead of 0.05 mg/m^3, a total of 5 grams of soil per cubic meter would be required. Particulate concentrations of 5 grams per cubic meter would create visibility problems which would stop work. Because of the low concentration of lead in the soil particulate monitoring will not be performed.

5.2 Physical Hazards

Flammable/combustible liquids: may be ignited by heat, sparks, or flames. Monitoring must be conducted to access the potential for flammable atmospheres.

Physical hazards may exist from the process of constructing monitoring wells and collecting sub-surface soils samples. Extreme care is called for when working around drill rigs and other heavy machinery. Any person within 20 feet of drill rig must wear hard hat, steel toe safety boots and safety glasses.

Personnel collecting surface water samples from the golf course pond and Lake Danielson must use a boat. Wearing personal floatation devices and paying attention to the dangers of capsizing should minimize the risks associated with this activity.

Most field activities are anticipated to occur outdoors during daylight hours. Should intrusive activities be conducted at night, site illumination will be provided in accordance with 29CFR1926.56. Water level monitoring will occur at night during the pump test. Each worker will be provided a flashlight for use in areas that do not receive proper illumination from fixed lights.

Sanitation facilities will be provided by DDRC. Alternate facilities may be identified when working at some of the more distant off-post sites.

5.3 Heat Stress

Adverse weather conditions are important considerations in planning and conducting site operations. Hot or cold weather can cause physical discomfort, loss of

TABLE 5.1

HEALTH AND PHYSICAL HAZARD AND RECOGNITION QUALITIES[1] OF SITE CONTAMINANTS

Compound	PEL[2]	TLV[3]	IDHL[4]	Warning Conc.[5]	Ionization Potential	Comments
Acetone	750 ppm	750 ppm	20,000 ppm	100 ppm	9.7	Vapor irritating to eyes and mucous membranes. Prolonged excessive contact may cause defatting of the skin.
Arsenic	0.5 mg/m^3	0.2 mg/m^3	100 mg/m$^{3(Ca)}$	--	NA	Poisonous by inhalation of dust or ingestion, symptoms are characteristic of severe gastritis. Carcinogenic.
Barium	0.5 mg/m^3	0.5 mg/m^3	1,100 mg/m^3	--	NA	May ignite itself if exposed to air. Contact may cause burns to skin and eyes.
beta BHC (Lindane)	0.5 mg/m$^{3(S)}$	0.5 mg/m$^{3(S)}$	1,000 mg/m^3	21.3 mg/m^3	NA	Ingestion or absorption may result in headaches, nausea, respiratory difficulty, irritation of eyes, nose and throat.
Carbon tetrachloride	2 ppm	5 ppm$^{(S)}$	300 ppm$^{(Ca)}$	200 ppm	11.47	Dizziness, staggering, anesthesia. May cause liver and kidney damage. Carcinogenic.
Chloroform	2 ppm	10 ppm	1,000 ppm$^{(Ca)}$	307 ppm	11.42	Headache, nausea, dizziness, drunkenness, narcosis. Carcinogenic.
Copper	0.1 mg/m^3	1 mg/m^3	--	--	NA	Eye and nose irritation, dermatitis.
DDT	1 mg/m$^{3(S)}$	1 mg/m^3	(Ca)	2.9 mg/m^3	NA	Ingestion of small doses results in tingling of lips, malaise, headache, sore throat and fatigue.
Dibutylphthalate	5 mg/m^3	5 mg/m^3	9,300 mg/m^3	--	NA	Irritation of upper respiratory tract.
1,2 Dichloroethylene	200 ppm	200 ppm	4,000 ppm	500	9.65	Nausea, vomiting, weakness, tremors, epigastric cramps, central nervous depression. Eye irritation.
Dieldrin	.025 mg/m$^{3(S)}$	0.25 mg/m$^{3(S)}$	450 mg/m$^{3(Ca)}$	0.41 mg/m^3	NA	Irritability, nausea, vomiting, headache, fainting, eye irritation. Carcinogenic.
Lead	0.05 mg/m^3	0.15 mg/m^3	700 mg/m^3	--	NA	Systemic chronic poison. Symptoms include aching bones and muscle, constipation and abdominal pain.
Mercury	0.05 mg/m$^{3(S)}$	0.1 mg/m$^{3(S)}$	28 mg/m^3	--	NA	Chest pains, headache, fatigue, eye and skin irritation and tremors.
Methyl Ethyl Ketone (2 Butanone)	200 ppm	200 ppm	3,000 ppm	25	9.5	Stinging of eyes and respiratory system, headache, dizziness, nausea and weakness.

