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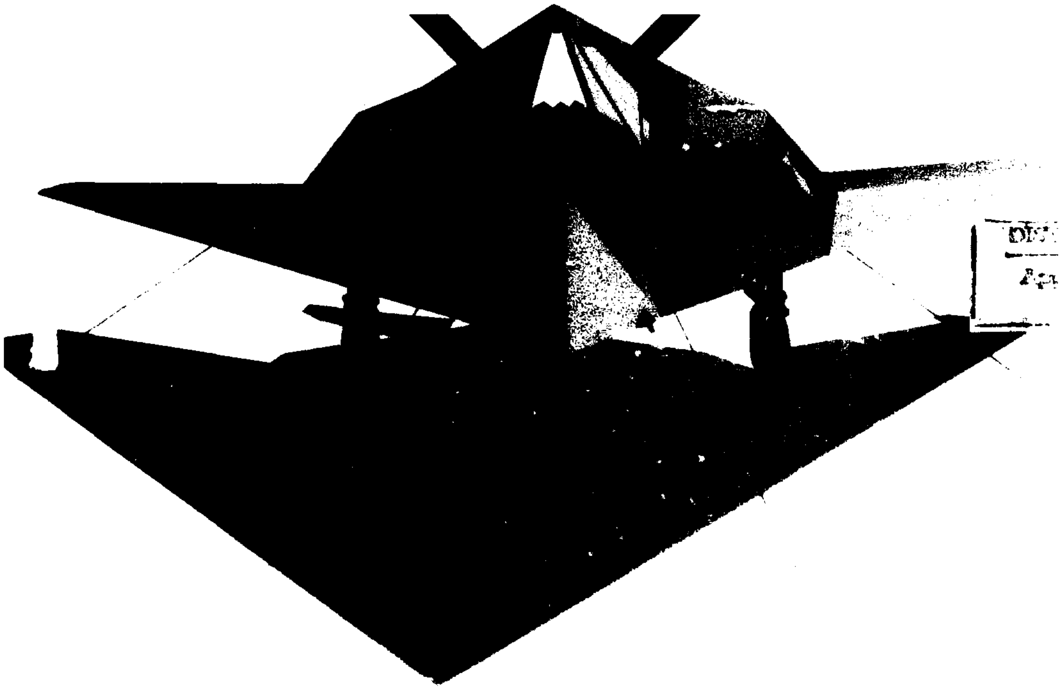
DEPARTMENT OF THE AIR FORCE

McClellan Air Force Base

Operable Unit D

Remedial Investigation Report

Delivery Order 5040
Volume 1 of 3



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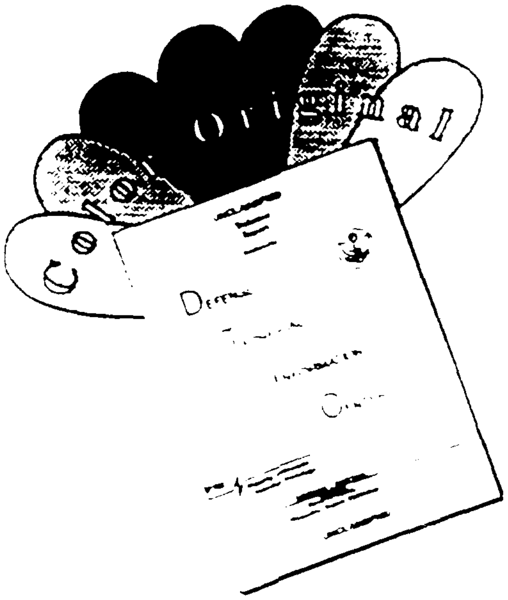

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Operable Unit D
Remedial Investigation Report

Volume 1 of 3

Prepared for

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SWE28722.40.12

June 1994

Notice

This report has been prepared for the Air Force by CH2M HILL for the purpose of aiding in the implementation of a final remedial action plan under the Air Force Installation Restoration Program (IRP). As the report relates to actual or possible releases of potentially hazardous substances, its release prior to an Air Force final decision on remedial action may be in the public's interest. The limited objectives of this report and the ongoing nature of the IRP, along with the evolving knowledge of site conditions and chemical effects on the environment and health, must be considered when evaluating this report, since subsequent facts may become known which may make this report premature or inaccurate. Acceptance of this report in performance of the contract under which it is prepared does not mean that the Air Force adopts the conclusions, recommendations, or other views expressed herein, which are those of the contractor only and do not necessarily reflect the official position of the Air Force.

Preface

CH2M HILL is contractor for Remedial Investigation (RI) activities within Operable Unit D at McClellan Air Force Base (McClellan AFB) in California. This RI is a primary document, as identified in the Interagency Agreement. This work is being conducted under Air Force Contract No. F04699-90-D-0035, Delivery Order No. 5040, Line Item 0014.

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CH2M HILL would like to acknowledge the cooperation of the McClellan AFB Office of Environmental Management for their assistance in expediting this project. In particular CH2M HILL acknowledges the assistance of Mr. Steve Hodge.

Executive Summary

The Operable Unit D Remedial Investigation was conducted to assess the magnitude of contamination of the vadose zone and groundwater within Operable Unit D (OU D), estimate the risks associated with the contamination, and evaluate existing and potential future remedial actions. The scope of remedial investigation field activities included the following:

- **Residential Crawlspace and Ambient Air Sampling** – Air samples were collected from four residences adjacent to the western boundary of the OU D cap. The samples were analyzed for VOCs at an offsite laboratory to assess the levels of contaminant exposures. Sampling was conducted on a quarterly basis from June 1992 to May 1993.

- **Soil Vapor Monitoring Well Sampling** – Soil gas samples were collected from nine vadose zone monitoring wells located at the perimeter of the OU D cap. The samples were analyzed for VOCs at an offsite laboratory to characterize contaminant concentrations and to provide supporting data for transport modeling and a mass estimate. Sampling was conducted on a quarterly basis from June 1992 to June 1993.

- **Shallow Soil Gas Survey** – Soil gas samples were collected at onbase and offbase locations at the perimeter of the OU D cap. The samples were analyzed for VOCs at an onsite laboratory to estimate the horizontal extent of shallow soil gas contamination. Confirmation analyses were conducted at an offsite laboratory. Sampling was conducted in September and October 1992.

- **Soil Borings and Well Installations** – Soil and downhole soil gas samples were collected while advancing nine borings for installation of soil vapor and groundwater monitoring wells. In situ groundwater samples were collected from four borings.

  Soil samples were analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), total metals, pesticides/polychlorinated biphenols (PCBs), dioxins dibenzofurans, total organic carbon, and bulk physical parameters. To minimize loss of volatiles, soil VOC samples were preserved in the field by immersion in methanol. All soil samples were analyzed at an offsite laboratory.

  Downhole soil gas samples were collected at intervals in each boring and analyzed for VOCs at an onsite laboratory. The downhole soil gas results and lithology were the primary basis for selection of soil VOC sample locations and soil vapor monitoring well screened intervals.

  Four *in situ* (*i.e.*, Hydropunch) groundwater samples were collected when the borings encountered the groundwater table. The samples were analyzed for VOCs at an offsite laboratory.

  Five multiple-completion soil vapor monitoring wells were installed in the soil borings. Four single-completion groundwater monitoring wells were installed as replacements for nearby wells that had become dry or will become dry in the near future.

- **Monitoring Well Sampling** – Soil vapor and groundwater monitoring wells were sampled to characterize the extent of vadose zone and groundwater contamination.

  Twelve soil vapor wells installed during the Remedial Investigation (RI) were incorporated into the quarterly monitoring program of nine previously installed wells. Five dry or partially submerged groundwater monitoring wells were sampled as soil vapor wells. Samples were analyzed for VOCs to assess the magnitude of vadose zone contamination.

- Twenty-nine groundwater monitoring and extraction wells were sampled at locations within the OU D cap and at outlying areas. Samples from wells near or within waste pit boundaries were analyzed for VOCs, SVOCs, pesticides PCBs, and dioxins dibenzofurans. Samples from wells not near source areas were sampled for VOCs only.

Data collected from the various phases of the investigation were summarized and evaluated. Contaminant transport mechanisms were modeled, mass estimates developed, and impacts to air and groundwater determined. A risk assessment was conducted to identify the contaminants posing the greatest threat and to evaluate potential exposures and adverse effects to human health. The effectiveness of existing remedial actions was assessed and potential future remedial actions discussed.

The conceptual model for OU D was refined using observational data and computer modeling using the Vapour-T program. The following interpretations were developed:

- Vapor-phase transport of VOCs in the vadose zone at OU D is a result of diffusive and advective movements. Contaminant migration by diffusion is due solely to concentration gradients and is slow relative to density-driven advective movement.

- Solution-phase transport of contaminants occurs when rainwater infiltrates the subsurface and contaminants become dissolved in the porewater. The contaminants are transported to the groundwater at the rate of infiltration. The low-permeability cap is effectively reducing rainwater infiltration and subsequent leaching of VOC and nonvolatile organic compounds (non-VOC) contaminants to the groundwater. The cap is not preventing the lateral migration of soil vapor VOCs.

- Vadose zone soil gas concentrations increase with depth below the ground surface. The maximum horizontal extent of VOC contamination occurs near the groundwater table and could be as far as 500 feet from the edge of the cap.

- Vadose zone VOC contamination poses a continuing threat to groundwater quality. The contaminants trichloroethylene (TCE) and 1,1-dichloroethylene (1,1-DCE) pose the greatest threats.

- Nonaqueous phase liquids (NAPLs) existing as residual contamination in the vadose zone underlying the capped waste pits will persist for at least 50 years without active remediation.

- Natural attenuation will not be adequate to remediate vadose zone VOC contamination.

- The VOCs are the most widespread contaminants in the OU D vadose zone and groundwater. Non-volatile compounds, including SVOCs, pesticides PCBs, and dioxins/dibenzofurans, are found primarily within the boundaries of the cap.

Contaminant mass estimates of chlorinated VOCs in the vadose zone were developed using historical and RI soil and soil gas data. Calculations indicate that TCE, 1,1,1-trichloroethane (1,1,1-TCA), 1,1-DCE, 1,1,2-trichloro-1,2,2-trifluorethane (Freon 113), and tetrachloroethylene (PCE) account for over 99 percent of the speciated VOC mass in the vadose zone. The contaminant TCE accounts for approximately 30 to 40 percent of the total speciated mass. The contaminant 1,1,1-TCA contributes about 28 to 44 percent. Non-chlorinated VOCs, such as petroleum hydrocarbons, may also contribute to the total VOC mass.

Within the risk assessment, exposure scenarios were developed, health risks were estimated for complete pathways, and hazard indexes were calculated. Significant findings of the risk assessment include the following:

- No current significant adverse carcinogenic or noncarcinogenic health risks are posed by VOCs or non-VOCs originating within OU D.
- The seven VOC contaminants that pose the greatest potential human health risks include vinyl chloride, 1,1,1-TCA, TCE, PCE, Freon 113, 1,2-DCA, and 1,1-DCE.
- Exposures attributed to indoor air inhalation of VOCs in Building 1093 do not pose a significant health threat.
- The VOC levels in residential crawlspace and ambient air samples are similar to background concentrations. The source of VOCs cannot be conclusively determined from the available data.
- No known exposure pathway exists from the domestic use of groundwater. Offbase well users were placed on municipal water supplies in a previous remedial action. However, it is uncertain if any domestic well water use has resumed. Potential exposures to groundwater from sprinkler irrigation do not represent a significant health risk (1.4x10[illegible] increased lifetime cancer risk).
- Estimated increased lifetime cancer risk for a hypothetical future onbase resident is 8x10[illegible] from ingestion of groundwater.
- *There are no exposure pathways for exposure to onbase surface and* subsurface soils. As long as the low-permeability cap remains in place, future pathways are also prevented

Contaminants and media that will require remediation were determined by comparing site data to regulatory standards and recommendations and risk-based criteria. Target areas for vadose zone VOCs extend vertically to the groundwater table and horizontally up to about 500 feet from the edge of the cap.

Summaries, discussions, and interpretations of remedial investigation data are provided in Chapters 1 through 8 of the Operable Unit D Remedial Investigation report. Additional and more detailed historical and RI data summaries, calculations, assumptions, sampling techniques, and analytical methodologies are provided in Appendixes A through K.

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Glossary of Terms

1,1-DCE	1,1-dichloroethylene
1,1-DCA	1,1-dichloroethane
1,1,1-TCA	1,1,1-trichloroethane
1,2-DCE	1,2-dichloroethylene
1,2-DCA	1,2-dichloroethane
AB	Assembly Bill
adsorption	The attraction of ions or compounds to the surface of a solid. For organic compounds, the organic carbon content of soil is the most important adsorption mechanism.
advection	The process of transfer of fluids (vapors or liquids) through a geologic formation in response to a pressure gradient. Advective mechanisms involve density-driven movement of gas phase contaminants caused by gravitational forces.
AFTAC	Air Force Technical Applications Center
AOC	area of concern
aquifer	an underground zone of earth, gravel, or porous stone that yields water
ARARs	Applicable or Relevant and Appropriate Requirements
ARB	(California) Air Resources Board
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
Cal/EPA	California Environmental Protection Agency
CCR	California Code of Regulations
CEPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (the Superfund law)
cis-1,2-DCE	cis-1,2-dichloroethylene
CL	clay

CLP	Contract Laboratory Program
COCs	contaminants of concern
COPC	chemicals of potential concern
CS	Confirmed Site
CSL	close support laboratory
CVRWQCB	Central Valley Regional Water Quality Control Board
CWA	Clean Water Act
desorption	the process of removing an absorbed or adsorbed substance
DET	Detachment
DHS	State of California Department of Health Services, now known as DTSC, Department of Toxic Substances Control
DHSG	downhole soil gas
diffusion	The process by which contaminants move from regions of high concentration to regions of low concentration. The random molecular motion is governed by Fick's Second Law.
DNAPL	dense nonaqueous phase liquid
DOT	Department of Transportation
DPDO	Defense Property Disposal Office
DPR	(Cal State) Department of Pesticide Regulation
DQO	data quality objective
DTSC	State of California Department of Toxic Substances Control
ECAO	(U.S. EPA) Environmental Criteria and Assessments Office
EDB	ethylene dibromide; 1,2-dibromomethane
EE/CA	Engineering Evaluation/Cost Analysis
EIR	Emission Inventory Report
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
eV	electronvolt
FAA	Federal Aviation Administration

FID	flame ionization detector
Freon 11	dichlorodifluoromethane
Freon 12	trichlorofluoromethane
Freon 113	1,1,2-trichloro-1,2,2-trifluoroethane
FS	feasibility study
GC	gas chromatograph
GC/MS	gas chromatograph/mass spectrometer
GC/TCD/FID/MS/HECD/PID	gas chromatograph/thermal conductivity detector/flame ionization detector/mass spectrometer/Hall electrolytic conductivity director/photoionization detector
HA	health advisory
HCl	hydrochloric acid
HEAST	Health Effect Assessment Summary Tables
HI	Hazard Index
HPCDD	heptachlorinated dibenzodioxin isomers
HPCDF	heptachlorinated dibenzofuran isomers
HQ	Hazard Quotient
ICP	inductively coupled plasma
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
LDR	land disposal restrictions
McClellan AFB	McClellan Air Force Base
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDL	method detection limit
ML	silt
MS	matrix spike
MSD	matrix spike duplicate

MSDS	Material Safety Data Sheet
msl	mean sea level
NAPLs	nonaqueous phase liquids
NCP	National Oil and Hazardous Substances Contingency Plan
NFA	no further action
NFI	no further investigation
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
OCDD	octachlorodibenzo-p-dioxin
OCDF	octachlorodibenzofuran
OEHHA	(Cal EPA) Office of Environmental Health Hazard Assessment
offgas	The airstream discharged from a soil vapor extraction system. Before being released to the atmosphere, this contaminated airstream will require some form of treatment to remove the contamination.
OSWER	(U.S. EPA) Office of Solid Waste and Emergency Response
OU D	Operable Unit D
PCB	polychlorinated biphenyls
PCDDs	polychlorinated dibenzodioxins; any or all of 75 possible chlorinated dibenzo-p-dioxin isomers
PCDFs	polychlorinated dibenzofurans; any or all of 135 possible chlorinated dibenzofuran isomers
PCE	perchloroethylene or tetrachloroethylene
PID	photoionization detector
ppbv	parts per billion by volume in air
ppmv	parts per million by volume in air
PRGs	preliminary remedial goals
PRL	potential release location
QA	quality assurance
QA/QC	quality assurance/quality control

QC	quality control
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design/Remedial Action
RfC	reference concentrations, usually expressed in units of mg/m^3
RfD	reference dose, usually expressed in units of mg/kg-day
RI/FS	remedial investigation/feasibility study
RI	remedial investigation
RME	reasonable maximum exposure
ROD	Record of Decision
RPDs	relative percent differences
RPM	Remedial Project Manager
RRF	relative response factor
SARA	1986 Superfund Amendments and Reauthorization Act
SCWG	(Cal EPA) Standards and Criteria Work Group
SDWA	Safe Drinking Water Act
SF	slope factor
SM	silty sand
soil gas	gas present in soils
sorbed	attached or held
sorption	the process of sorbing; taking up and holding as by adsorption or absorption
SP	sand
SVE	soil vapor extraction
SVMW	soil vapor monitoring well
SVOCs	semivolatile organic compounds
SWMU	solid waste management units
TBCs	to-be-considered criteria

TCDDs	tetrachlorinated dibenzo-p-dioxins; any or all of the 22 possible tetrachlorinated dibenzo-p-dioxin isomers
TCDD-dioxin	2,3,7,8-tetrachlorodibenzo-p-dioxin; the most toxic of the dioxin isomers
TCDFs	tetrachlorodibenzofurans; any or all of the 138 possible tetrachlorinated dibenzofuran isomers
TCE	trichloroethylene
TCM	trichloromethane; chloroform
TPH	total petroleum hydrocarbons
trans-1,2-DCE	trans-1,2-dichloroethylene
TSD	treatment, storage, and disposal
UHP	ultra-high purity
UST	underground storage tank
vadose zone	soils above the water table
VapourT	a finite element, two-dimensional contaminant transport model
VOCs	volatile organic compounds
volatilization	the act of evaporating or causing to be evaporated
VZMW	vadose zone monitoring well

Chapter 1
Introduction

Chapter 1
Introduction

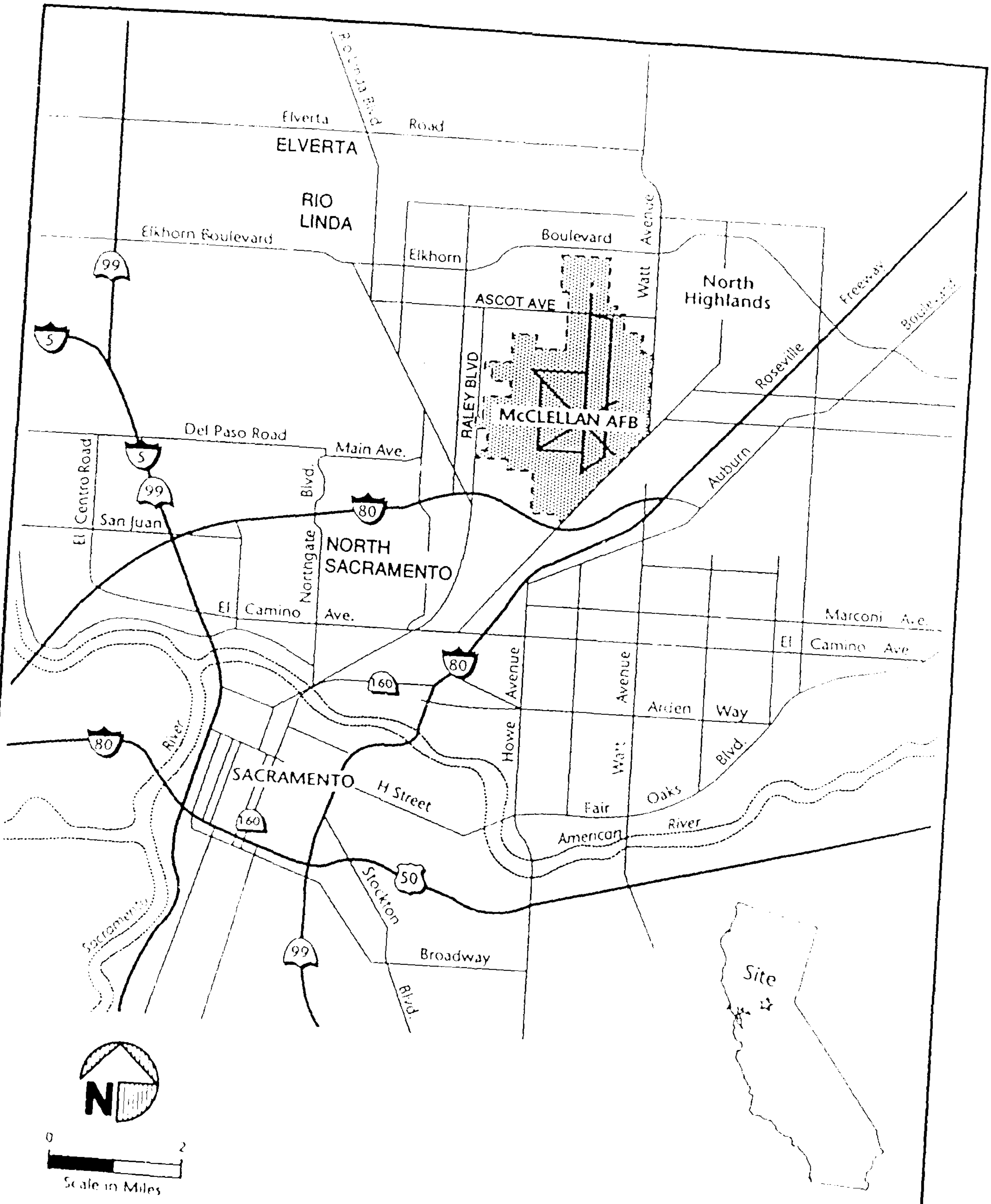
1.1 Subject and Purpose of the Remedial Investigation

In 1981, the Department of Defense developed a program to identify and evaluate suspected contamination problems resulting from past hazardous waste disposal practices for Air Force Installations. Once the evaluation was complete, the Installation Restoration Program (IRP) was developed to control migration of contaminants and hazards to the public and the environment. The IRP serves as a basis for response actions on Air Force installations under the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In 1981, McClellan Air Force Base (AFB), an Air Force Logistics Command Center, initiated the first phase of the IRP. McClellan AFB is located approximately 7 miles north of downtown Sacramento, California, as seen in Figure 1-1. In July 1987, McClellan AFB was placed on the National Priorities List (NPL) as the highest-ranked Air Force installation. Operable Unit (OU) D is an area on McClellan AFB that is highly contaminated because of historical disposal operations. An Operable Unit is a discrete part of an overall site and can be examined separately if the remedial action for the OU can be done expeditiously, is cost effective, controls contaminant sources or migration, and is consistent with the final site remedy. OU D is located in the northwest corner of McClellan AFB, as seen in Figure 1-2.

The purpose of this RI report is to present the objectives and the approach of the RI; define the conceptual model for OU D; present and interpret the analytical data; assess the risk generated by the contaminants present in OU D; define the problems presented by those contaminants; identify the present remedial actions and their effectiveness; and identify potential future actions.

1.2 Site History

The IRP has identified 10 OU's in the vadose zone, (A, B, B1, C, C1, D, E, F, G, and H,) and 1 in the groundwater, (Groundwater (GW) OU). Currently, there are 258 sites distributed among the 10 Base OU's. The sites were categorized as: Confirmed Sites (CSs)—sites where contamination has been confirmed with sampling data; Potential Release Locations (PRLs)—sites where contamination has been reported or suspected but not verified with sampling data; Areas of Concern (AOCs)—areas where a release may occur; and Study Areas (SAs)—sites under investigation. Table 1-1 shows the distribution of the sites among the OUs.



SOURCE RADIAN CORP

FIGURE 1-1
LOCATION OF McCLELLAN AIR FORCE BASE

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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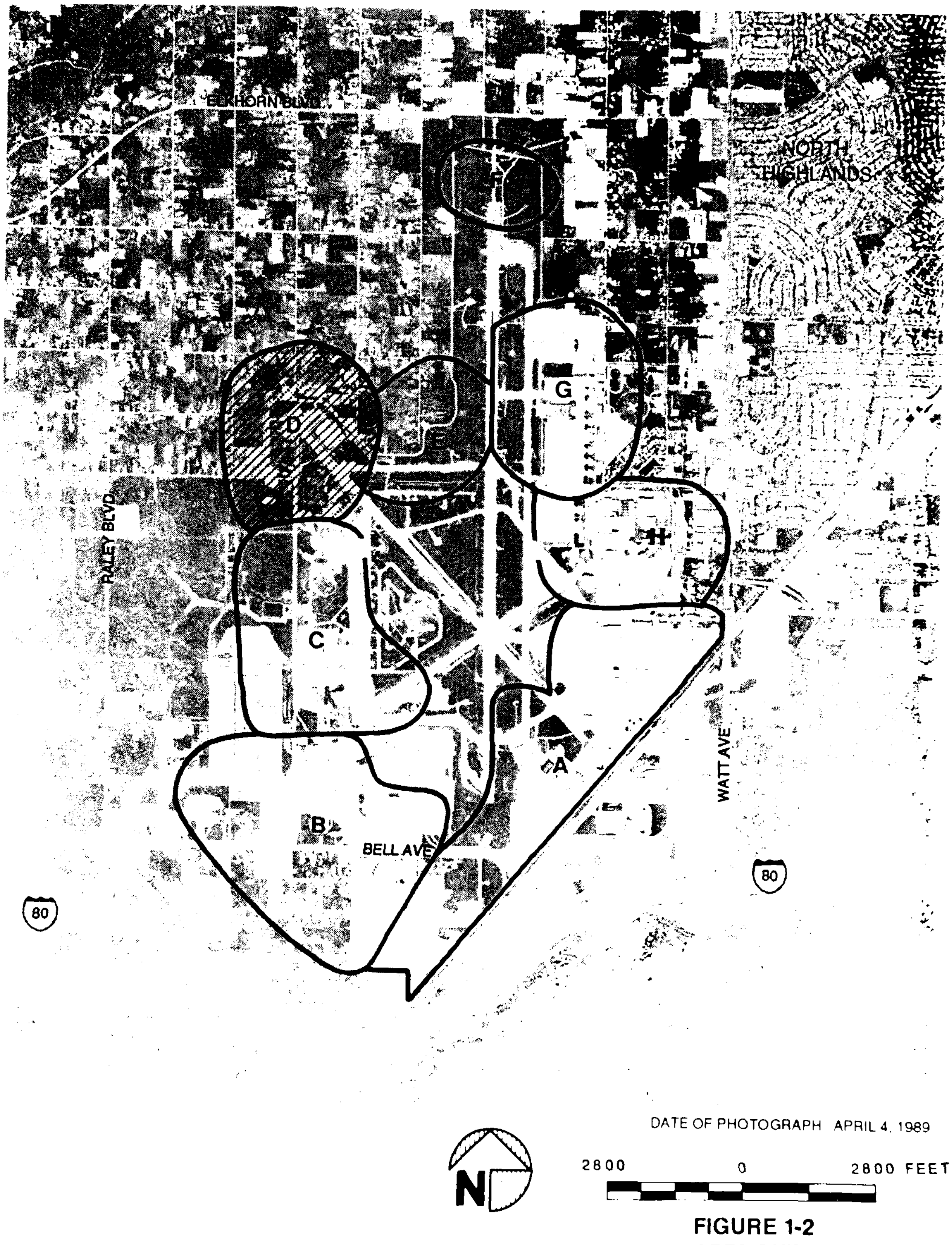

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FIGURE 1-2 APPROXIMATE LOCATION OF OU D

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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Table 1-1
Distribution of Sites in Operable Units

Operable Unit	Number of Sites	Operable Unit	Number of Sites
A	CSs - 25 PRLs - 35 SAs - 61	D	CSs - 10 PRLs - 3 AOCs - 2
B	CSs - 7 PRLs - 22 SAs - 18	E	PRLs - 2
B1	PRLs - 1 SAs - 1	F	PRLs - 1
C	CSs - 9 PRLs - 32 AOCs - 1	G	PRLs - 9
C1	CSs - 3 PRLs - 3	H	PRLs - 8

The operations at McClellan AFB relate to management, maintenance, and repair of various aircraft, electronics, and communications equipment. These activities have been conducted since the Base was established in 1936 and have required the use of various hazardous and toxic materials. Figure 1-3 presents the sites and features of OU D. A summary of the past OU D operations is presented below and a schedule is shown in Figure 1-4. A detailed list of the OU D operations is presented in Appendix F, the Preliminary Assessment Technical Memorandum.

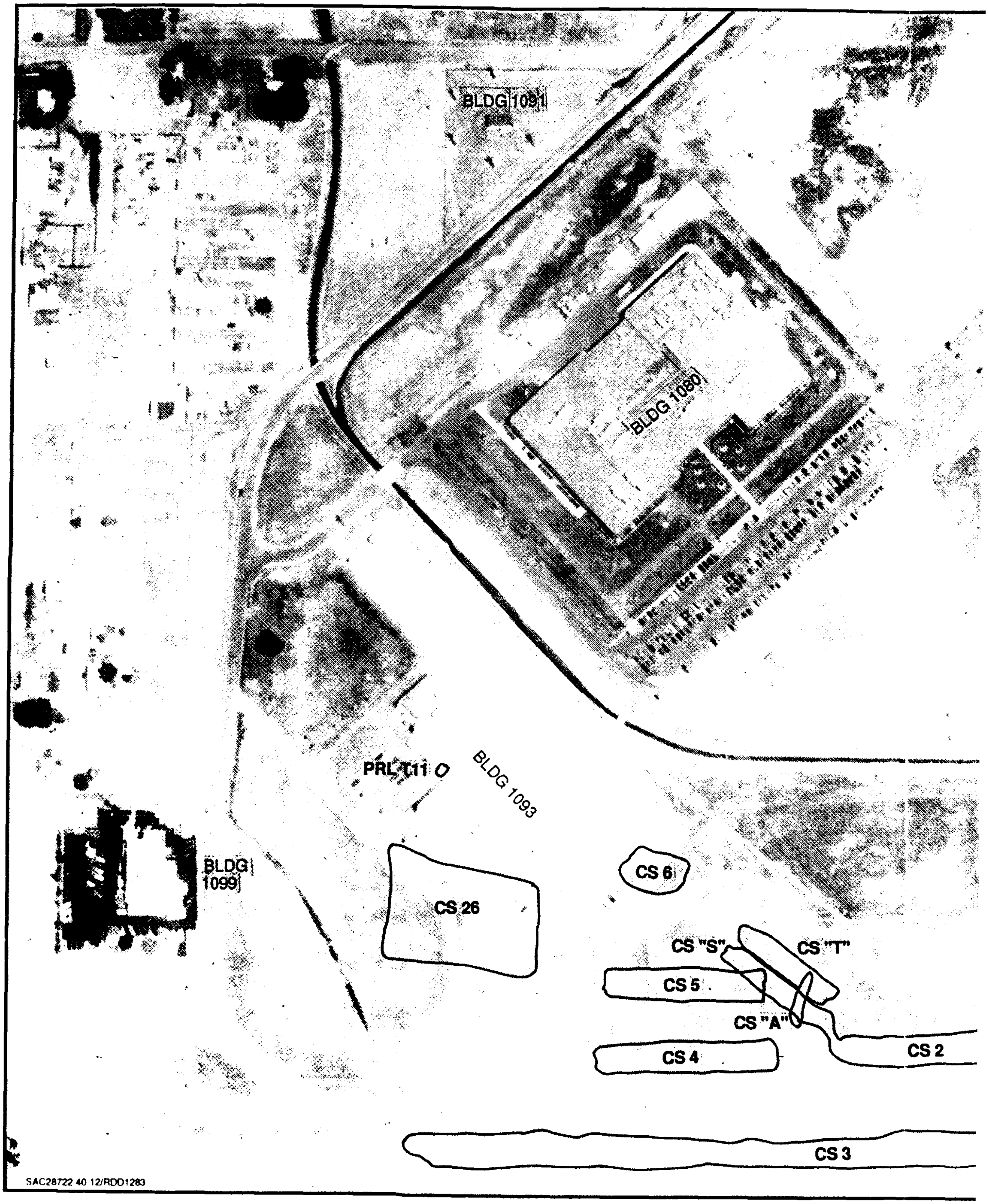
In the early 1940s, Building 713 was the first building constructed in OU D. In the 1950s, PRL 27 was the first disposal area created. Confirmed Sites 1 and 2 were also opened and used for waste disposal and fire training.

Beginning in the late 1960s, trichloroethylene-contaminated materials were disposed of in pits.

In the early 1960s, PRL 27 and CS 1 were closed. Building 1099 was constructed and CSs 3, S, and T were opened. In the late 1960s, CSs 3, S, and T were closed. Disposal of trichloroethylene-contaminated materials into waste pits was initiated and CS 4 was opened.

In the early 1970s, the trichloroethylene (TCE) disposal was eliminated, and CSs 5, 6, 26, and A were opened. Potential Release Location 33 was opened for only 4 months. In the late 1970s, CSs A, 2, 5, 6, and 26 were closed. Building 1093 was constructed, and PRL T11 was installed.

In the 1980s, Buildings 1066 and 1080 were constructed. Building 713 was demolished. CS 4 was closed, and the Area D Cap was constructed over CSs 1, 2, 3, 4, 5, A, S, and T.



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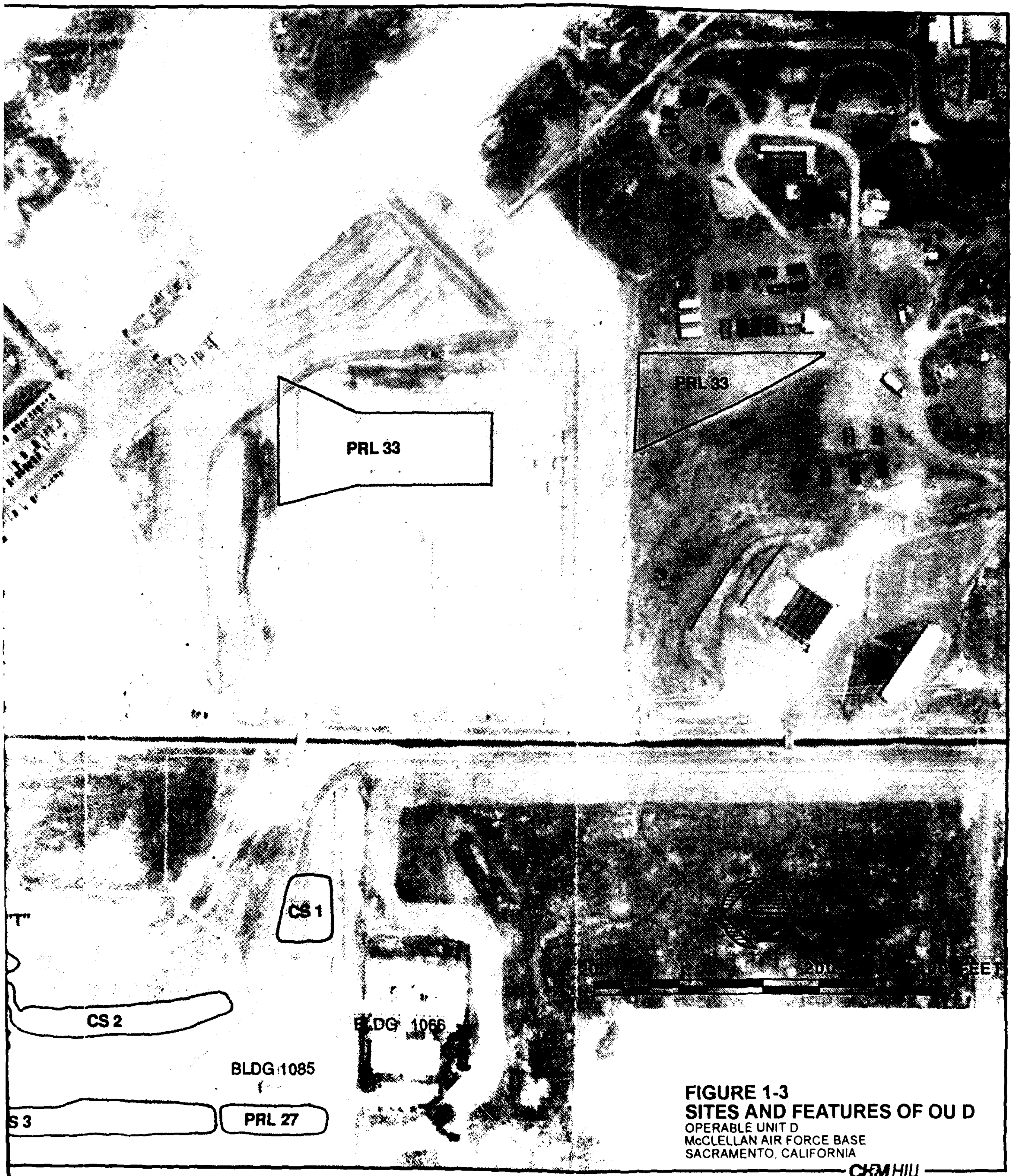

FIGURE 1-3
SITES AND FEATURES OF OU D
OPERABLE UNIT D
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SACRAMENTO, CALIFORNIA

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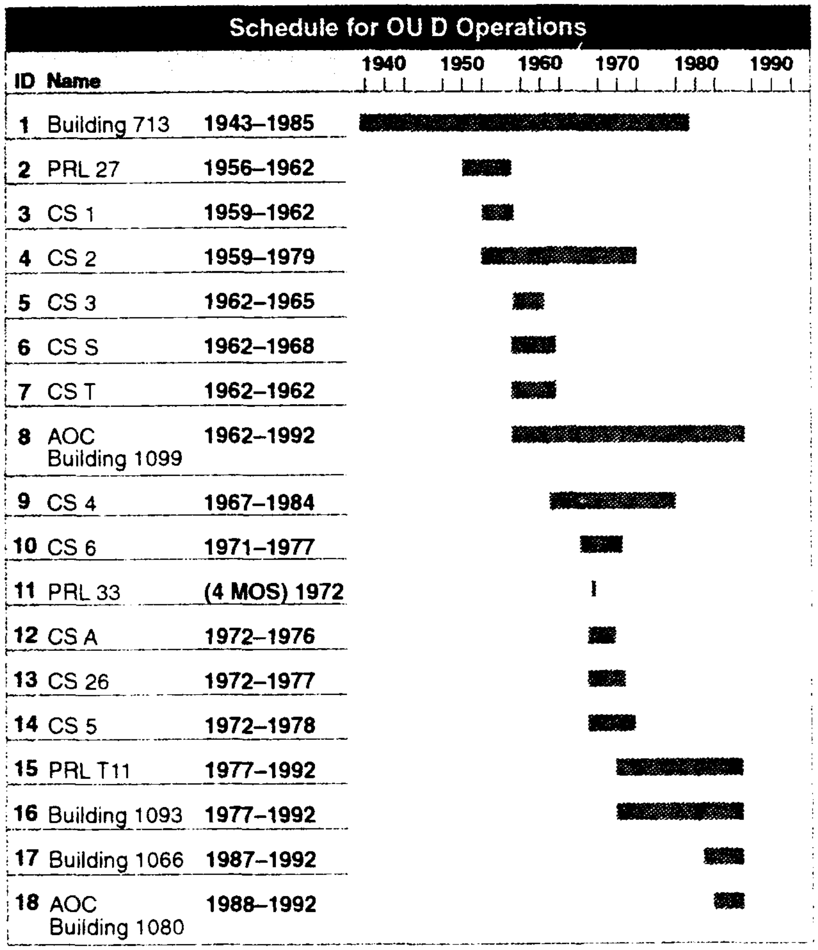

ID	Name	
1	Building 713	1943–1985
2	PRL 27	1956–1962
3	CS 1	1959–1962
4	CS 2	1959–1979
5	CS 3	1962–1965
6	CS S	1962–1968
7	CS T	1962–1962
8	AOC Building 1099	1962–1992
9	CS 4	1967–1984
10	CS 6	1971–1977
11	PRL 33	(4 MOS) 1972
12	CS A	1972–1976
13	CS 26	1972–1977
14	CS 5	1972–1978
15	PRL T11	1977–1992
16	Building 1093	1977–1992
17	Building 1066	1987–1992
18	AOC Building 1080	1988–1992

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FIGURE 1–4
SCHEDULE OF OPERATIONS
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Currently, Buildings 1080, 1066, 1093, and 1099 are present and in operation. All the waste pits are closed, and eight of the pits reside under the Area D Cap.

1.2.1 Previous Investigations

Prior to the RI, other investigations have been conducted. A detailed description of these investigations is given in the *Operable Unit D Preliminary Assessment* (CH2M HILL, 1992). The first investigation was conducted in 1981 by McClellan AFB personnel who studied the past disposal practices at McClellan AFB to identify all the disposal sites. In late 1981, CH2M HILL investigated the historic waste handling and disposal practices to determine the potential for migration of hazardous materials offbase. In 1983, Engineering Science installed 48 monitoring wells to determine the extent of groundwater contamination and migration.

In 1984, McClellan AFB sampled the sludge from CS 4. That same year, CH2M HILL conducted a Site Characterization Study on OU D to determine the hydrogeology beneath the area and to characterize the waste disposal pits and their surrounding soil. CH2M HILL also conducted a shallow exploration program to characterize the waste in the pits and assess the lateral and vertical extent of contamination from OU D.

In 1985, a Source Control Feasibility Study was conducted to evaluate the various alternatives for controlling the existing hazardous waste in OU D. In 1991, CH2M HILL investigated the variations of sampling media with the collection of soil gas to evaluate sampling and analytical methods.

During the previous investigations, VOC, semivolatile organic compound (SVOC), and metals contamination was found in the soil, soil gas, and groundwater beneath OU D. However, the lateral extent of contamination for soil and soil gas could not be defined. A more detailed discussion of the results of the previous investigations is presented in Appendix F, Preliminary Assessment Technical Memorandum.

The Agency of Toxic Substances and Disease Registry (ATSDR) investigated and evaluated McClellan AFB. The ATSDR found areas west of and near OU D to be a "public health hazard" because contaminant sources at OU D have contributed to environmental contamination. ATSDR defines a "public health hazard" as a site that contributes to contamination to which people on- and offsite have been, are, or could be exposed. The estimated exposures from the groundwater, ambient air, and soil exposure pathways for contaminants of concern (volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), and metals) could cause adverse health effects to any of the exposed population.

The ATSDR recommended that offsite ambient air sampling in and around the homes near OU D or other areas with high soil gas concentrations should be continued. It was also recommended that a residential well use survey should be conducted to define the groundwater impact west of OU D.

1.3 Fieldwork Summary

The RI fieldwork includes residential crawlspace and ambient air sampling, shallow soil gas sampling, deep soil gas sampling, soils investigation, and groundwater investigation. The RI fieldwork was initiated in June 1992 by the first quarterly sampling of residential crawlspace and ambient air. Detailed descriptions and results of the RI fieldwork are present in the Appendixes A through E.

Residential crawlspace and ambient air samplings were conducted on a quarterly basis from June 1992 to May 1993. Four residential crawlspace and four ambient air locations were sampled on a quarterly basis. The sampling effort was performed to determine the levels of contaminant exposure to residents living adjacent to the Area D Cap and to provide data to support the risk assessment discussed in Chapter 5. The detailed description and results are presented in Appendix A, Residential Crawlspace and Ambient Air Technical Memorandum.

Shallow soil gas sampling was conducted from September 1992 to October 1992. Forty-two offbase and 28 onbase locations were sampled at depths ranging from 5 to 10 feet below ground surface (bgs). The sampling effort was to determine the horizontal extent of shallow soil gas contamination from OU D to offbase residential areas and to determine the borehole locations for collecting deep soil gas data. The sampling effort was also performed to determine the extent of contamination and risk onbase and to identify hot spots. The detailed description and results are presented in Appendix B, Shallow Soil Gas Survey Technical Memorandum.

Deep soil gas sampling was conducted from June 1992 to June 1993. Twenty-five soil vapor monitoring wells were sampled. Downhole soil gas samples were collected from nine borings. The sampling effort was conducted to further characterize the VOC contamination in the vadose zone and provide data for the mass estimate in the vadose zone. The downhole soil gas sampling was used to determine the screened intervals for the soil vapor monitoring wells. The detailed description and results are presented in Appendix C, Deep Soil Gas Technical Memorandum.

The soil investigation was conducted from May to June 1993. Historical data from soil borings were evaluated, and 17 additional soil locations were sampled. The sampling effort was to assess the magnitude of VOC and non-VOC contamination in vadose zone soils; determine if CSs 6 and 26 are sources of contamination; provide data to support the mass estimate in the vadose zone; and define lithology. The detailed description and results are presented in Appendix D, Soils Investigation Technical Memorandum.

The groundwater investigation was conducted from May to June 1993, and 29 groundwater locations were sampled. The sampling effort was to evaluate the nature and extent of VOC, SVOC, dioxin, and pesticide/PCB groundwater contamination in the vadose zone. The detailed description and results are presented in Appendix E, Groundwater Investigation Technical Memorandum.

The RI fieldwork was conducted in general accordance with the *Final Copy Work Plan Operable Unit D Field Investigation* (CH2M HILL, 1993). Any deviations from the Work Plan are presented in the following subsection.

1.3.1 Deviations from Work Plan

The following incidents are deviations from the sampling procedures:

- Borings C1, C5, C8, and Monitoring Well MW-1073 were not completed because offbase access could not be obtained. McClellan AFB has recently received access and will complete these borings in October 1993.
- A field blank could not be collected during the May 1993 residential crawlspace and ambient air sampling because of a faulty canister sent from the laboratory.
- During a June 1992 residential crawlspace sampling, the flowmeter on a 24-hour canister failed, and the canister went to ambient air pressure.
- The deep soil gas sample collected from C2-S was lost because of a leaky canister.
- For the groundwater investigation, no Hydropunch sample was collected at C7 after four attempts because silt would build up and clog the Hydropunch intake screen.

The following incidents are deviations from the analytical procedures:

- The downhole soil gas samples from Monitoring Well (MW)-241 were analyzed offsite in the Corvallis laboratory instead of at the onsite laboratory because the onsite laboratory did not have sufficient staff to handle the number of samples to be analyzed. The analytical procedure used by the Corvallis lab was identical to that used by the onsite lab.
- There were elevated detection limits on the June 1992 TO-14 soil gas samples for MW-1 through MW-9 because of the dilutions needed to quantify the high concentration of some of the compounds.

1.4 Summary of Previous Remedial Actions

Several remedial actions have already been initiated at OU D. These remedial actions are excavation and capping, placing local residents on city water, the groundwater extraction system, and the soil vapor extraction (SVE) system. Chapter 7 discusses the existing remedial actions in detail and presents all the locations of existing remedial action in Figure 7-1.

By 1984, only CSs 6 and 26 had been excavated and backfilled. In 1985, CS 4 was excavated and the Area D Cap was placed over eight of the CSs: CSs 1, 2, 3, 4, 5, S, A, and T. The Cap was placed over the pits to prevent infiltration from precipitation and to control offgas emissions.

In 1986 and 1987, 500 offbase residences were connected to the municipal water supply system. The switch to the municipal water system was initiated when the contaminated groundwater plume under OU D was found to have migrated offbase.

The groundwater extraction system was established in 1987. Six extraction wells pump contaminated groundwater from OU D. The water is conveyed from OU D by pipeline to the groundwater treatment plant located south of the Area D cap.

The SVE system was constructed in 1992 and was in operation in 1993. The SVE system was installed for a treatability study to determine its effectiveness in removing VOC contaminants and less mobile compounds from waste pits and the native soil. The SVE system is currently not a full-scale remedial action but will be considered for expansion during the OU D Vadose Zone Feasibility Study.

Chapter 2
Project Objectives and Approach

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Project Objectives and Approach

2.1 Project Objectives

The overall objective for Operable Unit D (OU D) is to achieve a timely and cost-effective reduction in contamination to levels that are protective of human health and the environment. The project objectives are consistent with the Installation Restoration Program (IRP) objectives to assess past hazardous waste disposal and spill sites on Air Force installations and develop remedial actions consistent with the National Contingency Plan (NCP) for any sites that pose a threat to human health and welfare or the environment. Specific project objectives are to:

- Develop a streamlined approach to the Remedial Investigation/Feasibility Study (RI/FS) to reduce the time necessary to implement a remedial action.
- Recognize uncertainties and identify the critical factors that, once known, can reduce the uncertainties to acceptable levels. Balance the need to reduce the uncertainties with the demands for resources and time.
- Develop robust and flexible solutions that can be implemented in the face of uncertainty and that can be improved as future conditions become known.
- Continually develop and integrate improvements to the remedial action to reduce cleanup time and effort.
- Establish a mechanism that can be used to achieve remedial action decisions at other OUs with volatile organic compound (VOC) contamination in the vadose zone.

The remedial investigation is the first step toward selecting a remedy for the contamination at OU D. The purpose of the RI is to collect enough data for OU D to reduce the uncertainty in contaminant type and distribution to a level that is acceptable for the FS so that remedial alternatives can be fairly evaluated and selected.

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The objectives of the RI are to:

- Determine which contaminants will require remedial action.
- Identify target volumes for developing and evaluating remedial action alternatives.
- Identify the uncertainties in site conditions and how they affect the conceptual model.

- Quantify risks to human health and the environment posed by vadose zone and groundwater contamination within OU D.

- Identify future vadose zone and groundwater data needs that will reduce uncertainties.

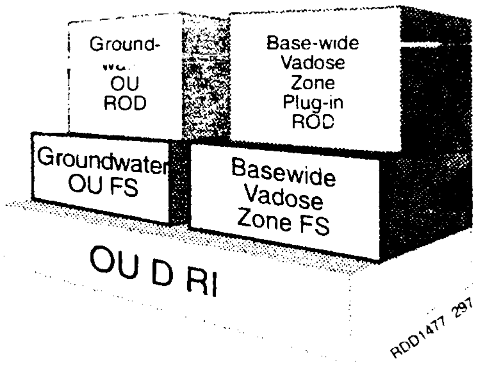
- Evaluate the effectiveness of existing remedial actions within OU D.

- Provide groundwater data within OU D to support the Basewide Groundwater OU project.

- Provide the data to support the development and evaluation of remedial action alternatives in the OU D Vadose Zone FS.

2.2 Approach to Operable Unit D Remedial Investigation/Feasibility Study

The current strategy for OU D will allow McClellan Air Force Base (McClellan AFB) and the agencies to achieve an Interim Record of Decision (ROD) by March 1995. The approach is designed to streamline the RI/FS process and reduce the time necessary to implement a remedial action. The focus is on reducing the amount of information gathered prior to selection of a remedy. This requires a program with enough flexibility built-in to accommodate implementation of remedial actions in the face of uncertainty. Operable Unit D is suited to this approach because: (1) previous work for McClellan AFB has resulted in a good understanding of site conditions; (2) groundwater and soil vapor extraction (SVE) systems have been operating or pilot tested; and (3) a good working relationship with the regulatory agencies has been established.



The remedial investigation will support two RODs that address the contamination within OU D. The groundwater contamination will be addressed by the Groundwater Operable Unit FS and ROD. The vadose zone contamination will be addressed by the Basewide Vadose Zone Plug-in FS and Plug-in ROD. Interactions among the projects are discussed in Section 2.3.

The ROD for the VOCs in soil will utilize two specialized approaches. The first is called a "presumptive remedy approach" and the second is called the "plug-in approach." The ROD for the non-VOCs in soil will use the plug-in approach only. EPA Region IX has successfully implemented these approaches for sites with VOC contamination in the vadose zone. The approaches appear well suited for McClellan. AFB. A specialized approach to the risk assessment will also be necessary.

2.2.1 The Presumptive Remedy Approach

The presumptive remedy approach takes advantage of the conditions at a site being so well suited to a particular technology that the technology can be presumed to work. The presumptive remedy is considered when a remedial technology has repeatedly been shown to work in the range of conditions present at a site, and there are no apparent conditions at the site that are markedly different from the conditions under which the technology has previously been tested or used (EPA 1993b, EPA 1993c).

The presumed remedy will be SVE. At OU D, an SVE treatability investigation is being conducted that indicates SVE is very effective at removing VOC contaminants from the vadose zone.

2.2.2 The Plug-in Approach

The plug-in approach is a way of structuring a remedy decision that can be used for multiple areas within a larger site that share similar physical and contaminant properties. The multiple areas are distinct areas of contamination within McClellan AFB and are referred to as subsites. A plug-in remedy first identifies a standard remedial alternative (e.g., SVE), and then defines the range of conditions that the alternative can address. When other sites at McClellan AFB are identified that **require remedial action and satisfy the range of conditions specified**, they can be "plugged in" to the ROD. This will allow remedial action to be implemented at sites across McClellan AFB without going through the entire FS process.

In a traditional ROD (as will be the case for the groundwater) several alternatives are identified for a single site. The Plug-in ROD selects a remedy for a given range of conditions. In other words, instead of matching several remedies to contamination at OU D, the plug-in approach matches several sites at McClellan AFB to a single remedy. This concept is illustrated in Figure 2-1.

In a traditional ROD several alternatives are identified for a single site. The Plug-in ROD selects a remedy for a given range of conditions.

The plug-in approach involves six steps:

1. Develop Existing Site Profile – Identify the range of common conditions among areas at McClellan AFB.
2. Identify and Evaluate the Remedial Alternatives and evaluate against the No- Action Alternative.
3. Define the Remedy Profile – Identify the range of conditions that the alternatives can address.
4. Identify Enhancements to the Remedial Alternatives – Investigate potential technologies that may broaden the remedy profile or enhance the presumed alternative.

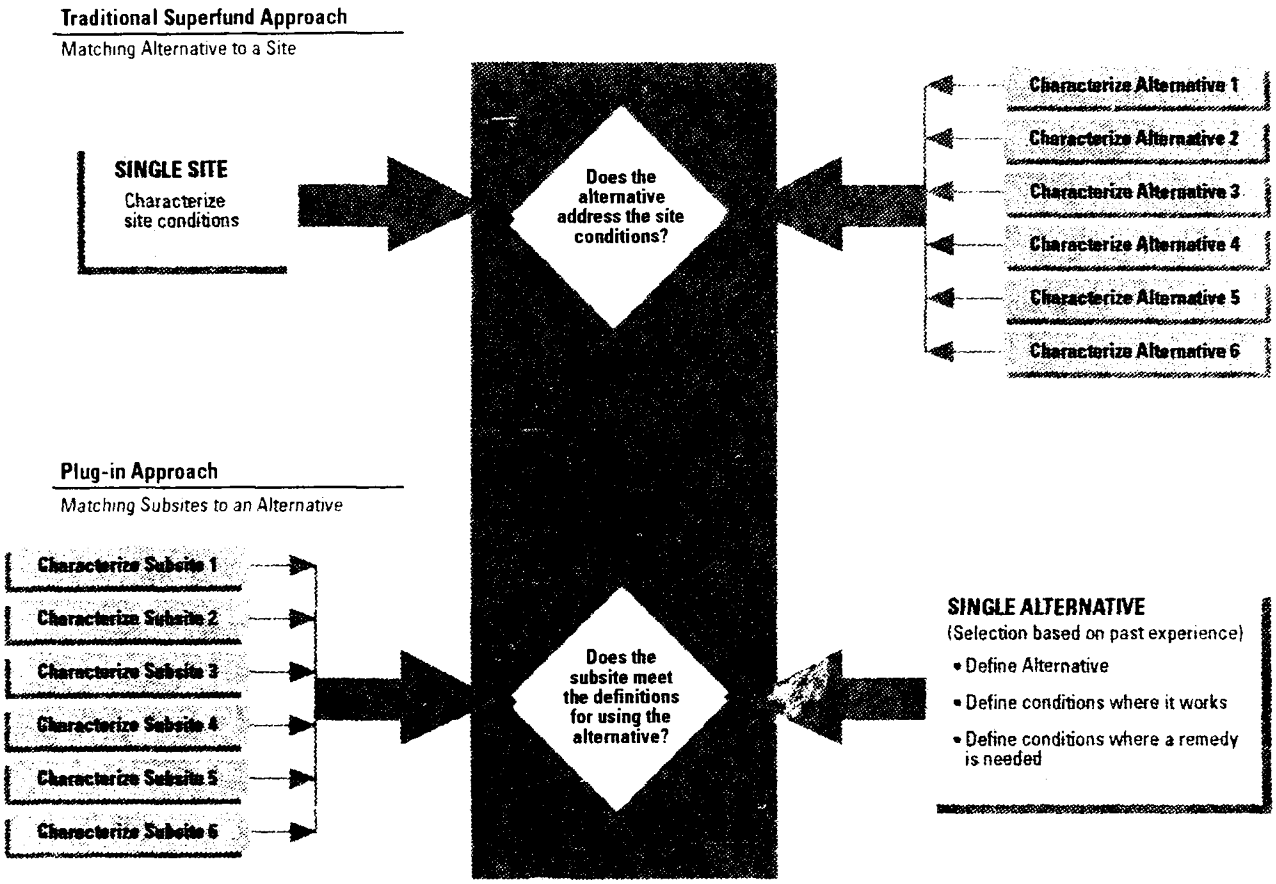


FIGURE 2-1
COMPARISON OF TRADITIONAL VERSUS PLUG-IN APPROACHES
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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5. Define the Plug-in Criteria – Establish the basis for determining whether to carry out a remedial action for a particular area.

6. Make Decision – At the plug-in decision point, a determination is made as to whether to plug in a specific subsite and require the selected remedial action.

A conceptual picture of the plug-in approach is shown in Figure 2-2. Detailed components of the plug-in approach will be presented in the Basewide Vadose Zone FS.

The plug-in approach will save a significant amount of time and resources, both for McClellan AFB and the agencies.

The use of the plug-in approach at McClellan will allow remedial action to begin at contaminated sites without redundant remedy selection processes. This will save a significant amount of time and resources, both for McClellan AFB and the agencies. It will also focus the collection of data at subsites on the most likely remedial alternative. Thus, there are less data to collect in remedial design, and actual remedial action can begin sooner.

2.2.3 Risk Assessment Approach

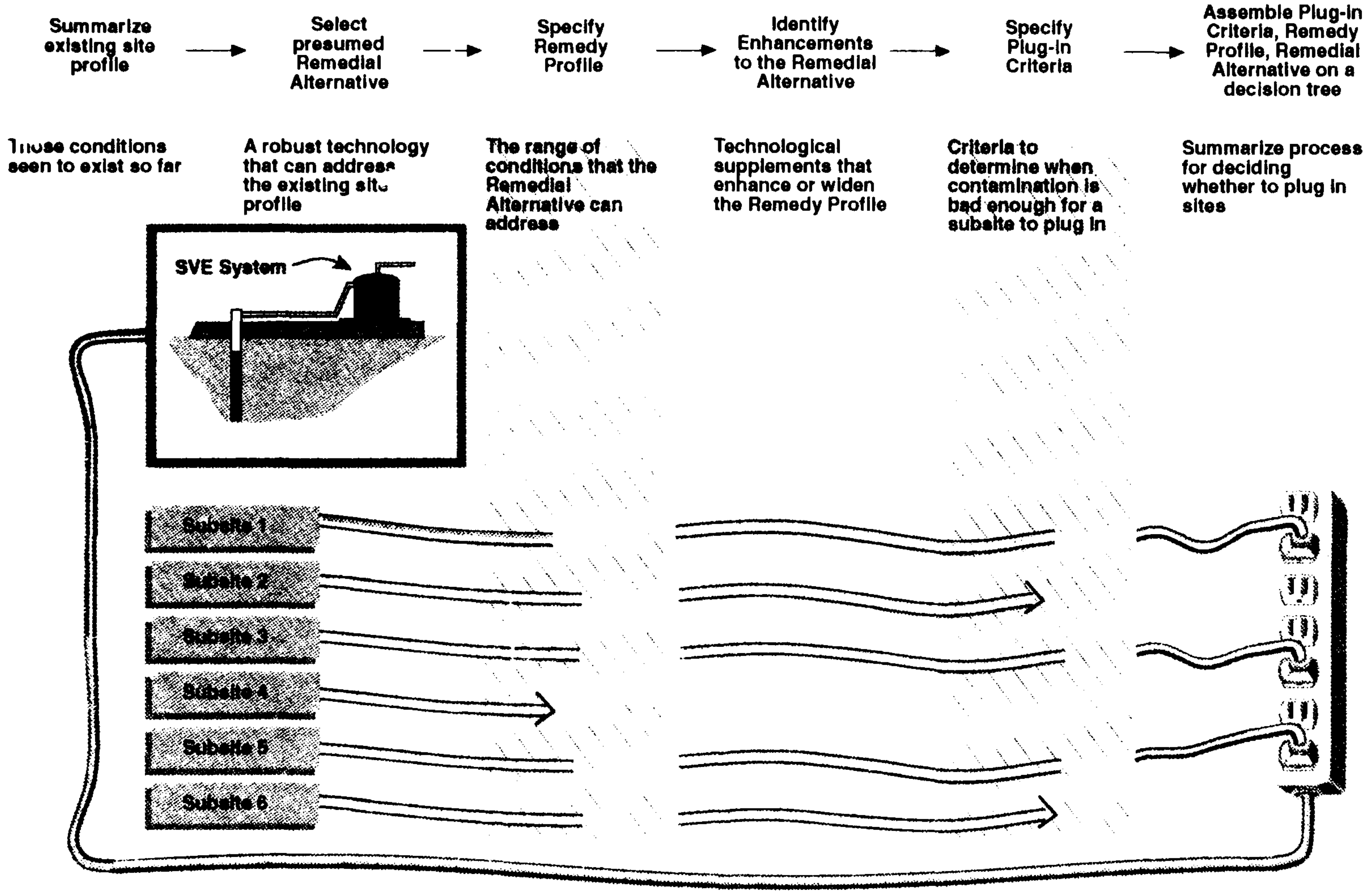
A baseline risk assessment is conducted as part of the RI to provide the decision-makers with an understanding of the actual and potential risks to human health and the environment posed by contamination at OU D. This information is used to determine whether a current threat exists that warrants remedial action.

The risk assessment provides an understanding of the actual or potential risks to human health and the environment.

The risk assessment will support the plug-in approach. The plug-in approach requires a specialized strategy for risk assessment because the selection of a remedy occurs prior to characterizing all subsites that may eventually plug in. The risk assessment is a tool for decisionmaking within the context of the plug-in process at McClellan AFB. The questions that the risk assessment must support, with regard to soils, are:

- What is the level of risk (attributable to contaminants in soil at a subsite) that triggers the implementation of the selected Remedial Alternative?
- Does the contamination at a particular subsite result in a threat that meets or exceeds the level established above?
- Once a cleanup is undertaken at a subsite, when can the cleanup be considered complete?

Two of these questions, the first and third, are not directly answered by the risk assessment. Rather, the evaluation of risk supports a decision concerning these questions. The first question represents the setting of the "Plug-in Criteria." The second question represents **using** the Plug-in Criteria in a specific case. The third question represents the setting of "cleanup goals."



Summarize existing site profile →
Those conditions seen to exist so far

Select presumed Remedial Alternative →
A robust technology that can address the existing site profile

Specify Remedy Profile →
The range of conditions that the Remedial Alternative can address

Identify Enhancements to the Remedial Alternative →
Technological supplements that enhance or widen the Remedy Profile

Specify Plug-In Criteria →
Criteria to determine when contamination is bad enough for a subsite to plug in

Assemble Plug-In Criteria, Remedy Profile, Remedial Alternative on a decision tree
Summarize process for deciding whether to plug in sites

FIGURE 2-2
STRUCTURE OF THE PLUG-IN PROCESS
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Once the plug-in process is executed, the risk assessment for contaminants in soils becomes a baseline risk assessment. Under the plug-in approach, subsites at McClellan AFB are independently characterized. A decision is made as to whether each subsite needs the selected remedial alternative. This decision is made by comparing subsite data to the Plug-in Criteria. The risk assessment included in this RI does not calculate the risk for a given subsite outside OU D, but it does lay the groundwork for the calculations. The Basewide Vadose Zone FS will present a template for making these risk calculations for subsites at McClellan AFB. Once a subsite is characterized, site data only need to be inserted into the template to arrive at the baseline risk. A baseline risk assessment for contaminants in soil is, in effect, complete each time the plug-in process is completed for a subsite.

2.3 Interactions with Other IRP Projects

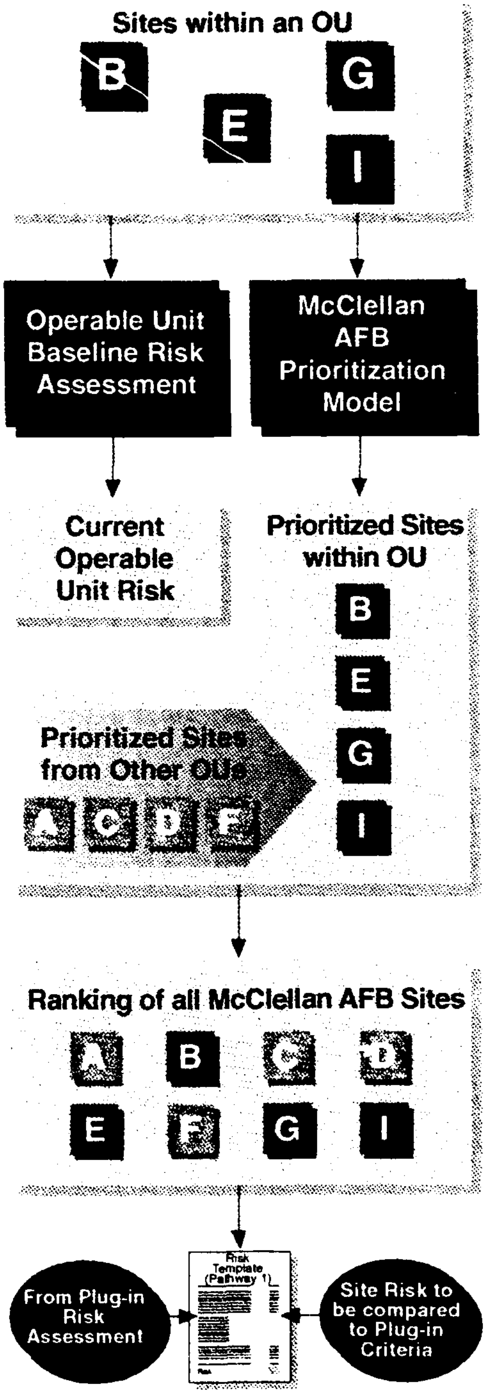
McClellan AFB IRP is dynamic and complex, and many of the projects are interrelated. To understand the OU D RI Report, it is necessary to define how the projects within OU D fit into the IRP.

The OU D projects interact with several other IRP projects, principally the Basewide Groundwater OU, the Basewide Engineering Evaluation/Cost Analysis (EE/CA) for VOCs in the vadose zone, and the evaluation of innovative treatment technologies.

The projects currently planned for OU D can be separated into vadose zone projects and groundwater projects (each will require treatment projects). The adjacent figure is an illustration of the interactions between these projects.

Vadose zone projects include the following:

- Preparation of an RI to determine the nature and extent of vadose zone contamination to support the risk assessment and FS.
- Preparation of an FS that covers the remedial action alternatives for the VOCs, semivolatile organic compounds (SVOCs), and metals contamination Basewide. The FS will be designated the Basewide Vadose Zone FS and will be used to support RODs that can be used to implement remedial actions at OU D and other sites across McClellan AFB. The FS will support two separate RODs. One for the non-VOCs and one for the VOCs.
- Collection of performance and cost data for hot air injection and SVE with catalytic oxidation at Site S.
- Initial testing of the electron beam treatment technology for vapor phase VOCs.



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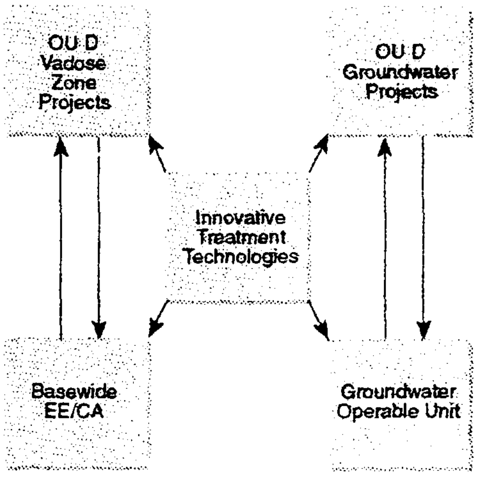

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- Removal action to halt migration of soil gas beyond the Base boundaries. This removal action would be performed under the authority of the Basewide EE/CA.

The vadose zone projects interact with the Basewide Groundwater OU, the Basewide EE/CA, and the evaluation of innovative treatment technologies as follows:

- **Interactions with the Basewide Groundwater OU**—The scope of the Basewide Groundwater OU is the performance of an FS and Interim ROD, Basewide groundwater monitoring, and Basewide groundwater remedial actions. The vadose zone projects from OU D will provide the following information to the Groundwater OU FS and Interim ROD:

  - The existing data on sources of contamination within OU D will be used in the interpretation of the groundwater data and in the development of target volumes for groundwater remedial actions.

  - The ongoing treatability studies at Site S will provide performance and cost data for catalytic oxidation of VOCs in offgas and the electron beam technology for destruction of VOCs in offgas. These data will be used in the Groundwater OU FS.

  - The Basewide Vadose Zone FS will be prepared several months later than the Groundwater OU FS, but the screening of vadose zone technologies and alternatives can be integrated into the Groundwater OU FS. The Groundwater OU FS needs to evaluate the potential interactions of the vadose zone remedial actions with the selected groundwater alternatives.

  - The interaction of the SVE removal action project that is scheduled to begin conceptual design in November 1993, and the potential interactions with the groundwater alternatives will be evaluated in the Groundwater OU FS.

  The Groundwater OU will provide the monitoring requirements for the groundwater within each OU (additional wells, analytical parameters, and frequency) to each geographic OU (A through H). The wells will be installed as part of the OU data collection efforts and will be monitored under the Groundwater OU.

- **Interactions with the Basewide EE/CA for VOCs in the Vadose Zone**—The scope of the EE/CA is SVE removal actions at highly contaminated sites across the Base. The vadose zone projects from OU D will provide the following information to the Basewide EE/CA.

    - The RI and SVE treatability test data from Site S will be used in the EE/CA to evaluate the removal action alternatives.

    - The testing of the electron beam treatment technology at Site S will provide information useful in the continuous improvement of the SVE systems across the Base.

  The Basewide EE/CA and the Basewide Vadose Zone FS appear redundant because they both are implementing SVE across the Base. The principle difference between the two projects is the extent and duration of the SVE action. The Basewide EE/CA will evaluate the necessity of SVE removal actions in highly contaminated areas but will not evaluate the full extent of the remedial action. The Basewide Vadose Zone FS will evaluate the full extent of SVE remedial actions according to potential impacts to public health and the environment, the performance data from the Site S SVE Treatability Study, and the first removal actions.

- **Interactions with Testing and Development of Innovative Technologies Across the Base**—The Basewide Vadose Zone FS will use the available data from the Solidification/ Stabilization Treatability Study (Site 22, OU C) and the Ex Situ Soils Bioremediation Treatability Study for SVOC and metals contamination. The SVE Treatability Study data will be used for the Basewide Vadose Zone FS.

The OU D groundwater projects include:

- Additional investigations to determine the nature and extent of (VOC and non-VOC) contamination including replacing dry or nearly dry wells.

- Extraction and treatment of AB-Zone groundwater

The OU D groundwater projects interact with the Basewide Groundwater OU and the Basewide Vadose Zone FS as follows:

- **Interactions with the Basewide Groundwater OU**—The groundwater projects from OU D will provide the following information for the Groundwater OU FS and Interim ROD:

    - Additional water quality and water level data will be used to refine target volumes for remedial actions particularly for deeper aquifer zones (B and C).

    - System response and performance data will be collected from the operation of the extraction system within OU D. These data will be used to develop and simulate groundwater remedial actions.

  - The groundwater monitoring locations, frequency, and analyses will be provided in the Basewide Groundwater OU. New wells will be installed as part of the OU D data collection.

- **Interactions with the Basewide Vadose Zone FS**— Groundwater investigations will provide data for evaluating interactions between the vadose zone and groundwater. The potential impacts of the vadose zone remedial actions on the groundwater will be evaluated in the Basewide Vadose Zone FS. These evaluations will require calculating the benefits to groundwater resulting from removal of vadose zone contaminants. Groundwater data will be used in the Basewide Vadose Zone FS to estimate acceptable residual quantities of contaminants in the vadose zone that will not generate a detectable flux to groundwater. This acceptable residual quantity will assist in the formulation of cleanup goals for the vadose zone.

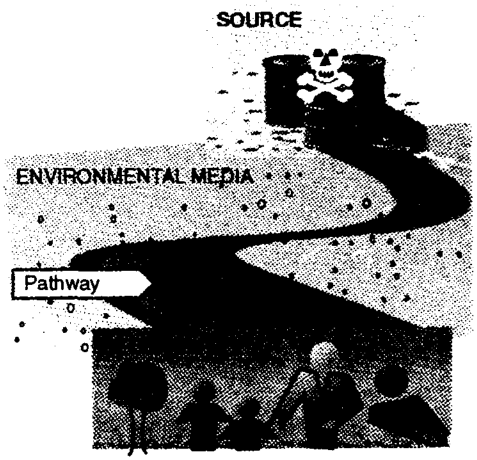
Chapter 3
Conceptual Model

Chapter 3
Conceptual Model

A conceptual model for a specific site can mean many different things. McClellan Air Force Base (McClellan AFB) offers the following definition for a conceptual model, which is the definition used in this report:

Conceptual Model *A mental or physical construct of a site(s) system that depicts processes affecting the transport of contaminants from the source(s) through environmental media to receptors.*

Transport, **sources**, **media**, and **receptors** are the key words in this definition that drive the way the conceptual model for Operable Unit D (OU D) is developed. The conceptual model will be used to clarify the processes that impact contamination as it moves from sources through pathways located within environmental media to receptors.



Elements of the Conceptual Model

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The development of a conceptual model is a necessary part of any remedial investigation. A well-constructed conceptual model leads to a better understanding of the site and can be used by the investigator to identify additional data needs, help select the best remedial action for the site, or provide a rational basis for performing risk evaluations. The adjacent figure is an illustration of the fundamental elements of the conceptual model. There are four basic elements that need to be considered when building a conceptual model:

1. **Source:** The source of contamination should be identified so that the types and magnitude of contamination within the source, the location and size of the source(s), and the time frame over which releases from the source have occurred are known.

2. **Media:** The physical properties of the media through which contamination will move need to be identified. Subsurface soils both above and below the water table are a common type of environmental media. For the case of subsurface soils, it is important to know the characteristics of the soil matrix, the groundwater, and the soil air. The physical characteristics of the media can have a profound impact on the transport and transformation of contamination. As examples, the mobility of volatile organic compounds (VOCs) through the soils can be severely retarded if the organic content of the soil is high; similarly, the mobility of metals is strongly a function of the soil's pH.

3. **Pathway:** Pathways provide the connection between source and receptor. The nature and location of the source and receptor, as well as the properties of the environmental media that separate them, need to be known before pathways can be identified. A good understanding of contaminant

transport processes is a necessity to identify appropriate pathways. Pathways are identified in detail in the risk assessment (Chapter 5). A summary of the pathways at OU D is presented in this chapter for incorporation into the conceptual model.

4. Receptor: Receptors are the humans, animals, groundwater or, plants that are exposed to the contamination. A list of receptors for OU D is developed in the risk assessment (Chapter 5). A summary of receptors is provided in this chapter for incorporation into the conceptual model.

The development of a conceptual model for OU D is particularly challenging because of: (1) complex subsurface characteristics, which are critical to elucidate if an accurate picture of pathways through environmental media is to be developed, and (2) the number of interrelated remedial actions that are already being implemented at the site. These remedial actions have a profound impact on the transport processes governing contaminant movement through environmental media. These factors along with information on source areas and possible receptors are combined in this chapter to provide an overall conceptual model for OU D.

3.1 Limitations on the Data Used to Develop the Conceptual Model

Before proceeding with a description of the conceptual model for OU D, the data types used to develop the conceptual model along with the corresponding data limitations are summarized. Data obtained during the remedial investigation may be categorized into five different groups: (1) ambient air and crawlspace air, (2) shallow soil gas, (3) soil vapor monitoring well (SVMW) and downhole soil gas, (4) soils, and (5) groundwater. A brief description of these five data types along with corresponding limitations is presented in Table 3-1.

Data obtained during the remedial investigation may be categorized into five different groups: (1) ambient air and crawlspace air, (2) shallow soil gas, (3) soil vapor monitoring well (SVMW) and downhole soil gas, (4) soils, and (5) groundwater.

The data types summarized in Table 3-1 are all used in one form or another to develop the OU D conceptual model, despite the cited limitations. The OU D conceptual model developed in this chapter should be thought of as a constantly evolving tool that is subject to change as more data become available and uncertainties are reduced to lower levels.

Table 3-1
Data Types and Limitations at Operable Unit D

Data Type	Data Use	Data Limitation
Ambient Air and Crawlspace Air	The purpose of the air sampling was to estimate the amount of contaminant exposure to residents living adjacent to OU D. The data were used to support a risk assessment (see Chapter 5). A Level III analytical level was obtained for these data.	The risk assessment found that the air data did not exceed background levels for VOCs. This made it impossible to deduce whether a surface flux of VOCs from the subsurface to the air exists at OU D. The conceptual model will assume that such a surface flux exists; however, the risks associated with the flux cannot be quantified with current data.
Shallow Soil Gas	The shallow soil gas data were used to help estimate the horizontal extent of vadose zone VOC contamination and also to help determine locations for taking deeper soil gas samples. The data were generally at an analytical level of II (onsite mobile lab), but 10 percent of the samples were confirmed using a Level III analytical level (offsite laboratory).	The shallow soil gas data were used to help define the locations to take deeper soil gas data measurements. However, the use of soil gas data to delineate the horizontal extent of contamination is limited because shallow soil gas samples are only taken at a depths of approximately 5 to 10 feet bgs. The horizontal extent of VOC contamination developed as part of OU D's conceptual model is based in part on shallow soil gas data, and also on the results of contaminant transport modeling.
SVMW and Downhole Soil Gas	SVMW and downhole soil gas samples were taken to characterize the vertical and horizontal distribution of VOC contamination. These data are used to support mass estimate calculations. The data are obtained at an analytical level of III (offsite analysis at a certified laboratory) for SVMW samples and Level II for downhole soil gas samples.	SVMW data were obtained from 12 wells constructed during the RI, and 9 previously existing wells, for a total of 21 SVMWs. The SVMWs are grouped in clusters of three, yielding seven discrete locations where the vertical distribution of VOCs was measured. In addition, five dry or nearly dry groundwater monitoring wells were also sampled for soil gas. Downhole soil gas data were obtained from nine different borings, five of which were completed as SVMWs. In total, the vertical distributions of VOCs were estimated at 16 discrete points. This is approximately one sampling location for every 9 acres of land at OU D. There may be variations in the contaminant distribution between data points that are not detected.
Soils	Soil data were obtained for VOCs, semivolatile organic compounds (SVOCs), pesticides/polychlorinated biphenyls (PCBs), metals, and dioxins. The data were taken to characterize the vertical and horizontal extent of soils contamination. The soil VOC data were also compared to the soil gas VOC information to establish a relationship between the two. Soils testing was performed at an analytical level of III.	No notable limitations. The data are reasonably adequate to define the extent of contamination so that remedial design can begin.
Groundwater	Groundwater data were obtained for VOCs, SVOCs, pesticides/PCBs, and dioxins. The data were taken to estimate the horizontal and vertical extent of contamination in the groundwater. Groundwater testing was performed at an analytical level of III.	No notable limitations. The data are reasonably adequate to define the extent of contamination so that remedial design can begin.

3.2 Previous Conceptual Models of Operable Unit D

Operable Unit D has a long history that extends back to the early 1940s. Several changes have occurred at OU D over the years, many of which have had a significant impact on the transport of contamination through the subsurface. Five different events at OU D have been identified that have had the most profound impacts on the discharge and transport of contaminants in the subsurface: (1) waste pit operation, (2) limited excavation of wastes from the pits, (3) construction of an impermeable cap, (4) implementation of a groundwater extraction system, and (5) implementation of a soil vapor extraction (SVE) treatability study. In addition to these five events, groundwater levels at OU D have been subject to significant long-term decline. The timeline during which each of these events occurred is shown in Figure 3-1.

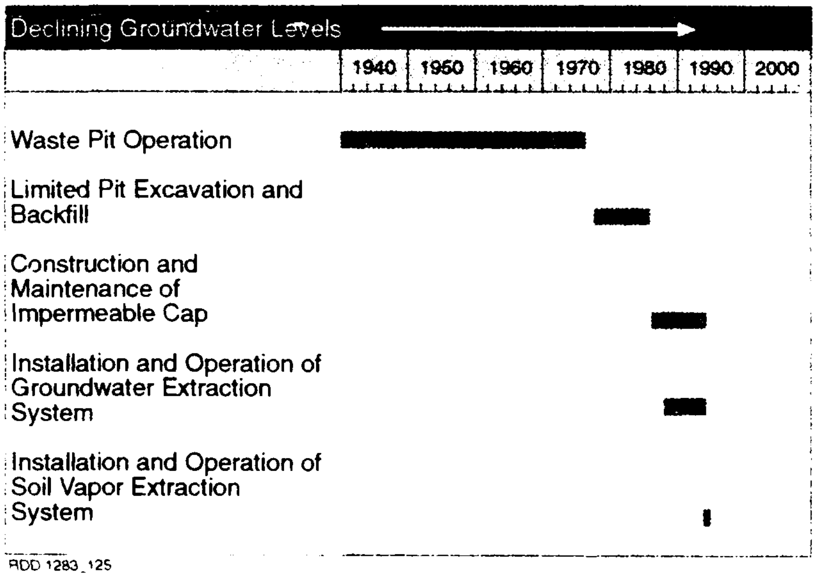


FIGURE 3-1
EVENTS THAT LED TO CURRENT CONCEPTUAL MODEL OF OPERABLE UNIT D
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Each of the five events shown in Figure 3-1, along with the long-term water table declines, created a particular conceptual model of the site for the time period during which the event occurred. When the waste pits were in operation, precipitation entered the waste easily and infiltrated down to the groundwater table where contamination could move and spread. Ground surface exposure to the contamination was also probably occurring because there was no barrier between personnel disposing of the waste and the waste pits.

When limited pit excavations occurred in the late 1970s, some of the waste material was removed, and there was less waste exposed to infiltrating precipitation and less waste that could create exposures at the ground surface. However, the waste that was left in place still would have acted as a source of groundwater contamination, and some ground surface exposures still would have occurred.

The first significant remedial action at OU D occurred in 1986 with the completion of the impermeable cap over the waste pits. The cap functions to minimize the amount of incoming infiltration, and thereby minimizes leaching of contaminants to groundwater. Also, the cap is a barrier between the waste pits and personnel at the ground surface, minimizing the potential for surface exposures. However, contamination is not completely immobilized by the cap. Volatile organic contaminants still have the potential to diffuse out radially from underneath the cap where they will again have the potential to become entrained in infiltrating rainwater and be transported downward to the groundwater; alternatively, the contaminants may diffuse to the ground surface, creating surface exposures.

A groundwater extraction system was placed into operation in 1987. This system captures contaminated groundwater that underlies the OU D waste pits and treats the groundwater at the surface. This system prevents the contaminated groundwater under OU D from spreading, and potentially contaminating aquifer systems that are currently clean. The groundwater extraction system does not affect the lateral migration of VOC contamination in the vadose zone.

An SVE system treatability study was placed into operation in early 1993. This system is designed to counteract the passive migration of VOC contamination in the vadose zone under the cap and, by creating a subsurface suction, remove contaminated vapors from the waste pits and underlying soil. Treatability study data to date have shown that, over a 1-month time period of operation, the pilot-scale SVE system removed and treated nearly 25,000 pounds of VOCs. The SVE system was shut down in May 1993 because of excessive hydrochloric acid (HCl) in the offgas treatment stream. The system is scheduled to go back online in January 1994, equipped with a scrubber that will remove the HCl from the airstream.

An illustration of how the OU D conceptual model has changed over time is provided in Figure 3-2.

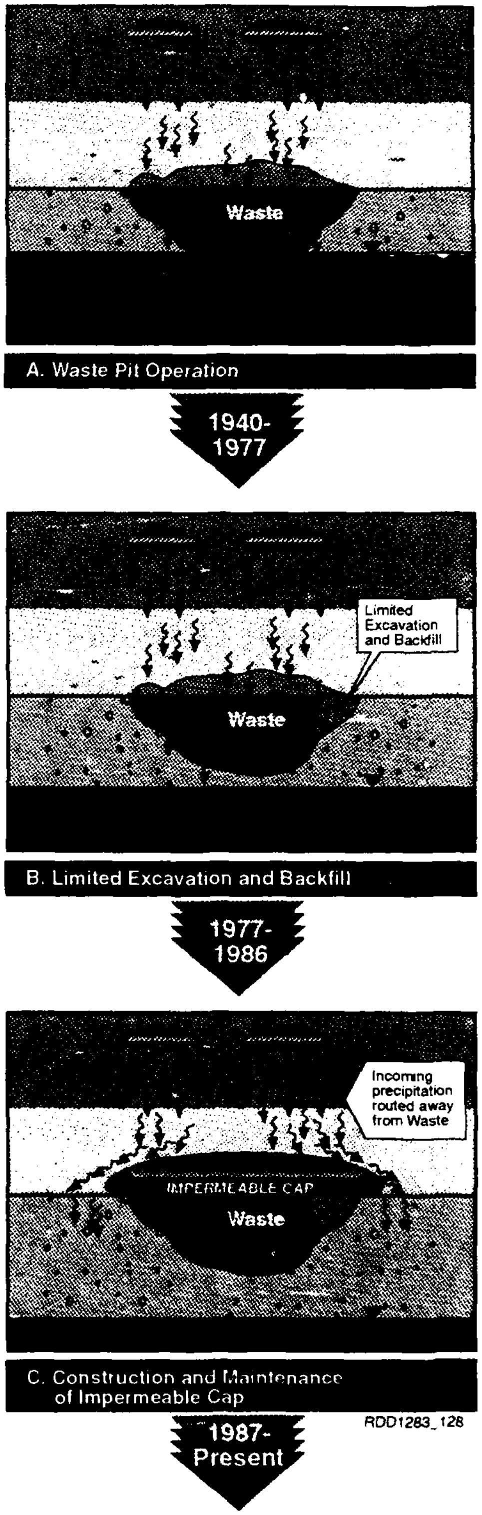


FIGURE 3-2
CONCEPTUAL MODEL CHANGES OVER TIME
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

3.3 The Operable Unit D Conceptual Model

The four elements of the conceptual model: sources, environmental media, pathways, and potential receptors are all characterized individually before assembling them together to form the overall conceptual model for OU D.

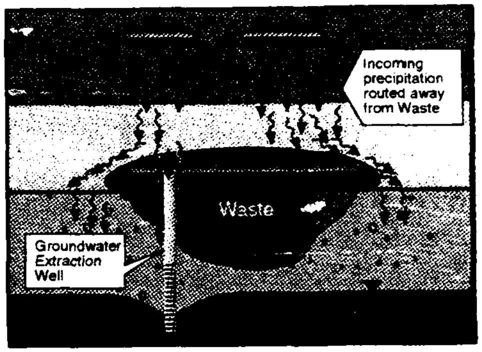
3.3.1 Sources

As described in Chapter 1, OU D began as a series of individual waste pits that were excavated and used as depositories for waste types generated by McClellan AFB activities. A variety of different waste types were disposed of in these pits, including different fuels, oils, solvents, and miscellaneous solid wastes. According to waste sampling data obtained during a 1984 site characterization study, the total source volume beneath the area D cap is estimated at 43,100 cubic yards (CH2M HILL, 1985).

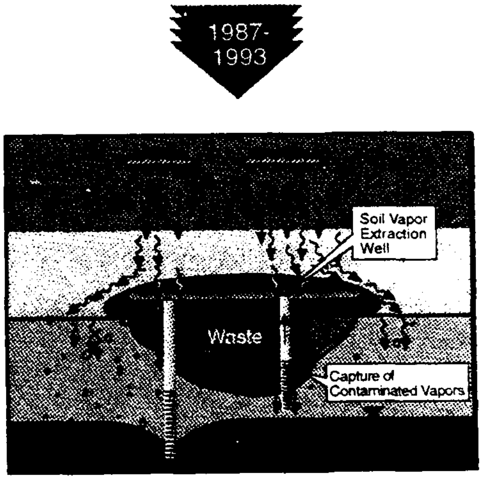
Waste samples were taken during the 1984 site characterization study. The maximum detections for a variety of contaminants from the former waste pit areas (source areas) are summarized in Table 3-2. Waste pits CS 1 through 6, CS 26, CS S, and CS T were sampled in 1984, and CS S was further characterized in 1991. Detailed discussion of the soil results is given in Appendix F. The large variety of contaminant types reflected in Table 3-2 illustrates the complexity of the waste mixtures that were disposed of in the source areas.

Table 3-2
Contaminant Characteristics of the Source Area[a]

Contaminant	Maximum Waste Pit Concentration[b] (μg/kg)	Maximum Concentrations from 1991 SVE Treatability Study[c] (μg/kg)
Volatile Organic Compounds		
Trichloroethylene	350,000	172,000
Toluene	330,000	160,000
1,1,1-Trichloroethane	300,000	687,000
Xylenes, Total	140,000	35,000
1,1-Dichloroethane	110,000	16,000
trans-1,2-Dichloroethylene	75,000	35,000
Acetone	65,000	170,000
Ethylbenzene	45,000	6,700
Tetrachloroethylene	36,000	425,000
4-Methyl-2-pentanone	18,000	14,000
Chlorobenzene	17,000	200,000
Vinyl Chloride	15,000	70
Methylene Chloride	7,600	4,588,000



D. Installation and Operation of Groundwater Extraction System



E. Installation and Operation of Soil Vapor Extraction System

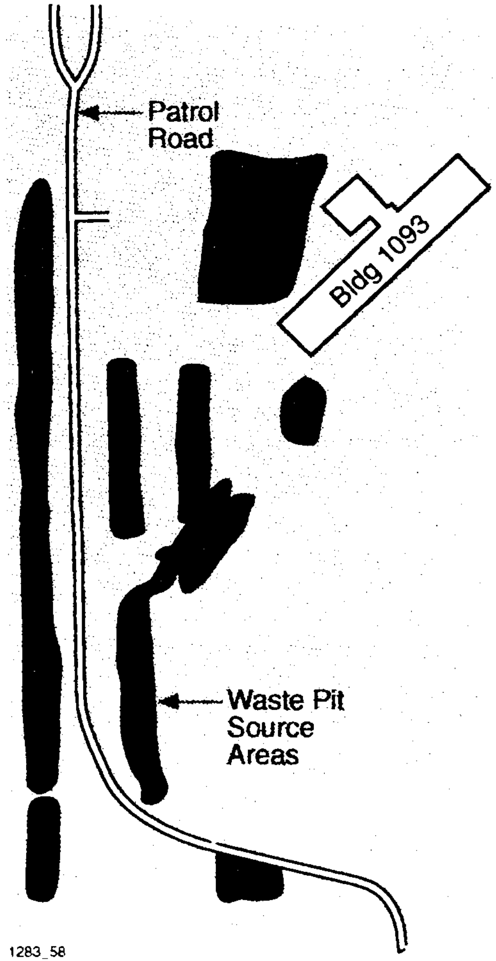
RDD1283_201

1993-Present

FIGURE 3-2
CONCEPTUAL MODEL CHANGES OVER TIME
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Table 3-2
Contaminant Characteristics of the Source Area[a]

Contaminant	Maximum Waste Pit Concentration[b] (μg/kg)	Maximum Concentrations from 1991 SVE Treatability Study[c] (μg/kg)
1,1-Dichloroethylene	6,800	1,600
2-Hexanone	1,300	1,700,000
Carbon disulfide	160	ND
Chloroform	ND	1.4
Freon 113	NA	14,000
1,2-Dichloroethane	ND	2,620
Benzene	ND	300
Carbon Tetrachloride	ND	32
Semivolatiles		
1,4-Dichlorobenzene	520,000	150,000
1,2-Dichlorobenzene	380,000	21,000
bis(2-ethylhexyl)phthalate	250.000	61,000
4-Methylphenol	76,000	5,100
Naphthalene	64,000	3,200
1,3-Dichlorobenzene	42,000	28,000
di-n-butyl phthalate	19,000	550
2-4-Dimethylphenol	15,000	620
Phenol	13,000	280
1,2,4-Trichlorobenzene	4,900	4,000
3,4-Benzofluoranthene	2,900	ND
Benzo(k)fluoranthene	2,900	ND
Phenanthrene	2,000	2,000
Pyrene	2,000	ND
Fluoranthene	1,800	580
Chrysene	760	ND
Anthracene	440	ND
Benzo(a)anthracene	370	ND
Fluorene	170	ND
Benzyl Alcohol	NA	49,000
Butyl Benzyl Phthalate	ND	2,000
2-Methyl naphthalene	ND	8,800
2-Methyl phenol	NA	65
Benzoic acid	NA	170
1,2,4 Trichlorobenzene	ND	4,000
Metals		
Chromium	33,000,000	77.9
Lead	4,500,000	136
Copper	4,200,000	197
Cadmium	150,000	40



1283_58

Table 3-2
Contaminant Characteristics of the Source Area[a]

Contaminant	Maximum Waste Pit Concentration[b] (μg/kg)	Maximum Concentrations from 1991 SVE Treatability Study[c] (μg/kg)
Nickel	55,000	ND
Cyanide	100	ND
Zinc	ND	98
PCBs		
Aroclor 1260	8.5	ND

Note:
ND = Not detected.
NA = Not analyzed.

[a] Maximums detected during 1984 site characterization study.
[b] A total of 55 samples were analyzed and evaluated.
[c] A total of 9 samples were analyzed and evaluated.

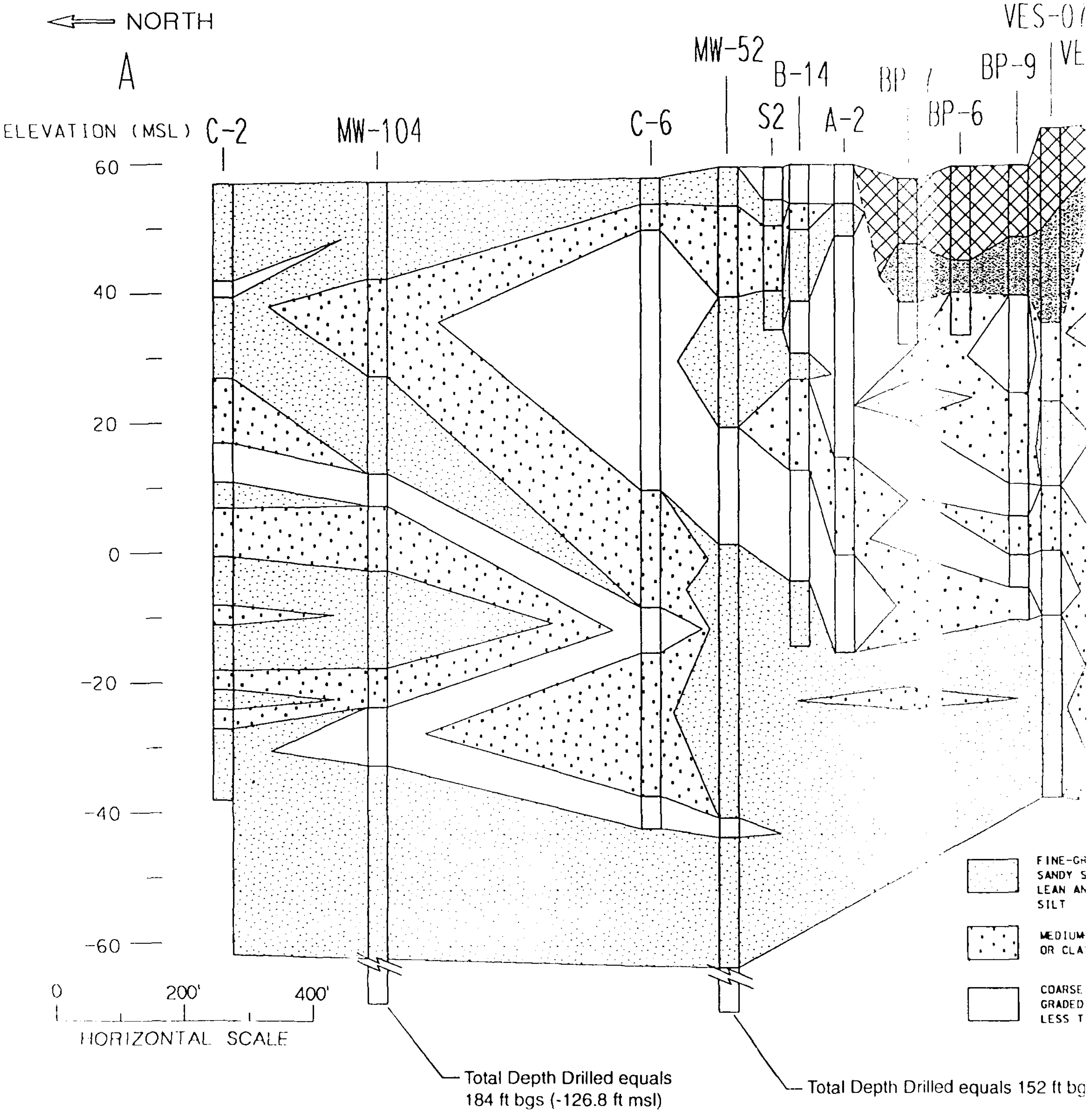
3.3.2 Environmental Media

Three different media have the potential to be affected by contamination that migrates from the sources: (1) soils above the water table (the vadose zone), (2) the groundwater, and (3) air above the ground surface. A discussion on the different properties of these media is presented in this section, along with a general description of how these properties affect contaminant transport. More specific discussions on the extent of contamination in these media may be found in Chapter 4.