TABLE 5.1 (Continued)

HEALTH AND PHYSICAL HAZARD AND RECOGNITION QUALITIES[1/] OF SITE CONTAMINANTS

Compound	PEL[2/]	TLV[3/]	IDHL[4/]	Warning Conc.[5/]	Ionization Potential	Comments
Nickel	0.1 mg/m^3	1.0 mg/m^3	(Ca)	--	NA	Mild irritant and allergen. Slightly toxic if inhaled or ingested. Carcinogenic.
Polychlorinated Biphenyls	0.05 mg/m^3(S)	0.5 mg/m^3	5 mg/m^3(Ca)	--	NA	Vapors cause severe irritation of eyes and throat and cause eye and lung injury. Carcinogenic.
Polynuclear Aromatic Hydrocarbons (PAH's)	--	0.2 mg/m^3	400 mg/m^3	--	NA	Contact may cause burns to skin and eyes.
1,1,2,2 Tetrachloroethane	1 ppm(S)	1 ppm(S)	150 ppm(Ca)	5 ppm	11.1	Vapor is moderately irritating. Nausea, vomiting, tremors and abdominal pain. Carcinogenic.
Tetrachloroethylene	25 ppm	50 ppm	500 ppm(Ca)	50	9.3	Vapor can effect central nervous system and cause anesthesia, liquid can irritate skin after prolonged contact. Carcinogenic.
1,1,1 Trichloroethane	350 ppm	350 ppm	1,000 ppm	400 ppm	--	Vapors cause slight smarting of eye or respiratory system.
1,1,2 Trichloroethane	10 ppm(S)	10 ppm(S)	500 ppm(Ca)	135 ppm	11.0	Vapors can effect central nervous system, irritation of nose and eyes. Carcinogenic.
Trichloroethylene	50 ppm	50 ppm	1,000 ppm(Ca)	400 ppm	9.5	Vapors cause slight smarting of eye or respiratory system if present in high concentrations. Carcinogenic.

1/ Information summarized from Sax, 1979, *Dangerous Properties of Industrial Materials*, Fifth Edition; OSHA regulations contained in *20 CFR 1910.1000*; EPA. 1983. *Response Safety Decision-Making Workshop* manual; ACGIH. 1990-91 *Threshold Limit Values*; and NIOSH 1990. *Pocket Guide to Chemical Hazards*.

2/ PEL: Permissible Exposure Limit expressed as ppm unless otherwise indicated. OSHA limit as found in *29 CFR 1910.1000*.(1990 version).

3/ TLV: Threshold Limit Value expressed as ppm unless otherwise indicated. From Plunkett, E.R., *Handbook of Industrial Toxicology*, 1976; or ACGIH 1990-91.

4/ IDHL: Immediately dangerous to life or health. Expressed as ppm unless otherwise indicated. *NIOSH Pocket Guide to Chemical Hazards*, 1990.

5/ Warning concentration is the odor threshold of the substance. *1983 EPA Response Safety Decision Making Manual.* When a range is given, use the highest concentration.

(S) SKIN NOTATION refers to potential contribution to exposure due to direct contact.

26 76

efficiency, and personal injury. Of particular importance is heat stress resulting when protective clothing decreases natural body ventilation. Heat stress can occur even when temperatures are moderate. One or more of the following recommendations will help reduce heat stress:

- Provide plenty of liquids. To replace body fluids (water and electrolytes) lost due to sweating, use a 0.1 percent salt water solution,

  more heavily salted foods, or commercial mixes. The commercial mixes may be preferable for those employees on a low-sodium diet.

- Provide cooling devices to aid natural body ventilation. These devices, however, add weight, and their use should be balanced against worker efficiency.

- Long cotton underwear acts as a wick to help absorb moisture and protect the skin from direct contact with heat-absorbing protective clothing.

- Install mobile showers and/or hose-down facilities to reduce body temperature and cool protective clothing.

- In extremely hot weather, conduct non-emergency response operations in the early morning or evening.

- Ensure that adequate shelter is available to protect personnel against heat, cold, rain, snow, or other adverse weather conditions which decrease physical efficiency and increase the probability of accidents.

- In hot weather, rotate workers wearing protective clothing.

- Good hygienic standards must be maintained by frequent change of clothing and daily showering. Clothing should be permitted to dry during rest periods. Workers who notice skin problems should immediately consult medical personnel.

5.3.1 Effects of Heat Stress

If the body's physiological processes fail to maintain a normal body temperature because of excessive heat, a number of physical reactions can occur. They can range from mild reactions such as fatigue, irritability, anxiety, and decreased concentration, dexterity, or movement to death. Specific first aid treatment for mild cases of heat stress is provided in the American Red Cross first aid book. The location of this book should be known at all times by the site manager and the book should be readily available for reference in the field. Medical help must be obtained for the more serious cases of heat stress.