Properties of the Vadose Zone Medium

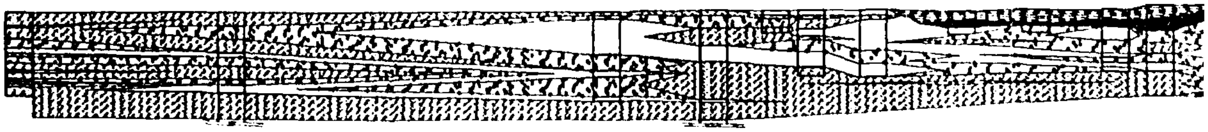
Subsurface materials consist of varying amounts of clay, silt, and sand with occasional occurrences of gravel. These materials were deposited in a fluvial/alluvial environment that has yielded a heterogeneous formation, which has been roughly divided into the vadose zone and aquifer zones A through E.

Within the vadose zone, deposition of materials occurred primarily through shallow braided streams. According to site stratigraphy and available geologic literature the width of these streams is highly variable, ranging from as narrow as 10 feet to several hundred feet wide. Because braided streams are generally unstable and prone to continual channel migration, the channel or stream deposits within the vadose zone at OU D are extremely complex and can be defined only in approximate terms. Locations of ancient depositional channels are inferred using lithology from well and boring logs, and are therefore referred to as lithologic channels. Figures 3-3 and 3-4 illustrate site stratigraphy in cross section, and Figure 3-5 is a schematic rendering of lithologic channels in 10-foot elevation increments.



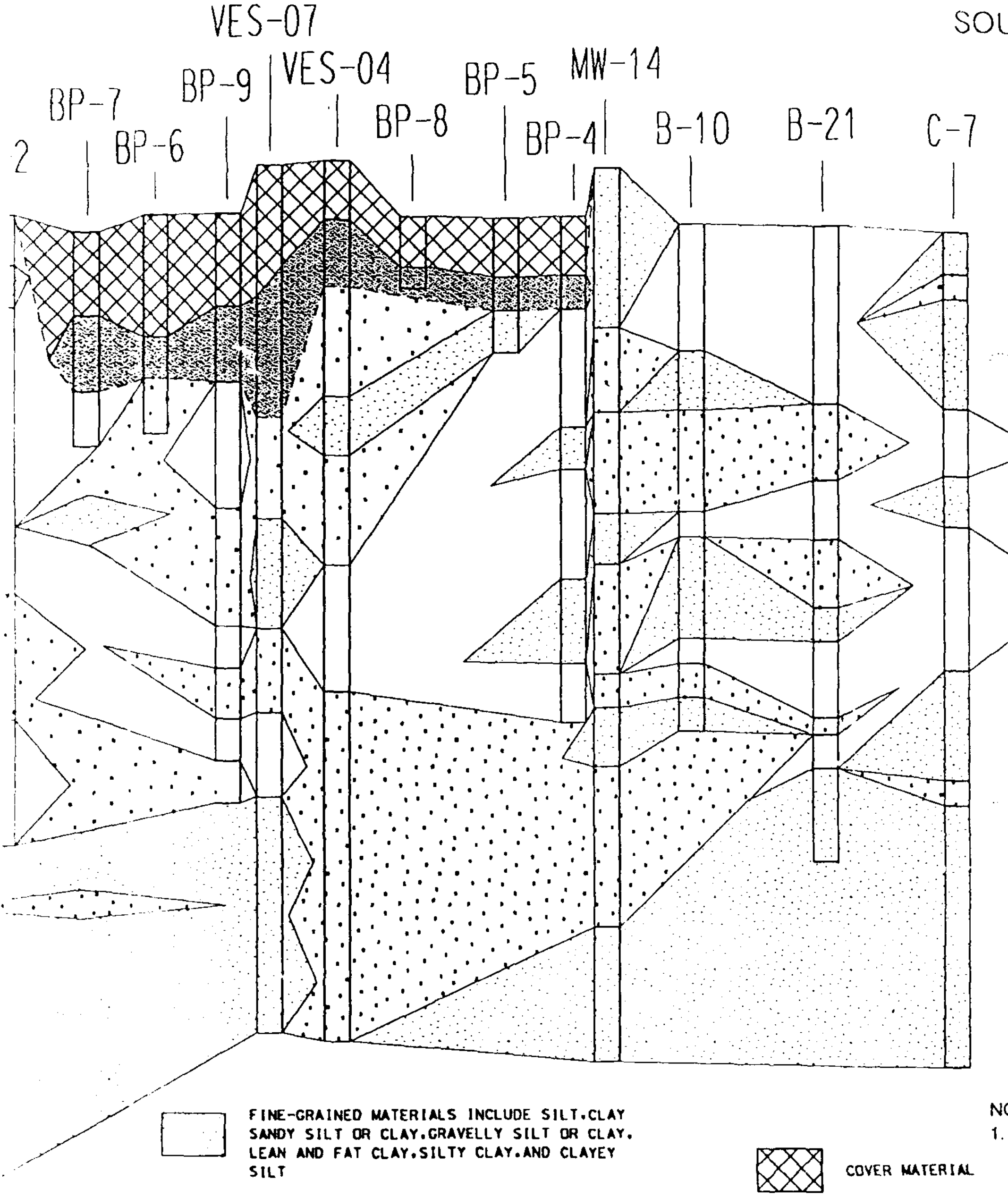
Total Depth Drilled equals 184 ft bgs (-126.8 ft msl)

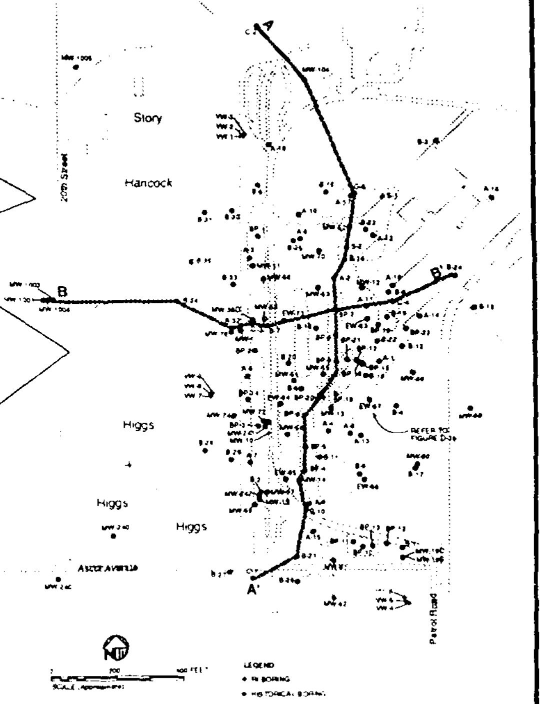
Total Depth Drilled equals 152 ft bg



CROSS SECTION A-A' SH

R001477 401





Cross Section Location
SITE MAP

☐ FINE-GRAINED MATERIALS INCLUDE SILT, CLAY SANDY SILT OR CLAY, GRAVELLY SILT OR CLAY, LEAN AND FAT CLAY, SILTY CLAY, AND CLAYEY SILT

▨ MEDIUM-GRAINED MATERIALS INCLUDE SILTY OR CLAYEY SAND OR GRAVEL

☐ COARSE-GRAINED MATERIALS INCLUDE POORLY GRADED OR WELL GRADED SAND OR GRAVEL WITH LESS THAN 5% FINES

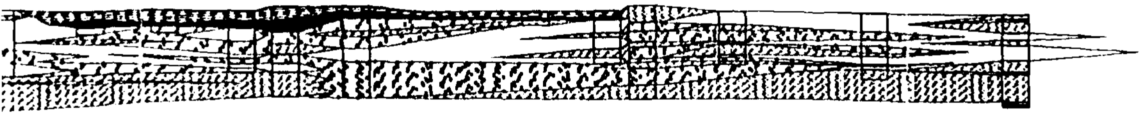
▦ COVER MATERIAL

▩ WASTE

NOTES:

1. Stratigraphy has been simplified so that layers with a thickness of 2 feet or less have generally been omitted. The vertical scale of 1 inch equals 20 feet does not permit presentation of these layers.
2. Stratigraphic relationships are not presented below the A Zone because there is insufficient data within the cross section.
3. Water levels presented in monitoring wells were measured in July 1992.
4. Lithologic logs for borings shown in cross sections are presented in Attachment D-2, at the end of Volume 3.
5. Lithology presented in more detail in Appendix D.

Depth Drilled equals 152 ft bgs (-92.9 ft msl)

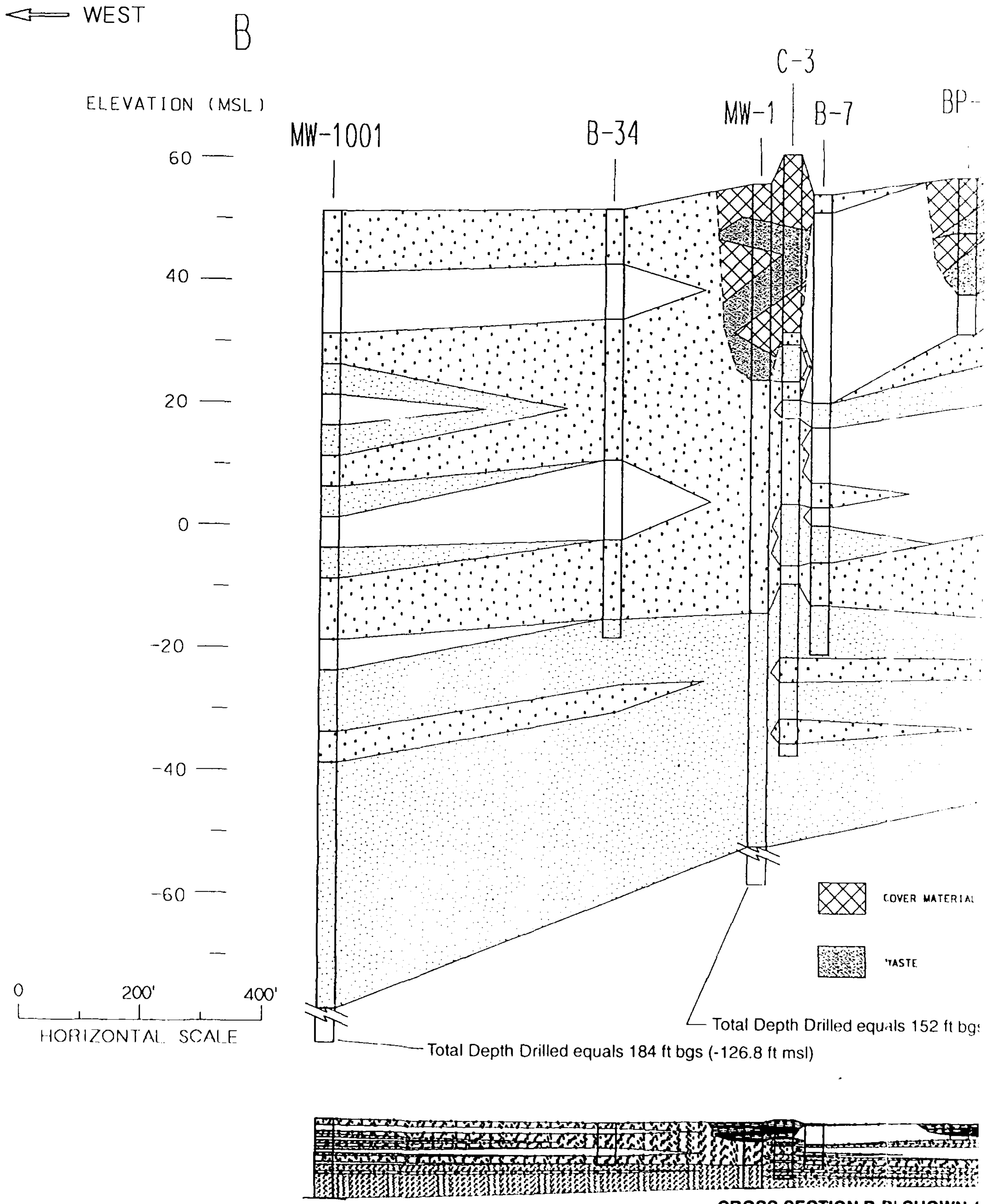


CROSS SECTION A-A' SHOWN AT TRUE SCALE

FIGURE 3-3
CROSS SECTION A-A'

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

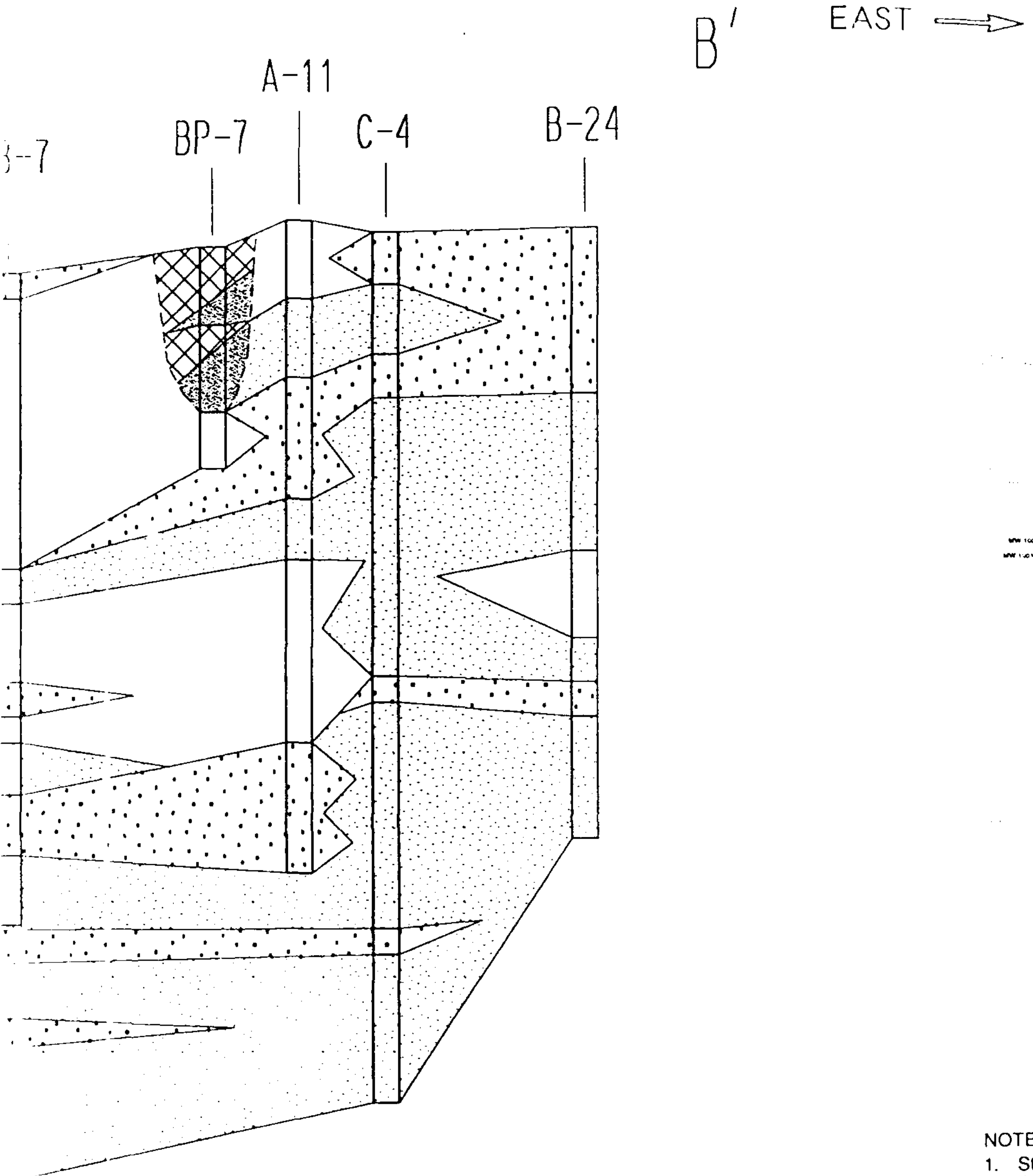


Total Depth Drilled equals 152 ft bg

Total Depth Drilled equals 184 ft bgs (-126.8 ft msl)

CROSS SECTION B-B' SHOWN A

RDD1477 402



▨ COVER MATERIAL

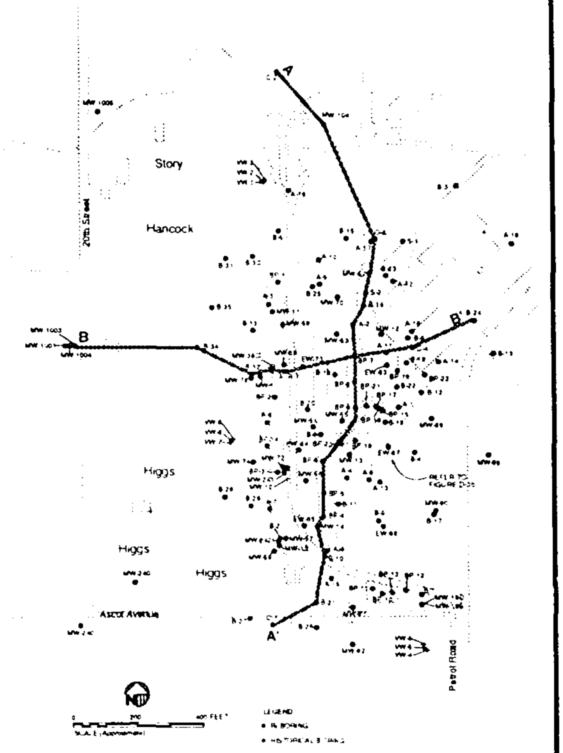
▒ WASTE

░ FINE-GRAINED MATERIALS INCLUDE SILT, CLAY SANDY SILT OR CLAY, GRAVELLY SILT OR CLAY, LEAN AND FAT CLAY, SILTY CLAY, AND CLAYEY SILT

⁘ MEDIUM-GRAINED MATERIALS INCLUDE SILTY OR CLAYEY SAND OR GRAVEL

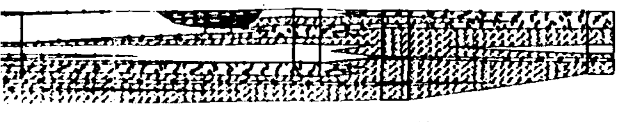
☐ COARSE-GRAINED MATERIALS INCLUDE POORLY GRADED OR WELL GRADED SAND OR GRAVEL WITH LESS THAN 5% FINES

rilled equals 152 ft bgs (-92.9 ft msl)



Cross Section Location
SITE MAP

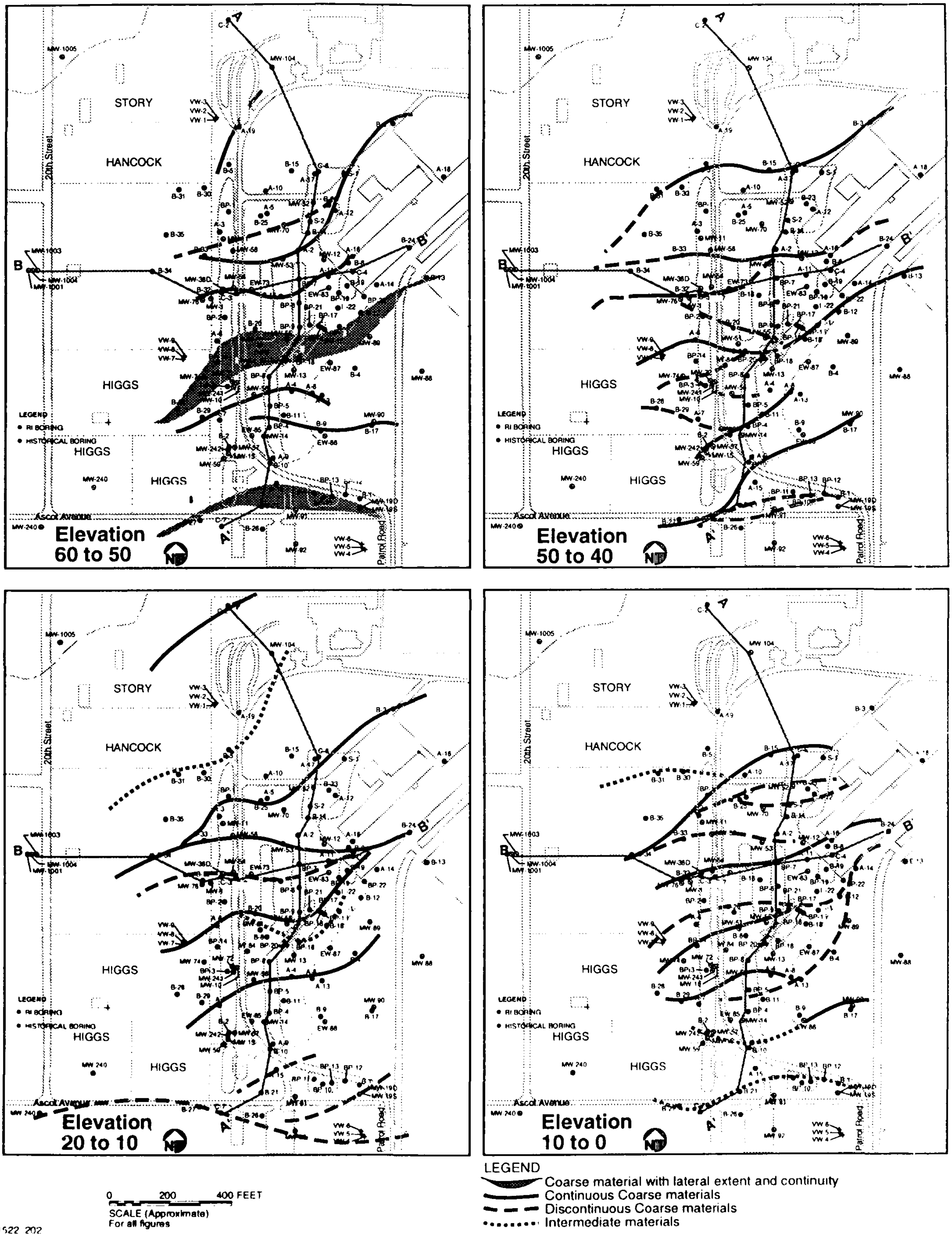
NOTES:
1. Stratigraphy has been simplified so that layers with a thickness of 2 feet or less have generally been omitted. The vertical scale of 1 inch equals 20 feet does not permit presentation of these layers.
2. Stratigraphic relationships are not presented below the A Zone.
3. Water levels presented in monitoring wells were measured in July 1992.
4. Lithologic logs for borings shown in cross sections are presented in Attachment D-2, at the end of Volume 3.
5. Lithology presented in more detail in Appendix D.



CTION B-B' SHOWN AT TRUE SCALE

FIGURE 3-4
CROSS SECTION B-B'
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


Elevation 60 to 50
Elevation 50 to 40
Elevation 20 to 10
Elevation 10 to 0
STORY
HANCOCK
HIGGS
20th Street
Ascot Avenue
Patrol Road
A
A'
B
B'
MW-1005
MW-1003
MW-1004
MW-1001
MW-104
MW-240
MW-92
MW-88
MW-90
C-2
C-7
A-19
A-18
A-10
B-3
B-15
B-24
B-26
B-27
B-31
B-30
B-35
B-13
VW-1
VW-2
VW-3
VW-4
VW-5
VW-6
VW-7
VW-8
VW-9
MW-19D
MW-19S
LEGEND
● RI BORING
● HISTORICAL BORING
N
LEGEND
Coarse material with lateral extent and continuity
Continuous Coarse materials
Discontinuous Coarse materials
Intermediate materials
0
200
400 FEET
SCALE (Approximate)
For all figures

RDD1522.202

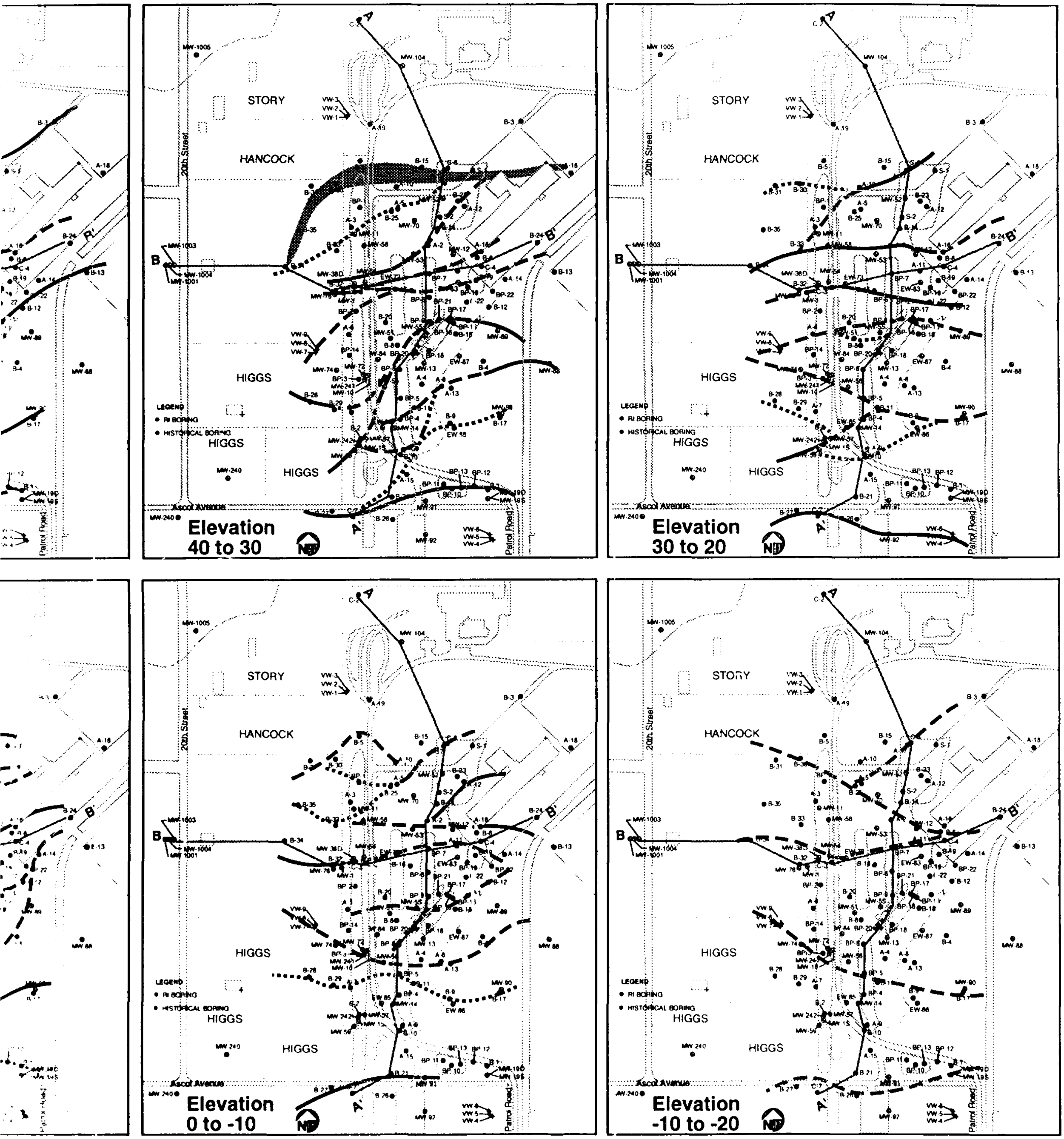


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FIGURE 3-5
SCHEMATIC LOCATIONS OF LITHOLOGIC CHANNELS

OPERABLE UNIT D McCLELLAN AIR FORCE BASE

CH2M HILL

Because most of the A-, B-, and BP- borings drilled in 1984 were drilled to 80 feet bgs or less, the available lithologic information decreases significantly below 80 feet bgs. For this reason, and because this report focuses upon the vadose zone, lithologic channel locations below Elevation -20 (approximately 80 feet bgs) are not presented, although a portion of the A aquifer zone is shown in the cross sections.

Following is the approach for development of cross sections and lithologic channel locations:

- **Obtain Borehole Data** – Well and boring logs from historic and current operations are obtained.
- **Divide Lithology** – Lithology indicated in logs is divided into three soil types: coarse, intermediate, and fine materials. Rationale for these soil types is included in Appendix D.

  Because there is abundant fill and waste material in the top 30 feet of various pits at OU D, waste is mapped as a fourth lithologic unit. (Waste has not been consistently presented in borehole and well logs; therefore, not all waste that exists at OU D has been mapped.) This minimizes the potential for confusing fill with naturally occurring materials.
- **Prepare Stratigraphy in Plan View** – Lithology for each borehole is plotted in plan view on an OU D map in successive 10-foot elevation increments. The resulting maps give an approximate depiction of the depositional setting specific elevations. This construction requires no additional adjustments because these units were deposited in a relatively level setting with little to no tectonic or structural disturbances.
- **Develop Stratigraphy in Plan View and Locate Lithologic Channels** – Cross sections and lithologic channel locations are developed through an iterative process linking laterally continuous coarse-grained units between successive plan view maps.

The coarse materials shown in Cross Sections A-A' and B-B' correspond generally to the lithologic channels in Figure 3-5. In general, the confidence with which a channel can be located is directly proportional to the vertical or lateral extent of the coarse deposit. Therefore, a channel with little to no migration or a channel with significant width can be identified with more certainty than a small channel that frequently migrates. For example, during deposition between Elevations 60 to 30 feet msl, channels appear more persistent in both lateral and vertical extent. In Figure 3-5, a single heavy line or fill pattern defines continuous or laterally extensive coarse deposits, respectively. Where coarse deposits have reduced lateral continuity, a dashed line defines their location. In contrast, between Elevation 0 to -10 feet msl, the channels are less persistent and more sinuous. These deposits appear to reflect a relatively quiet depositional regime; therefore, the lithologic channels are also defined by intermediate materials, corresponding to the reduced carrying capacity of the streams. The lithologic channels defined by intermediate materials are shown as dotted lines in Figure 3-5.

The transport of contamination through the vadose zone soils is influenced by a variety of soil properties, including intrinsic permeability in the vertical and horizontal directions, water saturation, and organic carbon fraction. Estimated values of these properties for sand and silty clay units at OU D are summarized in Table 3-3 and discussed in Appendixes C and D. The impact that each of these properties has on contaminant transport is also included in Table 3-3.

As can be seen by reviewing the data in Table 3-3, the sand units generally have higher intrinsic permeabilities and lower percent saturations than the finer-grained silty units. The implication is that contaminated soil gas will more easily move in the sandy units of the vadose zone in both the horizontal and vertical directions.

Organic carbon fractions for the sand units are not available. However, previous experience has shown that sand generally has organic fractions that are lower than finer-grained silt and clay material (Bohn, et al., 1985). If this is the case at OU D, organic contaminants will more easily adhere to the fine-grained units. Therefore, the silty units in the vadose zone provide a mechanism for slowing the transport of contaminants in the subsurface.

In the vadose zone, VOCs will partition into at least four phases as listed below, and as shown in the pull quote figure to the right.

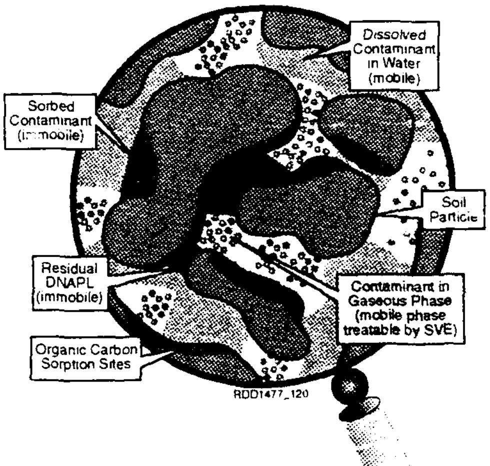
1. Free or residual VOC product present on the nonwetted surfaces of soil particles. This is the "pure product" form of the VOCs and is referred to as nonaqueous phase liquid (NAPL).

2. VOCs dissolved in the porewater.

3. VOCs sorbed (attached) to the mineral and organic components of the soil particles.

4. Vapor-phase VOCs which are present as gas in the interstitial pore spaces of the soil. This is the phase targeted by the SVE treatability study at OU D. The dissolved and pure product phases are also addressed by the SVE system because they volatilize into the vapor-phase, as previous vapor phase VOCs are removed from the soil.

An illustration of the four phases in the soil matrix is provided in the figure to the right.



VOC PARTITIONING IN VADOSE ZONE

Properties of the Groundwater Medium

The water table under OU D exists at approximately 100 feet below ground surface (bgs). For the purposes of classifying the hydrogeology under OU D, three different water bearing units have been identified:

1. Zone A—ground surface to 134 feet bgs. The zone becomes saturated at a depth of approximately 99 feet bgs. This zone used to have a saturated thickness substantially thicker than 35 feet, but groundwater declines in recent years have led to near desaturation of this zone.

2. Zone B—134 to 194 feet bgs.

3. Zone C—194 to 274 feet bgs.

Table 3-3
Vadose Zone Soil Properties at Operable Unit D

Property	**Sand Units**	**Silty Clay Units**	**Impact on Contaminant Transport**
Vertical Intrinsic Permeability (darcies)[a]	0.02 to 1.5	0.001 to 0.5	Low intrinsic permeabilities imply more resistance to contaminant transport either in solution or in gaseous phases.
Horizontal Intrinsic Permeability (darcies)[a]	0.1 to 1.7	0.1 to 1.5	Low intrinsic permeabilities imply more resistance to contaminant transport either in solution or in gaseous phases.
Percent Saturation (%)	47 to 75	63 to 86	As percent saturation increases, the ability of the vadose zone medium to convey air flow decreases because there is less air in the voids and more water.
Fraction Organic Carbon (--)	Not Available	0.001 to 0.006	High organic carbon fractions in the soils allow for more retardation of organic chemicals during transport because they tend to adsorb to the organic material in the soil matrix.

[a] Intrinsic permeabilities are based on laboratory tests. Field permeability testing at Site S indicates higher permeabilities ranging from 3 to 200 darcies. Nine sample locations were evaluated in Site S.

The extraction system appears to successfully stop the lateral movement of contaminated groundwater in the A and B Zones.

Prior to the installation and operation of the six groundwater extraction wells in 1987, groundwater movement was in a south/southwesterly direction in the A Zone, and north/northeasterly direction in the B and C Zones. The extraction system appears to successfully stop the lateral movement of contaminated groundwater in the A and B Zones. (Chapter 7 of this report provides more detail on the extraction system.) Data also suggest that the vertical movement of groundwater beneath OU D is impeded by the extraction wells. Data suggest that the extraction system may not capture all of the flow in Zone C, but Zone C is not thought to be contaminated at this time (refer to Appendix E).

The majority of contamination that enters the groundwater from the vadose zone at OU D will be captured and eventually removed by the extraction system. Some contamination may not be captured if it enters the groundwater at a location that is not subject to influence from the extraction system.

Properties of the Air Medium

The air medium has the potential to be impacted by VOC contaminants that migrate from the OU D source areas through the ground surface. Ambient air in open space has the potential to become contaminated, as does air in more confined crawlspace areas that may have little enough ventilation to allow contamination to build up. In addition, contamination has the potential to migrate into indoor air as might occur at Building 1093. Because of their volatile nature, VOCs are the only contaminant type that have the potential to contaminate this media. Air sampling has been performed during this Remedial Investigation (RI), the results of which are summarized in Chapter 4. Detailed summaries of crawlspace and ambient air data are provided in Appendix A. Risks associated with the inhalation of contamination that may migrate into the air media are discussed in Chapter 5.

3.3.3 Pathways

As described in Chapter 5, there are three different exposure pathways of concern at OU D:

1. Inhalation of VOCs that migrate from the source areas into Building 1093.

2. Exposure of residents that live offbase to VOCs that migrate from the source areas to groundwater and avoid capture by the groundwater extraction system.

3. Exposure of residents that live offbase to VOCs that migrate from the source areas into ambient air and air that exists in crawlspaces.

This section describes the transport and transformation mechanisms that will impact the contamination as it moves through these three pathways. Detailed exposure assumptions and risk evaluations for these pathways are discussed in Chapter 5.

Vadose Zone Transport Processes

VOCs may be subject to significant transport in the vadose zone when they reside in one of the following three phases: (1) gaseous, (2) solution, or (3) pure product (NAPL) phase. The significant transport processes are different depending on the VOC phase. Transport in each of these phases is discussed separately.

Contaminant properties that affect transport are presented in Appendix J, for the chlorinated VOCs trichloroethylene (TCE), 1,1,1-trichloroethane (1,1,1-TCA), 1,1-dichloroethylene (1,1-DCE), tetrachloroethylene (PCE), and Freon 113. Mass estimate calculations performed in Appendix G indicate that these five contaminants comprise over 99 percent of the speciated VOC mass in the vadose zone. Non-chlorinated VOCs, such as petroleum hydrocarbons, are also likely to contribute significantly to the total VOC mass. The focus of this section is on the transport of VOCs, because at this time VOCs are the primary contaminant type detected in groundwater (see Appendix E). Other types of contaminants such as SVOCs, dioxins, or heavy metals also have the potential to migrate downward to the groundwater table, particularly if they become entrained in VOC NAPL that moves down under the influence of gravity. In fact, as shown in Appendix E, some contaminants have been detected in the groundwater. Additional groundwater data will be obtained during the basewide interim groundwater response action to ensure the selection of a groundwater treatment system that can accommodate all of the contaminants found in groundwater.

Gaseous-Phase Transport. Both diffusive and advective mechanisms impact the transport of VOCs in the gaseous phases. Modeling studies have been conducted (Mendoza and Frind, 1990) that evaluate the difference between diffusive and advective gaseous transport mechanisms. Diffusive movement caused solely by soil gas concentration gradients results in nearly uniform spreading of contamination outward from vadose zone source areas. Diffusive movement also tends to be slower than advective movement. Diffusive dominated migration in the vadose zone usually occurs in highly impermeable soils (Mendoza, 1992), which do not exist at OU D. Advective mechanisms involve density-driven movement of the gas phase contaminants because of gravitational forces. Advection causes a movement bias downward (in the direction of gravity) Gaseous-phase contaminant movement under OU D results from a superposition of both diffusive and advective processes.

Gaseous-phase contaminant movement under OU D results from a superposition of both diffusive and advective processes.

A summary of theoretical gaseous-phase transport of 1,1-DCE from under the OU D cap after a time period of 50 years is provided in Figure 3-6. A detailed description of the modeling assumptions that were used to generate Figure 3-6 are presented in Appendix J. The effects of advection can clearly be seen in the figure, where the contaminant concentration contours "bulge out" at the groundwater table. The implication is that, at any particular location laterally away from the cap, gaseous-phase concentrations in the vadose zone increase with depth. Shallow soil gas data alone therefore has limited use in estimating the true three-dimensional extent of VOC contamination.

Solution-Phase Transport. Where it can occur, vertical infiltration of precipitation is the most significant mechanism for transporting solution-phase contamination vertically downward to the groundwater table. The VOC contaminants become dissolved in the porewater and are transported downward at the rate of infiltration.

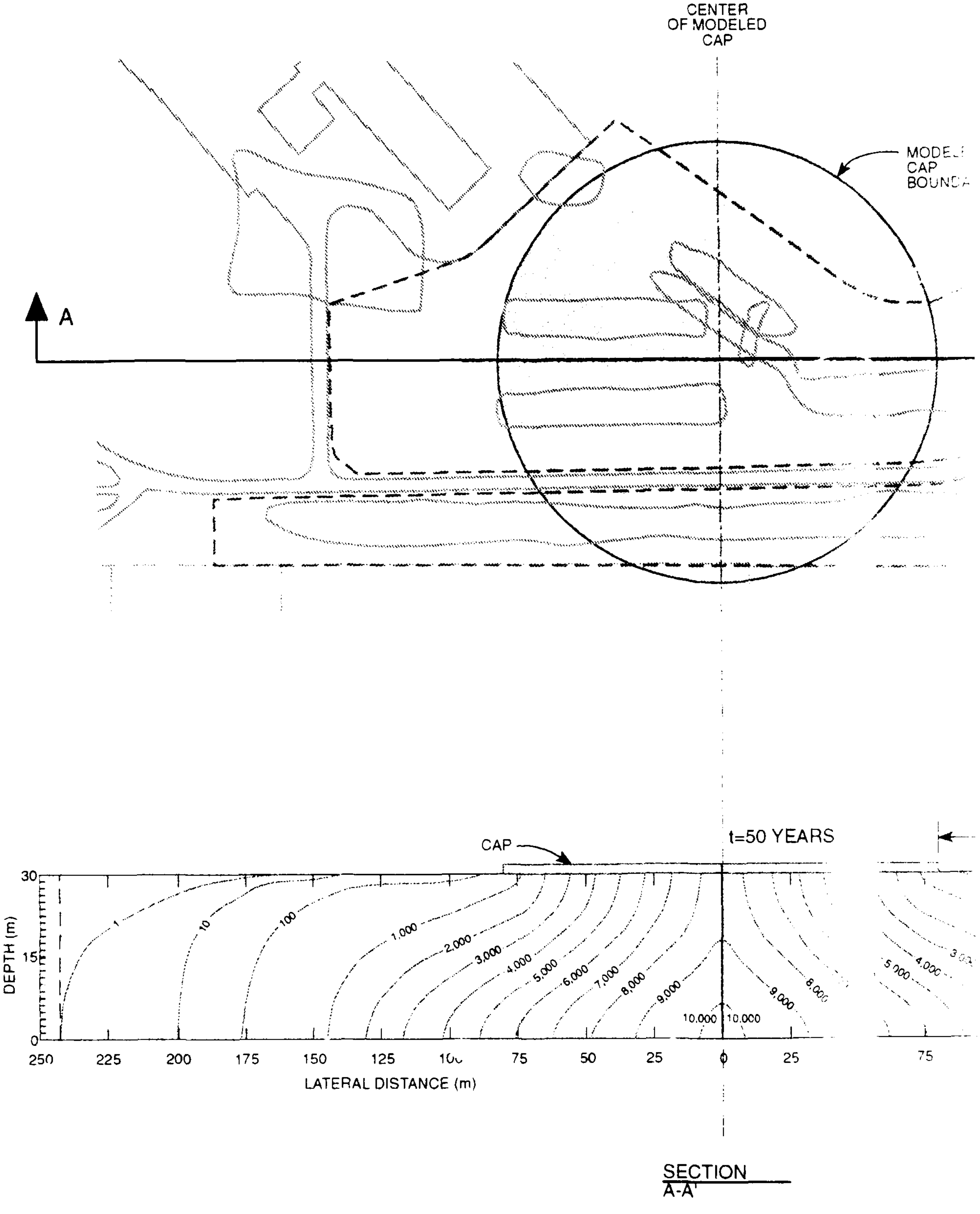
Where it can occur, vertical infiltration of precipitation is the most significant mechanism for transporting solution-phase contamination vertically downward to the groundwater table.

The impermeable OU D cap currently inhibits the infiltration of precipitation through contaminated regions that underlie the cap. Solution-phase contaminant transport is therefore probably minimal under the cap. However, when gaseous-phase VOCs migrate laterally into areas that are not protected by the cap, infiltrating precipitation will dissolve some of the contamination and transport it to the groundwater table. During the time period when the cap did not exist (1943 to 1984) precipitation came in direct contact with the waste, and vertical solution-phase contaminant transport to groundwater did occur.

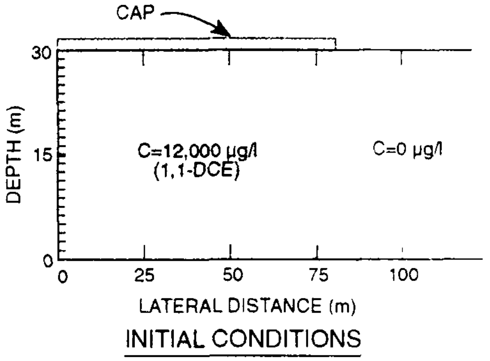
The second mechanism that may be responsible for solution-phase transport in the vadose zone is the regional decline in groundwater levels. In the 1950s, the groundwater table at OU D was approximately 70 feet higher than it is today and may have been in direct contact with the waste material. As the water level declined, dissolved contaminants would have retreated with the groundwater, but some of the contamination would remain behind in the vadose zone as residuals. This concept is illustrated in Figure 3-7. This "smear zone" of contamination may include SVOCs and metals, as well as VOC contamination.

Nonaqueous-Phase Liquid Transport. There are two significant forces that impact the transport of NAPLs in the vadose zone: (1) gravitational forces and (2) capillary forces (surface tension) (Cohen and Mercer, 1993). Gravitational forces pull the NAPLs downward toward the water table. Capillary forces resist this gravitational force via surface tension effects between soil particles. When gravitational forces are exactly counterbalanced by capillary forces, the NAPLs will lie at rest in the vadose zone.

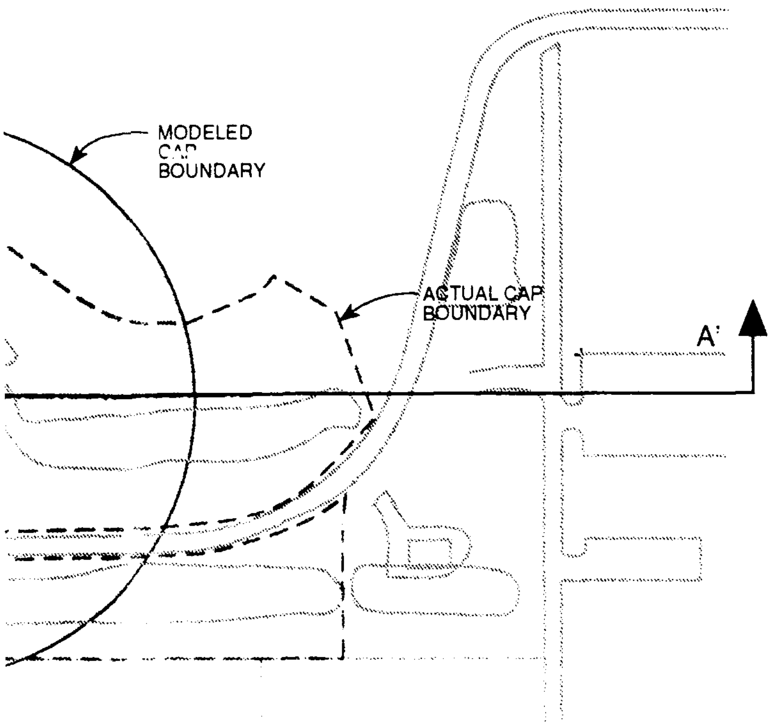
It is not known if NAPLs at OU D are lying at rest or still progressing under gravitational forces toward the water table. The OU D cap will not prevent the downward migration of NAPLs. If they are still moving downward, large "slugs" of contamination may eventually enter the groundwater. The point of entrance would almost certainly be within the zone of influence of the groundwater extraction system because the NAPLs are expected to exist in the former waste pit areas. However,


CENTER
OF MODELED
CAP
MODEL
CAP
BOUNDA
A
CAP
t=50 YEARS
30
15
0
DEPTH (m)
1
10
100
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
10,000
9,000
8,000
3,000
4,000
5,000
250
225
200
175
150
125
100
75
50
25
0
25
75
LATERAL DISTANCE (m)
SECTION
A-A'

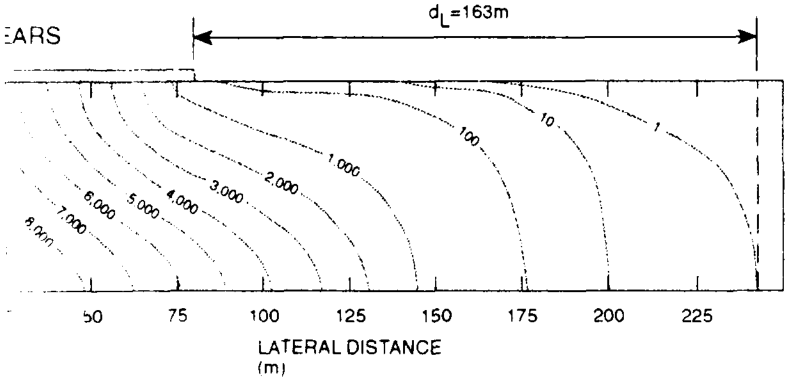
R001477.136



INITIAL CONDITIONS



NOTE
CONCENTRATION CONTOURS IN UNITS OF µg/l



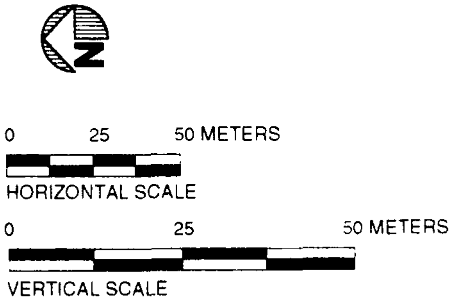


FIGURE 3-6
PREDICTED TRANSPORT
OF 1,1-DCE (µg/l)
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

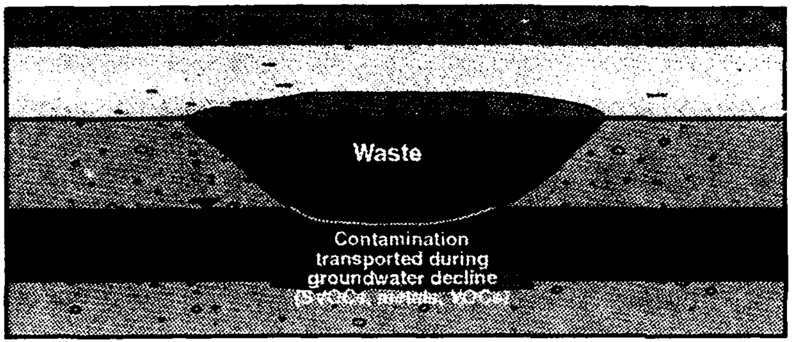


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FIGURE 3-7
ILLUSTRATION OF SMEAR ZONE
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

the NAPLs may not be captured by the extraction system if gravitational forces are large enough to overcome the hydraulic gradients imposed by the extraction system and drive the NAPL contamination from the A and B Zones into deeper aquifer systems (C, D, and E Zones). To date, data do not indicate groundwater contamination in deeper aquifer systems, but the potential does exist.

Natural Attenuation and Transformation of Contamination

As identified in the risk assessment, seven chlorinated VOCs are of major concern at OU D: TCE, 1,1,1-TCA, 1,1-DCE, PCE, Freon 113, 1,2-DCA, and vinyl chloride (a highly toxic product of chlorinated-VOC degradation). Transformation pathways are depicted in Figure 3-8. The 1,2-DCA and vinyl chloride have been detected at OU D at low levels, as described in Chapter 4. Their presence suggests that some natural attenuation may be occurring. In addition, 1,1-DCE, a much more common VOC at OU D, may also be a degradation product. Data are inadequate to assess rates of transformation; however, the high levels of TCE and 1,1,1-TCA that are still present at OU D indicate that natural transformation is not rapid enough to realistically remediate the contamination at OU D. Natural attenuation of Freon 113 is not well understood. Freon 113 is ubiquitous within OU D and is likely not transforming rapidly in the subsurface.

Groundwater Transport Processes

After contamination enters the groundwater via transport from source areas in the vadose zone, the contaminants will generally move in the direction of groundwater flow. However, the contamination will not move at the same rate of flow as groundwater because of transport retardation attributed to sorption/desorption on the soil matrix.

As discussed previously, long-term groundwater declines in the aquifer systems underlying OU D have occurred in both the A and B Zones. These declines have now nearly resulted in desaturation of the A Zone.

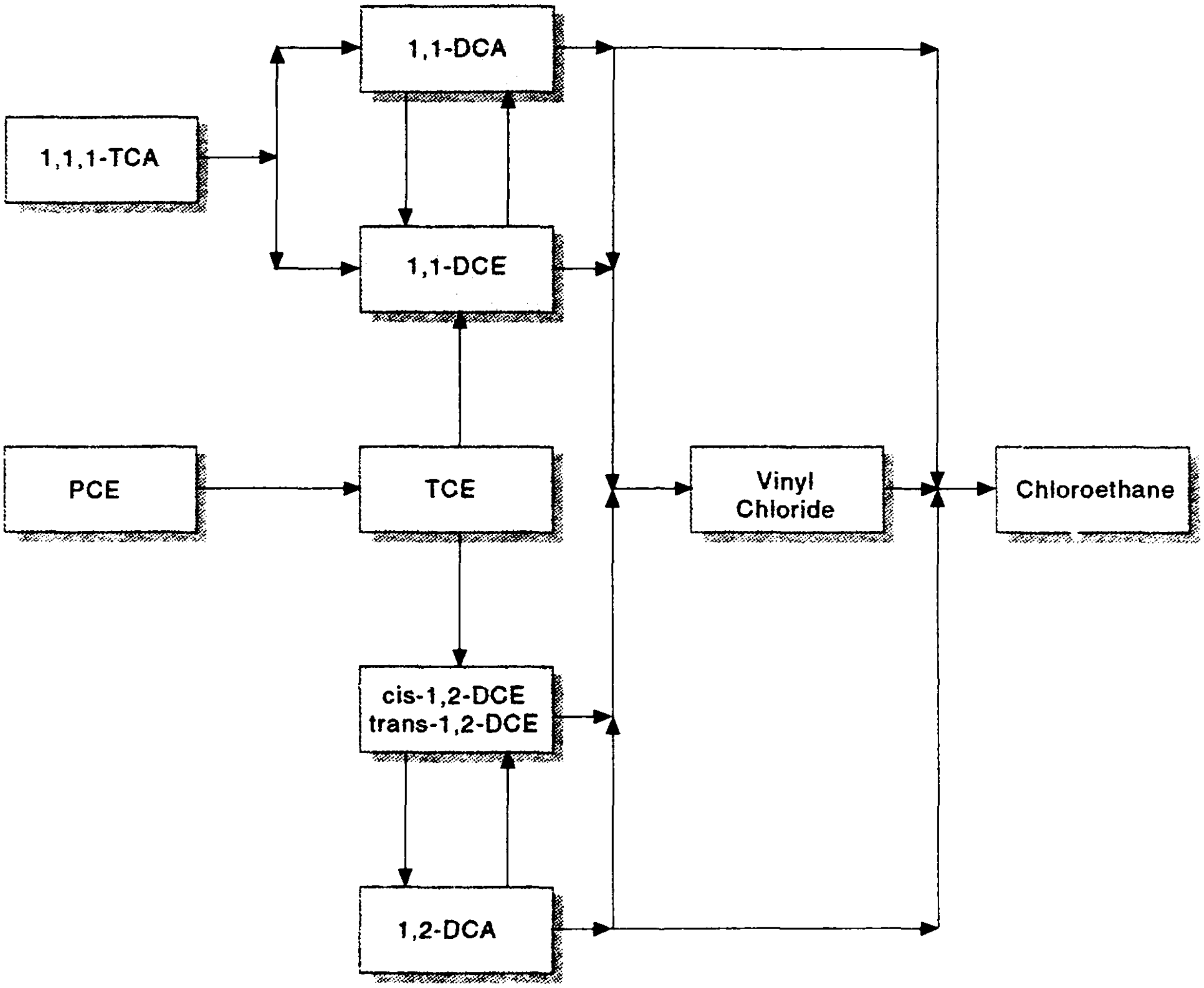

FIGURE 3-8
POTENTIAL TRANSFORMATION PRODUCTS FOR CHLORINATED CONTAMINANTS FOUND AT OPERABLE UNIT D
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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CH2MHILL

As the groundwater levels decline, a larger distance of vadose zone soil develops that can act as a buffer between the source areas and the groundwater. Also, contamination that is dissolved in the groundwater will move down vertically with the decline in water levels. Water level hydrographs for the A and B Zones which show the water level declines over the last 9 years are provided in Figures 3-9 and 3-10. A hydrograph of a monitoring well cluster showing water level changes near the boundary of influence of the groundwater extraction system is provided in Figure 3-11. A large decline of roughly 10 feet is noted in the B Zone well in the first quarter of 1988. The reason for this temporary decline is not known, and may be an anomalous data point.

The groundwater extraction system has created gradients in the groundwater under OU D that capture contamination and force it to flow through extraction wells, where the contaminated groundwater is removed and treated. The extraction system influences both the A and B aquifer zones. Water level contour maps used to show the extent of horizontal capture in these two zones are shown in Figures 3-12 and 3-13. A water level contour map used to illustrate the areas at OU D where vertically upward flow is induced, and vertical capture of contamination is obtained is shown in Figure 3-14. Data shown on Figures 3-12, 3-13, and 3-14 are from June and July 1992 because this is the most recent complete snapshot of the data. Wells installed during 1993 are shown on the figure, but data from these wells are not directly comparable to 1992 data because of the regional decline in water elevation.

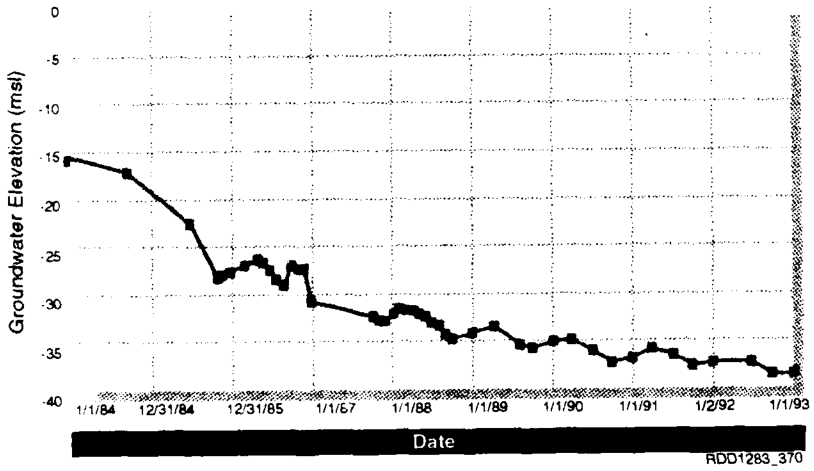

FIGURE 3-9
A-ZONE HYDROGRAPH FOR WELL MW-10
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

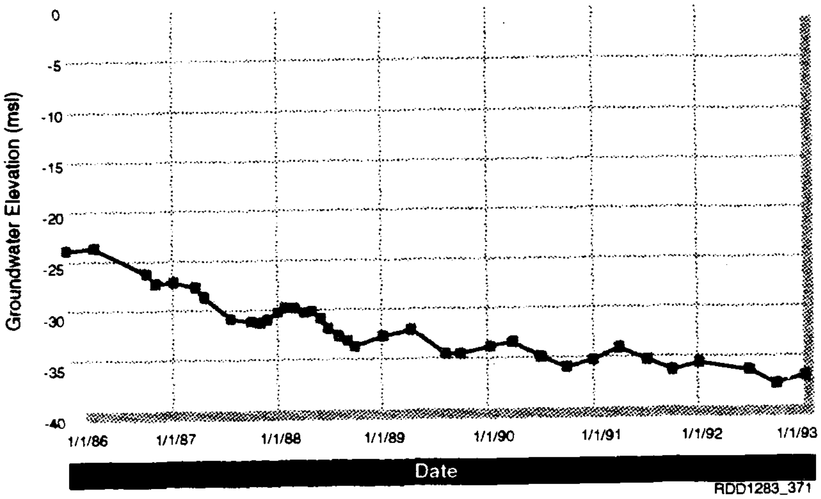

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FIGURE 3-10
B-ZONE HYDROGRAPH FOR WELL MW-59
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

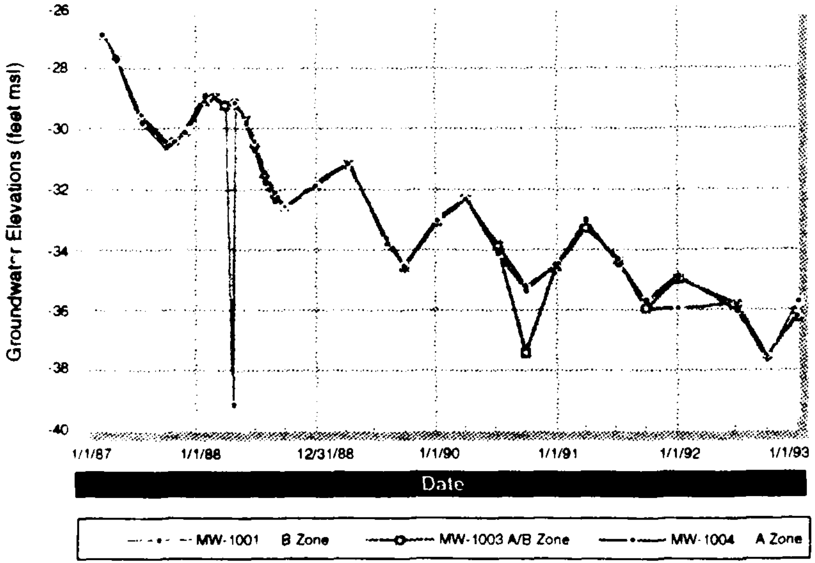

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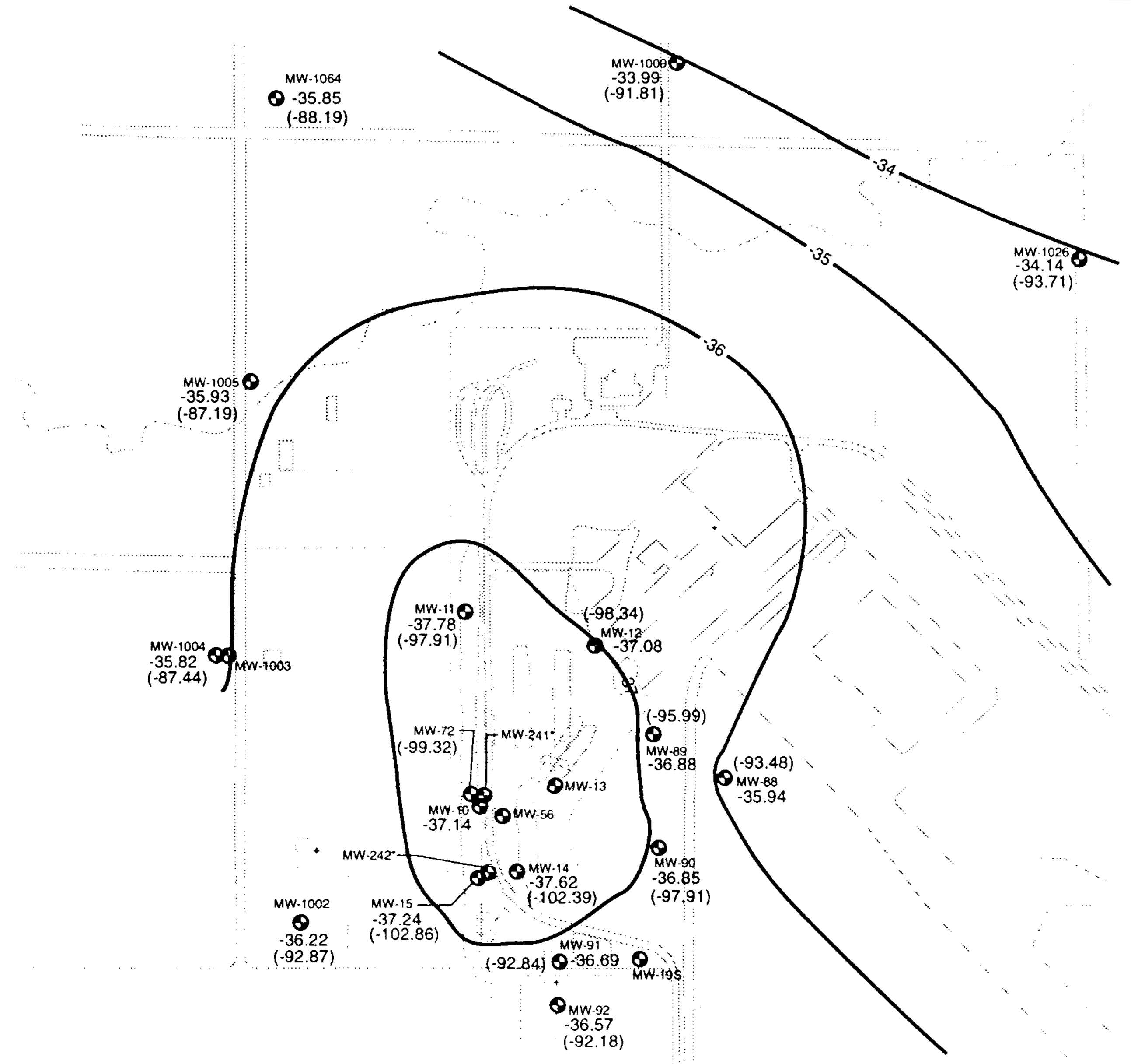
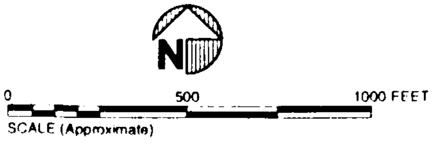
FIGURE 3-11
CLUSTER WELL HYDROGRAPH
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



LEGEND

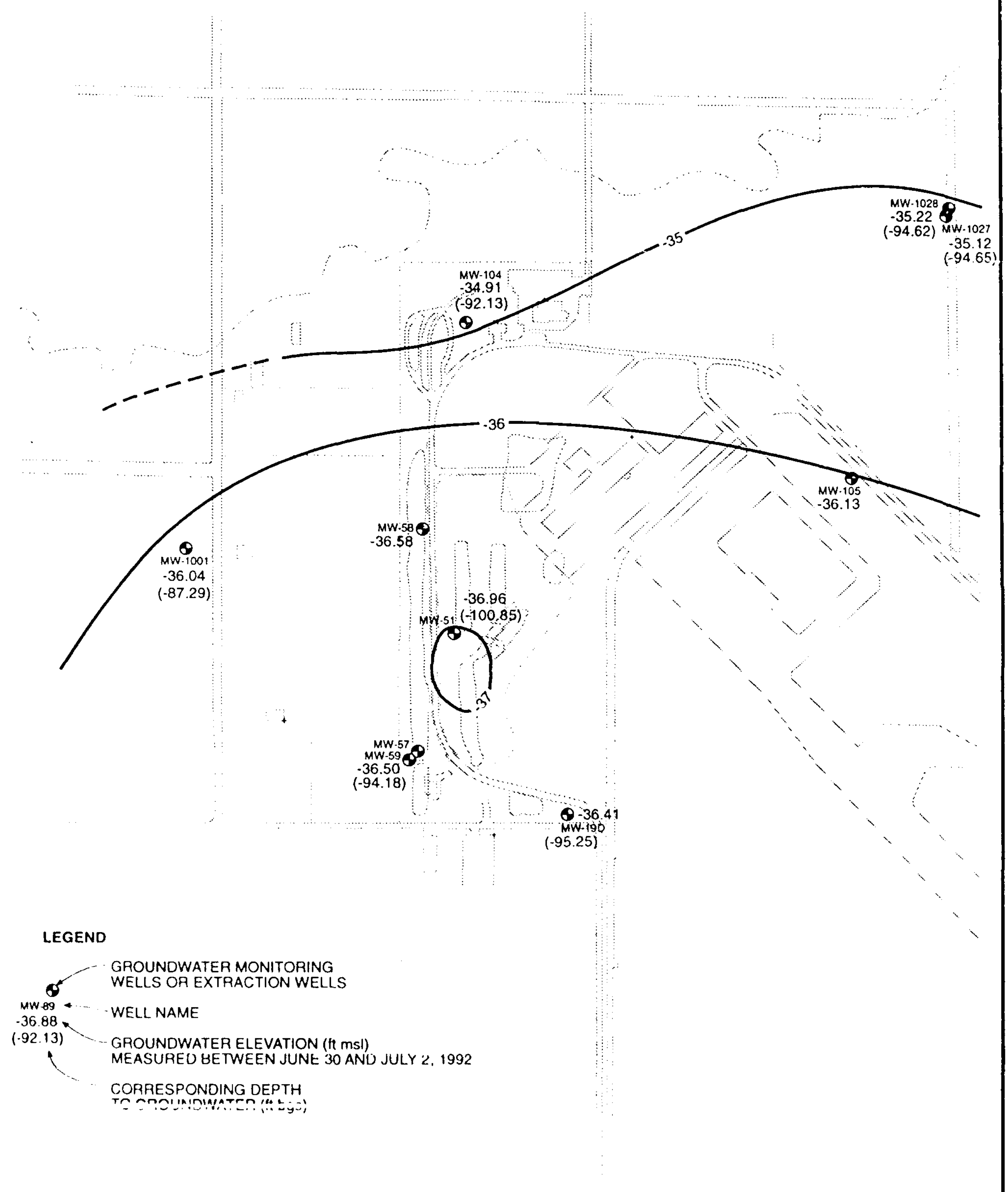
●	GROUNDWATER MONITORING WELLS OR EXTRACTION WELLS
MW-89	WELL NAME
-36.88	GROUNDWATER ELEVATION (ft msl) MEASURED BETWEEN JUNE 30 AND JULY 2, 1992
(-91.81)	CORRESPONDING DEPTH TO GROUNDWATER (ft bgs)
MW-241*	WELL INSTALLED IN JUNE 1993

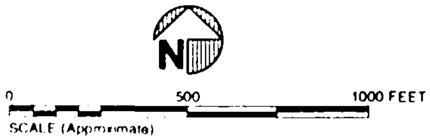


RDD1477 31)

FIGURE 3-12
A ZONE GROUNDWATER LEVELS JULY 1992
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



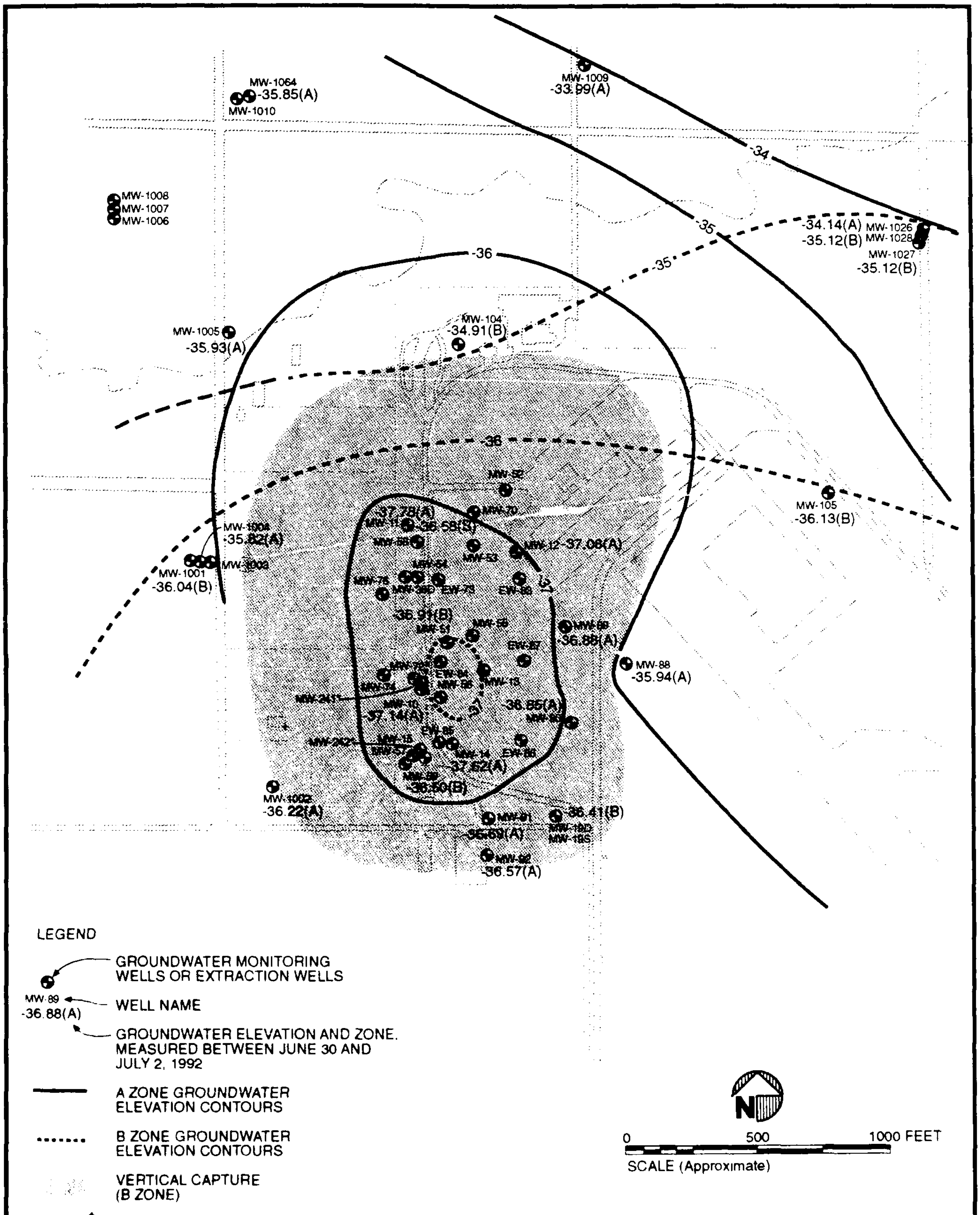


RDD1177 329

FIGURE 3-13
B ZONE GROUNDWATER LEVELS JULY 1992

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



MW-241* WELL INSTALLED IN JUNE 1993

FIGURE 3-14
AREA OF UPWARD
GROUNDWATER FLOW JULY 1992
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

3.3.4 Receptors

As identified in the risk assessment (Chapter 5), three different types of receptors have been identified for OU D:

1. **Onsite workers at Building 1093**—McClellan AFB employees that work at Building 1093 have the potential to be exposed to soil gas contamination that migrates from the source areas through the vadose zone and enters Building 1093 through cracks in the foundation.

2. **Offbase residents that use groundwater wells**—When a groundwater problem was first identified at OU D, McClellan AFB placed effected groundwater users on a municipal water supply system to try to minimize residential exposures to the contamination. Some of the groundwater wells may have been reconnected and may be used for sprinkler irrigation purposes. Although direct evidence that this has happened does not exist, persons in contact with this sprinkler water are considered receptors. ATSDR has identified this as a possible pathway since all of the wells have not been abandoned. Several community members asked ATDSR during a public meeting about risks associated with use of groundwater for irrigation.
3. **Offbase residents immediately west of OU D**—There are four residences to the west of OU D that have crawlspaces that can accumulate soil gas contamination as it migrates laterally away from the source areas. McClellan AFB has been monitoring contaminant concentrations in the crawlspaces. The contaminants may migrate into the living spaces from the crawlspaces. Residents that may be exposed to contaminants in crawlspaces and living spaces are also considered receptors.

Chapter 5 provides a detailed discussion of the risks posed to these receptors. At this time, on the basis of the risk assessment, exposure caused by inhalation of VOCs at the surface is not thought to pose a significant risk. Figure 3-15 is a conceptual diagram illustrating the relationship of the three receptor types to the OU D source area.

3.4 Conceptual Model for Operable Unit D

The four elements of the conceptual model (source, media, pathways, and receptors) may now be assembled together to create a working version of a conceptual model for OU D. Figure 3-16 is an illustration of this conceptual model. The cap boundary, estimated maximum lateral extent of vadose zone contamination, estimated zone of influence of the SVE system, and estimated zone of influence of the groundwater extraction system are all shown on the conceptual model figure.

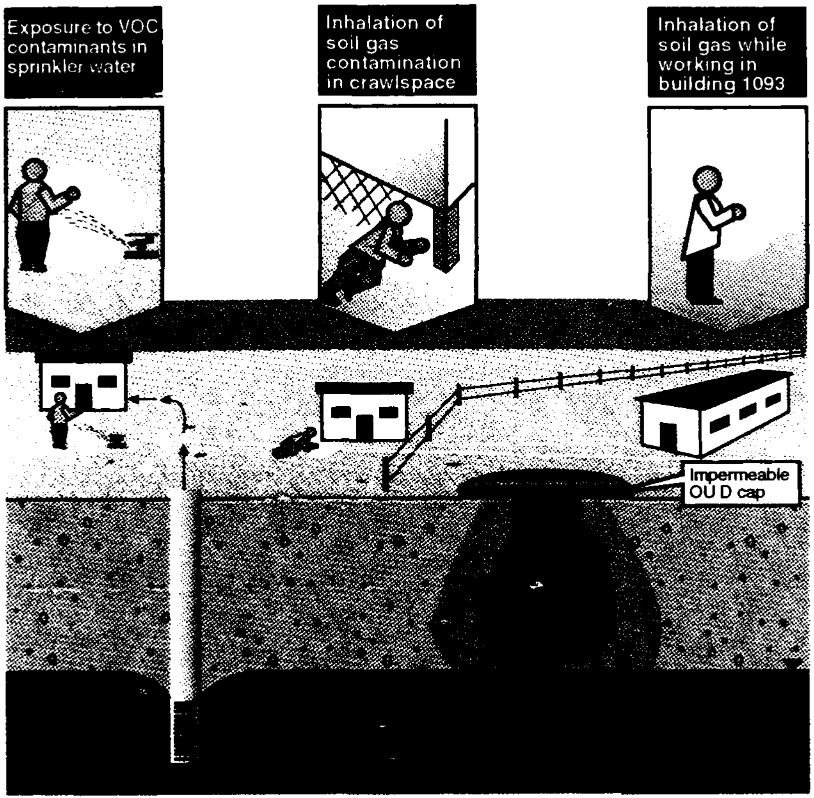


FIGURE 3-15
RECEPTORS AT OPERABLE UNIT D
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

The following notes should be made regarding the conceptual model:

1. The estimated lateral extent of vadose zone VOC contamination is based on VapourT modeling, as described in Appendix J.

2. The estimated zone of influence for the SVE system was taken as 100 feet beyond the cap boundary, derived from oxygen increases measured in vadose zone monitoring wells when the SVE system was turned on. Discussion on these oxygen increases is presented in Appendix C. The Basewide EE/CA for McClellan AFB states that the SVE system at OU D may be impacting the entire area under the cap. However, it is not known if the current SVE system can clean up OU D within a reasonable time frame. As described in Chapter 8, additional data are needed during remedial design to determine the final configuration of SVE wells at OU D.

3. The estimated zone of influence of the groundwater extraction system was based on water level evaluations, as presented in Appendix E.

As can be seen from Figure 3-16, the maximum lateral extent of VOC contamination in the vadose zone extends significantly beyond the cap boundary, and likely exceeds the current zone of influence of the SVE system. The "hot spots" of contamination in the immediate vicinity of the cap area are captured and treated by the SVE system, but some of the VOC contamination does avoid SVE capture. A larger fraction of the total lateral extent of VOC contamination is encompassed by the groundwater extraction system zone of influence. This means that most of the contamination that infiltrates into the groundwater from the vadose zone will be captured and eventually treated by the groundwater extraction system. There may be, however, some areas of the vadose zone contamination that enter the groundwater at lateral distances large enough from the center of the groundwater extraction system to avoid capture. Water quality data have not indicated that this has occurred yet, but monitoring should be continued to check for the possibility.

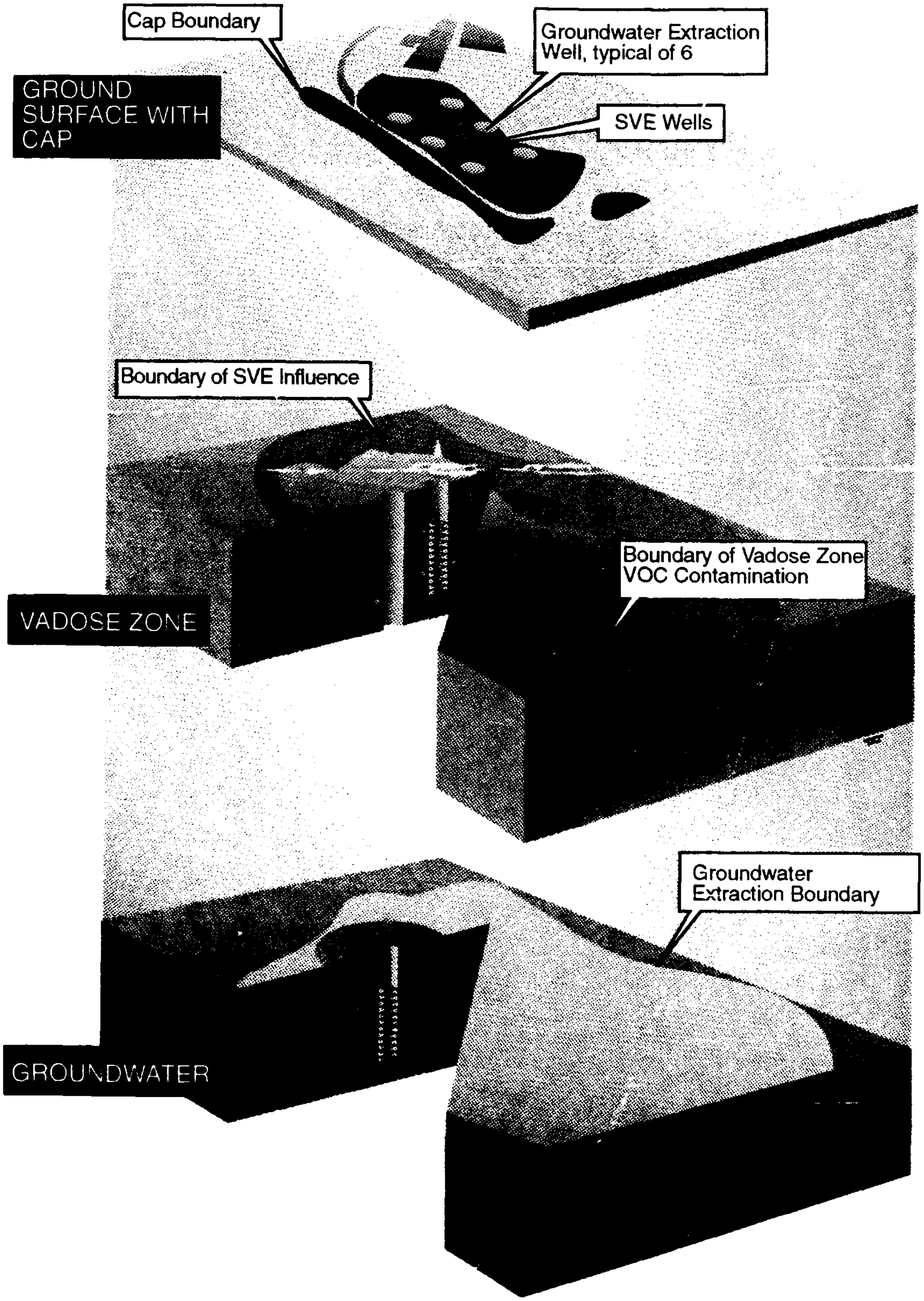


FIGURE 3-16
CONCEPTUALIZATION OF OU D
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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Chapter 4
Analytical Results and Interpretation

Chapter 4
Analytical Results and Interpretation

This chapter provides summary results and interpretations of data collected during remedial investigations within Operable Unit D (OU D) at McClellan Air Force Base (McClellan AFB). Included are summaries and interpretations of residential crawlspace and ambient air data, soil data, shallow soil gas survey data, soil vapor monitoring well (SVMW) data, and groundwater monitoring well data. More detailed data from each investigation are provided in Appendixes A through K.

4.1 Analytical Results

This section summarizes analytical results from ambient air, soil, soil gas, and groundwater collected during fieldwork conducted to support the OU D Remedial Investigation (RI) and historical investigations. Ranges of concentration and contaminant frequencies are given for each contaminant type (*e.g.*, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs)).

4.1.1 Crawlspace and Ambient Air Samples

Detailed summaries of residential crawlspace, ambient air, and domestic groundwater well airspace data, including time series plots, compound-specific comparisons to background levels, and data evaluations, are provided in Appendix A.

Crawlspace and ambient air samples have been collected from the Higgs, Ackman, Hancock, and Story residences during three sampling episodes from 1984 to 1993. Each RI sample was collected over 24 hours using evacuated stainless steel canisters equipped with airflow regulators. The samples were analyzed for low-concentration VOCs to evaluate the levels of airborne contaminant exposure to the residents. The following list summarizes the sampling programs that have been conducted:

- **1992 to 1993** – Crawlspace and ambient air sampling conducted by CH2M HILL during June 1992, September 1992, February 1993, and May 1993. One domestic groundwater well airspace sample was collected in June 1992. The analytical results for this sampling effort are provided in Appendix A, Attachment A3.

- **1986 to 1987** – Crawlspace and background ambient air sampling conducted by McClellan AFB during April 1986, July 1986, October 1986, and January 1987. The analytical results for this sampling effort are provided in Appendix A, Attachment A2

- **1984 to 1985** – Crawlspace and domestic groundwater well airspace sampling conducted by the California Department

> of Health Services (DHS), now the Department of Toxic Substances Control (DTSC), during October 1984, December 1984, and February 1985. Analytical results for this sampling effort are provided in Appendix A, Attachment A1.

Compounds detected during June 1992, September 1992, February 1993, and May 1993 crawlspace and ambient air sampling included several halogenated and aromatic VOCs. Concentrations of VOCs in the crawlspaces and ambient air near the residences were generally similar to the concentrations in the background ambient air (see Appendix A). The most frequently detected compounds included: 1,1,1-trichloroethane (1,1,1-TCA); 1,1-dichloroethylene (1,1-DCE); 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene; 1,4-dichlorobenzene; benzene; carbon tetrachloride; dichlorodifluoromethane (Freon 12); ethylbenzene; methylene chloride; xylenes; styrene; tetrachloroethylene (PCE); toluene, trichloroethylene (TCE); and trichlorofluoromethane (Freon 11).

Vinyl chloride was not detected in any crawlspace or ambient air sample during the 1992 and 1993 sampling efforts. The compound-specific detection limits for vinyl chloride ranged from 0.080 to 0.20 ppbv, except for one ambient air sample collected in June 1992 that had a detection limit of 1.0 ppbv. Vinyl chloride was not found above a detection limit of 0.03 ppbv during the 1984-85 sampling. During the 1986-87 sampling, vinyl chloride was not found above a detection limit of 1.174 ppbv.

Vinyl chloride was not detected in any crawlspace or ambient air sample during the 1992 and 1993 sampling efforts.

Historical data from the 1986-87 and 1984-85 crawlspace and ambient air sampling were generally similar to the data collected in 1992-93. Similar species and concentrations of airborne compounds were detected during each effort. Concentrations detected in crawlspace and ambient air samples generally were less than 1 ppbv, and generally resembled concentrations detected in background samples collected near McClellan AFB, and in background samples collected in the Sacramento area by the California Air Resources Board. Concentrations of 1,1,1-TCA were noticeably elevated from background levels during sampling in 1992. One ambient air sample, collected in June 1992, detected a concentration of 2,600 ppbv which exceed a health-based limit in air (the Preliminary Remediation Goal) of 184 ppbv. A second (duplicate) sample collected at the same time, however, detected a concentration of 57 ppbv; the wide difference between these two results suggests that they should be used with caution. Concentrations of 1,1,1-TCA detected during the two sampling rounds in 1993 resembled background concentrations.

Crawlspace concentrations of VOCs were generally similar to those found in the background ambient air.

Sources of the contaminants detected in ambient air located in offbase areas could originate from lateral migration of soil gas or groundwater from sites under the cap, and subsequent diffusion from soil surfaces near the residences. However, there are other likely sources for the detected contaminants in air. Aromatic hydrocarbons, such as benzene, toluene, xylene, ethylbenzene and trimethylbenzenes, also originate from automobile exhaust. Several of the chlorinated VOCs detected in air, including Freons, 1,1,1-TCA, and methylene chloride could originate systems underlying OU D have occurred in both the A and B Zones. These declines have now nearly resulted in desaturation of the A Zone.

from emissions from permitted industrial sources at McClellan AFB. Evaluation of soil gas contaminant concentrations offbase, presented in Appendix H, suggests that the concentrations detected in air are likely to be related to sources other than lateral migration of soil gas contamination from sites at OU D.

The range of concentrations for contaminants of potential concern (COPCs) in air are given in Figure 4-1. The rationale used in selecting the COPCs is provided in the risk assessment (Chapter 5).

The frequencies of COPCs are depicted in Figure 4-2.

4.1.2 Soil Samples

Vadose zone soil samples have been collected within OU D during three major investigations. These have included a 1984 pre-cap investigation to characterize waste pit and subsurface soil contaminants, a 1991 investigation within Site S to evaluate implementation of soil vapor extraction (SVE), and the 1993 OU D RI. Detailed summaries of the 1993 RI soil data, including sampling techniques, analytical methodologies, and data validation, are provided in Appendix D. Data summaries of the RI data combined with historical data are provided in Attachment D1, Tables D1-1 through D1-8 (refer to Volume 3). The following sections summarize the results of the RI and historical soil analyses conducted within OU D.

Soil samples have been collected and analyzed for several classes of chemical contaminants, including VOCs, SVOCs, total metals, pesticides/polychlorinated biphenyls (PCBs), and dioxins/dibenzofurans. Following are brief synopses of detected soil contaminants:

Soil Volatile Organic Compounds

Several chlorinated and aromatic VOCs have been detected in the soil during the RI and historical investigations. A complete listing of all detected VOCs in soil is provided in Attachment D1, Table D1-2 (Volume 3). Remedial investigation soil VOC data are also discussed and summarized in Appendix D. The ranges of concentrations for VOC COPCs in soil are depicted in Figure 4-3. The COPCs generally are VOCs detected in soil. The VOCs are of concern because they can migrate through the soil and into groundwater or the ambient air. The SVOCs and metals are generally of lesser concern. These contaminants are generally detected under the cap or in deep soil. The SVOCs and metals have less of a tendency to migrate in soil and the cap prevents direct contact. The rationale for selection of the COPCs in soil is discussed further in Chapter 5.

The frequencies of volatile organic COPCs found in RI and historical soil samples are shown on Figure 4-4.

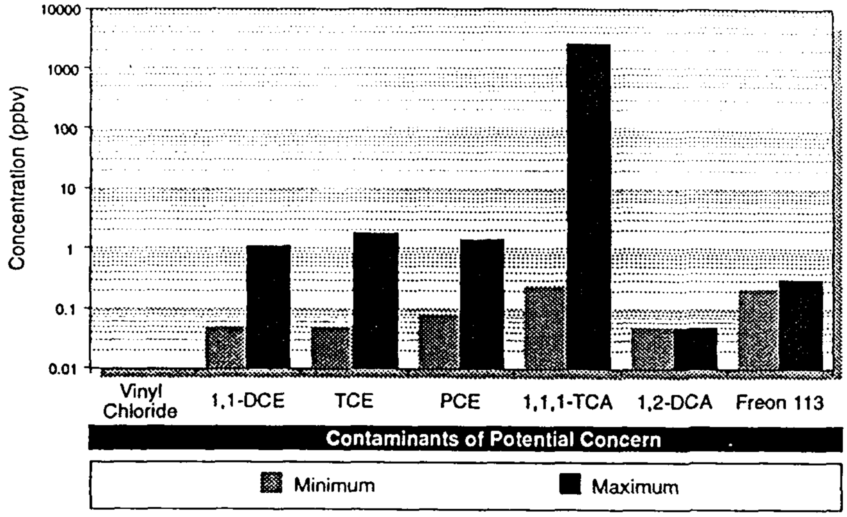

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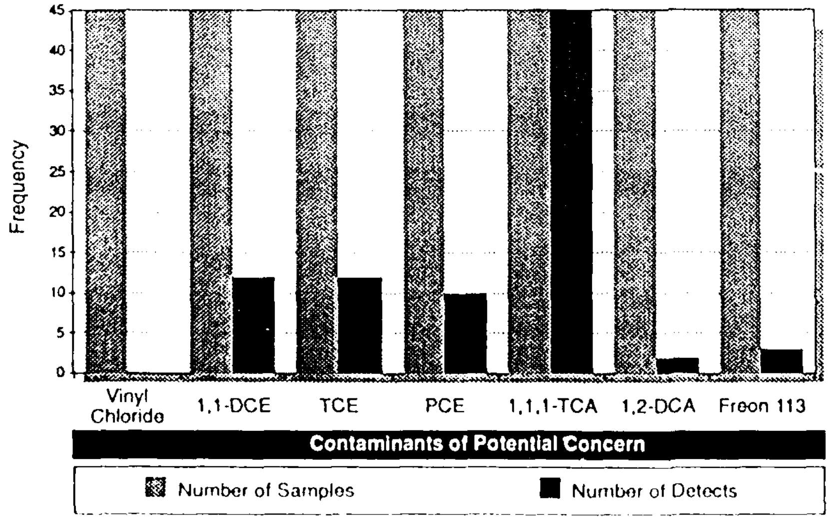
FIGURE 4-1 CONCENTRATIONS OF CONTAMINANTS OF POTENTIAL CONCERN CRAWLSPACE AND AMBIENT AIR SAMPLES JUNE 1992 THROUGH MAY 1993
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



RDD1477_282

FIGURE 4-2 FREQUENCIES OF CONTAMINANTS OF POTENTIAL CONCERN CRAWLSPACE AND AMBIENT AIR SAMPLES JUNE 1992 THROUGH MAY 1993
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

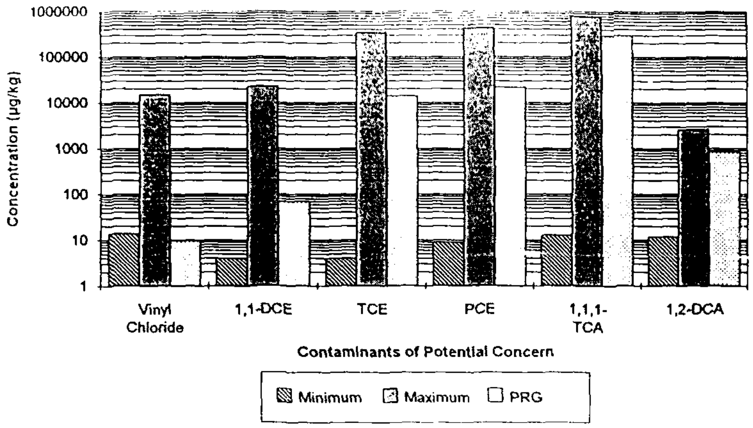


FIGURE 4-3
CONCENTRATIONS OF CONTAMINANTS OF POTENTIALCONCERN SOIL VOCs
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

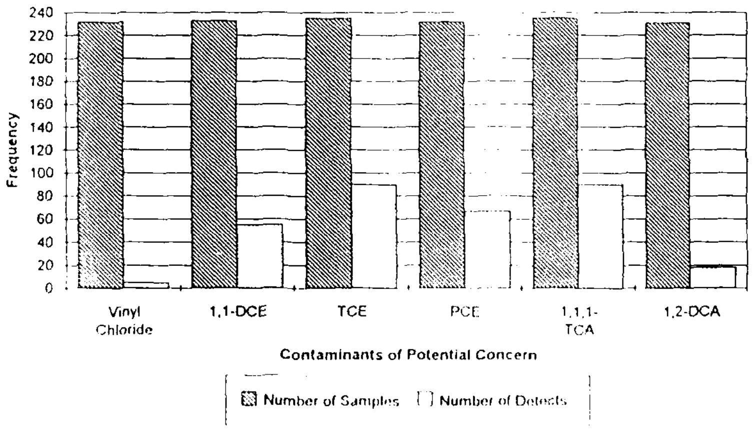


FIGURE 4-4
FREQUENCIES OF CONTAMINANTS OF POTENTIAL CONCERN SOIL VOCs
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Soil Semivolatile Organic Compounds

SVOCs detected in soil during the RI and historical investigations have primarily included phthalates, dichlorobenzene isomers, and polynuclear aromatic hydrocarbons. A complete listing of all SVOCs detected in soil is provided in Attachment D1, Table D1-3 (Volume 3). Remedial investigation soil SVOC data are also discussed and summarized in Appendix D. The ranges of concentrations for SVOC COPCs in soil are depicted in Figure 4-5. As previously discussed, SVOCs are generally of lesser concern than VOCs. The rationale for selection of SVOCs as COPCs in soil is discussed further in Chapter 5.

The SVOCs detected during the RI were limited to trace quantities of di-n-butyl phthalate, di-n-octyl phthalate, and bis(2-ethylhexyl) phthalate. However, these compounds are common laboratory contaminants, often reported during soil analyses. During data validation, seven di-n-butyl phthalate and four bis(2-ethylhexyl) phthalate results were qualified as non-detects because of method blank contamination. Although the remaining phthalate results were not qualified because of method blank contamination, the results are also suspect and likely to be laboratory artifacts.

The frequencies of semivolatile COPCs in soil are shown on Figure 4-6.