5.3.2 Heat-related problems include:

- Heat rash: Caused by continuous exposure to heat and humid air and aggravated by chafing clothes. Decreases ability to tolerate heat as well as being a nuisance.
- Heat cramps: Caused by profuse perspiration with inadequate fluid intake and chemical replacement, especially salts. Signs include muscle spasm and pain in the extremities and abdomen.
- Heat exhaustion: Caused by increased stress on various organs to meet increased demands to cool the body. Signs include shallow breathing; pale, cool, moist skin; profuse sweating; and dizziness and lassitude.
- Heat stroke: The most severe form of heat stress. Body must be cooled immediately to prevent severe injury and/or death. Signs include red, hot, dry skin; no perspiration; nausea; dizziness and confusion; strong, rapid pulse; and possibly coma. Medical help must be obtained immediately.

5.3.3 Heat Stress Monitoring

Monitoring of personnel wearing impervious clothing will begin when the ambient temperature is 70°F or above. Table 5.2 presents the suggested frequency for such monitoring. Monitoring frequency will increase as the ambient temperature increases or as slow recovery rates are observed. Heat-stress monitoring will be performed by a person with a current first-aid certification, who is trained to recognize heat-stress symptoms. For monitoring the body's recuperative abilities from excess heat, one or more of the techniques listed below will be used.

To monitor the worker, measure:

- Heart rate: Count the radial pulse during a 30-second period as early as possible during the rest period.

TABLE 5.2

SUGGESTED FREQUENCY OF PHYSIOLOGICAL MONITORING FOR FIT AND ACCLIMATIZED WORKERS[1/]

Adjusted Temperature[2/]	Normal Work Ensemble[3/]	Impermeable Ensemble
90°F (32°C) or above	After each 45 minutes of work	After each 15 minutes of work
87.5°-90°F (30.8°-32.2°C)	After each 60 minutes of work	After each 60 minutes of work
82.5°-87.5°F (23.1°-30.8°C)	After each 90 minutes of work	After each 90 minutes of work
77.5°-82.5°F (25.3°-28.1°C)	After each 120 minutes of work	After each 90 minutes of work
72.5°-77.5°F (22.5°-25.3°C)	After each 150 minutes of work	After each 120 minutes of work

1/ For work levels of 250 kilocalories/hr.

2/ Calculate the adjusted air temperature (ta adj) by using this equation: ta adj°F+ (13 x %.sunshine). Measure air temperature (ta) with a standard mercury-in-glass thermometer, with the bulb shielded from radiant heat. Estimate percent sunshine by judging what percent of time the sun is not covered by clouds that are thick enough to produce a shadow (100 percent sunshine = no cloud cover and a sharp, distinct shadow; 0 percent sunshine = no shadows).

3/ A normal work ensemble consists of cotton coveralls or other cotton clothing with long sleeves and trousers.

- If the heart rate exceeds 110 beats per minute at the beginning of the rest period, the next work cycle will be shortened by one-third and the rest period will remain the same.

- If the heart rate still exceeds 110 beats per minute at the next rest period, the following work cycle will be reduced by one-third.

- Oral temperature: Use a clinical thermometer (3 minutes under the tongue) or similar device to measure the oral temperature at the end of the work period (before drinking).

  - If the oral temperature exceeds 99.6°F (37.6°C) the next work cycle will be reduced by one-third without changing the rest period.

  - If the oral temperature still exceeds 99.6°F (37.6°C) at the beginning of the next rest period the following cycle will be reduced by one-third.

  - No worker will be permitted to wear a semipermeable or impermeable garment when oral temperature exceeds 100.6°F (38.1°C).

5.4 Cold Exposure

Persons working outdoors in temperatures at or below freezing may suffer from cold exposure. During prolonged outdoor periods with inadequate clothing, effects of cold exposure may even occur at temperatures well above freezing. Cold exposure may cause severe injury by freezing exposed body surfaces (frostbite) or results in profound generalized cooling, possibly causing death. Areas of the body which have high surface area-to-volume ratios such as fingers, toes, and ears are the most susceptible to frostbite.

Local injury resulting from cold is included in the generic term frostbite. There are several degrees of damage. Frostbite of the extremities can be categorized into:

- Frost nip or incipient frostbite: characterized by sudden blanching or whitening of skin.

- Superficial frostbite: skin has a waxy or white appearance and is firm to the touch, but tissue beneath is resilient.

- Deep frostbite: tissues are cold, pale, and solid; extremely serious injury.

Systemic hypothermia is caused by exposure to freezing or rapidly dropping temperature. Its symptoms are usually exhibited in five stages: (1) shivering; (2) apathy, listlessness, sleepiness, and (sometimes) rapid cooling of the body to less than 95°F; (3) unconsciousness, glassy stare, slow pulse, and slow respiratory rate; (4) freezing of the extremities; and (5) death.

6.0 EMERGENCY RESPONSE PLAN

6.1 Responsibilities

The purpose of the Emergency Response Plan is to provide an immediate source of information that can be utilized in an emergency. In the event of an emergency work will cease. The Site Safety Manager will coordinate activities to assist injured personnel and control release of hazardous substances in order to minimize the risk to project team members and the public. At least one person trained and certified in first aid and CPR will be on site during all on-site operations.