Soil Total Metals/Inorganics

Several metals were detected in soil during the RI and historical investigations. A complete listing of all detected metals in soil is provided in Attachment D1, Table D1-5 (Volume 3). Remedial investigation soil metals data are also discussed and summarized in Appendix D.

Soil naturally contains varying levels of metals. Therefore, the detected soil metals data are compared to designated background levels in Figure 4-1 (refer to Section 4.2.2) to distinguish between metals that are probably natural and those that were introduced as contaminants. The source of the listed background levels is the *Consensus Statement on Background Inorganic Constituents in Subsurface Soils at McClellan AFB* (RADIAN, 1993). (For the purpose of comparison with regulatory values, the EPA Region IX Preliminary Remediation Goals (PRGs) are also provided in Table 4-1.)

The metals above background levels detected during the RI and historical investigations are listed in Attachment D1, Table D1-5a (Volume 3). Remedial investigation soil metals above background levels are listed in Table D-6B, page D-33. The ranges of metals concentrations above background levels and the corresponding background limits are depicted in Figure 4-7.

The frequencies of metals detected above background levels are shown on Figure 4-8.

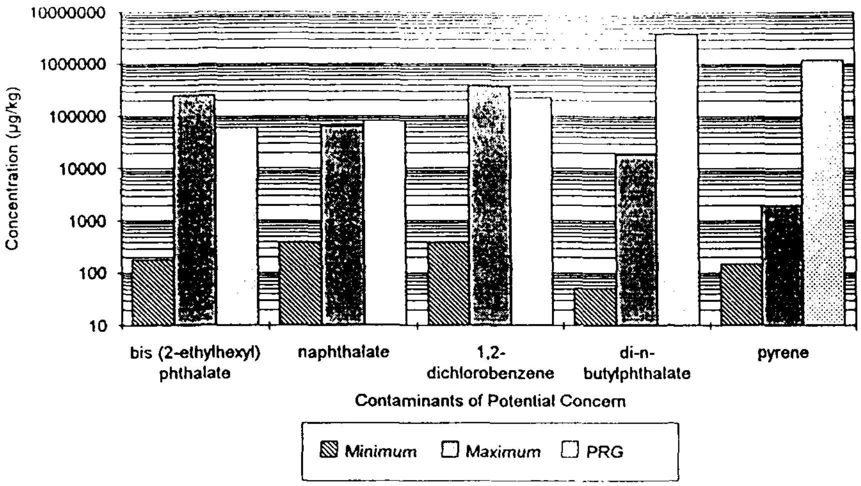


FIGURE 4-5
CONCENTRATIONS OF CONTAMINANTS OF POTENTIAL CONCERN SOIL SVOCs
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

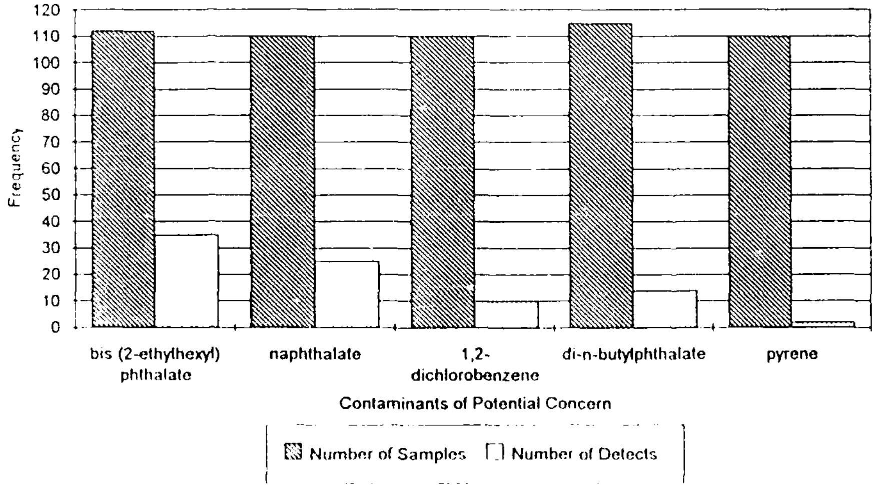


FIGURE 4-6
FREQUENCIES OF CONTAMINANTS OF POTENTIAL CONCERN SOIL SVOCs
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

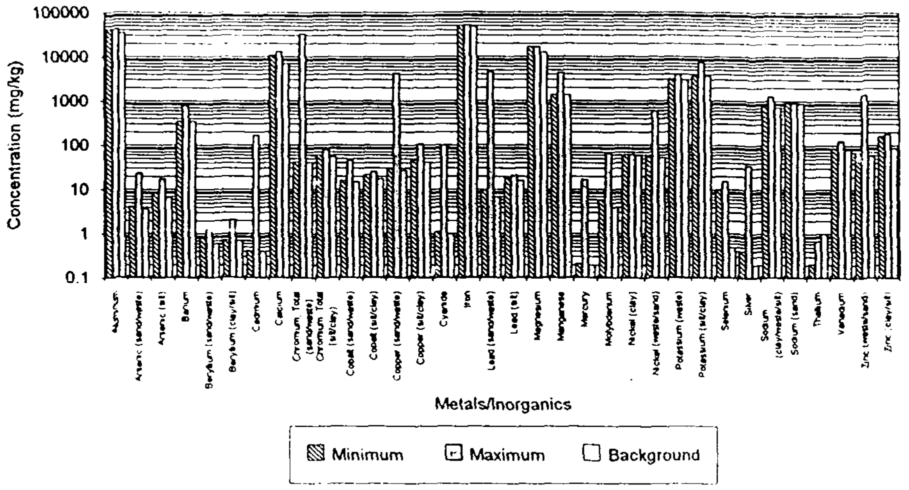


FIGURE 4-7
CONCENTRATIONS OF TOTAL METALS ABOVE BACKGROUND

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

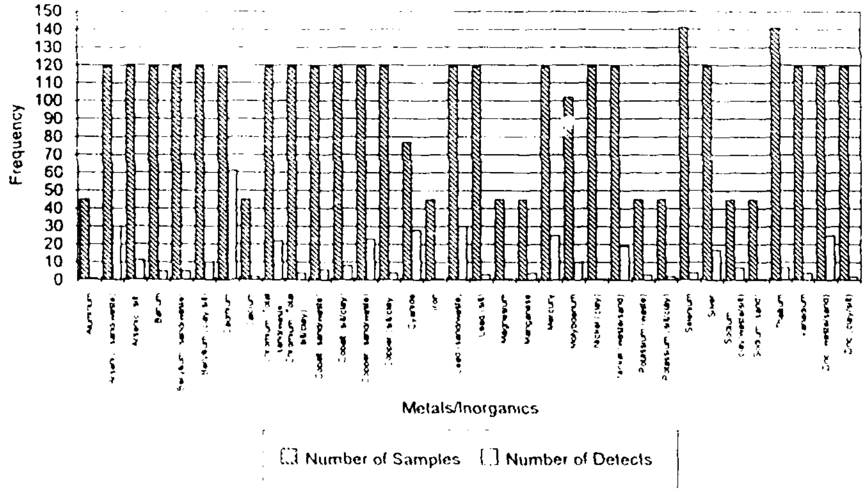


FIGURE 4-8
FREQUENCIES OF TOTAL METALS ABOVE BACKGROUND

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Soil Pesticides/Polychlorinated Biphenyls

Only limited quantities of pesticides/PCBs have been detected in the vadose zone soil at OU D. Pesticides and PCBs were not detected in any 1993 RI soil sample. Historically, pesticides/PCBs were detected in soil underlying the cap within Site S. The detected compounds included: Arochlor-1260, -1254, -1016, -1221, -1232, -1242, -1248; Heptachlor; alpha-, beta-, delta-, and gamma-BHC (benzenehexachloride); p-p'-DDD ("DDT"), p-p'-DDE, Aldrin, and Endrin. Historical pesticide/PCB data summaries are provided in Attachment D1 (Volume 3).

Soil Dioxins/Dibenzofurans

Soil dioxins and dibenzofurans detected during the RI and historical investigations within Site S have included limited quantities of polychlorinated dibenzodioxin and dibenzofuran isomers (PCDDs), including: octachlorodibenzo-p-dioxin (OCDD), heptachlorinated dibenzo-p-dioxins (total HpCDDs), hexachlorinated dibenzofurans (total HxCDFs), heptachlorinated dibenzofurans (total HpCDFs), and octachlorodibenzofuran (OCDF). A complete listing of all detected soil dioxins and dibenzofurans is provided in Attachment D1, Table D1-4 (Volume 3). Remedial investigation soil dioxins/dibenzofurans data are also discussed and summarized in Appendix D. The ranges of concentrations for the detected dioxins are depicted in Figure 4-9.

The soil data reported may not be representative of the actual dioxin contamination present within OU D. Evaluations of the dioxin/dibenzonfuran RI data indicate that much, but not all, of the reported contamination with OCDD is associated with reported concentrations of the same congener in method blank samples. Therefore, OCDD detected in the field samples is most likely a consequence of laboratory contamination. Apparent detections of other dioxins and furans may also be the result of analytical interferences and/or present as common laboratory contaminants.

All dioxin and furan congeners are conservatively assumed to be COPCs. The toxicological data that are available for TCDDs and TCDFs are not complete. However, a considerable body of toxicological data exists for 2,3,7,8-TCDD that indicates a wide range of adverse health effects at very low doses. Fewer data are available for 2,3,7,8-TCDF, but they are sufficient to form the basis of a belief that it is similar in its toxicological properties to 2,3,7,8-TCDD. Relatively little is known about the toxicology of the higher chlorinated PCDDs and PCDFs (*i.e.*, penta- through octachlorinated PCDD and PCDF). Some data suggest that some of the penta-, hexa-, and hepta-PCDD and PCDF isomers are also hazardous.

The frequencies of detected soil dioxins are shown on Figure 4-10.

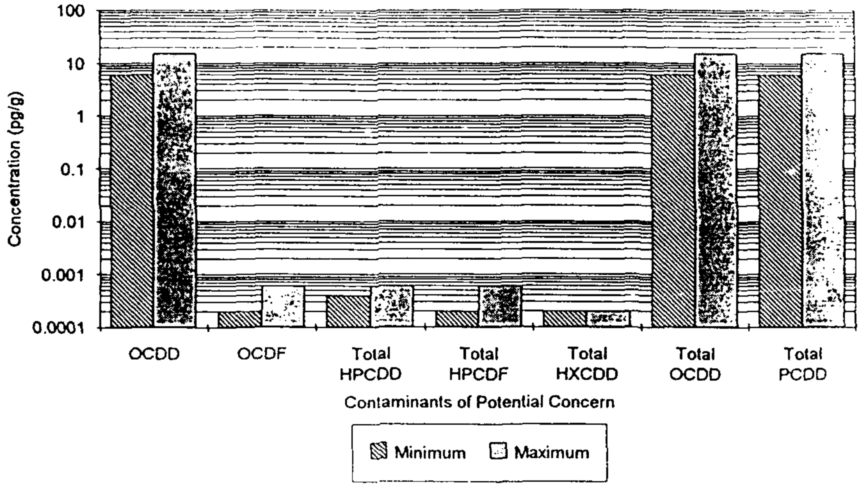


FIGURE 4-9 CONCENTRATIONS OF SOIL DIOXINS OF POTENTIAL CONCERN

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

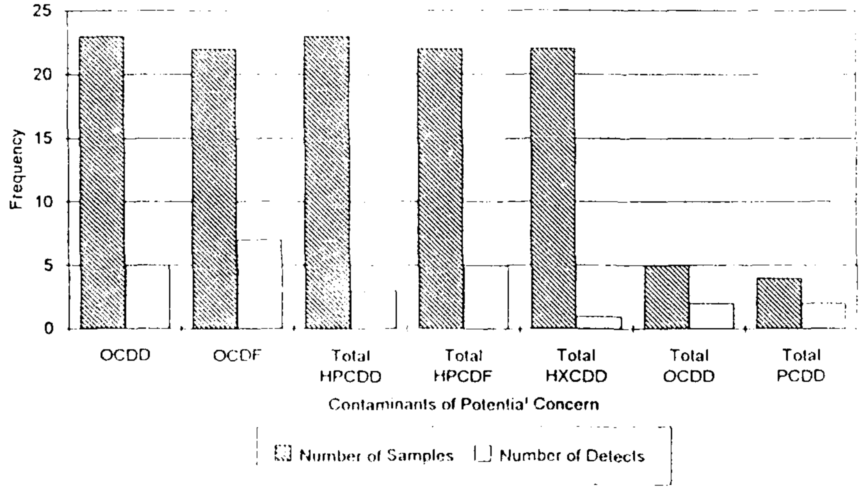


FIGURE 4-10 FREQUENCIES OF SOIL DIOXINS OF POTENTIAL CONCERN

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

4.1.3 Soil Gas Samples

Detailed summaries of RI soil gas sampling techniques, analytical methodologies, and data are provided in Appendixes B and C.

Vadose zone soil gas samples were collected during three investigations between June 1992 and June 1993. These three investigations included:

- **June 1993**—Sampling of 12 SVMWs installed as part of the RI, 9 previously existing SVMWs, and 5 dry or partially submerged groundwater monitoring wells. The nine previously installed SVMWs had previously been sampled in June 1992, September 1992, and February 1993 (refer to Appendix C).
- **May to June 1993**—Downhole soil gas samples were collected while advancing borings for the installation of RI SVMWs and groundwater monitoring wells (refer to Appendix C).
- **September to October 1992**—A shallow soil gas survey collected soil gas samples from onbase and offbase locations around the perimeter of the OU D cap (refer to Appendix B).

Additionally, summaries of soil gas data from pre-SVE operations within Site S are included. The Site S data provide VOC contaminant characterization in source areas not represented by other soil gas samples.

Remedial Investigation Soil Vapor Monitoring Well Samples

The SVMWs sampled during the RI included C2-M, C2-D, C4-S, C4-M, C4-D, C6-S, C6-M, C6-D, C7-S, C7-M, and C7-D. Soil vapor wells SVDMW-1 though SVDMW-9 were also sampled. Dry or partially submerged groundwater monitoring wells that were sampled included MW-14, MW-90, MW-106, MW-107, and MW-1002. Sampling locations are shown in figures provided in Appendix C.

Compound molecular weights are used to convert soil gas concentrations from μg/l to ppbv.

For the following contaminants, a conversion from 1 μg/l to pppv would yield the following:

- *Vinyl chloride—391.2*
- *1,1-DCE—252.2*
- *Freon 113—130.5*
- *1,2-DCA—247.1*
- *1,1,1-TCA—183.3*
- *TCE—186.2*
- *PCE—147.4*

Soil gas concentrations are given in units of micrograms per liter (μg/l). Unlike concentrations in water, contaminants in soil gas cannot be converted from μg/l to parts per billion (ppb) by simply changing the units. Conversion of the gas-phase concentrations of individual compounds requires application of the Universal Gas Law. Compound molecular weights are used in the gas law equation to calculate parts per billion by volume (ppbv) concentrations from μg/l concentrations.

Figure 4-11 shows the ranges of concentrations for VOC COPCs in soil gas detected in the SVMWs and dry groundwater wells sampled in June 1993. These data provide a "snapshop" of the contaminant conditions that existed during the RI.

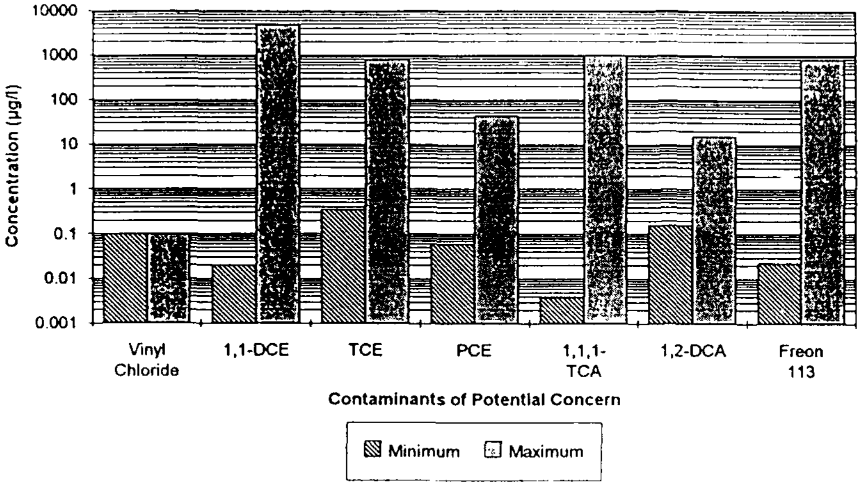


FIGURE 4-11
CONCENTRATIONS OF
CONTAMINANTS OF
POTENTIAL CONCERN
SOIL VAPOR
MONITORING WELLS
JUNE 1993
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

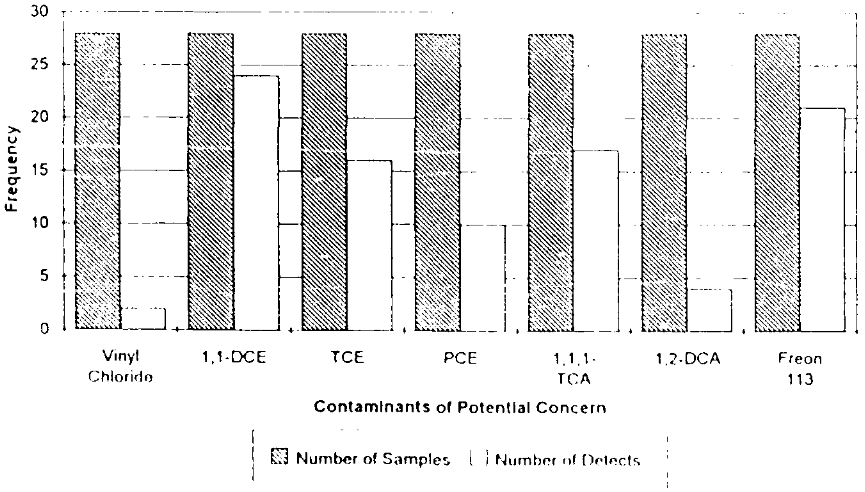


FIGURE 4-12
FREQUENCIES OF
CONTAMINANTS OF
POTENTIAL CONCERN
SOIL VAPOR
MONITORING WELLS
JUNE 1993
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

The frequencies of VOC COPCs in soil gas collected from SVMWs are shown on Figure 4-12.

Time series plots of representative COPCs in soil gas, 1,1-DCE, and TCE that were detected in soil vapor wells SVDMW-1 through SVDMW-9 are shown in Figures 4-13, 4-14, and 4-15. These COPCs in soil gas were selected for plotting time series primarily because of the completeness of their data sets. There were a sufficient number of detected concentrations to develop meaningful data plots. While other VOC COPCs in soil gas were also detected between June 1992 and June 1993, the data are less complete.

The data represented in Figures 4-13, 4-14, and 4-15 are subject to several uncertainties and qualifications. In particular, the dynamic nature of the soil gas contaminant levels is important to note. During the sampling period, the SVE pilot plant within Site S was in intermittent operation at varying extraction flow rates, pressures, and durations. Between March and April 1993, approximately 24,000 pounds of VOCs were removed. Because of the SVE system, the subsurface conditions within OU D are highly disturbed. Operation of the system induces complex movements of soil gas contaminants, generally towards the extraction well(s) along preferential pathways (*e.g.*, sand layers). Additionally, some soil gas contaminants are more mobile than others under the same conditions. The variable nature of the data may reflect the changing distribution of contaminants in subsurface under the influence of the SVE plant. Also during SVE operations, the subsurface environment is changed from states of reduced oxygen content to those of higher oxygen content. The degree of this effect is variable and depends largely on the distance from the extraction well and depth below the ground surface. The changing oxygen levels may affect the production of certain chemical degradation products (*e.g.*, vinyl chloride) that favor reduced oxygen environments.

Apparent fluctuations in the levels of some contaminants (*e.g.*, TCE) may also be the consequence of relatively low concentrations and variable detection limits. For example, in June 1992 and June 1993, elevated detection limits resulted when high concentrations of other VOC analytes were present. These other compounds required sample dilution to quantify. This dilution masked the relatively low concentrations of TCE that were likely present.

Downhole Soil Gas Samples

Downhole soil gas samples were collected while advancing soil borings C2, C3, C4, C6, C7, MW-237, MW-240, MW-241, and MW-242. The sample locations are shown in figures provided in Appendix C. Figure 4-16 shows the ranges of concentrations of VOC COPCs in soil gas.

The frequencies of VOC COPCs collected during downhole soil gas sampling are shown on Figure 4-17.

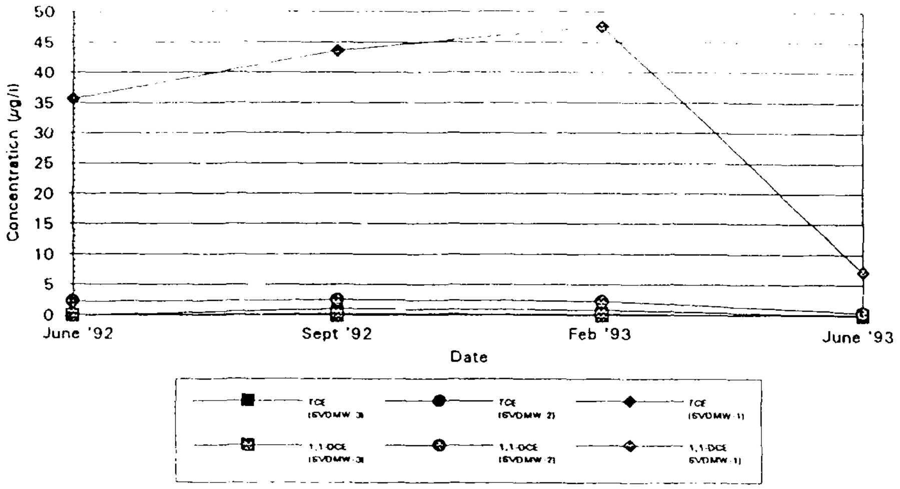


FIGURE 4-13
TIME SERIES PLOT FOR 1,1-DCE AND TCE SOIL VAPOR MONITORING WELLS SVDMW-1, SVDMW-2, SVDMW-3

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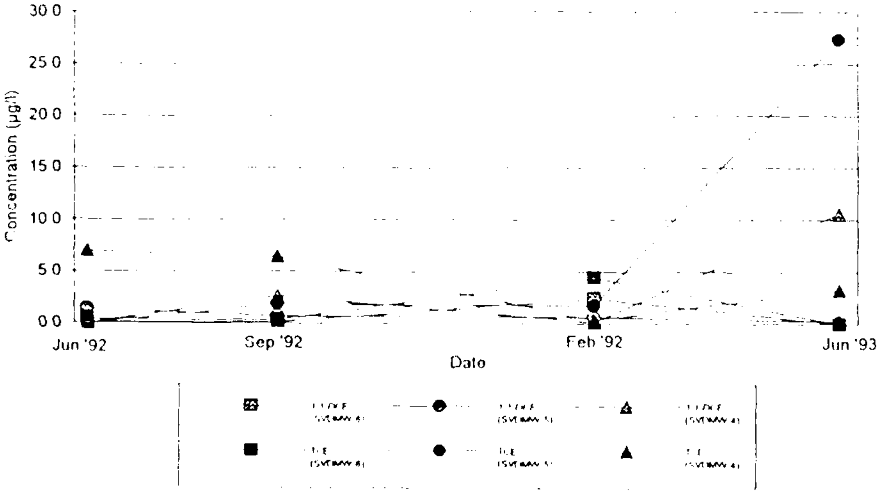

FIGURE 4-14
TIME SERIES PLOT FOR 1,1-DCE AND TCE SOIL VAPOR MONITORING WELLS SVDMW-4, SVDMW-5, SVDMW-6

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McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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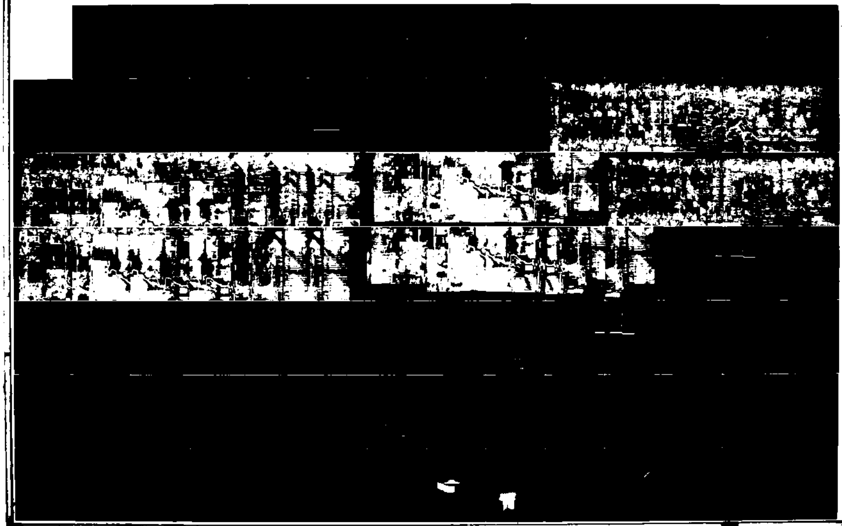

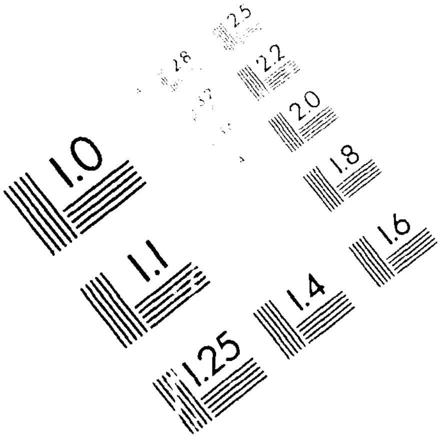

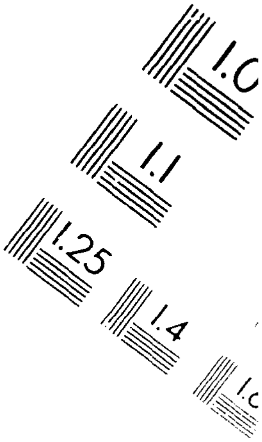

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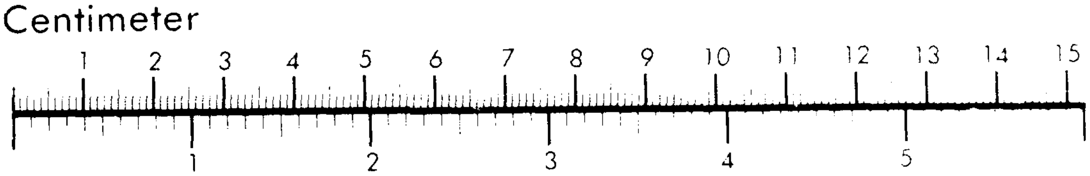

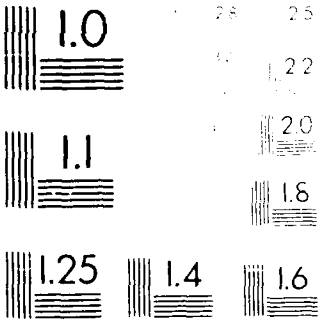

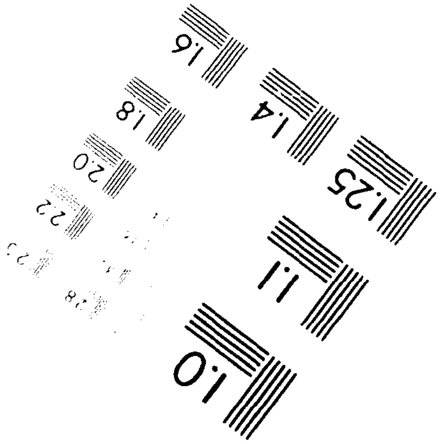

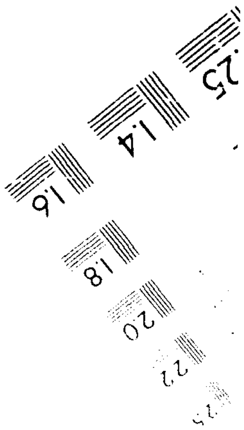

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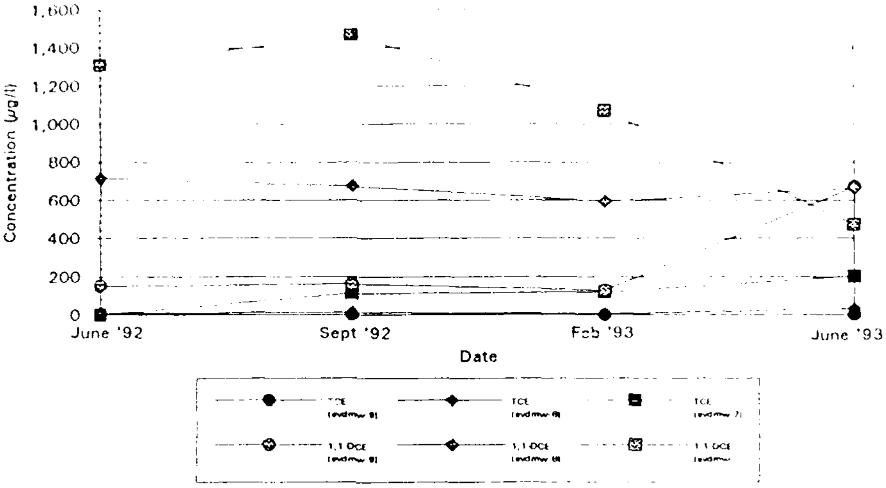


FIGURE 4-15
TIME SERIES PLO
1,1,-DCE AND TCE
VAPOR MONITORI
WELLS SVDMW-7,
SVDMW-8, SVDMW
OPERABLE UNIT D
McCLELLAN AIR FORCE BAS
SACRAMENTO, CALIFORNIA

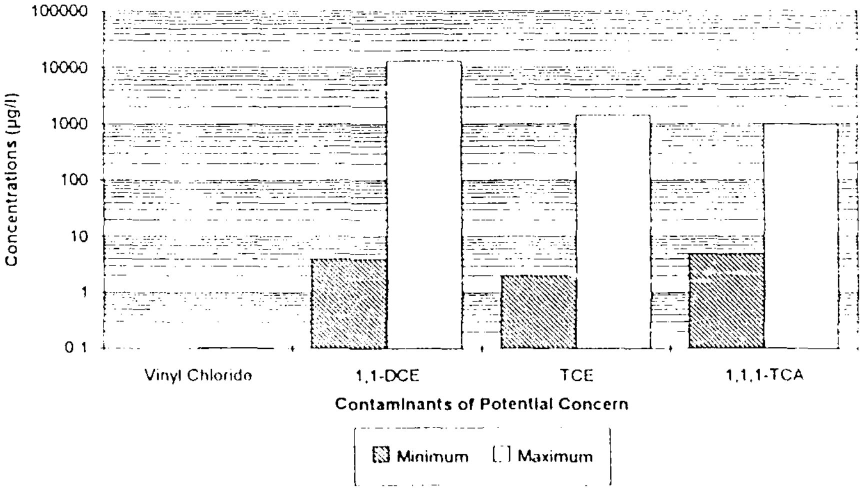


FIGURE 4-16
CONCENTRATION
CONTAMINANTS O
POTENTIAL CONC
DOWNHOLE SOIL
MAY/JUNE 1993
OPERABLE UNIT D
McCLELLAN AIR FORCE BAS
SACRAMENTO, CALIFORNIA

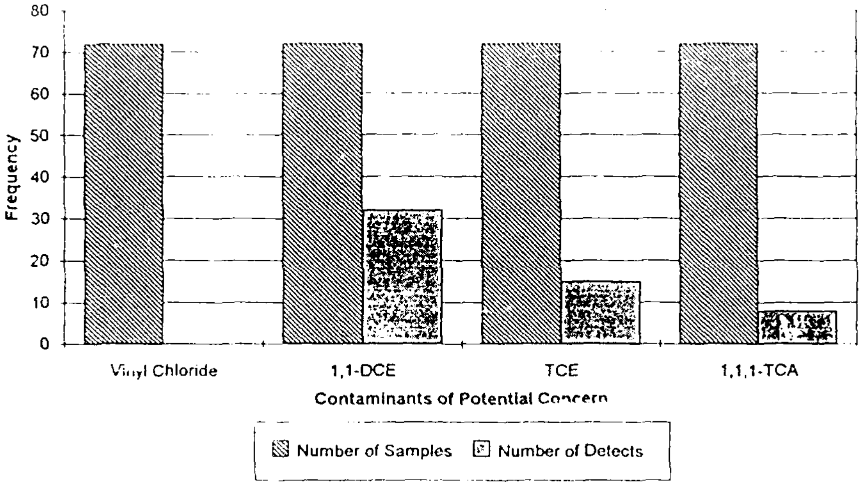


FIGURE 4-17
FREQUENCIES OF CONTAMINANTS OF POTENTIAL CONCERN DOWNHOLE SOIL GAS MAY/JUNE 1993
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Shallow Soil Gas Samples

Figure 4-18 shows the ranges of concentrations for VOC COPCs in soil gas encountered during the shallow soil gas survey conducted in September and October 1992 (refer to Appendix B).

The majority of samples were analyzed at an onsite laboratory using gas chromatography (GC) methods. Additional samples were also collected for confirmation analyses using EPA Method TO-14 and GC/mass spectrometry (GC/MS). When compared to the onsite laboratory results for the same location, the confirmation sample results are generally higher for the same target analyte. More extensive descriptions and comparisons of the onsite and offsite laboratory data are provided in Appendix B, Attachment B1, Table B1-1.

The frequencies of VOC COPCs in soil gas collected during shallow soil gas sampling are shown on Figure 4-19.

The areal extent of soil gas VOCs is represented by conceptual plots of 1,1-DCE contamination at three depth intervals. The contaminant 1,1-DCE was selected as a representative compound because of three primary factors:

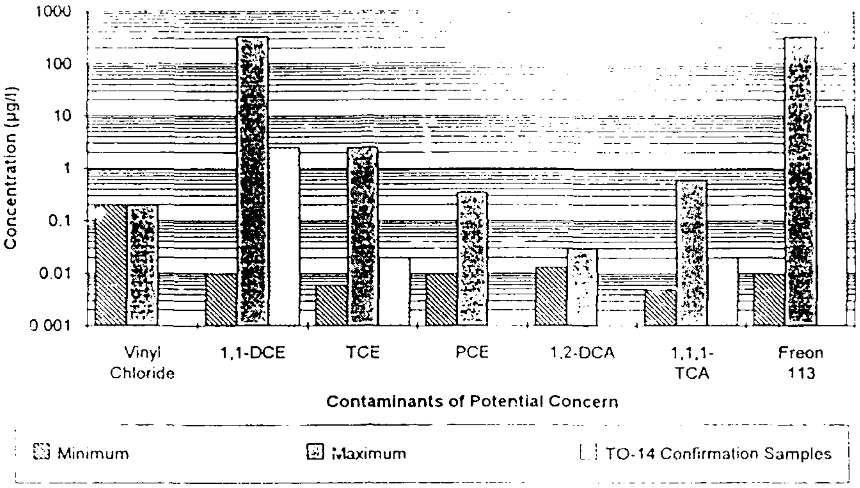


FIGURE 4-18
CONCENTRATIONS C
CONTAMINANTS OF
POTENTIAL CONCEF
SHALLOW SOIL GAS
SEPTEMBER/OCTOB
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

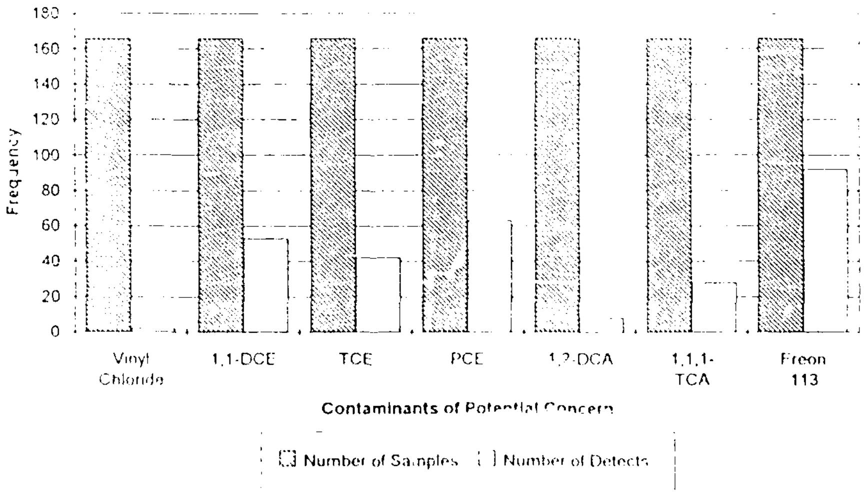


FIGURE 4-19
FREQUENCIES OF
CONTAMINANTS OF
POTENTIAL CONCEI
SHALLOW SOIL GAS
SEPTEMBER/OCTOE
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

- **Frequency of occurrence**—The most frequently detected soil gas contaminant within OU D is 1,1-DCE.

- **Mobility**—Relatively high vapor pressure and Henry's constant imply a high vapor phase mobility for 1,1-DCE (refer to the conceptual model in Chapter 3 and contaminant transport modeling presented in Appendix J).

- **Risk**—1,1-DCE was identified as a COPC in soil gas in the OU D risk assessment (refer to Chapter 5).

Figures 4-20, 4-21, and 4-22 show the estimated extent of 1,1-DCE in designated shallow, medium, and deep monitoring zones, respectively.

4.1.4 Groundwater Samples

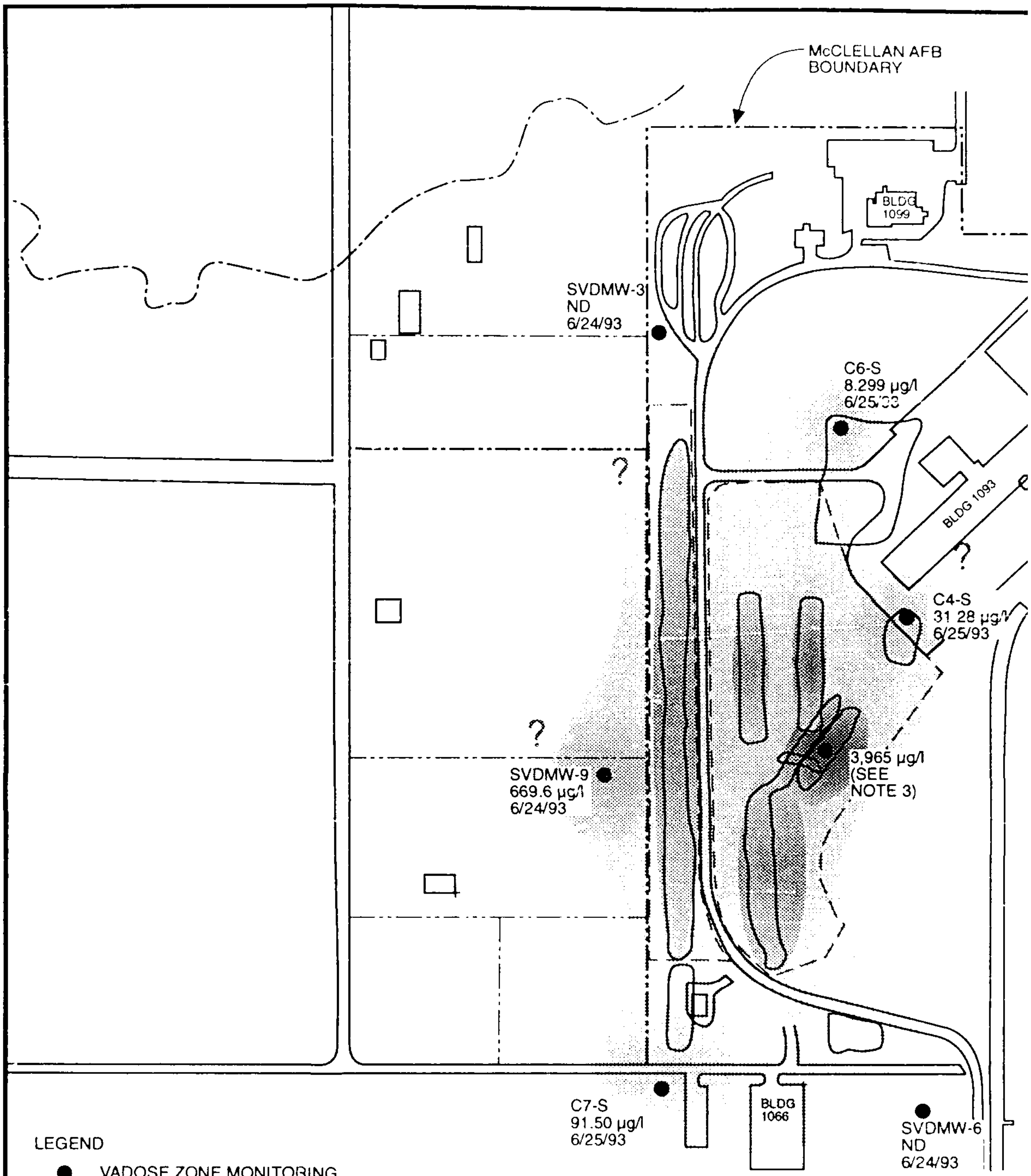
Detailed summaries of groundwater monitoring well and in situ (*i.e.*, Hydropunch) groundwater sample data are provided in Appendix E. 1992

The groundwater beneath OU D contains a wide variety of contaminants. The contamination is concentrated in the area beneath the cap. The groundwater contamination is characterized as either VOC contamination or non-VOC contamination. The VOC contaminants included halogenated (*e.g.*, vinyl chloride, 1,1-DCE, TCE) and aromatic compounds (*e.g.*, benzene). Historically, concentrations of VOCs in the tens of parts per million range have been measured from groundwater samples taken from beneath the cap. The non-VOC contamination has consisted of SVOCs, pesticides or PCBs, and metals. During the RI, samples taken from extraction wells and monitoring wells beneath the cap were also analyzed for dioxins/dibenzofurans. Dioxin/dibenzofuran compounds are also considered non-VOCs. Groundwater samples for metals analyses were not collected during the RI. A description of the extent of VOC and non-VOC contamination follows.

Groundwater Volatile Organic Compounds

VOCs are the most widespread contaminant throughout the OU groundwater.

VOCs are the most widespread contaminant throughout the OU D groundwater. From a summary of historical groundwater sampling results, TCE, 1,1-DCE, and 1,1,1-TCA are the most widely detected VOCs and are identified as the contaminants of concern within the groundwater. The criteria for selection of these compounds are provided in Appendix H. Groundwater VOC concentrations outside of the area of the cap are generally less than 5 μg/l in the A and B Zones. Monitoring wells MW-237 and MW-240 were installed downgradient of the OU D cap area during the RI. These wells were installed as replacement wells 1992 for MW-1002 and MW-106, respectively. Those wells had become dry because of the regional decline in water levels. Toluene was detected in samples from Well MW-237 at 2 μg/l. Toluene was the only VOC detected in the groundwater samples from MW-237 and MW-240.



LEGEND

● VADOSE ZONE MONITORING WELL LOCATION

? EXTENT OF CONTAMINATION NOT DELINEATED BY DATA

ND NONDETECT

NOTE:

1. DARKER SHADING INDICATES HIGHER CONCENTRATIONS.
2. SHALLOW MONITORING ZONE EXTENDS FROM APPROXIMATELY GROUND SURFACE TO 33 FEET BGS (Approximately 24 feet mean sea level elevation)
3. AVERAGE CONCENTRATION AT SITE S (Table 2, Monthly Operations Reports, Preoperations SVE Treatability Investigation, Sites, OU D, CH2M HILL, March 1993)

0 300 600

SCALE (Approximate)

FIGURE 4-20
1,1-DCE CONCENTRATIO
SHALLOW DEPTH
MONITORING ZONE

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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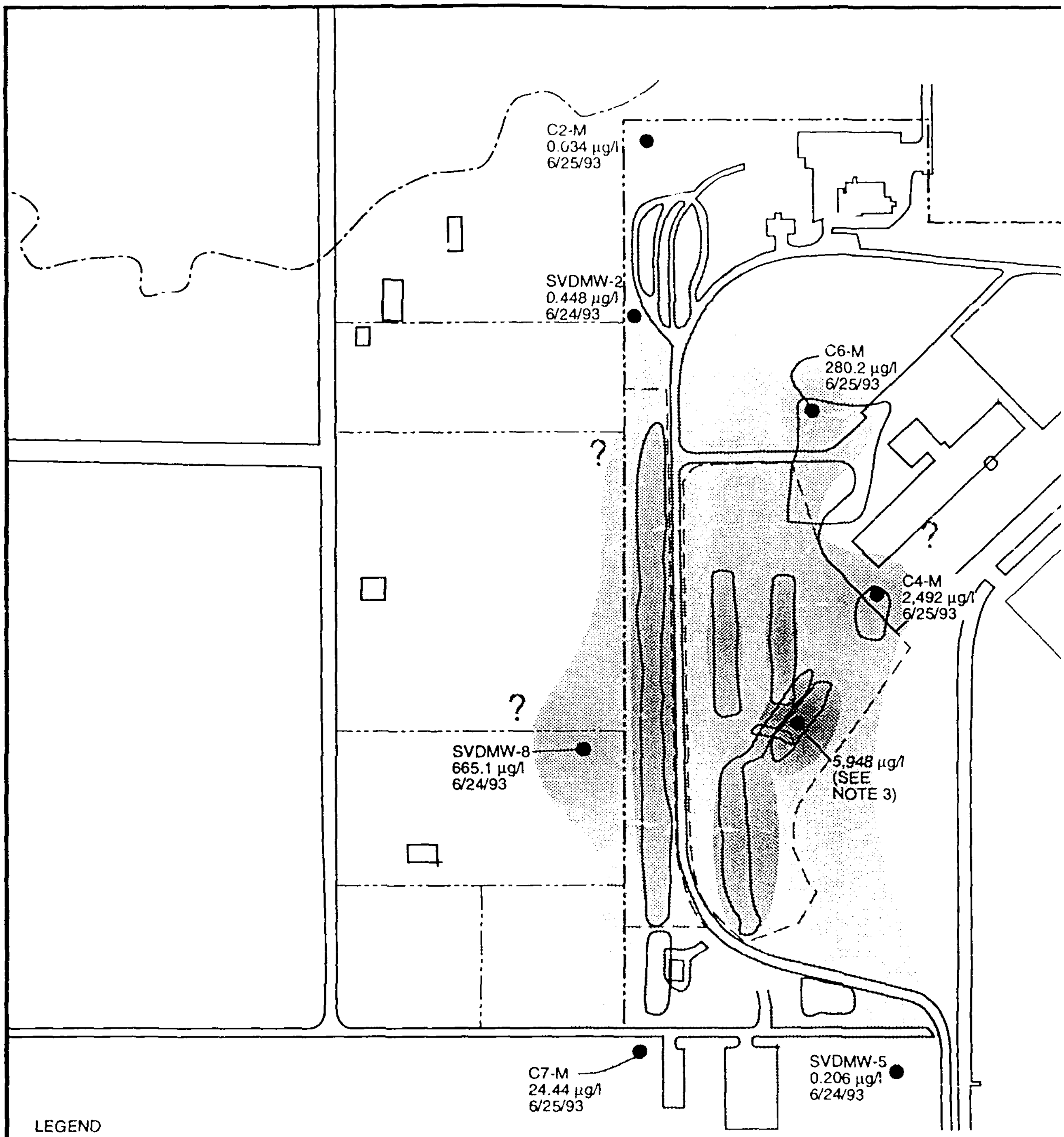


LEGEND

●	VADOSE ZONE MONITORING WELL LOCATION
?	EXTENT OF CONTAMINATION NOT DELINEATED BY DATA
ND	NONDETECT

N

0 300 600 FEET

SCALE (Approximate)

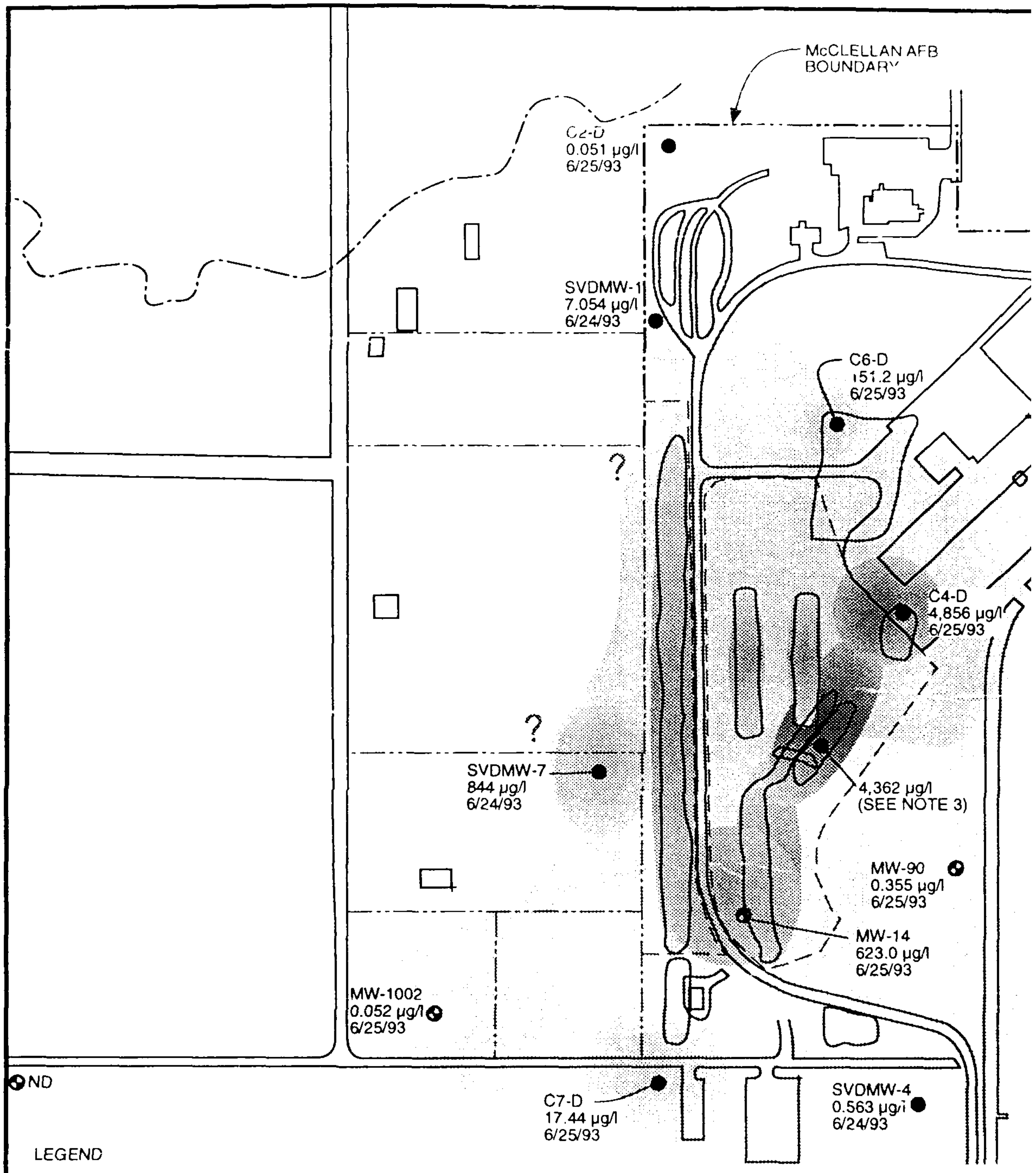
NOTE:

1. DARKER SHADING INDICATES HIGHER CONCENTRATIONS.
2. MEDIUM DEPTH MONITORING ZONE EXTENDS FROM APPROXIMATELY 36 TO 75 FEET BGS (24 TO -15 feet mean sea level elevation)
3. AVERAGE CONCENTRATION AT SITE S (Table 2, Monthly Operations Reports, Preoperations SVE Treatability Investigation, Sites, OU D, CH2M HILL, March 1993)

RDD1477 100

FIGURE 4-21
1,1-DCE CONCENTRATIONS
MEDIUM DEPTH MONITORING ZO
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



LEGEND

● VADOSE ZONE MONITORING WELL LOCATION

? EXTENT OF CONTAMINATION NOT DELINEATED BY DATA

ND NONDETECT

N

0 300 600 F

SCALE (Approximate)

NOTE:

1. DARKER SHADING INDICATES HIGHER CONCENTRATIONS.
2. DEEP MONITORING ZONE EXTENDS FROM APPROXIMATELY 75 TO 105 FEET BGS (-15 TO -45 feet mean sea level elevation)
3. AVERAGE CONCENTRATION AT SITE S (Table 2, Monthly Operations Reports, Preoperations SVE Treatability Investigation, Sites, OU D, CH2M HILL, March 1993)

FIGURE 4-22
1,1-DCE CONCENTRAT
DEEP MONITORING Z
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1477.101

CH2M HILL

The extent of VOC contamination in the A and B Monitoring Zones is shown on Figure 4-23. The VOC contaminant data from the most recent sampling efforts are provided on Figure 4-24. Similar data for non-VOCs are provided in Figure 4-25. (Figures 4-24 and 4-25 are provided at the end of this chapter.)