The work site will be evacuated if hazardous conditions are detected. The nature of the work to be performed is such that this is unlikely. The two major hazards that would require evacuation are the presence of organic vapors, described in Section 7 of this plan, and explosive conditions indicted by the explosimeter (greater than 20% of the lower explosive limit). If these conditions occur, personnel will evacuate the site and assemble at a place designated by the Site Safety Manager at the morning safety briefing.

6.2 Accidents and Injuries

Defense Distribution Region Central has its own emergency response system that should be alerted in the event of an emergency. If the emergency involves life threatening injuries, normal decontamination procedures will be bypassed. Normal decontamination procedures will be followed if injuries are not life threatening.

Table 6.1 lists telephone numbers of emergency contacts. The first contact should be to DDRC Security, who will arrange for an ambulance if needed. Figure 6.1 shows the route to Methodist Hospital Central. If injuries are serious they should be contacted and briefed as to the scope of the event if possible. To reach the hospital, exit the main gate, and proceed south on Airways Blvd. Take Interstate 240 west then Interstate

255

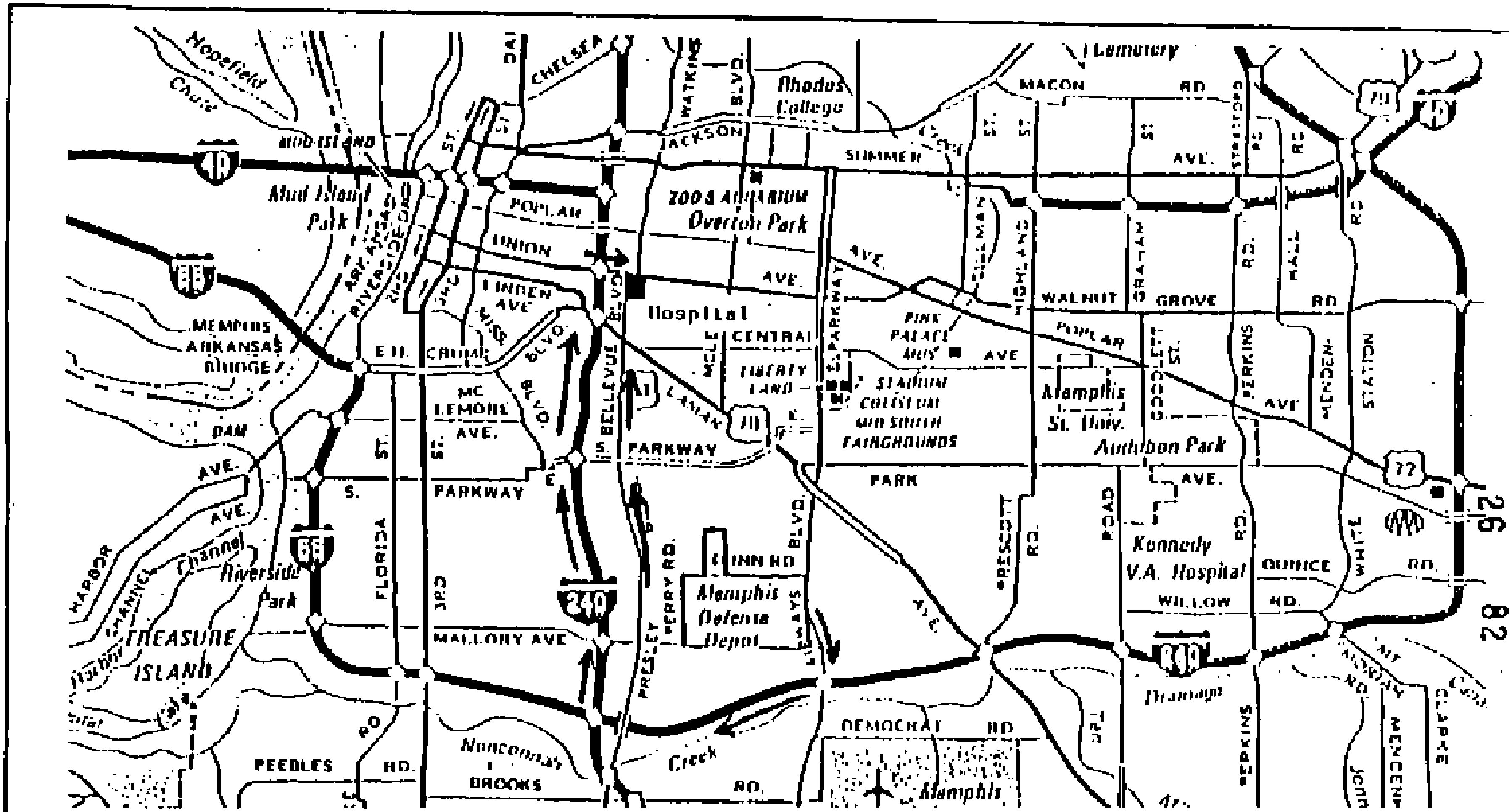


Figure 6.1 - Location of Hospital

Scale In Miles 0 1 2

Scale in Kilometers 0 1 2

DEFENSE DISTRIBUTION REGION CENTRAL MEMPHIS, TENNESSEE

DEFENSE LOGISTICS AGEN

ENGINEERING-SCIENCE St. Louis, Missouri

TABLE 6.1
EMERGENCY CONTACTS

DDRC Security	(901) 775-6677
DDRC Hazardous Materials Response Team Coordinator Randy Wilson	(901) 775-4910
DDRC Fire Marshall	(901) 775-6745
<u>City of Memphis</u>	
Fire Department	9 1 1
Police	9 1 1
Methodist Hospital Central 1265 Union Avenue	(901) 726-7600

north to Union Road. Proceed west to the hospital.

6.3 Incident Reporting

As soon as the emergency situation has been stabilized, the Site Safety Manager will notify the Contracting Office and the project manager of the incident. Within two days the Project Health & Safety Officer or Site Safety Manager will prepare an accident report for submission to USACE and ES.

6.4 Posting Requirements

This plan will be made available to all personnel both before site work begins and on-site at any time work is underway. The route to the hospital (Figure 6.1) will be conspicuously posted at all times.

7.0 LEVELS OF PROTECTION AND PERSONAL PROTECTIVE EQUIPMENT REQUIRED FOR SITE ACTIVITIES

7.1 Personal Protective Equipment

The personal protection level prescribed in the DDRC site is Level D (no respiratory or chemical protective clothing) with a contingency for the use of disposable Tyvek coveralls at Dunn Field. This requirement is based on the expected risk of exposure to chemical contaminants known to be present at the site. The highest levels of contamination have been found in the Dunn Field area. Therefore protective and monitoring requirements are greater at Dunn Field than in other areas of the post.

Ambient air monitoring of organic gases/vapors (by Photoionization Detectors such as an HNu or Photovac TIP, Flame ionization Detectors such as an OVA or colorimetric analysis with Dräger tubes) will be used to select the appropriate level of personal protection. Figure 7.1 outlines the actions prescribed depending upon the results of the monitoring. Figure 7.1 is designed for use in intrusive activities such as test borings, well installation and soil sampling. If conditions unsuitable for use of Level D protection are encountered, work will be terminated, the area evacuated and allowed to ventilate. If the thresholds established in Figure 7.1 are exceeded after the area has been allowed to ventilate, the Project Health and Safety Officer will be notified and field work will cease.