Groundwater Semivolatile Organic Compounds

In general, SVOCs are not widely distributed throughout the OU D groundwater. However, SVOCs were detected in trace amounts from several wells within or near the cap.

SVOCs are not widely distrib throughout the OU D ground-water.

The SVOCs detected during the RI included 1,2-dichlorobenzene, bis(2-ethylhexyl) phthalate, and di-n-butyl phthalate. However, the phthalate detections are suspect because of possible laboratory contamination and may not represent actual site conditions.

Historically, SVOCs have been detected in samples from wells more frequently than dioxins/dibenzofurans and pesticides/PCBs combined. The most frequently detected SVOCs have included bis(2-ethylhexyl) phthalate, di-n-butylphthalate, and phenol.

Groundwater Pesticides/Polychlorinated Biphenyls

Pesticide and PCB compounds do not have a wide distribution throughout the groundwater within OU D.

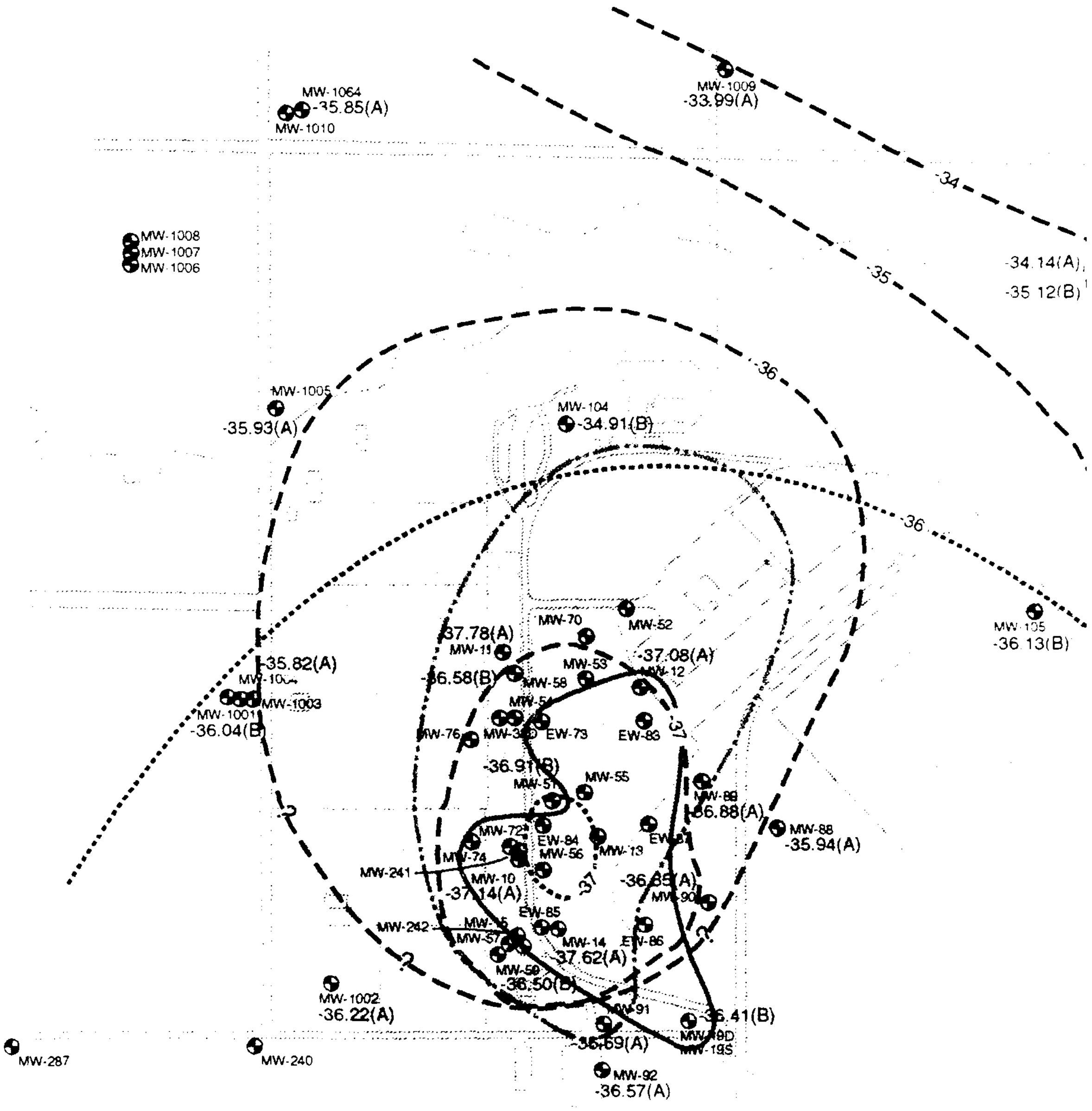
Pesticides and PCBs were not detected in groundwater samples collected during the RI.

Historically, pesticides have been detected in four monitoring wells within OU D. Pesticides have not been detected in groundwater samples from OU D wells since September 1984.

Groundwater Dioxins/Dibenzofurans

During RI sampling, samples from the extraction wells and existing and new monitoring wells were analyzed for dioxins. Dioxin compounds were only detected in groundwater originating from wells within the cap. The maximum detected value of dioxins in groundwater was less than 189 pg/l of OCDD in a sample from Well MW-91. Dioxin compounds were detected in two of the six extraction wells at levels below that found in MW-91.

The reported groundwater dioxin data may not be representative of the actual dioxin contamination within OU D. Evaluations of the dioxins/dibenzofurans RI data indicate that the detected dioxin compounds may be a result of laboratory contamination. Much, but not all, of the reported contamination is associated with method blank contamination (refer to Attachment E4–Groundwater Data Validation). Apparent detections of dioxins and dibenzofurans may also be the result of analytical interferences and/or present as laboratory contaminants.



LEGEND

GROUNDWATER MONITORING WELLS OR EXTRACTION WELLS

MW-89 WELL NAME

-36.88(A) DEPTH TO GROUNDWATER AND ZONE, MEASURED BETWEEN JUNE 30 AND JULY 2, 1992

— — — A ZONE GROUNDWATER ELEVATION CONTOURS

.... B ZONE GROUNDWATER ELEVATION CONTOURS

VERTICAL CAPTURE (B ZONE

—·— A ZONE TARGET VOLUME

—— B ZONE TARGET VOLUME

NOTES:

1. EXTENT OF CONTAMINATIC A AND B IS TAKEN FROM TI FINAL GROUNDWATER OPI FEASIBILITY STUDY (CH2M

2. MW-241 IS LOCATED ADJA(MW-10. MW-242 IS LOCATE TO MW-15.

N

0 500

SCALE (Approximate)

FIGURE 4-23
EXTENT OF VOC CONTAN
AND CAPTURE IN A AND
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2MH

Additional groundwater data for specific compounds and specific wells are presented in Appendix E.

Groundwater capture associated with the extraction system is also evaluated in Appendix E.

4.2 Data Interpretation

Chemical compounds including VOCs, SVOCs, pesticides/PCBs, dioxins, and metals/inorganics were detected in the soil and groundwater during the OU D RI and in previous investigations. The VOCs were also detected in the ambient air and in the soil gas throughout the investigation area. This section provides interpretations of data from air, soil, soil gas, and groundwater analyses.

4.2.1 Nature and Extent of Contamination

This subsection provides interpretations of the soil, soil gas, and groundwater contaminant data. Waste characterizations within source areas are provided in Chapter 3. The extent of VOCs, SVOCs, pesticide/PCBs, dioxins/dibenzofurans, and total metals above background levels in the vadose zone soil are described. Mass estimates of vadose zone VOC contamination using soil and soil gas data are provided. In groundwater, the extent of VOCs and non-VOCs are described and the effectiveness of the existing groundwater extraction system summarized.

Vadose Zone Contaminants

The most frequently detected and widespread vadose zone contaminants within OU D are relatively high-mobility VOCs. Less mobile contaminants such as SVOCs, pesticides/PCBs, dioxins/dibenzofurans, and total metals are generally limited to waste materials within the capped pits and in the underlying soil proximate to the pits.

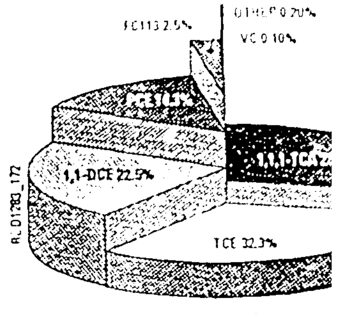
Volatile Organic Compounds. The VOCs of concern in the vadose zone are vinyl chloride, 1,1,1-TCA, TCE, 1,1-DCE, PCE, 1,2-DCA, and Freon 113. The rationale used in identifying the COPCs are described in Section 5.

Mass of Volatile Organic Compounds. Detailed descriptions of VOC mass estimating methodologies, assumptions, equations, and data are provided in Appendix G.

Mass estimates for VOC COPCs were developed using historical and RI soil and soil gas data. Computations indicate that TCE contributes approximately 30 to 40 percent of the total mass according to both soil and soil gas data. The contaminant 1,1,1-TCA contributes 44 percent on the basis of soils data, and 28 percent using soil gas data. In total, 1,1,1-TCA, PCE, TCE, 1,1-DCE, and Freon 113 compose over 99 percent of the speciated chlorinated VOC mass.

1,1,1-TCA, PCE, TCE, and Freon 113 compose 99 percent of the chlori mass.

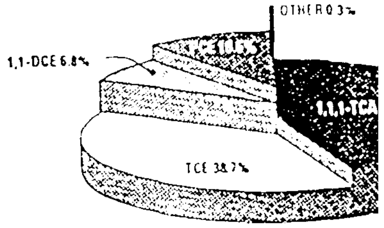
Estimates of contaminant mass using soil gas data were taken from soil vapor monitoring wells, shallow soil gas sampling, downhole soil gas sampling, and the SVE pilot plant at Site S (refer to Appendix G). The VOC data were used to construct polygons grouping sampling locations of similar concentrations. The polygons were then extended vertically to near the groundwater table and divided into layers of equal thickness (see Appendix G). Soil gas concentrations were then converted to total soil concentrations for each layer of each polygon and the total mass of contaminants calculated. Equilibrium contaminant partitioning was assumed in the calculations. The presence of NAPLs was not quantified using this methodology.



Soil Gas Data

The contaminant mass estimate using soil data was similarly developed using polygon-based volumes and soil VOC data. The soil data was assumed to represent all phases of contamination: sorbed to solids, dissolved in porewater, and interstitial vapor. The NAPL contamination, existing as a soil residual, would also be quantified using the soil data.

The adjacent chart depicts the mass distribution of vadose zone contaminants. Additional discussions of NAPL mass estimates and contaminant transport modeling are provided in Appendix J.



Soil Data

The calculated mass of VOCs using soil data are approximately three times greater than the mass using soil gas data. The total estimated mass of contamination from soil analyses is 38,346 kilograms. From assumed equilibrium soil gas analyses, the mass estimate is 13,506 kilograms of VOCs. The discrepancy between the two estimates can be attributed to two primary factors:

1. **NAPLs**—The NAPLs existing in the soil would not be correctly quantified using soil gas techniques. Assumptions of phase equilibrium are invalid when NAPLs are present. Soil gas data underestimate the true contaminant mass with the presence of NAPLs.

2. **Spatial Distribution of Samples**—Soil samples for VOC analyses are limited in horizontal and vertical extent. Extrapolation of soil VOC data from regions highly contaminated with NAPLs into other less contaminated regions could result in an overestimation of contaminant mass. Conversely, mass will be underestimated if the soil VOC data does not represent NAPL contamination.

Because of the undefined NAPL mass, both estimates probably greatly underestimate the total VOC contaminant mass. As additional soil and soil gas data are collected, the mass estimates will be refined to support the OU D Vadose Zone Feasibility Study.

The presence of NAPL may be inferred where:

- Chemical concentrations in soil exceed 10,000 mg/kg (greater than 1 percent of soil mass)

- Organic vapor concentrations in soil gas exceed 100 to 1,000 ppmv (Cohen and Mercer, 1993).

Subsurface NAPL distribution may defy definition, particularly at sites with heterogeneous strata and multiple release locations, such as OU D. Subsurface NAPL distribution can be exceptionally difficult to prove, even following extensive site investigation. NAPLs preferentially migrate through pathways such as fractures and sand layers and are affected by small-scale stratigraphic changes. Fine-grained silt or clay units must also be assumed to permit downward migration. Therefore, the ultimate path taken by NAPLs can be very difficult to characterize and predict. Generally, failure to directly observe NAPLs at a site does not mean they do not exist. If free-phase chemicals were used, handled, and disposed of at a site, the chances are high that NAPL is present (EPA, 1991a).

Indicators for the presence of NAPLs can be used, but each is approximate and has serious limitations. Approximate methods base an assessment of the NAPL presence on historical site use and groundwater and/or soil concentrations. The methodology is described in *Estimating Potential For Occurrence of DNAPL at Superfund Sites*, issued by the EPA's R.S. Kerr Environmental Research Laboratory in August 1991. In summary, a potential for NAPL is indicated if: (1) contaminant concentrations in groundwater are greater than 1 percent of pure-phase solubility or 1 percent of effective solubility; (2) organic concentrations in soil are greater than 10,000 mg/kg (1 percent of soil mass); (3) contaminant concentrations in groundwater calculated from water/soil partitioning relationships and soil samples are greater than pure-phase solubility or effective solubility; or (4) organic concentrations in groundwater increase with depth. Further discussion follows:

- Groundwater Concentrations—Organic compounds are rarely found in groundwater at concentrations approaching their solubility limits, even when the NAPL phase is known to exist. Observed concentrations in groundwater are usually more than a factor of 10 lower than the solubility, probably because of diffusional limitations of dissolution and dilution of the dissolved contaminants by dispersion (EPA, 1991b). Sites are known that have solvent NAPLs below the water table but only show very low aqueous phase concentrations in monitoring wells (less than 0.01 percent of pure-phase solubility) (Cherry, 1991). The detection of very low aqueous concentrations should not be interpreted as absence of NAPLs.

- Soil Concentrations—Qualitatively, soil samples that have contaminant concentrations in the percent range are indicative of NAPLs. However, NAPLs may also be present at low residual concentrations in soil. Analytical results from these samples may exhibit much lower constituent concentrations. Because NAPL entry areas into the subsurface can be very small, it is reasonable to expect that few boreholes will show the presence of residual NAPL.

  It is sometimes possible to qualitatively assess the presence of NAPLs using the equilibrium partitioning theory. If no NAPL is present, there is a theoretical maximum mass of chemical that can be contained in a soil sample. The theoretical maximum total soil concentration is a function of the solubility of the chemical in water, the saturated soil gas concentration, and the sorptive capacity of the soil. If NAPL exists, the theoretical maximum total soil concentration will be exceeded. The calculated porewater concentration would exceed the chemical solubility. The conclusion would be that dense nonaqueous phase liquid (DNAPL) is present in the soil sample.

Extent of Volatile Organic Compounds in the Vadose Zone. Soil vapor data collected during the RI are the primary basis for estimation of the extent of vadose zone VOC contamination. Remedial investigation soil data for VOCs are limited in numbers, vertical distribution, and areal extent. The majority of soil matrix VOC data come from historical investigations conducted in 1984 and 1991. Soil VOC data was primarily used to supplement the soil gas data in developing mass estimates. The horizontal and vertical extents of VOCs described by the soil vapor data are consistent with the conceptual model and contaminant transport calculations. Refer to Chapter 3 for detailed descriptions of the conceptual model. Appendix J provides descriptions of contaminant transport modeling of VOCs in the vadose zone.

Vadose zone VOCs may exten to 500 feet from the edge of t cap.

The estimated horizontal extent of 1,1-DCE soil gas data is shown in Figures 4-20, 4-21, and 4-22. 1,1-DCE was selected as a representative VOC because of that compound's mobility, prevalence, and potential human health risk. Figure 4-22 indicates that 1,1-DCE is present at concentrations exceeding 1,000 $\mu g/l$ near the groundwater table at distances up to approximately 200 feet from the edge of the cap. The existing data can only partially support interpretations of the extent of VOCs beyond approximately 200 feet. Soil gas VOCs probably do not extend to the same horizontal distance from all sides of the cap primarily because of the following factors:

Vertically, VOC concentration increase with depth.

- Concentration and contaminant species in the source areas (*i.e.*, pits)—parameters in the advective and diffusive transport of VOCs

- Location of the contaminant source areas—the physical location of a waste pit within the cap boundary (*e.g.*, north or south end of the cap)

- Stratigraphy and existence of preferential subsurface pathways (*i.e.*, high-permeability coarse-grained sand layers versus low-permeability overconsolidated silts and clays)

- Smear zone—soil gas contaminants originating from residual contamination left in the vadose zone as the local groundwater table has declined. The local groundwater flow direction has varied over the years from northwesterly to southwesterly

Contaminant source areas (*i.e.*, waste pits and residual contamination in the smear zone) and preferential subsurface pathways for VOC transport are not fully characterized over the entire site.

Concentrations of 1,1-DCE from soil vapor wells located north (C2-D, SVDMW-1), southwest (C7-D, MW-1002), and southeast (SVDMW-4, MW-90) of the cap indicate that levels may decline to less than 1 μg/l at distances of about 400 to 550 feet from the edge of the cap. However, these estimates must be regarded as extrapolations of the data. Additional soil gas data are necessary to fully define the extent of VOCs.

Theoretical calculations of 1,1-DCE transport by diffusive and advective mechanisms over 50 years result in a maximum lateral migration near the groundwater table of approximately 500 feet from the edge of the cap (refer to Appendix J).

Given the gaps in the empirical data and the uncertainties and approximations inherent in the transport modeling, the observed and theoretical extents of contamination are reasonably consistent. Soil gas VOCs with mobilities similar to 1,1-DCE can be expected to extend horizontally approximately 500 feet from the edge of the cap in some areas. VOCs with greater mobilities (*e.g.*, Freon 113) may have a greater horizontal extent. Vertically, concentrations will generally increase with depth below the ground surface.

Semivolatile Organic Compounds. The SVOCs detected in soil samples collected during the RI are limited in number and extent. The relatively low-mobility SVOCs do not appear to have migrated significantly from the proximity of the capped waste pits. In borings drilled through the capped pits in 1984 and 1991, the highest concentrations of SVOCs were found in the waste materials, with concentrations in the underlying soil decreasing with depth. Samples collected from borings drilled outside the boundaries of the waste pits were found to contain trace quantities of a limited number of SVOCs. These findings are consistent with the smear zone hypothesis discussed in development of the conceptual model (refer to Chapter 3).

Nonvolatile compounds do n appear to have migrated sign cantly from the waste pits.

Pesticides/Polychlorinated Biphenyls. Pesticides/PCBs were not detected in any RI soil sample. Historically, pesticides/PCBs have only been detected in samples collected within or underlying the waste pits. Pesticides/PCBs do not appear to have migrated significantly from the proximity of the capped waste pits. These data are also consistent with the conceptual model for compounds having relatively low mobilities.

Dioxins/Dibenzofurans. Dioxin compounds detected during the RI were limited to OCDD and total homologs of OCDD and PCDD. Dibenzofurans were not detected. Historically, dioxins/dibenzofurans have been detected only in samples within or immediately underlying a waste pit. However, even these dioxins data are suspect because of the laboratory contamination and may not represent actual site conditions. This data is consistent with the conceptual model for compounds having relatively low mobilities.

Total Metals Above Background Levels. Trace metals were detected in soil samples from many of the RI and historical borings. To assess the significance of the levels detected, each metal was compared to designated background concentrations and EPA Region IX PRGs.

The metals detected above background concentrations are tabulated in Attachment D1, Table D1-5a. Table 4-1 also summarizes the metals concentrations that were detected above background levels and the perspective PRGs associated with each metal are also provided.

Areally, metals above background concentrations appear well distributed in soil underlying the cap. Vertically, metals above background were detected throughout the vadose zone.

4.2.2 Impacts to Air

Volatile organic compounds in the vadose zone do not appear to pose a significant adverse impact to the air at OU D.

Table 4-1
Comparison of Metals Background Levels and Preliminary Remediation Goals, RI and Historical Data

Parameter	Lithology	Concentration Above Background[a]		Background Level[a] (mg/kg)	PRG[b] (mg/kg)
		Minimum (mg/kg)	Maximum (mg/kg)		
Aluminum	Silt	42,500	42,500	34,004	78,000
Arsenic	Sand/waste	4.1	24	3.7	0.97
Arsenic	Silt	7.9	17.3	6.5	0.97
Barium	Clay/silt/waste	345	784	342	5,500
Beryllium	Sand/waste	0.78	1.3	0.6	0.4
Beryllium	Clay/silt	0.72	2.1	0.7	0.4
Cadmium	Sand/silt/waste	0.41	170	0.4	39
Chromium, hexavalent	Silt	2	4.4	NE[c]	44
Chromium, total	Sand/waste	43.1	33,000	41.5	NE
Chromium, total	Silt/clay	59	77.9	53.9	NE
Cobalt	Sand/waste	16	45	15	NE
Cobalt	Silt/clay	21.6	25.1	17.5	NE
Copper	Sand/waste	29.2	4,200	26.7	2,900
Copper	Silt/clay	42.3	107	41.4	2,900
Cyanide	Sand/silt/waste	1.1	100	NE	1,600
Iron	Silt	51,500	51,500	46,293	NE
Lead	Sand/waste	9.6	4,500	6.8	500
Lead	Silt	18	20.8	15.9	500
Magnesium	Silt/clay	12,700	17,000	12,660	NE
Manganese	Silt/clay	1,420	4,400	1,355	7,800
Mercury	Waste/sand/silt	0.21	17.2	0.2	23
Molybdenum	Waste/sand	5.8	66	4	3,900
Nickel	Clay	62.4	62.4	60.6	1,600
Nickel	Waste/sand	54.3	590	52.2	1,600
Potassium	Waste	3,170	3,960	2,967	NE
Potassium	Silt/clay	3,660	7,340	3,651	NE
Selenium	Clay/silt	9.8	15.3	0.5	390
Silver	Waste/sand/clay/silt	0.41	35	0.2	390
Sodium	Clay/waste/silt	798	1,300	727	NE
Sodium	Sand	903	903	882	NE
Thallium (oxide)	Silt/sand/clay	0.2	0.68	NE	5.5
Vanadium	Silt/clay	85.3	127	80.5	550
Zinc	Waste/sand	69.3	1,400	58.6	23,000
Zinc	Clay/silt	103	180	85.5	23,000

[a] Reference: Consensus Statement on Background Inorganic Constituents in Subsurface Soils at McClellan AFB.

[b] Reference: Region IX Preliminary Remediation Goals (PRGs), Third Quarter 1993 (residential soils).

[c] NE = Not established.

Crawlspace and ambient air VOC concentrations were generally similar to those found in the background ambient air. The detected contaminants could have originated from the capped waste pits, followed by transport through the vadose zone, and eventual emission to the atmosphere. Alternatively, the contaminants could have originated from permitted facilities within McClellan AFB. Other possible sources of contamination are unrelated to activities at the Base. These include automobile exhaust or privately owned industrial emissions. Localized sources of contaminants such as paints, solvents, and cleaners may also contribute. The source(s) of the detected VOCs cannot be conclusively determined from the existing data.

Volatile organic compounds i vadose zone do not appear to a significant adverse impact t air.

4.2.3 Impacts to Groundwater

Widespread VOC contaminants pose a continuing threat to groundwater quality in the proximity of the capped waste pits at OU D. The non-VOC organic compounds do not appear to pose a significant adverse impact to the groundwater. Information supporting these assessments is provided in the following sections. (Sampling results for VOCs in groundwater are provided on Figure 4-24. Non-VOC results are provided in Figure 4-25.) Groundwater metals data are shown in Figures 4-25 and 4-27.

Widespread VOC contaminan pose a continuing threat to groundwater quality.

Nonvolatile organic compoun not appear to pose a significa adverse impact.

Volatile Organic Compounds

Impacts to groundwater posed by vadose zone VOCs were assessed using the results of sample data and contaminant transport modeling (refer to Appendix J). The impacts are expressed in terms of porewater concentrations at the point of entry into the groundwater. The modeled concentrations conservatively represent an upper boundary to the actual concentrations that are likely to exist. Dilution and mixing that would occur as the contaminated porewater enters the groundwater are not accounted for.

Adverse impacts to groundwa quality will persist because of contamination in the vadose

Adverse impacts to groundwater quality will persist because of VOC contamination in the vadose zone. As groundwater levels continue to decline, VOC contamination is likely to remain as residual contamination within the vadose zone. This will likely increase the target volume for vadose zone remediation. Most of the VOC contamination that enters the groundwater from the vadose zone will be captured and eventually removed by the existing groundwater extraction system. As lateral migration of VOCs continues, some future contamination may not be within the capture area.

Additional interpretations resulting from the contaminant transport modeling include:

- The NAPLs existing as residual contamination in the vadose zone underlying the capped waste pits will persist for at least 50 years without active remediation. Natural attenuation will not be sufficient to reduce NAPL contamination sources to acceptable levels.

Natural attenuation will not be sufficient to remediate vadose zone contamination.

- The contaminant TCE presents the greatest potential impact to groundwater quality. Estimated peak porewater concentrations of TCE at the groundwater table could be as high as 2,000 μg/l for an additional 50 years. The TCE concentrations decrease exponentially with horizontal distance from the cap. After 50 years, TCE could exist at a concentration of 1 μg/l approximately 40 meters from the edge of the cap. Some fraction of the TCE mass will probably biodegrade and form 1,1-DCE and vinyl chloride. However, insufficient data exist to quantify the long-term rates of biodegradation and masses of biodegradation end products. For the purposes of the modeling calculations, no biodegradation is assumed. This assumption will not affect remedial action decisions. The hypothetical 50-year extents of contamination for TCE, PCE, 1,1,1-TCA, 1,1-DCE, and Freon 113 are shown in Figure 4-28.

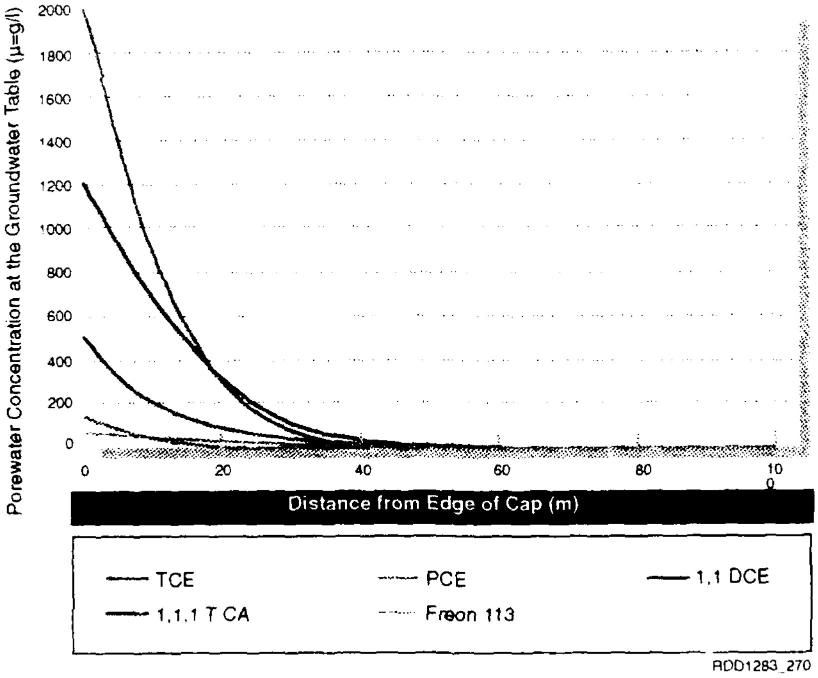


FIGURE 4-28
MODELED EXTENT OF
POREWATER CONTAMINATIO
50-YEAR PERIOD
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

- Elevated levels of VOCs near the groundwater table exist primarily because of density-driven advective and diffusive transport of contaminants in the vadose zone away from the source areas underlying the cap.

Historically, groundwater contamination within OU D has been measured in wells screened up to 185 feet bgs. (Data provided in Figures 4-24 and 4-25 summarize the VOC and non-VOC contaminants recently detected in monitoring and extraction wells.) VOC contaminant levels in extraction wells routinely exceed MCLs. For example, TCE concentrations range from 25 μg/l in EW-86 to 680 μg/l in EW-84. Levels of 1,1-DCE range from 100 μg/l (EW-86) to 3,400 μg/l (EW-73). Similarly, vinyl chloride concentrations range from 4.8 μg/l (EW-83) to 320 μg/l (EW-73). Other VOCs also exceed MCLs in other extractions wells (refer to Figure 4-24). In monitoring wells, similar VOCs are found, but at generally lesser frequencies and lower concentrations (as depicted in Figure 4-24). Groundwater VOC concentrations are generally less than MCLs in the deeper zones (*i.e.*, greater than about 150 feet bgs).

More extensive discussion of Basewide groundwater VOC contamination, including that within OU D, is provided in the Groundwater Operable Unit RI/FS.

Nonvolatile Organic Compounds

Nonvolatile organic compounds are not widely distributed throughout the OU D groundwater. This interpretation is supported by data summarized in the following list:

Nonvolatile organic compoun
not widely distributed throug
the OU D groundwater.

- SVOCs were detected in trace quantities from five RI wells within or near the OU D cap. None of the detected concentrations exceeded MCLs.

- Pesticides/PCBs were not detected in any RI groundwater sample. Historically, pesticides/PCBs have been detected in four groundwater monitoring wells within the boundaries of the cap. However, since September 1984, none have been detected.

- Dioxins/dibenzofurans were detected in groundwater samples collected from six RI wells within the cap. However, the results are suspect because of method blank contamination and may not represent actual site conditions.

- Detected non-VOCs were collected from wells within the capture zone of the groundwater extraction system.

- Conclusions regarding metals concentrations in groundwater are difficult to make. (Refer to the following text.)

Metals

Groundwater samples were not collected and analyzed for metals during the 1993 OU D RI. Historically, samples have been collected within OU D and analyzed for metals as part of the Basewide groundwater sampling program. The results of these metals analyses are provided in the Groundwater OU RI/FS (CH2M HILL, 1994). Additional groundwater data collection efforts will be completed as part of the Groundwater OU project. The results of groundwater metals analyses within OU D is depicted in Figures 4-26 and 4-27 (located at the back of this chapter).

The conclusion reached in the Groundwater OU RI/FS is that the extent of metals contamination within OU D cannot be delineated at this time. Understanding of the presence and extent of metal in groundwater is regarded as a data gap for the following reasons:

- A variety of field procedures have been used
- Background metals concentrations have not been established for the groundwater underlying McClellan AFB.

The available metals data are difficult to evaluate. Filtered and unfiltered groundwater samples have historically been collected, but the sample-specific sampling techniques have not been identified. It is difficult to determine if samples were filtered or unfiltered. For risk assessment purposes, samples should be unfiltered so that potential groundwater exposure hazards can be evaluated. Also, research is available that suggests that representative samples must be unfiltered and collected at low purge and sampling flow rates to avoid entraining suspended solids in the samples. From the available data, it is impossible to distinguish between unfiltered samples, filtered samples collected at high flow rates, or filtered samples collected at low flow rates. Therefore, when elevated metals concentrations are measured, it cannot be determined if the concentrations reflect actual contamination or they are elevated because the samples were unfiltered and collected at high flow rates. Conversely, if sample results are low or nondetect, it is not possible to distinguish between a filtered sample and an unfiltered sample collected at a low flow rate. The metals concentrations provided in Figures 4-26 and 4-27 can be attributed to at least three possible factors:

- Mineral dissolution, a natural occurrence from which background groundwater concentrations are established.
- Turbidity, caused by suspended solids drawn into the well during purging or sampling at high flow rates.
- Contamination from historical Base activities and leaching from source areas

Background metals concentrations in groundwater have not been established. It is not possible to distinguish between the presence of metals in groundwater from natural mineral dissolution and that from contamination. Maximum Contaminant Levels (MCLs) cannot be the only criteria by which the groundwater is evaluated. In some cases, groundwater metals may naturally occur at concentrations higher than MCLs. For example, background concentrations within the Sacramento Basin for arsenic and manganese have been recorded as high as 120 μg/l and 2,300 μg/l, respectively. The MCLs for both of these metals is only 50 μg/l. The Sacramento Basin background groundwater concentrations have not been accepted for the groundwater underlying McClellan AFB.

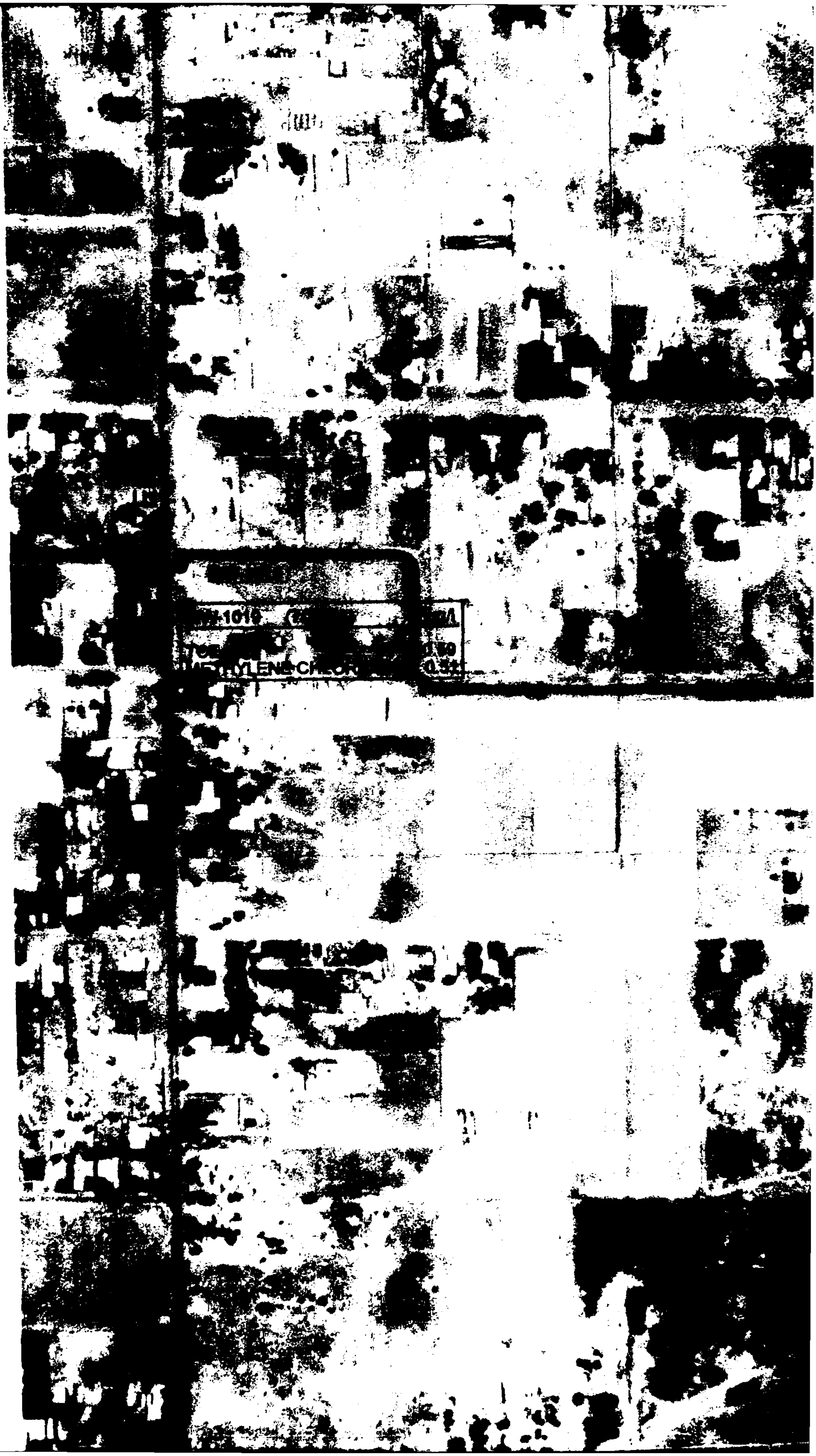
A more complete discussion of groundwater metals, including analytical results, is provided in the Groundwater OU RI/FS.


C STRE
ROAD


E (N)(E) 22
400
66
64
EXTENT OF B ZONE
MW-74 (8/8/93) ug/l
1.4
1.1
1-DCA
MW-74
(10Ft)
MW-57
(6/24/93)
MW-1002
(1002Ft)
BLDG 1066
(7/28/93)

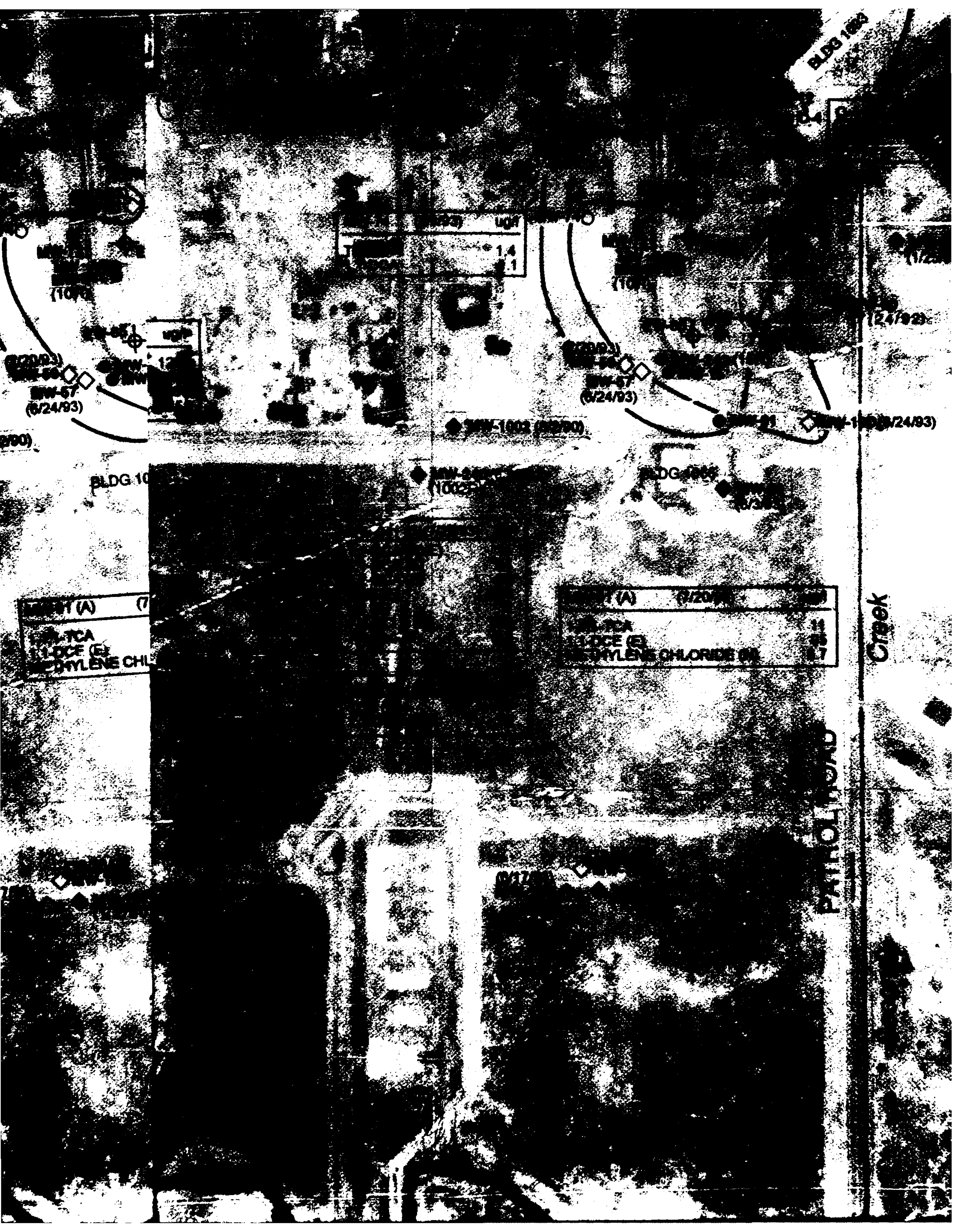

BLDG 1693
BLDG 1694
12
C-4
(1/25/90)
(2/4/92)
(9/24/93)
1.7
1.3
72
7.3
1.3
3. WELL ZONE


1-TCA
DCA
DCE
DCA
WELL
2.4
72
7.3
1.3
1.3
EX


1019
METHYLENE CHLOR
0.31


MW-10
1,1,1-T
1-DC
E
loroft
W-103 (A
1,1-
1-DC
Magnie


MW-74 (8/?/93) ug/l
1.4
1,1-DCA
1.1
MW-1
1,1-TCA (E)
DCE (E)
ug/l
MW-1
MW-100
MW-24
(1002ft)
(7/21/93)
(E)



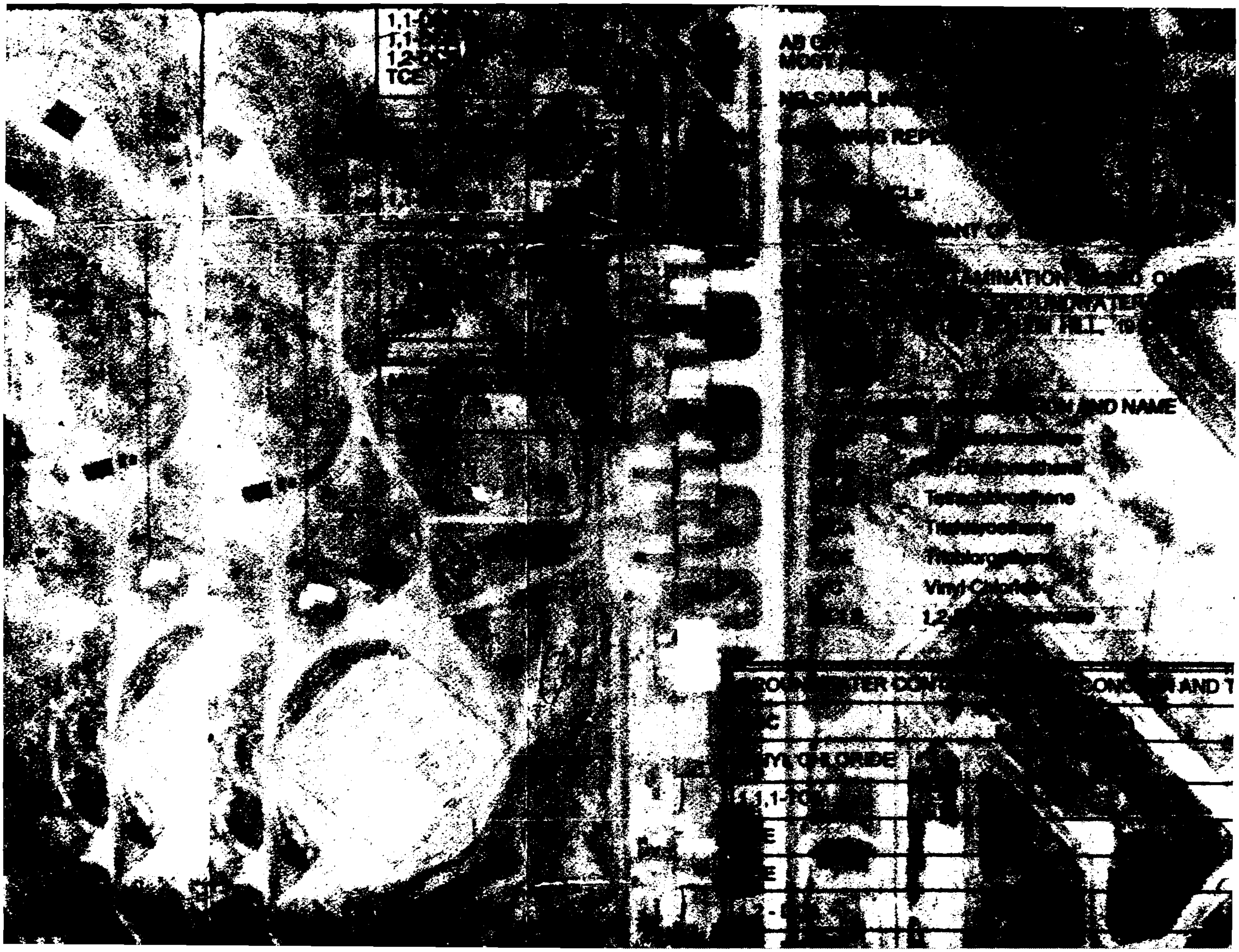
ug/l
1.4
(10/1
MW-67
(6/24/93)
(8/20/93)
MW-66
ug/l
(8/90)
BLDG 10
MW-1003 (8/8/90)
(8/24/92)
MW-67
(6/24/93)
MW-91
(6/24/93)
BLDG
(A)
1,1,1-TCA
1,1-DCE (E)
METHYLENE CHL
(A)
1,1,1-TCA
11
1,1-DCE (E)
METHYLENE CHLORIDE (B)
6.7
Creek
PATROL ROAD


(2/28/93)
EW-56
EW-57
(6/24/93)
EW-1
(6/24/93)
(5/4/93)
1,1,1-TC
1,1,2-TC
1,1-DCA
1,1-DCE
1,2-DCA (8/2/90)
PCE
TCE (E)
t-1,2-DCE
VC (E)
1,2-DCl B
1,4-DCl B
Chloroform
Benzene
Toluene (
1,1,1-TCA (N) 38
1,1,2-TCA (N) 1.7
1,1-DCA (N)(E)
1,1-DCE (E)
1,2-DCA (E)
PCE 1.
TCE (E)
t-1,2-DCE (N) 3.4
VC (E) 72
1,2-DCl B (N) 7.3
1,4-DCl B (N) 1.3
Chloroform (N) 1.3
Benzene (N)
Toluene (N)
3
EW-65 (A
1,1,1-TC
1,1-DCE
1,1-DCE
1,2-DCA
TCE (E
EW-65 (AB)
1,1,1-TCA
1,1-DCE
1,1-DCE
1,2-DCA
TCE
(A)
1,1-DCA
1,1-DCE (E)
METHYLENE CHLORIDE (E)
1,1,1-TCA
TCE (E)
1,1-DCE
TCE
1,1-DCE (E)
Creek

WELL ZONE INDICATED AS (N), (E), (AB)
1,1,1-TCA (N)
1,1-DCA (N)
1,1-DCA (N/E)
1,1-DCE (E)
1,2-DCA (E)
PCE
TCE (E)
t-1,2-DCE (N)
VC (E)
1,2-DCl B (N)
1,4-DCl B (N)
Chloroform (N)
Benzene (N)
Toluene (N)
35
1.7
1.
3.4
72
7.3
1.3
1.2
EW-65 (AB)
1,1,1-TCA
1,1-
1,1-
1,2-DCE
TCE
EXC
A ZO
CO
AB
OF
A ZO
REC
AB
MOST
NO SAMPLING
WAS REPLA
MCLs
NANT OF C
AMINATION
GROUNDWATER
HILL
ON AND NAME
Tetrachloroethene
Trichloroethene
Vinyl C
AND THE

SAC28722 40

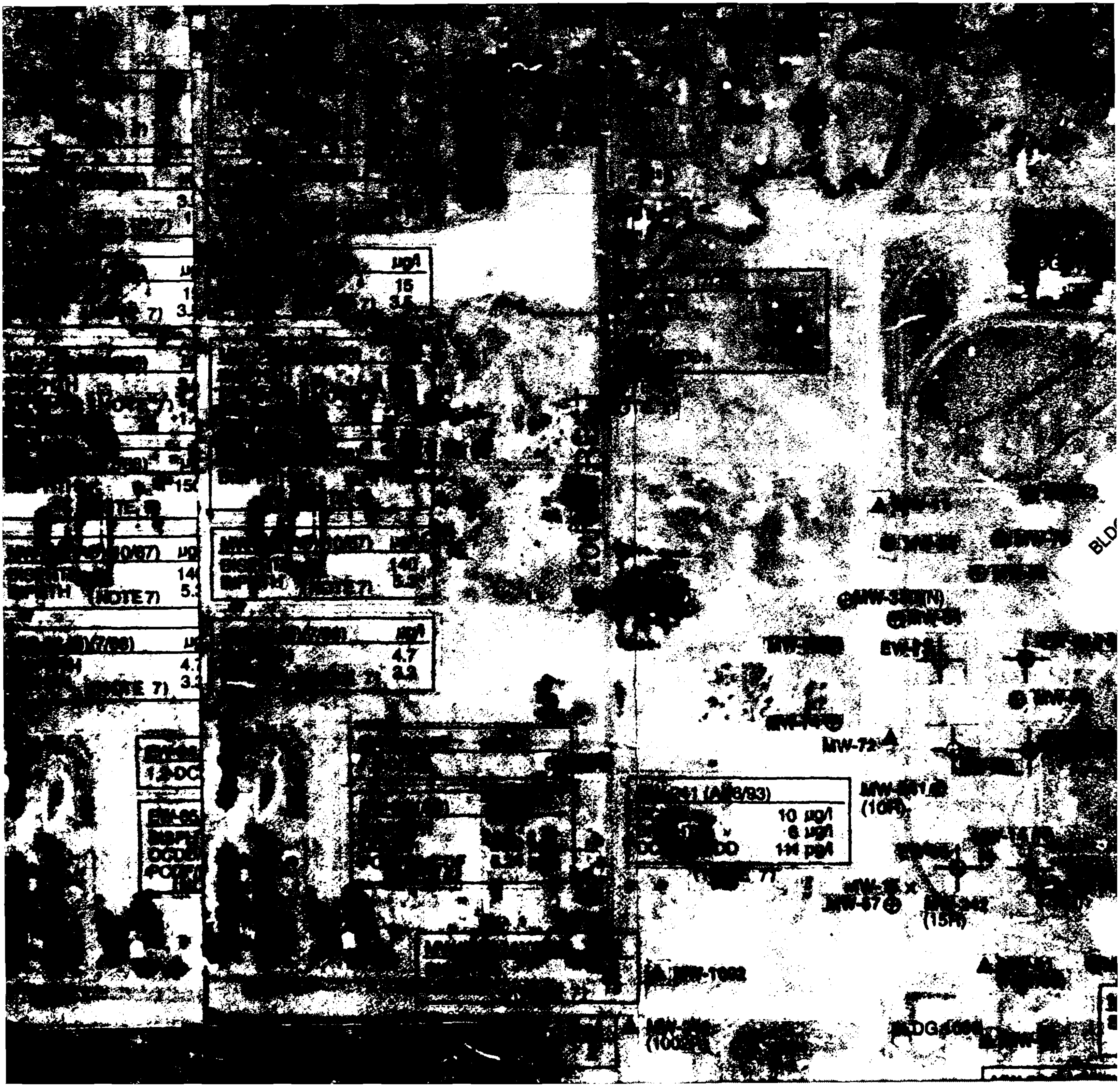

DCE (E) 95
HYLENE CHLORIDE (B) 8.7
PATRIOT ROAD


1,1-
1,1-
1,2-
TCE
AB C
MOST
NO SAMPLING
REPL
AMINATION
ATE
HILL 19
AND NAME
Tetrachloroethene
Vinyl Chloride
1,2-
GROUNDWATER CON
CONCEN AND T
VINYL CHLORIDE
1,1-

TIONS
UNIT

LLS

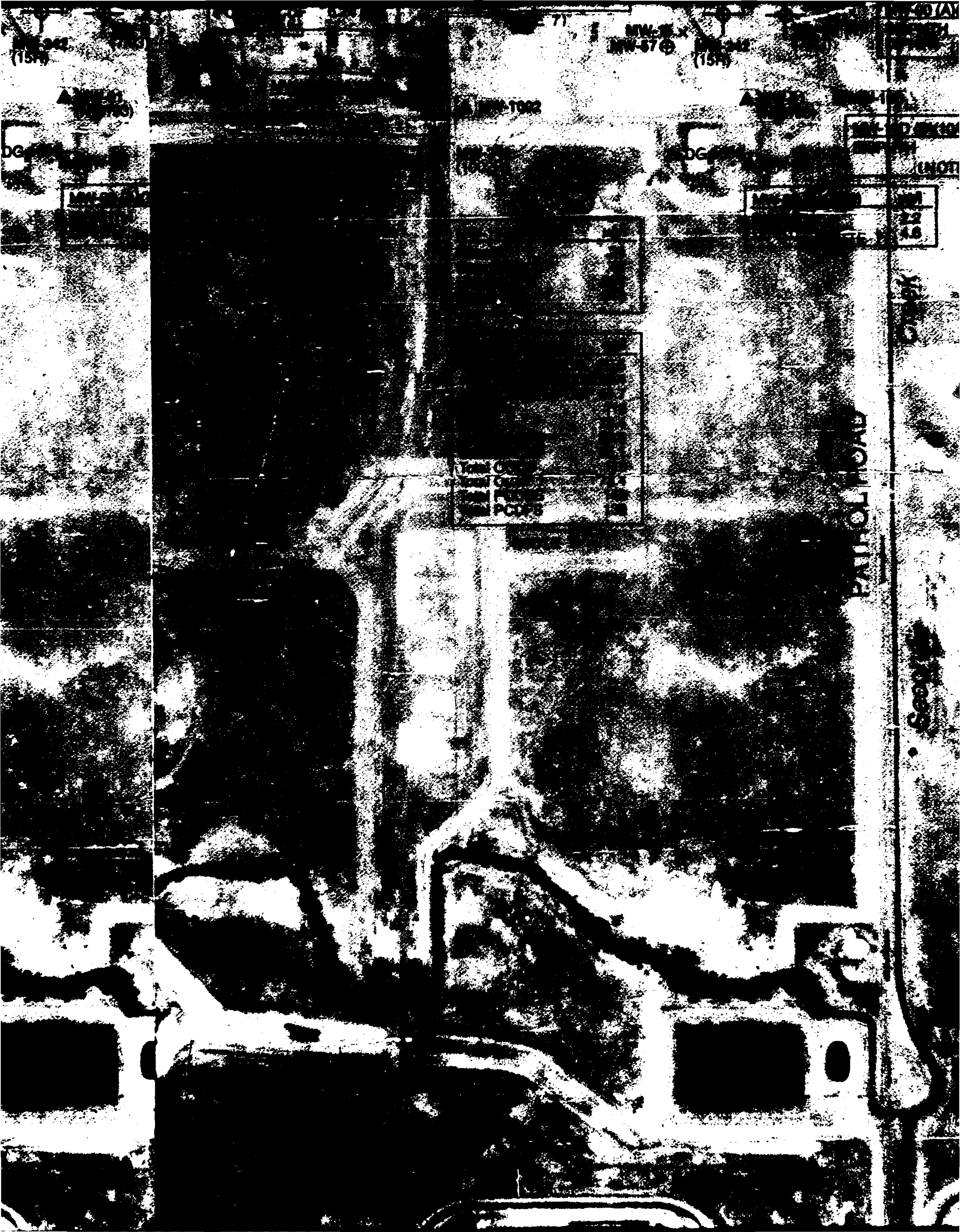
①



µg/l
15
(NOTE 7)
µg/l
14
(NOTE 7)
4.7
3.3
(NOTE 7)
MW-72
10 µg/l
6 µg/l
1.14 pg/l
(10ft)
MW-57
(15ft)
MW-1002
BLDG


17


MW-
MW-57
MW-1002
(1002)
Total OCDD 110
Total OCDF 73.4
Total PCDDS 149
Total PCDFS 139
NOTE


(15ft)
MW-57
(15ft)
(UNOT
2.2
4.6
Total
PCOPS
PATROL ROAD
Creek


ug/l
8.6
ug/l
8.6
(SEE 7)
1,2-Di
di-n-Buty
pthalene
chlorinated di
ABBREVIATIO

BETWEEN DESIGNATED

IS WELL
BECAUSE
ED BY

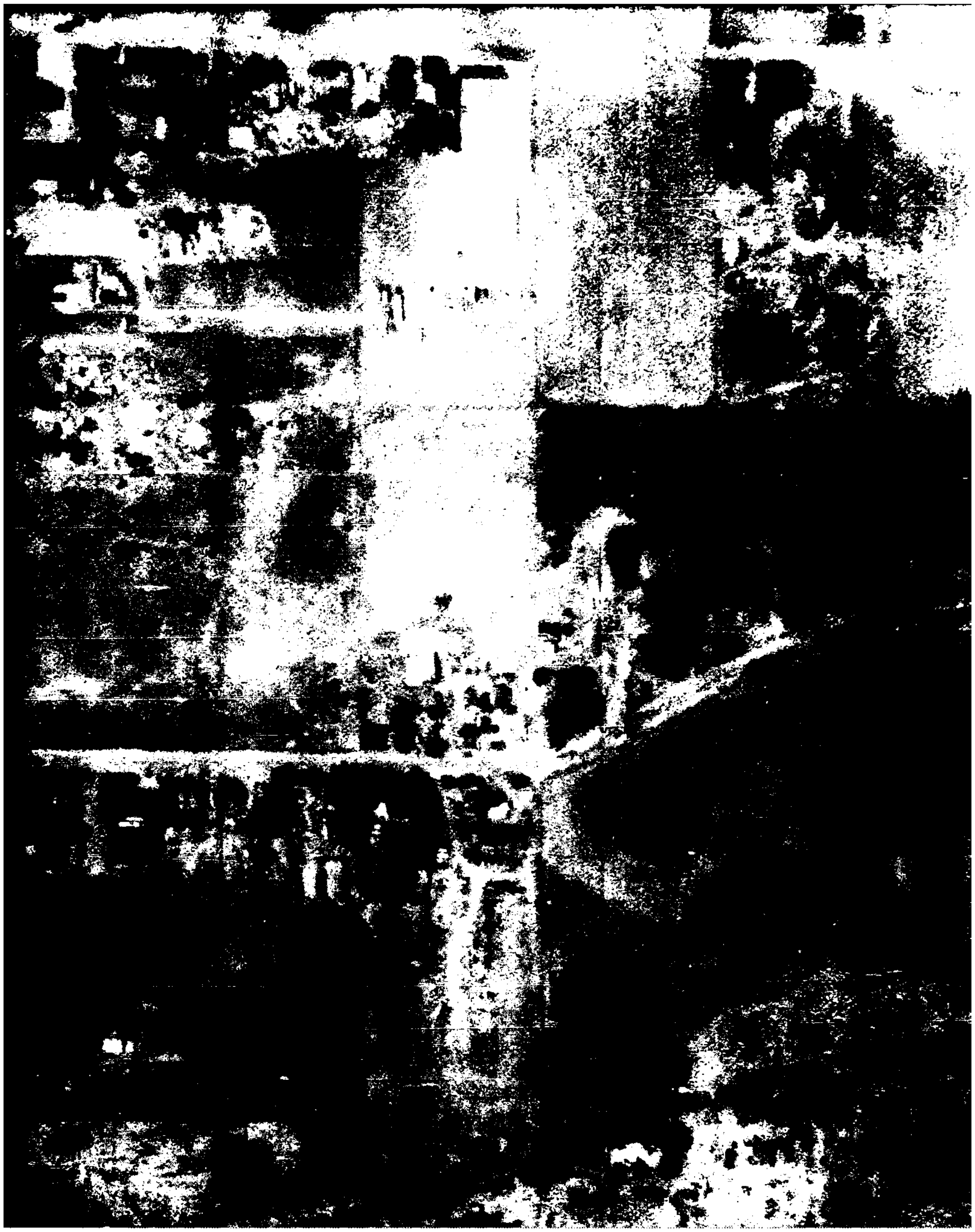
1,2-Dic
di-n-Butyl
Naphthalene
ene
chlorinated di

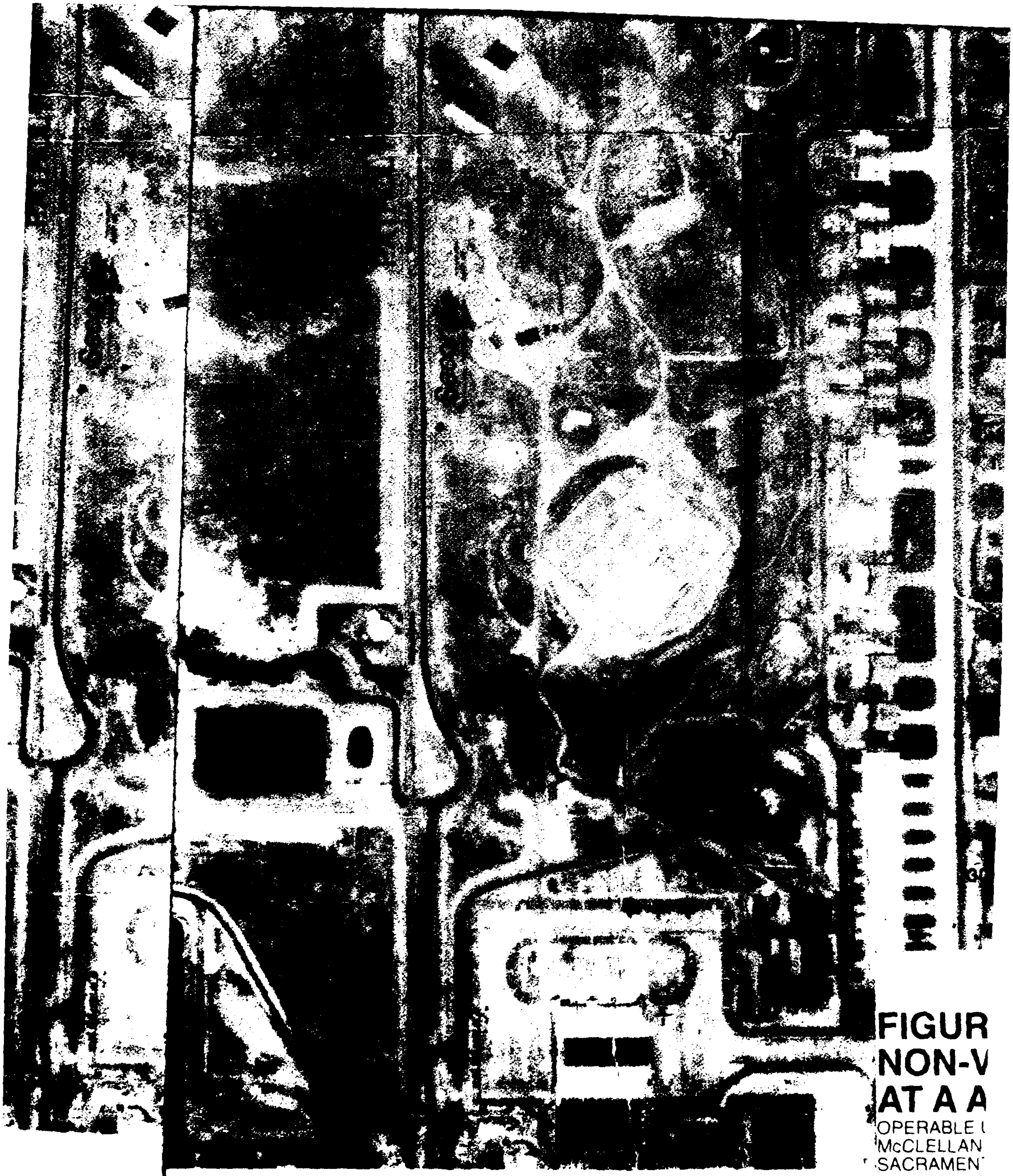
ABBREVIATION AND NAME

TH (2-Ethylhexyl) Phthalate
phthalate
ine
-p-dioxin
Any or all of the possible chlorinated -p-dioxin isomers
Any or all of the 135 possible chlorinated dibenzofuran isomers
Any or all of the 28 possible pentachlorinated dibenzofuran isomers

NOTES

1. MOST ING DATES ARE POSTED.
2. CO ST RECENT SAMPLING DAT VE DETECTION LIMITS.
3. WE (B), R (BAS).
CD CDD, and Total CD
Total
NT





FIGUR
NON-V
AT A A
OPERABLE (
McCLELLAN
SACRAMEN

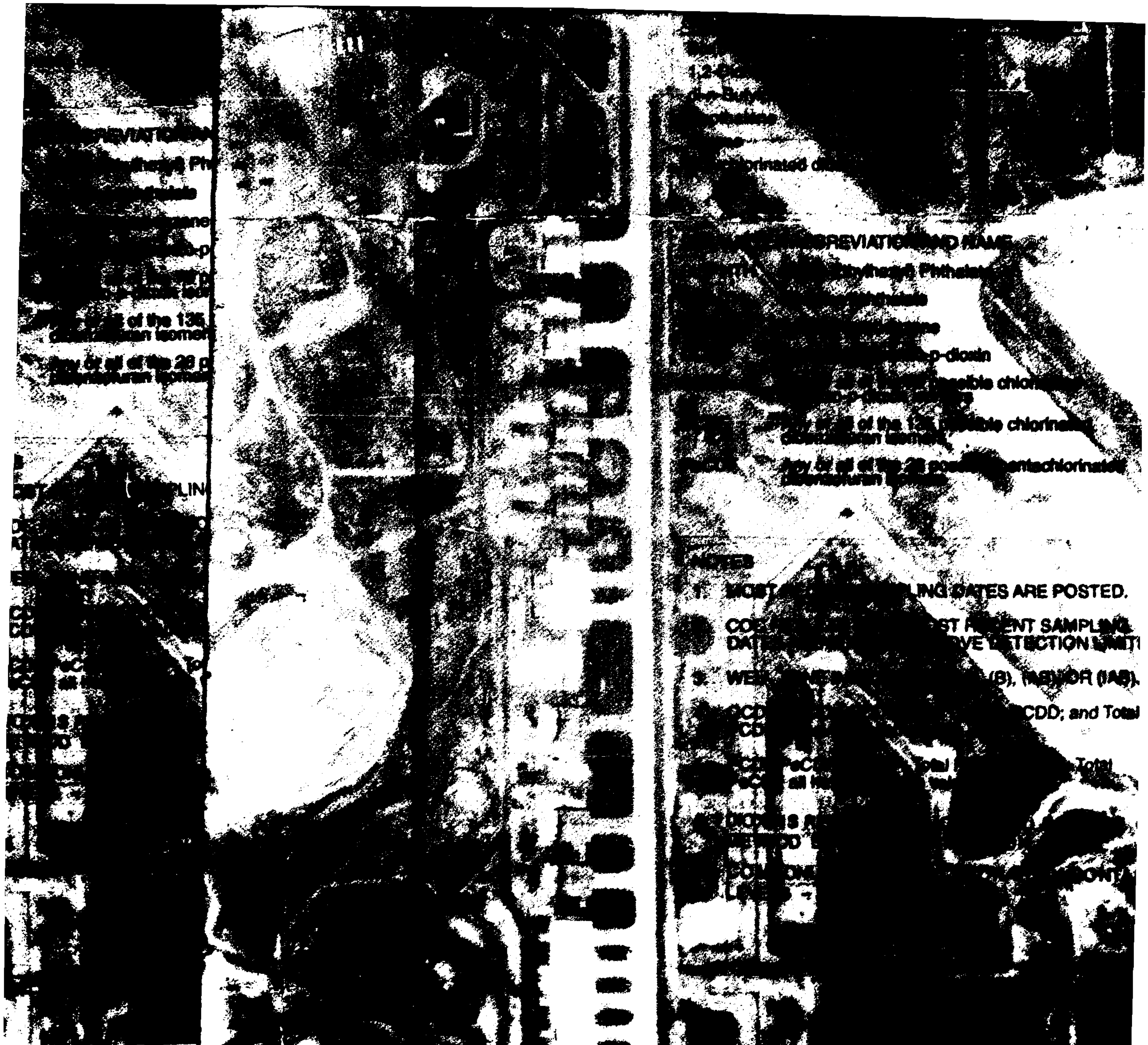


FIGURE 4–25
NON-VOC SAMPLING RESUI
AT A AND AB/B ZONE WELL

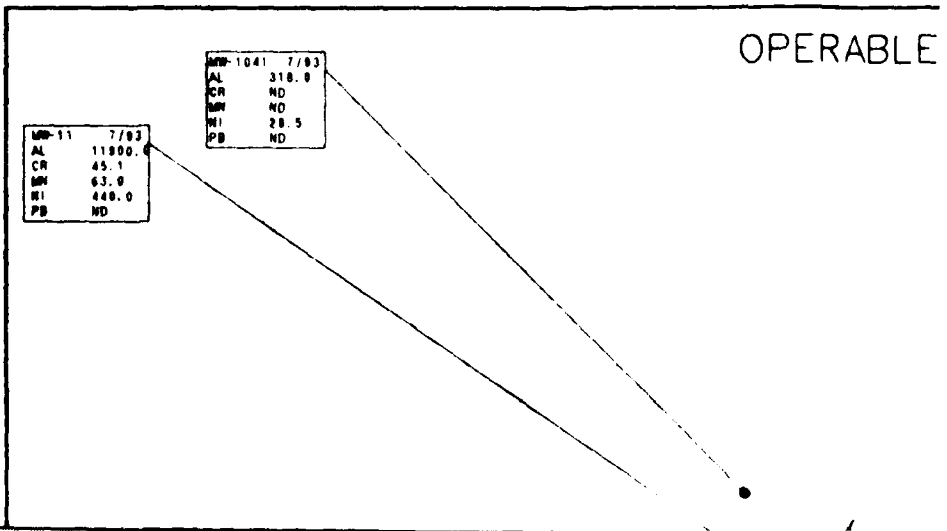
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

4–25
C SAMPL
D AB/B ZC
D
FORCE BASE
CALIFORNIA

LEGEND

MW-1041 7/93 AL 318.0 CR ND MN ND NI 28.5 PB ND	WELL NAME, MONTH AND YEAF AND METALS CONCENTRATION
═	WATER LEVEL CONTOURS (ft msl) JANUARY 1993
●	MONITORING WELL
⊠	BASE WELL OR CITY WELL
X	EXTRACTION WELL
-------------------	INDUSTRIAL WASTE LINE
- - - - -	SOURCE AREAS (SCREENED)

WELLS WITHOUT LABELS WERE NOT INCL
DATASET BECAUSE THEY WERE LAST SA
SEE FIGURES 4-42,4-43,4-44, AND 4-46
1994 FOR WELL NAMES.



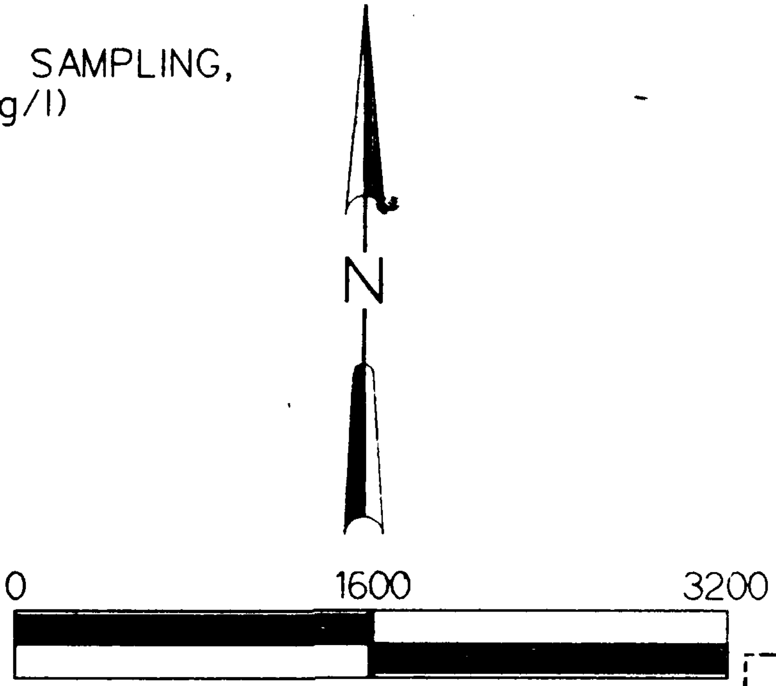
)F SAMPLING,) YEAR OF SAMPLING,
(ug/l) ATIONS (ug/l)

JRS

ELL

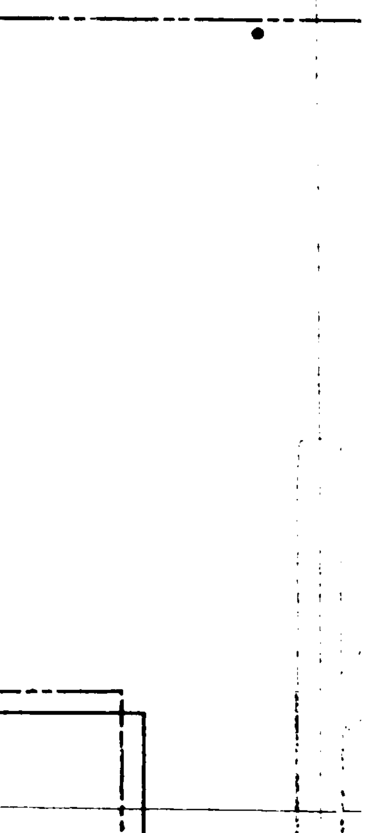
0 IED)

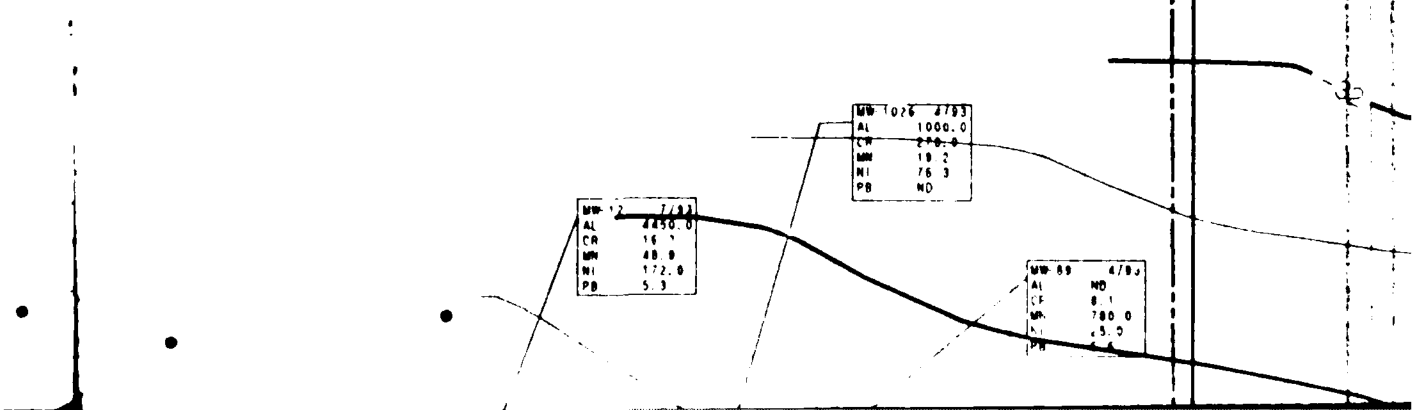
S



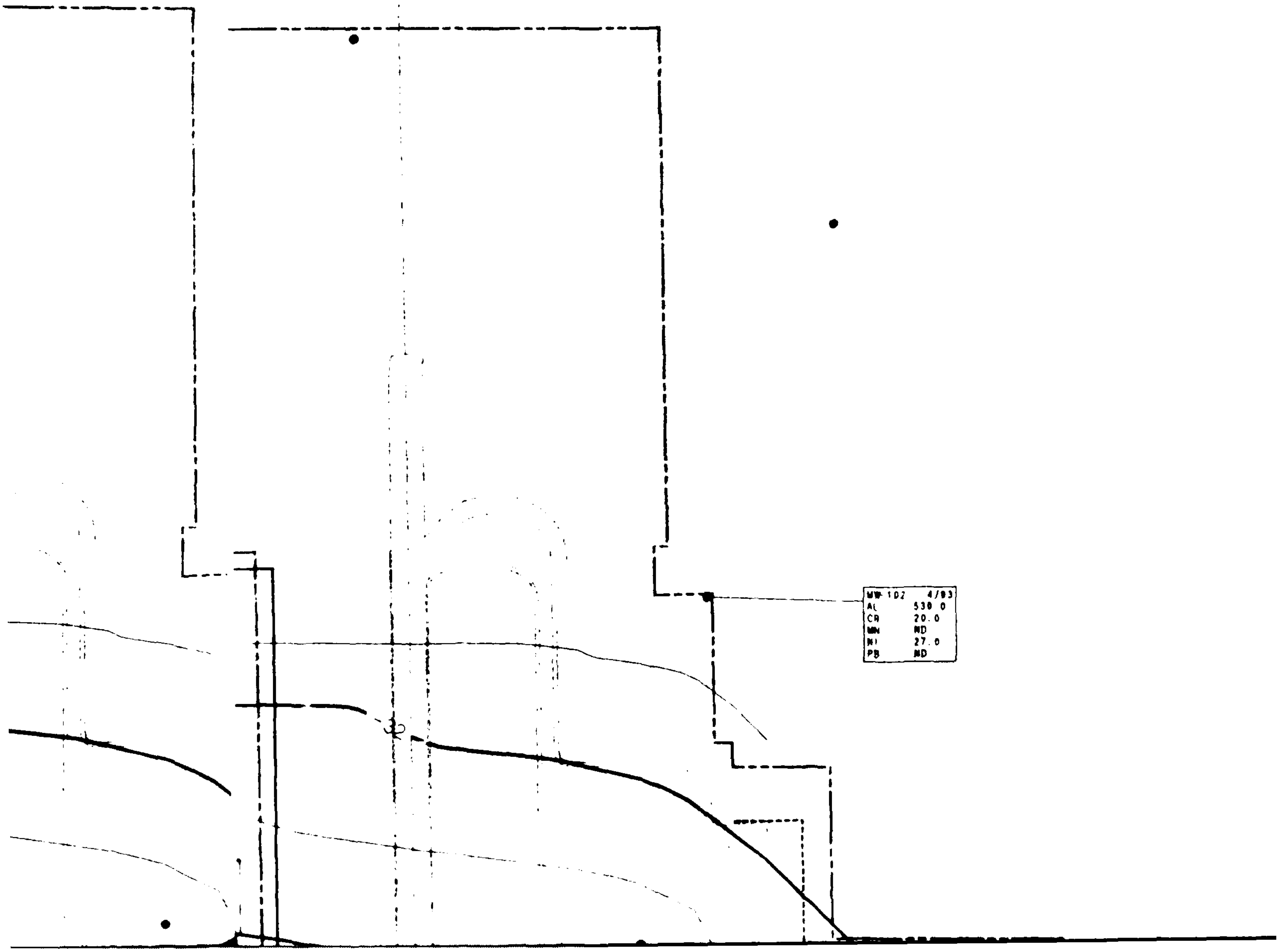
ED IN THE 'INCLUDED IN THE
LED BEFORE T SAMPLED BEFORE 1988.
WOU RI/FS, C4-46 GWOU RI/FS, CH2M HILL,

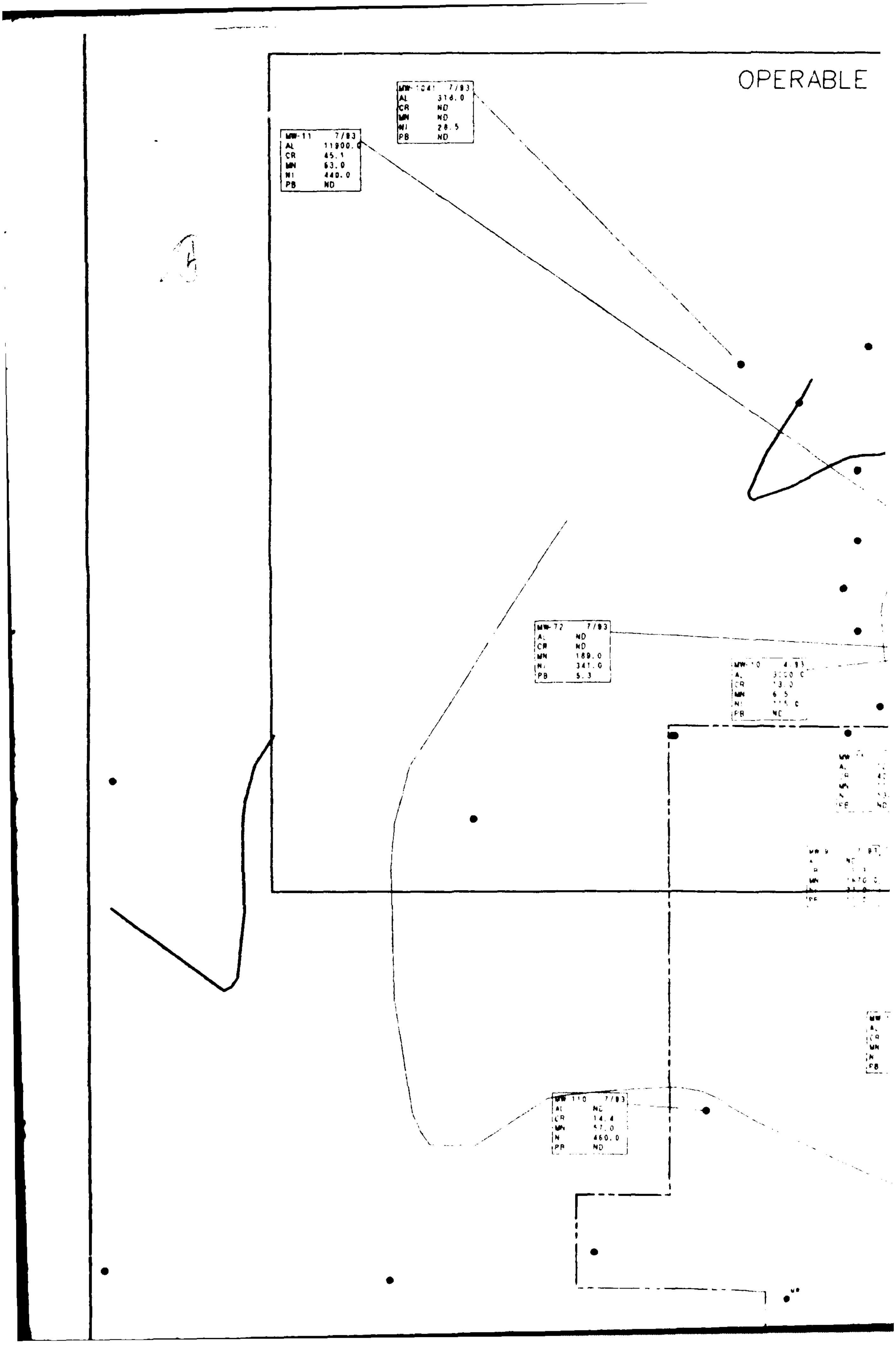
JNIT D ABLE UNIT D





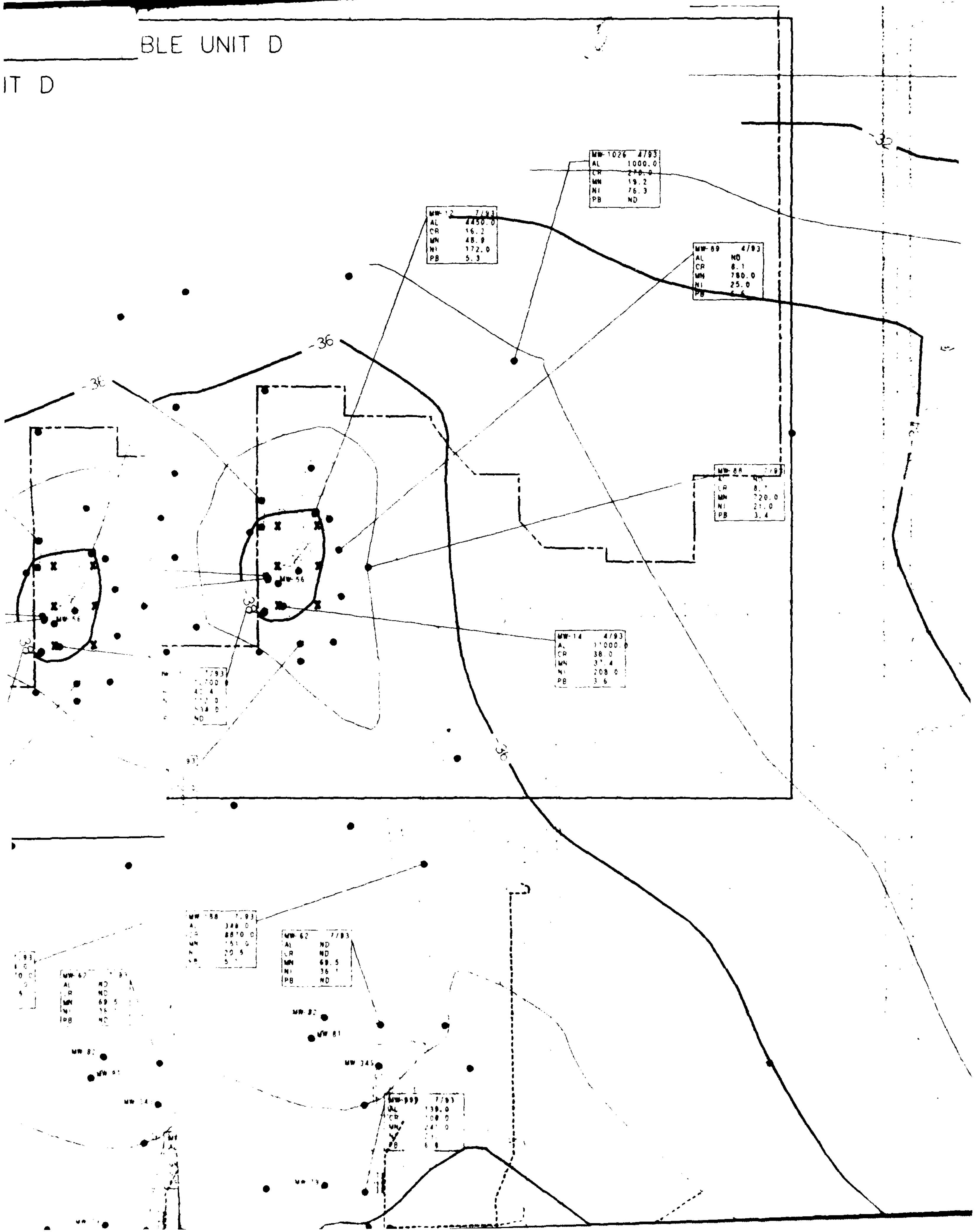
(3)

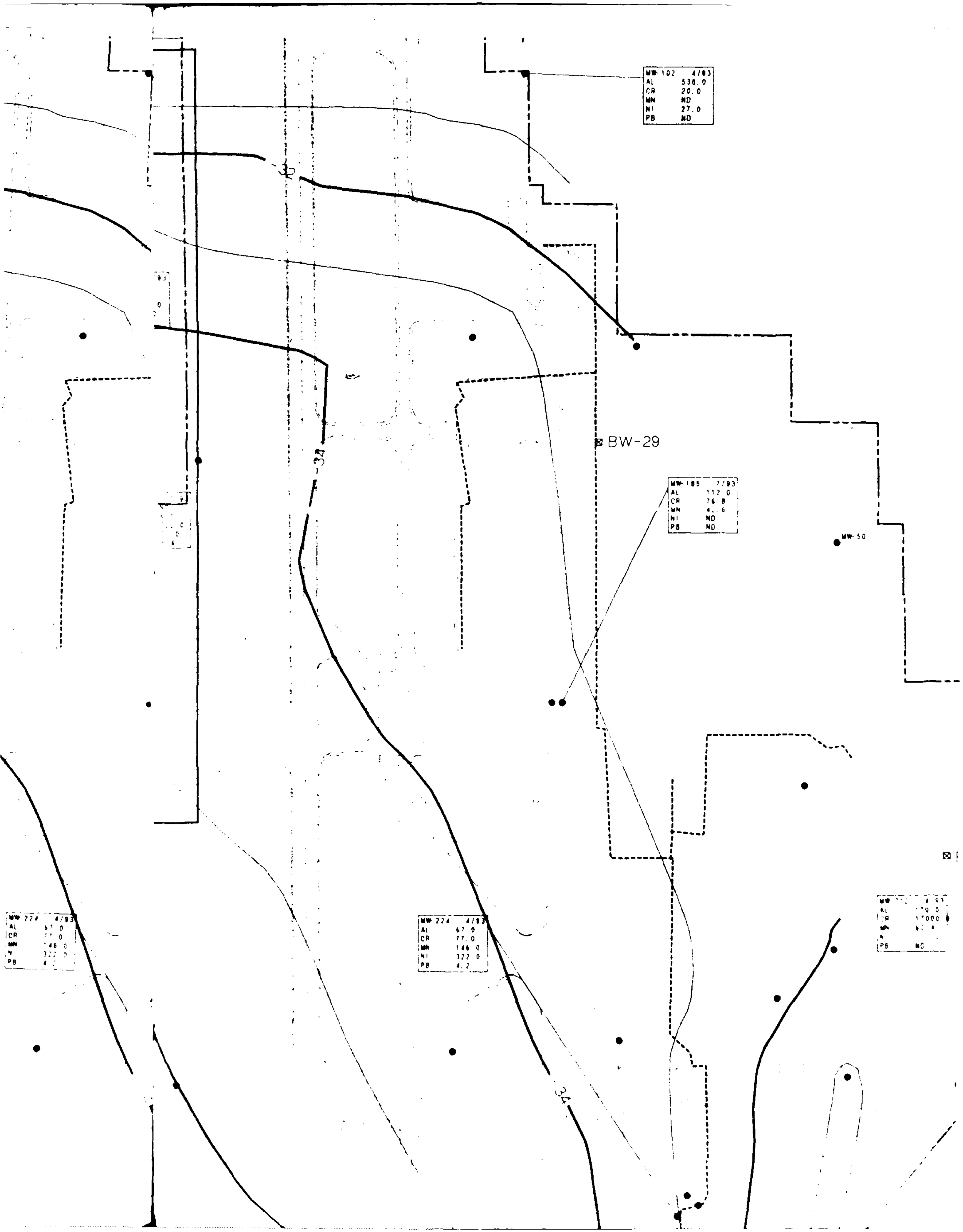


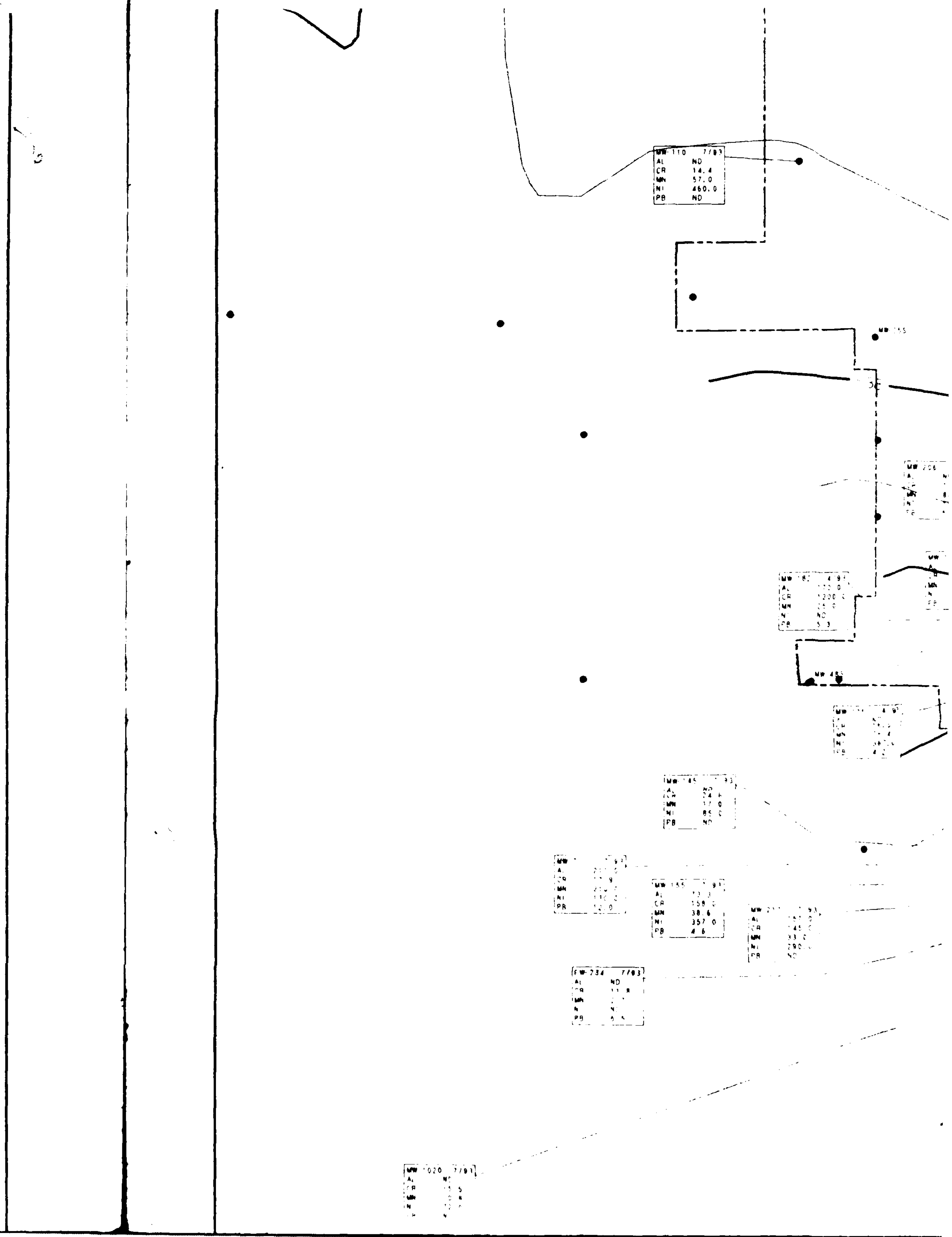

OPERABLE
MW-1041 7/93
AL 316.0
CR ND
MN ND
NI 28.5
PB ND
MW-11 7/93
AL 11900.0
CR 45.1
MN 63.0
NI 440.0
PB ND
MW-72 7/93
AL ND
CR ND
MN 189.0
NI 341.0
PB 5.3
MW-10 4/93
AL 3000.0
CR 13.0
MN 6.5
NI 115.0
PB ND
MW-110 7/93
AL ND
CR 14.4
MN 57.0
NI 460.0
PB ND
4