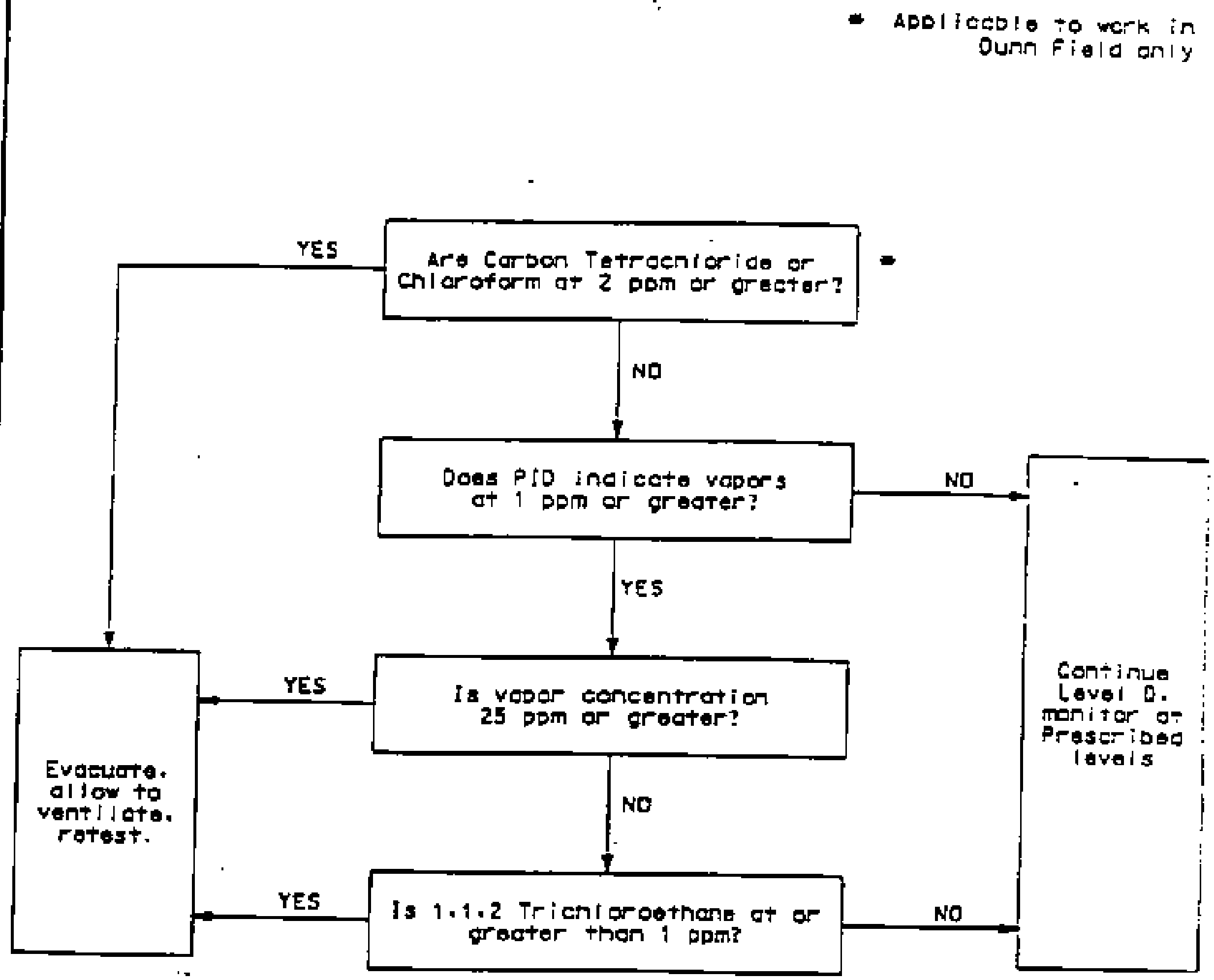


FIGURE 7-1:
RESPIRATORY PROTECTION CHART

DEFENSE DISTRIBUTION
REGION CENTRAL
MEMPHIS, TENNESSEE

DEFENSE LOGISTICS AGENCY

ENGINEERING-SCIENCE
St. Louis, Missouri

ES

The following personnel protective ensemble is required when handling contaminated samples or equipment:

Mandatory Equipment	Optional Equipment
▪ Vinyl or latex inner gloves	▪ Outer disposable boot covers
▪ Nitrile outer gloves	▪ Disposable Tyvek coveralls
▪ Leather or rubber safety boots	▪ Chemical goggles
	▪ Hard Hat

The following monitoring equipment is required only when engaged in intrusive activities, such as drilling, soil sampling and water sampling:

- Either an OVA, HNu, or Photovac TIP (Must be capable of detecting chloroform and carbon tetrachloride)
- Explosimeter
- Dräger tubes for 1,1,2,2 Tetrachloroethane, Carbon Tetrachloride and Chloroform in Dunn Field (1,1,2,2 Tetrachloroethane concentration estimated by using vinyl chloride tube VC 0.5/A with 10 strokes. Concentration of 1 ppm of 1,1,2,2 Tetrachloroethane will indicate 0.5 ppm vinyl chloride. Concentration of 3 ppm will indicate 1.0 ppm vinyl chloride.)

This equipment must be available within 100 feet of the field crew at all times that field activities are underway.

All personnel working within 20 feet of a drill rig or excavation equipment must be wearing a hard hat, safety glasses and steel toe safety boots.

7.2 Equipment Needs

Each field team shall have the following items readily available:

- Copy of site Health and Safety Plan including a separate list of emergency contacts
- First Aid Kit
- Eye Wash Bottle
- Paper Towels
- Duct Tape
- Water

- Plastic Garbage Bags
- Plastic drop cloth for decontamination
- Fire extinguisher

8.0 FREQUENCY AND TYPES OF AIR MONITORING

Air monitoring will be used to identify and quantify airborne levels of hazardous substances. On-site activities which may result in airborne contamination (i.e., drilling, sampling, etc.) require periodic air monitoring.

Type of Equipment	Minimum Calibration Frequency	Parameter(s) to be Measured	Minimum Sampling Frequency	Locations
Photoionization Detector	1/day	Organic Vapors	▪ 5-ft intervals (while soil boring) ▪ 4/hour for other site activities	▪ Breathing Zone ▪ Soil Borings ▪ Monitoring Wells
Explosivity Meter	1/day	Combustible gases	4/hour	▪ Soil Borings ▪ Monitoring Well installation
Dräger Tubes	None (check manufacturers requirements)	▪ Carbon Tetrachloride ▪ Chloroform ▪ 1,1,2,2 Tetrachloroethane ▪ 1,1,2 Trichloroethene	Upon detection of unknown compounds with photoionization detector	▪ Breathing Zone ▪ Soil Borings ▪ Monitoring Wells
Diffusion Vapor Monitor Badge	None	▪ Carbon Tetrachloride ▪ Chloroform ▪ 1,1,2,2 Tetrachloroethane	10 samples of 1 day duration on workers w/greatest chance of exposure (a minimum of 2 samples will be analyzed)	▪ Personal monitoring

Initial air monitoring will be provided by ES. ES will also perform personal monitoring during the site activities. ES health and safety officers will periodically confirm air monitoring data and review calibration and record keeping procedures.

During intrusive on-site operations at the work area, organic vapor concentrations in the breathing zone will be measured with a Flame Ionization Detector (FID) or a Photoionization Detector (PID). If organic vapor concentrations in the worker breathing zone are above 1 ppm, then perimieer monitoring of the extent of the elevated organic vapor concentration will be performed (after appropriate work site precautions are taken) to insure the safety of persons away from the work site. If the explosimiter indicates atmospheres exceeding 10 percent of the lower explosive limit, work will be conducted only with non-sparking tools and intrinsically safe instruments. Work will stop and the area evacuated if the explosimiter indicates atmospheres greater than 20 percent of the lower explosive limit.

Additional air monitoring requirements are necessary at Dunn Field where there is a possibility of encountering carbon tetrachloride and chloroform. Organic vapor monitoring requirements are outlined in Figure 7-1.

Worker exposure monitoring will be conducted to document any exposure of ES personnel to organic vapors received on-site. NIOSH approved diffusion vapor monitor badges will be used for personal exposure monitoring. The following general protocols will be followed:

- The badges will be worn by personnel with the greatest chance of exposure at sites where exposure is most likely;
- Badges will be exposed according to the manufacturers instructions for 8 hours;
- The two badges most likely to indicate the presence of contaminants based on the PID or FID results will be submitted for analysis by am AIHA accredited laboratory. If these samples indicate vapor concentrations safely below the PEL's, no other badges will be submitted for analysis;
- The laboratory analysis results will be disclosed to the employee(s) monitored; and
- The analysis results will be placed in the employee's permanent

medical file for documentation of any exposures received.

9.0 SITE CONTROL MEASURES

The following site control measures shall be followed in order to minimize potential contamination of workers, protect the public from potential site hazards, and to control access to the sites. Site control involves the physical arrangement and control of the operation zones and the methods for removing contaminants from workers and equipment. The first aspect, site organization, is discussed in this section. The second aspect, decontamination, is considered in the next section.

9.1 Site Organization - Operation Zones

If protective clothing, such as gloves and/or Tyvek suits are worn but respirators are not worn (Level D-modified), the field crew shall establish a decontamination area to avoid spreading contaminants off-site. The field team leader and/or site safety manager shall be responsible for establishing the decontamination area and for identifying and securing use at nearby sanitary facilities.

9.2 Site Security

Site security will be enforced by the site safety manager or a designated alternate who will ensure that only authorized personnel are allowed in the work area and that personnel have the required level of personal protective equipment.

Site security is necessary to prevent exposure of unauthorized, unprotected individuals in the work area.

9.3 Site Communication

Internal site communication is necessary to alert field team members in the work area of emergency conditions, to convey safety information, and to communicate changes or clarification in the work to be performed. If voice communication is not possible, the field team members will use pre-arranged hand signals (and responses). Radios and/or compressed air horns may also be used for communication.

9.4 Safe Work Practices

To ensure a strong safety awareness program during the operations, personnel shall have adequate training, this health and safety plan must be communicated to the employees, and standing work orders developed and communicated to the employees. Sample standing orders for personnel entering the work area are as follows:

- no smoking, eating, drinking;
- no matches/lighters in zone;
- use buddy system;
- wear appropriate personal protective equipment;
- avoid walking through puddles, stained soil;
- discovery of unusual or unexpected conditions will result in immediate evaluation and reassessment of site conditions and health and safety practices;
- conduct safety briefings prior to on-site work;
- conduct daily/weekly safety meetings as necessary;
- take precautions to reduce injuries from heavy equipment and other tools; and
- work only during daylight hours or with proper lighting if after dark or in heavily shaded areas.

The following guidelines will be followed while working on-site:

- Heavy Equipment - Only qualified operators will be allowed to operate heavy equipment. Subcontractors will be required to use the safe work guidelines included in the OSHA General Industry (29 CFR 1910) and Construction Industry (29 CFR 1926) Standards.
- Power Lines - When operating heavy equipment, such as drilling rigs near power lines, workers will take care to ensure that the boom or rigging always maintains a safe distance from power lines (10 ft minimum from lines < 50 KV). Higher voltage transmission lines will require longer set backs. These must be cleared with the particular utility. Any underground utility lines must also be located, and appropriate measures taken before any excavation work or drilling is done.
- Electrical Equipment - All electrical equipment will be properly grounded and class-approved for the location.
- Machine Guarding - All machinery on-site will be properly guarded to

prevent contact with rotating shafts, blades, or gears.