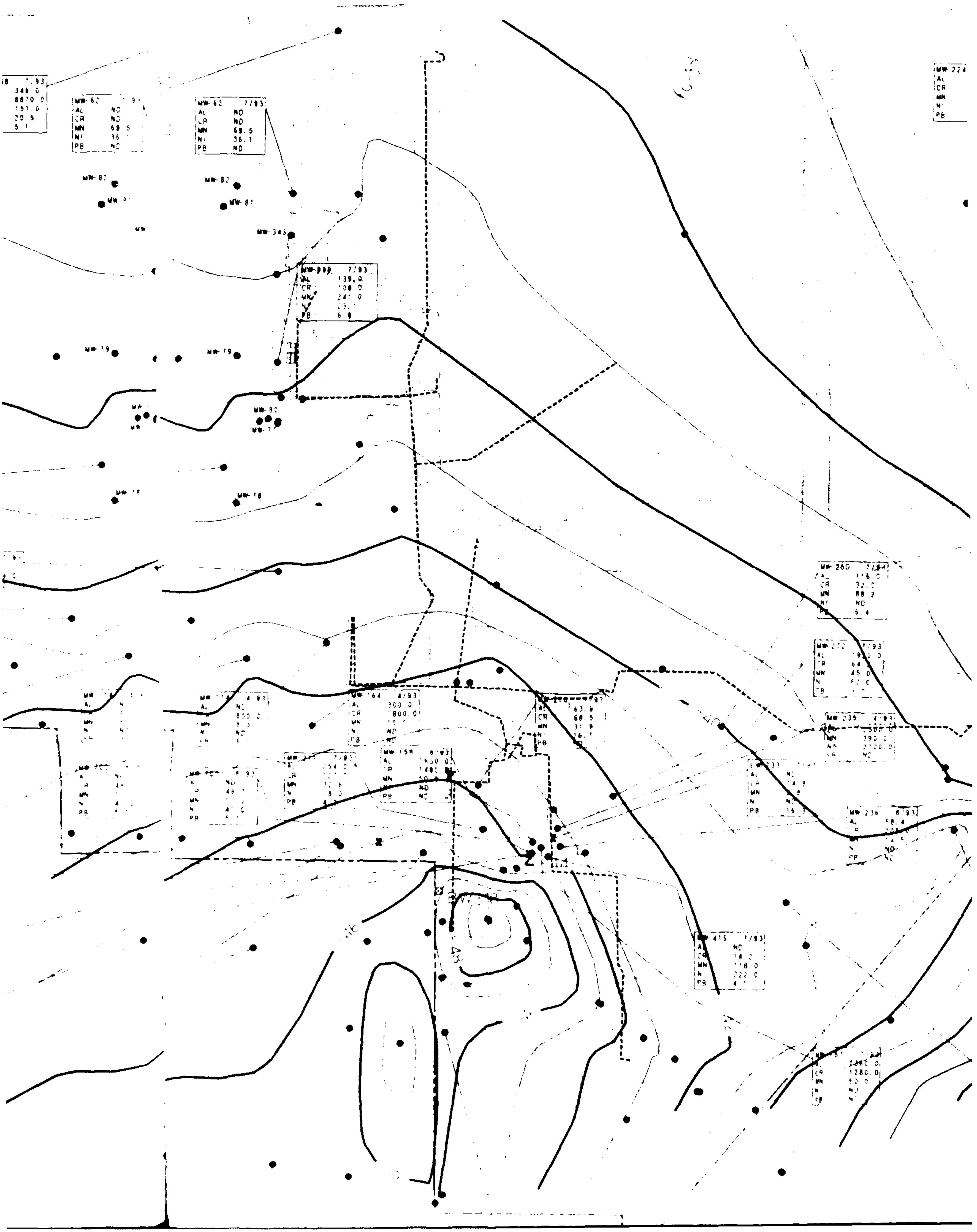
BLE UNIT D

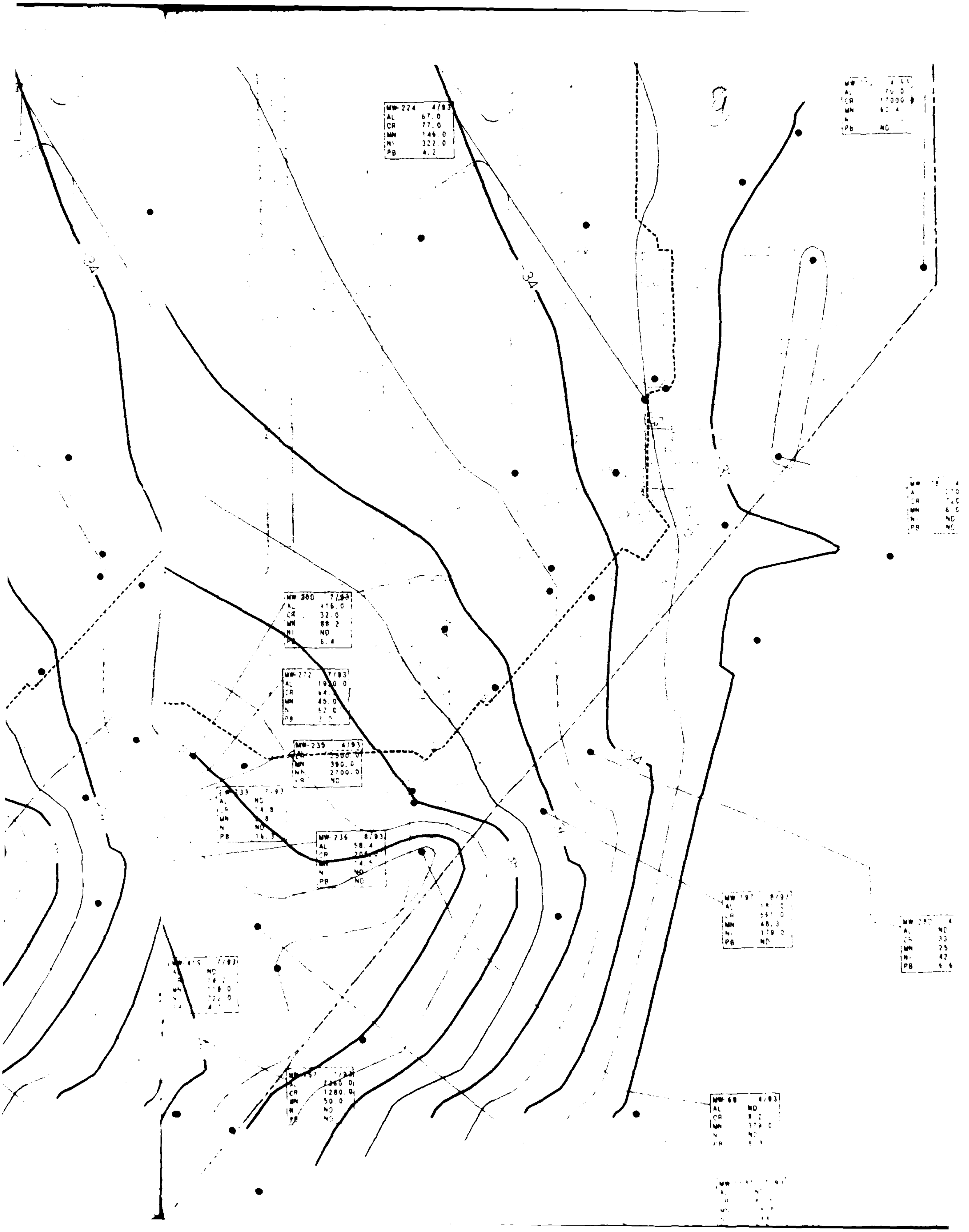
IT D

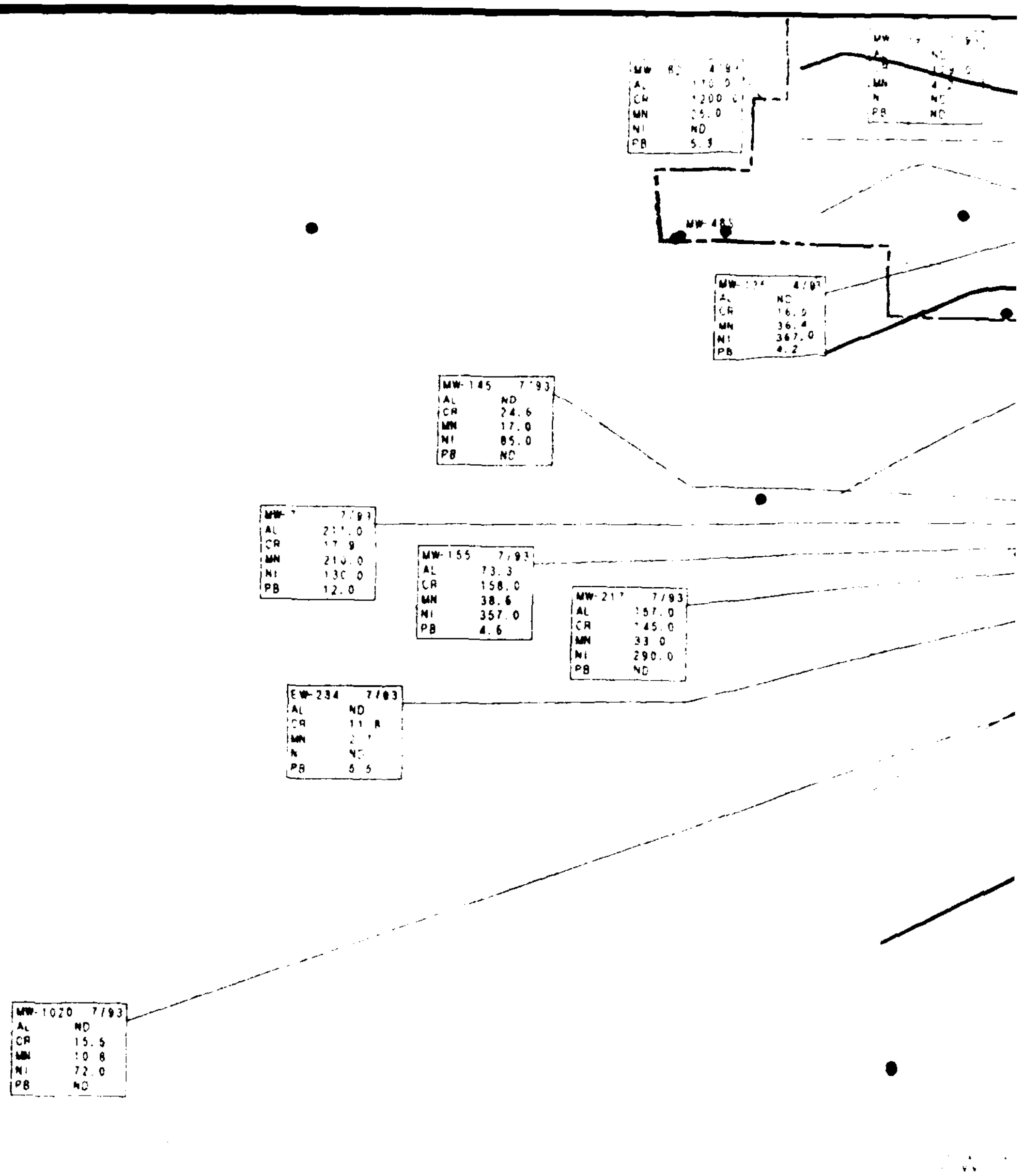



MW-102 4/93
AL 536.0
CR 20.0
MN ND
NI 27.0
PB ND
32
34
BW-29
MW-185 7/93
AL 112.0
CR 76.8
MN 4 6
NI ND
PB ND
MW-50
MW-224 4/93
AL 67.0
CR 77.0
MN 146.0
NI 322.0
PB 4.2
MW-224 4/93
AL 67.0
CR 77.0
MN 146.0
NI 322.0
PB 4.2
34
PB ND


MW-110 7/83
AL ND
CR 14.4
MN 57.0
NI 460.0
PB ND
MW-155
MW-206
MW-182
MW-483
MW-145
AL ND
CR 24.6
MN 17.0
NI 85.0
PB ND
MW-155
CR 158.0
MN 38.6
NI 357.0
PB 4.6
MW-211
CR 145.0
MN 33.0
NI 290.0
PB ND
FW-234 7/83
AL ND
PB
MW-1020 7/83
AL ND


7/93
348.0
8870.0
151.0
20.5
5.1
MW-62
AL ND
CR ND
MN 69.5
NI 36.1
PB ND
MW-62 7/93
AL ND
CR ND
MN 69.5
NI 36.1
PB ND
MW-82
MW-81
MW-82
MW-81
MW
MW-343
MW-999 7/93
AL 139.0
CR 108.0
MN 241.0
PB 6.0
MW-79
MW-79
MW-80
MW-18
MW-78
MW-164 4/93
AL 300.0
CR 1800.0
NI ND
PB ND
MW 4/93
CR 800.0
MW-158 8/93
AL 1630.0
CR 1480.0
MN 50.0
NI ND
PB ND
MW 7/93
MN 12.6
MW 4/93
AL ND
CR 46
MW-276 7/93
AL 63.6
CR 60.5
MN 31.9
NI 16.7
PB
MW-224
AL
CR
MN
NI
PB
MW-260 7/93
AL 116.0
CR 32.0
MN 88.2
NI ND
PB 6.4
MW-272 7/93
AL 1920.0
CR 64
MN 45.0
NI 62.0
PB
MW-235 4/93
MN 390.0
NI 2700.0
PB ND
MW-233
AL ND
CR 14.8
NI ND
PB 16.3
MW-236 8/93
AL 58.4
NI ND
PB ND
MW-415 7/93
AL ND
CR 14.2
MN 118.0
NI 222.0
PB 4
MW-157
CR 1280.0
MN 50.0
NI ND
Z
45
40
50

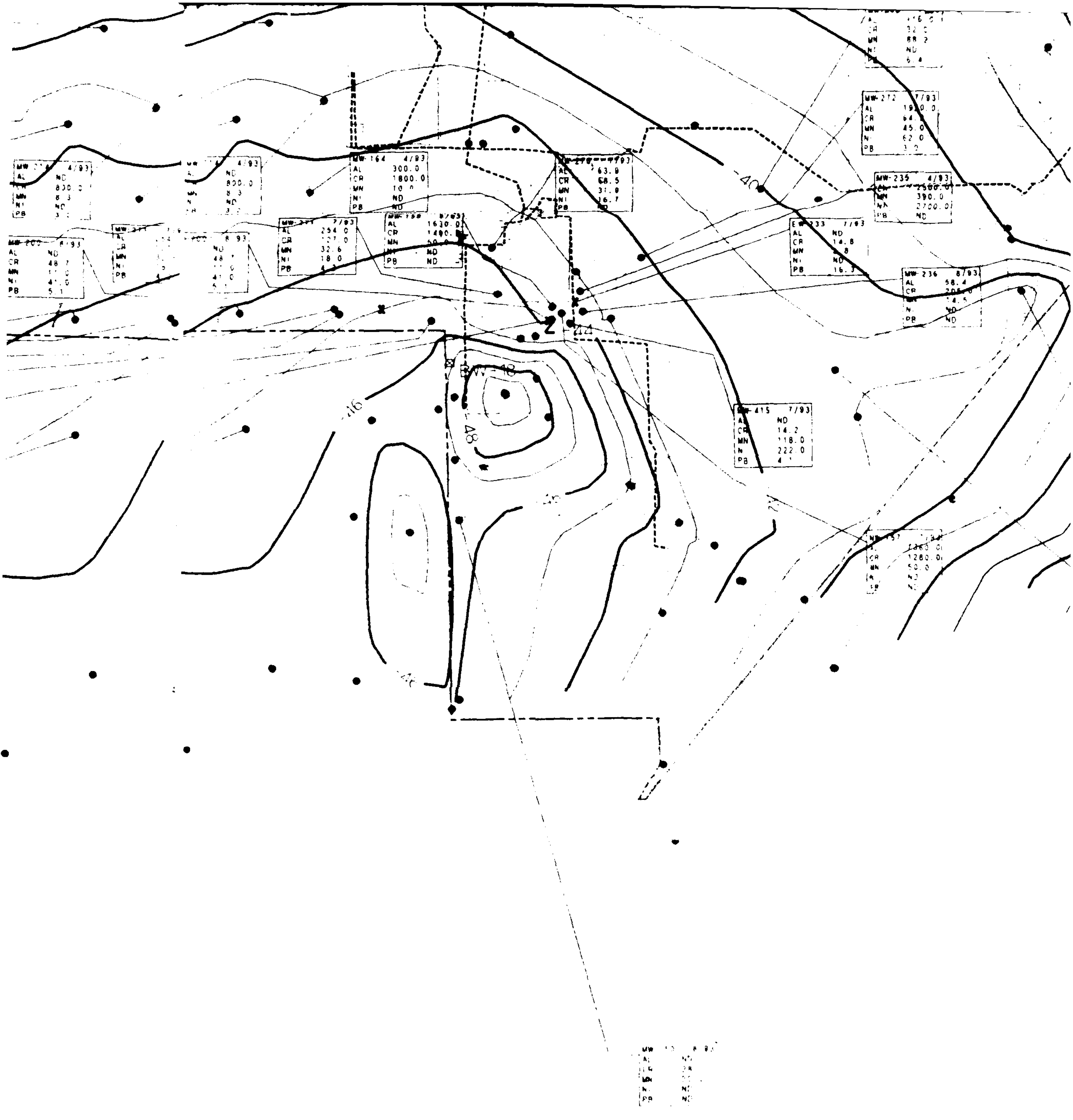

34
34
34
MW-224 4/93
AL 67.0
CR 77.0
MN 146.0
NI 322.0
PB 4.2
AL 70.0
CR 17000
PB ND
MW
MN
NI ND
PB ND
MW-280 7/93
CR 32.0
MN 88.2
NI ND
PB 6.4
MW-272 7/93
MN 45.0
MW-235 4/93
MN 390.0
2700.0
ND
7/93
AL ND
CR 14.8
PB 16.3
MW-236 8/93
AL 58.4
N ND
PB ND
MW 8/93
CR 561.0
MN 48.3
PB ND
MW
AL ND
CR 33
MN 25
PB 6.6
7/93
ND
118.0
CR 1280.0
MN 50.0
N ND
PB ND
MW-68 4/93
AL ND
N ND
MW



RDD 1454

NOTE: FIGURE FROM

MF 194/4 26.DGN



[illegible] CH2M HILL, 1994

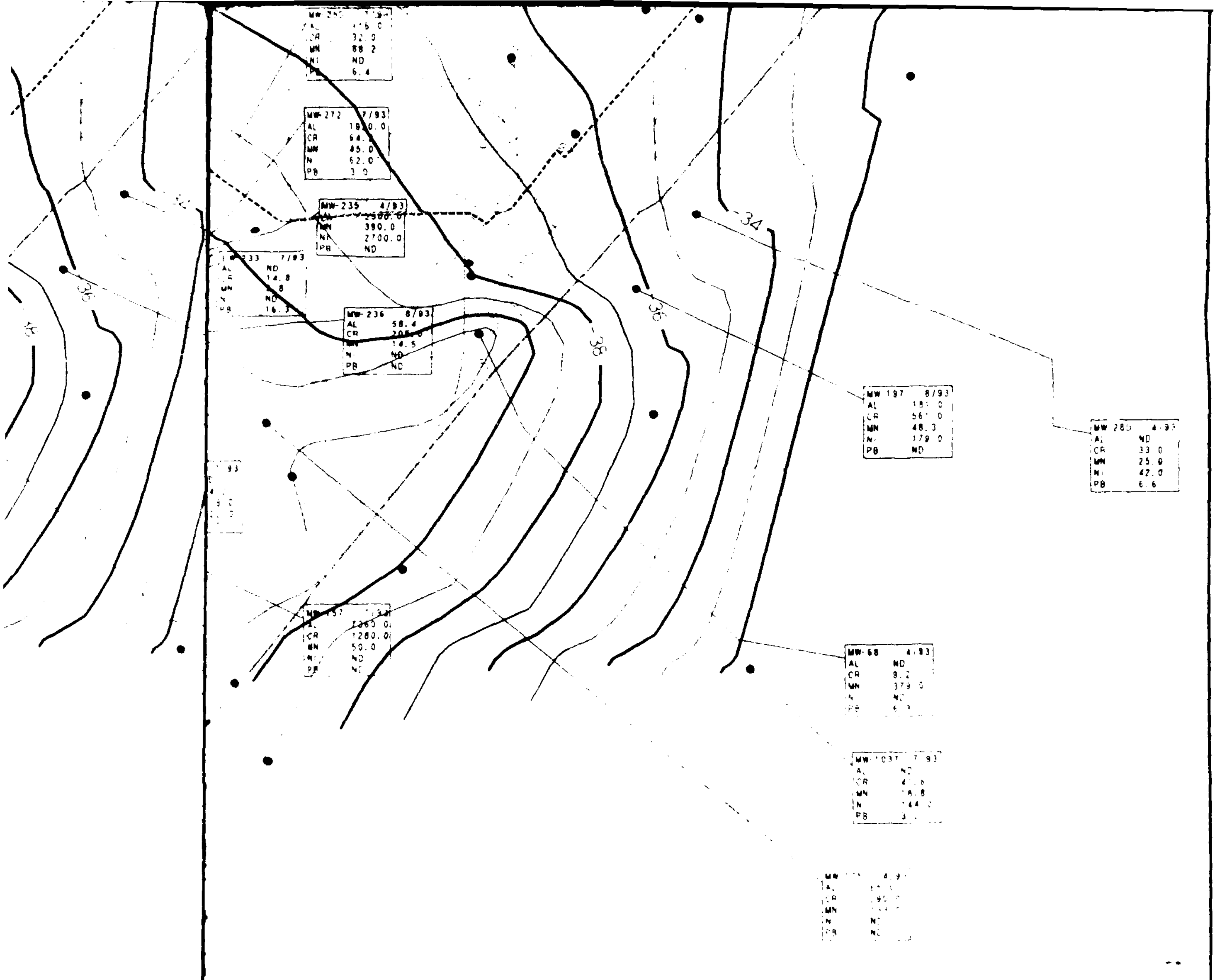


FIGURE 4-
METALS C
N GROUN
N THE A
OPERABLE UN
McCLELLAN A
SACRAMENTO,

FIGURE 4-26
METALS CONCENTRATIONS IN GROUNDWATER IN THE A ZONE

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

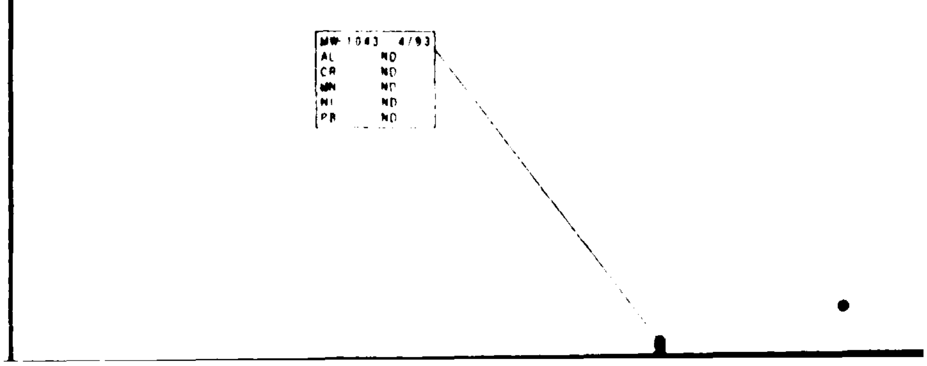
(1)

LEGEND

MW-54 4/93 AL ND CR ND MN 220.0 NI 370.0 PB 24.0	WELL NAME, MONTH AND YEAR AND METALS CONCENTRATIONS
———	WATER LEVEL CONTOURS (ft msl) JANUARY 1993
●	MONITORING WELL
■	BASE WELL OR CITY WELL
x	EXTRACTION WELL
- - - - -	INDUSTRIAL WASTE LINE
———	SOURCE AREAS (SCREENED)

WELLS WITHOUT LABELS WERE NCT INCLUDED IN THE
DATASET BECAUSE THEY WERE LAST SAMPLED BEFO
SEE FIGURES 4-42,4-43,4-44, AND 4-46 IN THE GWC
CH2M HILL, 1994 FOR WELL NAMES.

OPERABLE UNI

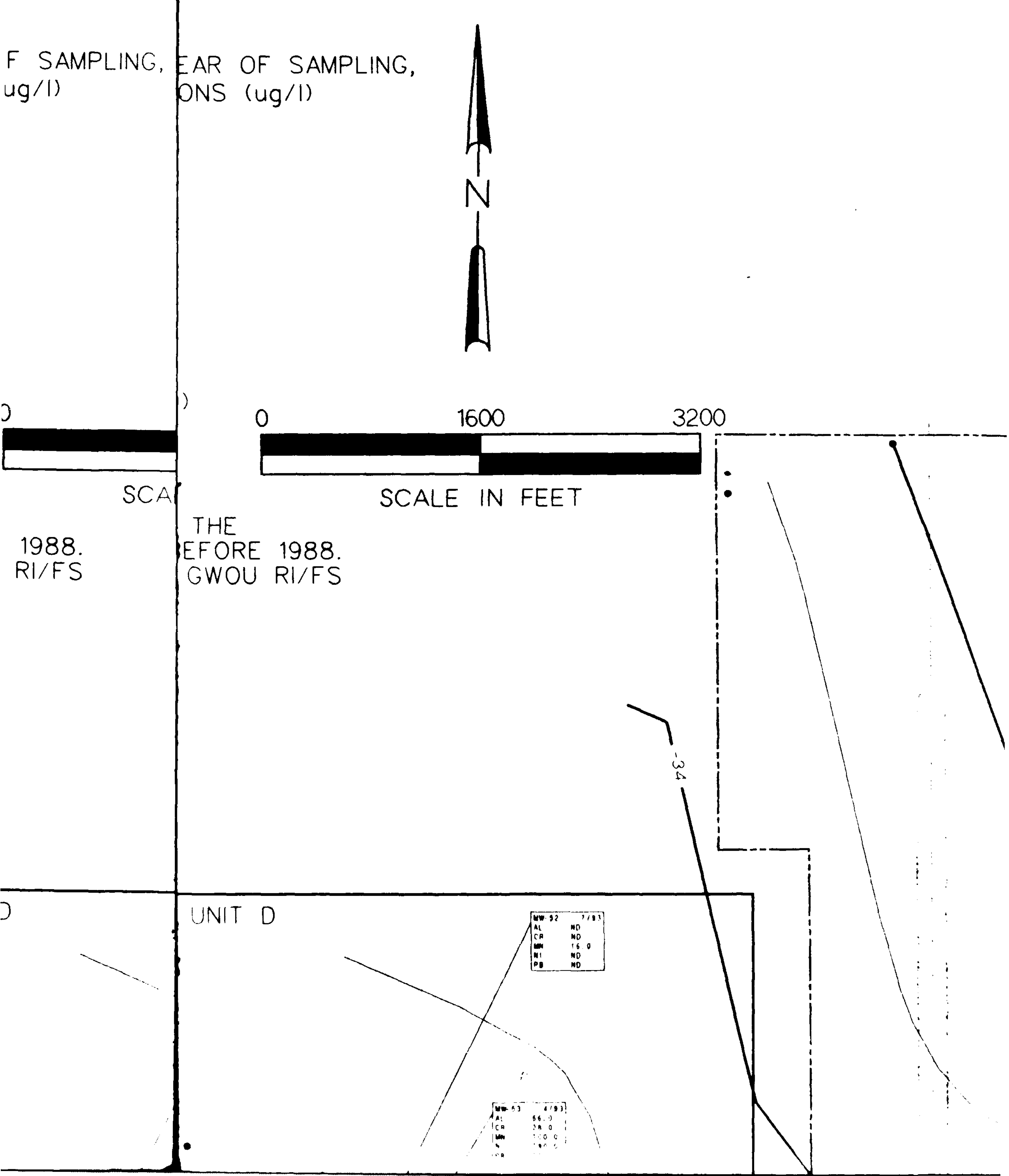


F SAMPLING,
ug/l)

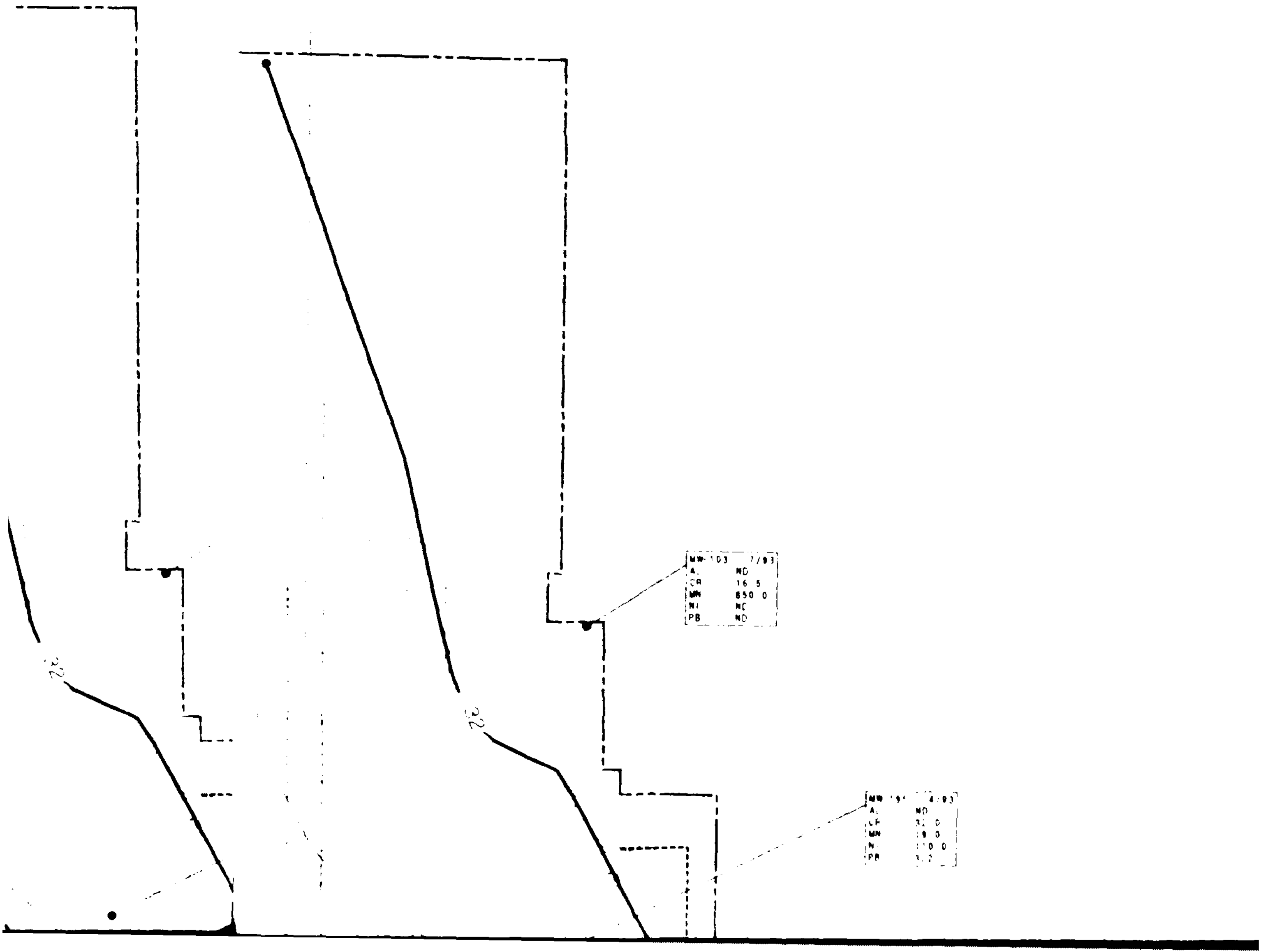
1988.
RI/FS

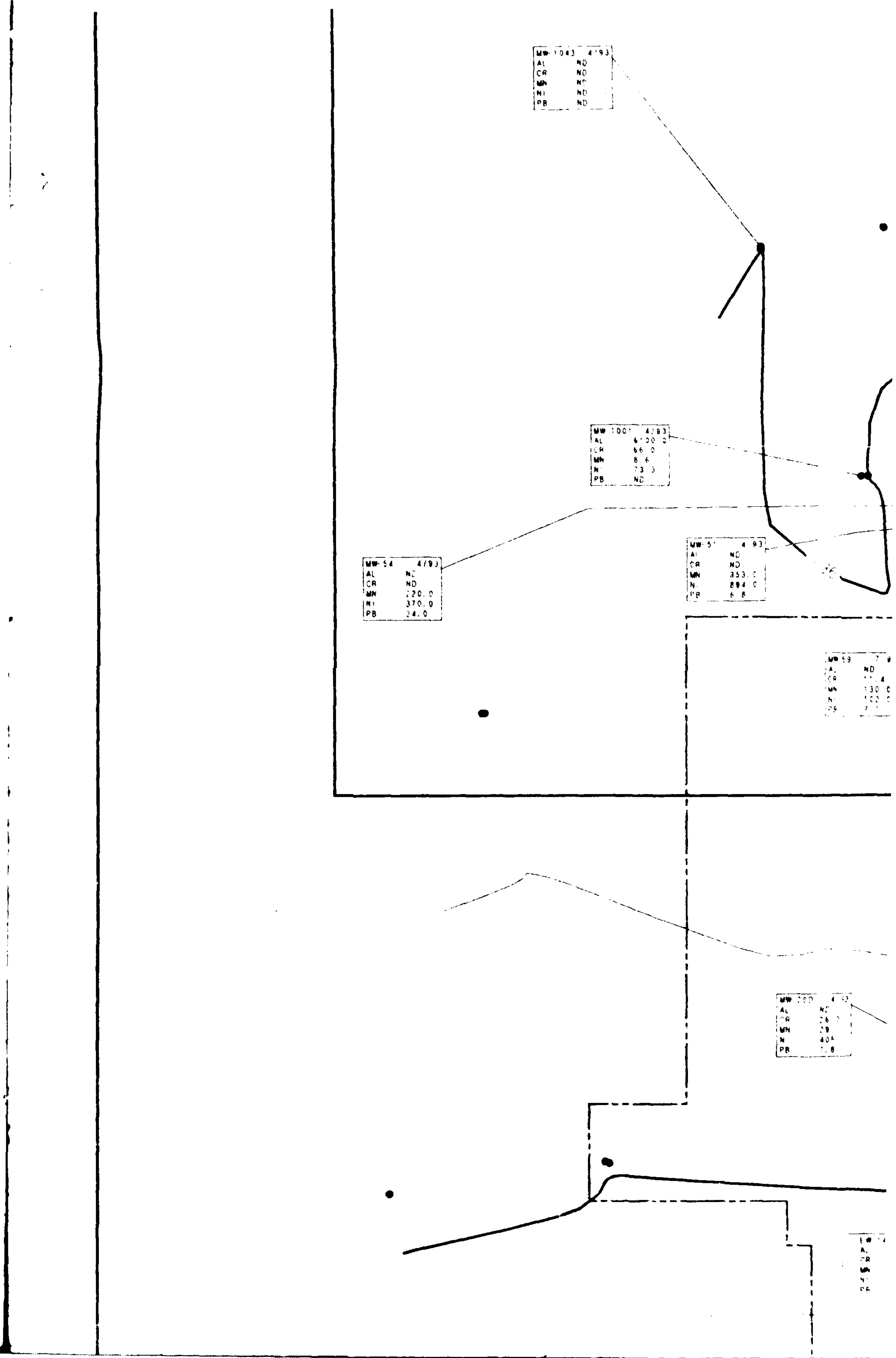
EAR OF SAMPLING,
ONS (ug/l)

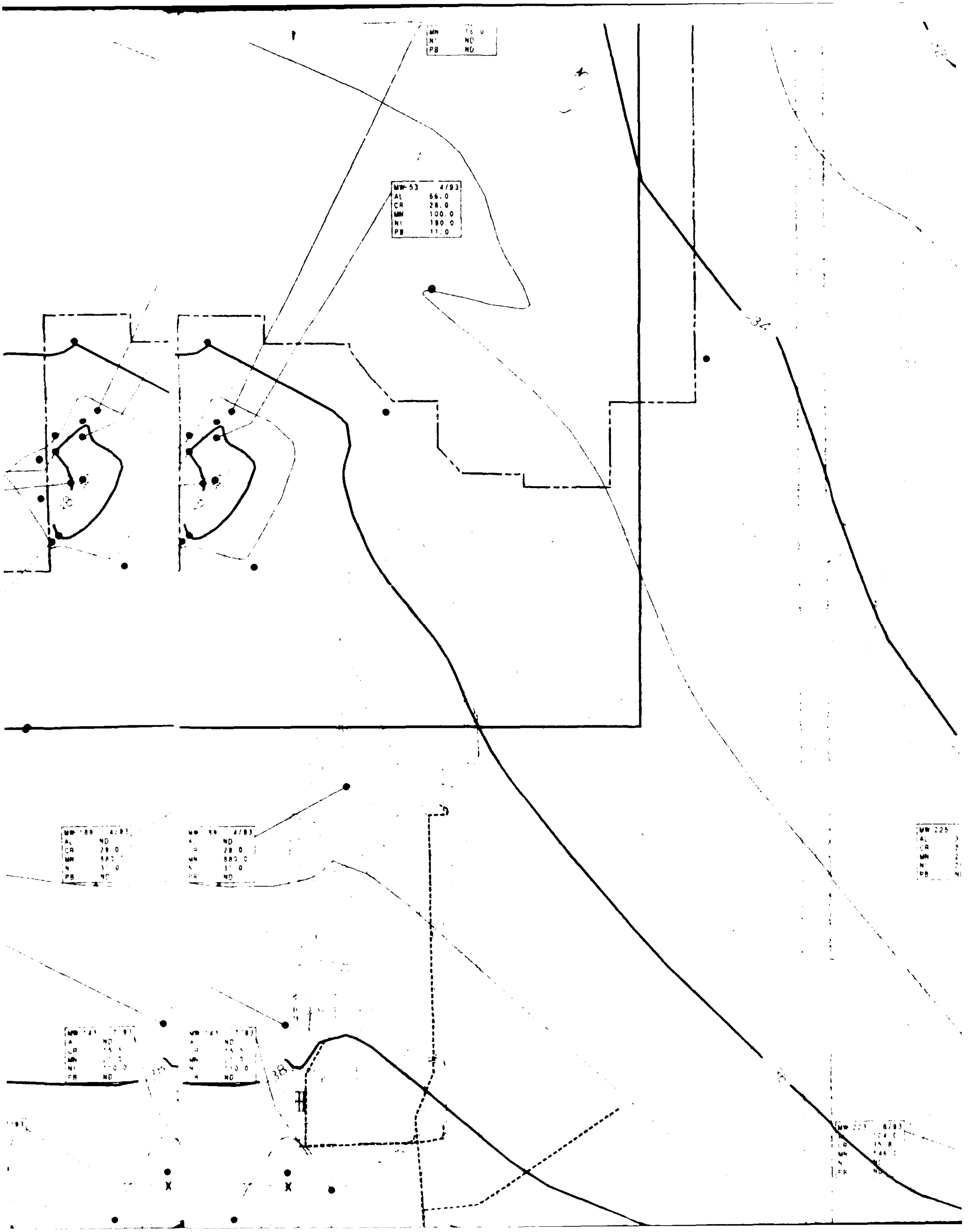
THE
EFORE 1988.
GWOU RI/FS



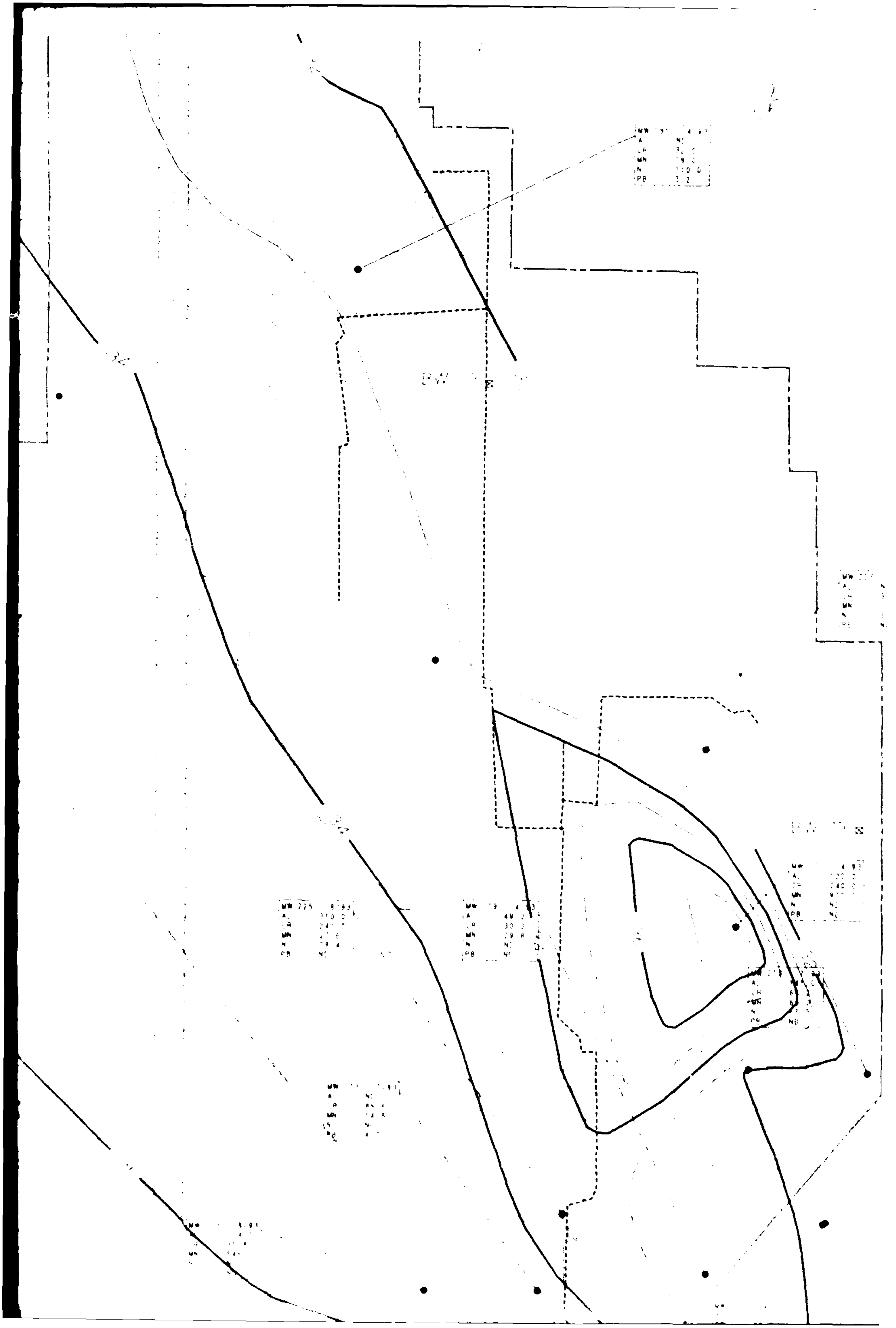
⑤


32
32
MW-103 7/93
AL ND
CR 16 5
MN 850 0
NI NC
PB ND
MW-19[illegible] 4/93
AL ND
CR 3[illegible] 0
MN [illegible]9 0
NI [illegible]0 0
PB 3 2

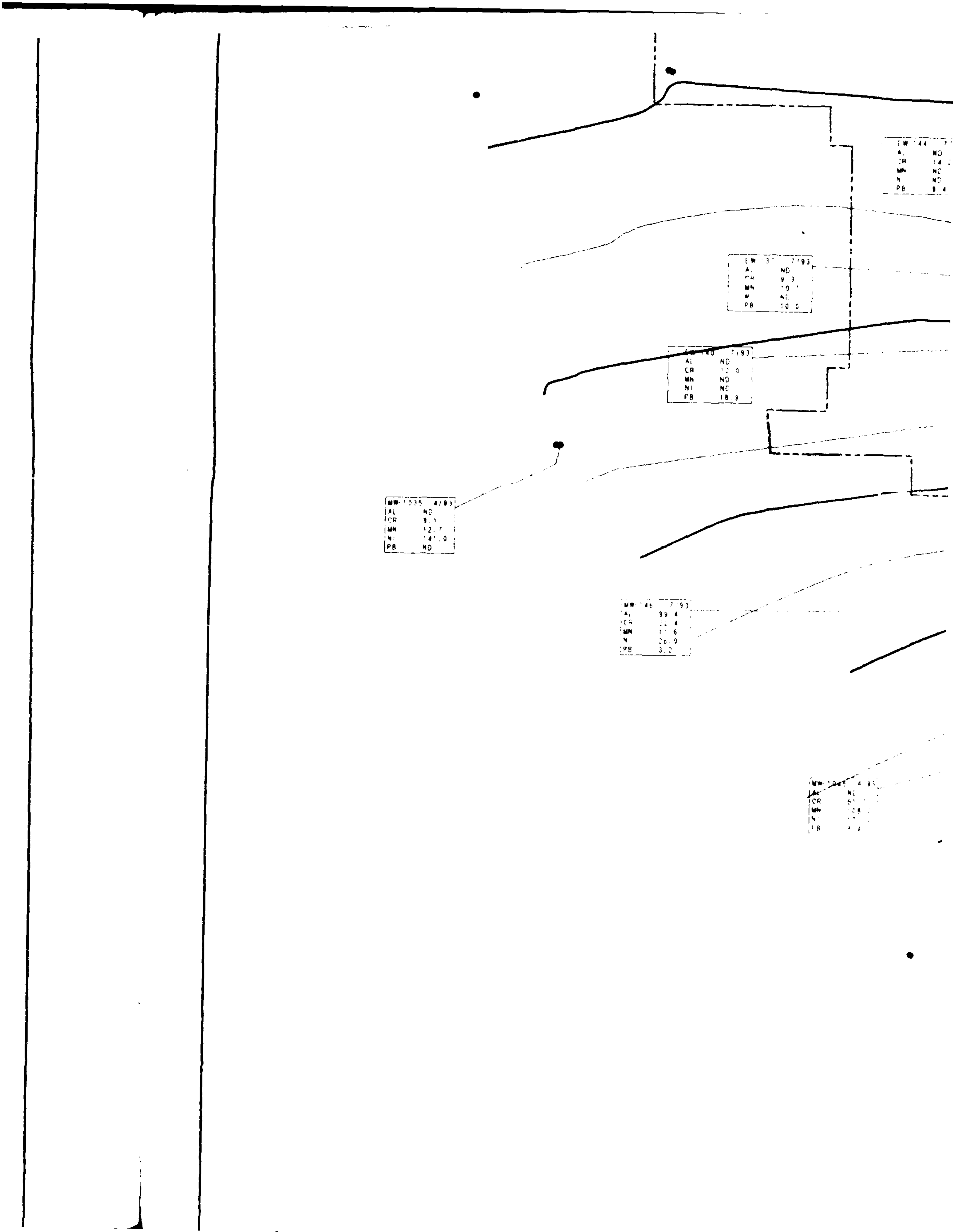

MW-1043 4/93
AL ND
CR ND
MN ND
NI ND
PB ND
MW-1001 4/93
AL 6100.0
CR 66.0
MN 8.6
NI 73.3
PB ND
MW-54 4/93
AL ND
CR ND
MN 220.0
NI 370.0
PB 24.0
MW-51 4/93
AL ND
CR ND
MN 353.0
NI 894.0
PB 6.8
MW-59 7
AL ND
CR 11.4
MN 130.0
NI 102.0
PB 7.1
MW-200 4/93
AL ND
CR 26.0
MN 29
NI 405
PB 7.8
EW-1
AL
CR
MN
NI
PB