- Flammable Materials - When work involves flammable materials, adequate ventilating and control of all ignition sources will be maintained. This may include:
  - Nonsparking tools
  - Explosion proof equipment (intrinsically safe)
  - Class-approved electrical equipment
  - Grounding and bonding of static electricity sources
  - No smoking or open lights
  - No welding

10.0 SITE SPECIFIC DECONTAMINATION PROCEDURES

10.1 Personnel Decontamination Procedures

A portable decontamination station will be carried with the field team, and will be set up at the site actively under investigation during field. The Level D-modified decontamination station will include provisions for collecting disposable protective equipment, washing boots, gloves, respirators (if used), and field instruments and tools, and washing hands, face, and other exposed body parts. On-site personnel will shower at the end of the work day. Refuse from decontamination that may considered hazardous will be left on-site for proper disposal by the Client.

Decontamination equipment will include:

- Plastic buckets and pails
- Scrub brushes and long-handled brushes
- Detergent
- Containers of water
- Paper towels
- Plastic garbage bags
- Potable water

11.0 AIR MONITORING EQUIPMENT USE AND CALIBRATION PROCEDURES

11.1 Photovac Tip 1 Air Analyzer

To use the Photovac Tip, press the power switch and unlock ZERO and SPAN controls by turning rings clockwise. Set span control to 5 and lock span control by turning locking ring counterclockwise. Allow Tip to sample clean air. Adjust zero control until display reads 0.00. Lock zero control by turning locking ring counterclockwise and observe sample concentration changes. Turn Tip off.

The Tip is used as a direct-reading instrument in conjunction with the span gas kit. In order to calibrate the Tip, press the power switch and unlock the zero and span controls by turning locking rings clockwise. Set span control to 5. Allow Tip to sample clean air. Adjust zero control until display reads 0.00. Connect bag of span gas to the tip inlet. Adjust span control until display indicates the span gas concentration (usually 100 ppm). Disconnect span gas bag. Sample clean air again and re-adjust zero control until display reads 0.00. Lock zero control in. Sample span gas again and readjust span control until display indicates the span gas concentration. Lock span control in. Observe sample concentrations. The concentration of total ionizables is displayed in span gas equivalent units. Turn Tip off.

11.2 HNu Photoionization Detector

To use the HNu, connect the probe to the instrument by matching the ALIGNMENT key in the probe connector to the 12-pin connector on the control panel and twist the probe connector until a distinct snap and lock is felt. Turn the function switch to battery check position. The needle should read within or above the green battery arc on the scaleplate. If the needle is in the lower position of the battery arc, the instrument should be recharged before use. If the red light comes on, the battery should be recharged. Next, turn the functions switch to the ON position and the instrument is ready to take direct air readings.

11.3 Dräger Tubes

Dräger Tubes can be used to give an instantaneous reading of various organic compounds. Their aim is to determine very small concentrations of a compound in the shortest amount of time. To sample with a Dräger Tube you use the Dräger Bellows Pump, select the appropriate tube (for example a tube marked Benzene to look for Benzene) and break off both ends on the pump's break-off plate. Insert the tube into the pump head (the tube should be inserted with the arrow pointing towards the pump). There is a given number of suction strokes for each tube/compound. Each box of tubes will have instructions for how many suction strokes are required for that compound.

11.4 Explosivity Meter

The Biosensor II is used for measuring oxygen and combustible gas levels. The ON/OFF switch is located on the front of the case. When you turn the unit on, wait a few seconds for the readings to stabilize. Check the battery charge and the alarms before using the Biosensor. Set the LEL indicator to 0 using the gas zero potentiometer on the side of the instrument.

To calibrate the Biosensor with span gas, attach the flow regulator to the calibration gas cylinder. Attach the sample lines and balloon as shown in the figure below. Fill the bulb/balloon with calibration gas. DO NOT OVERINFLATE. Feed more gas into the balloon as needed to keep it inflated. Wait for the readings to stabilize. Then using a small jeweler's screwdriver, adjust the span gas pot on the side of the instrument to obtain a steady reading which corresponds with the calibration gas concentration. Remove the calibration lines and let the Biosensor run for a full minute to flush out any excess span gas. Check readings, the combustible sensor should now be reading 000% LEL in fresh air.

Oxygen calibration is performed by adjusting the oxygen potentiometer until the instrument reads 20.9 percent.

ATTACHMENT 1

PLAN ACCEPTANCE FORM

PROJECT HEALTH AND SAFETY PLAN

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

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

Defense Distribution, Region Central, Memphis, Tennessee

____
Signed

____
Date

RETURN TO:

Office Health and
Safety Representative
Engineering-Science, Inc.
425 Woods Mill Road South
Suite 150
Chesterfield, MO 63017

FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE

FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE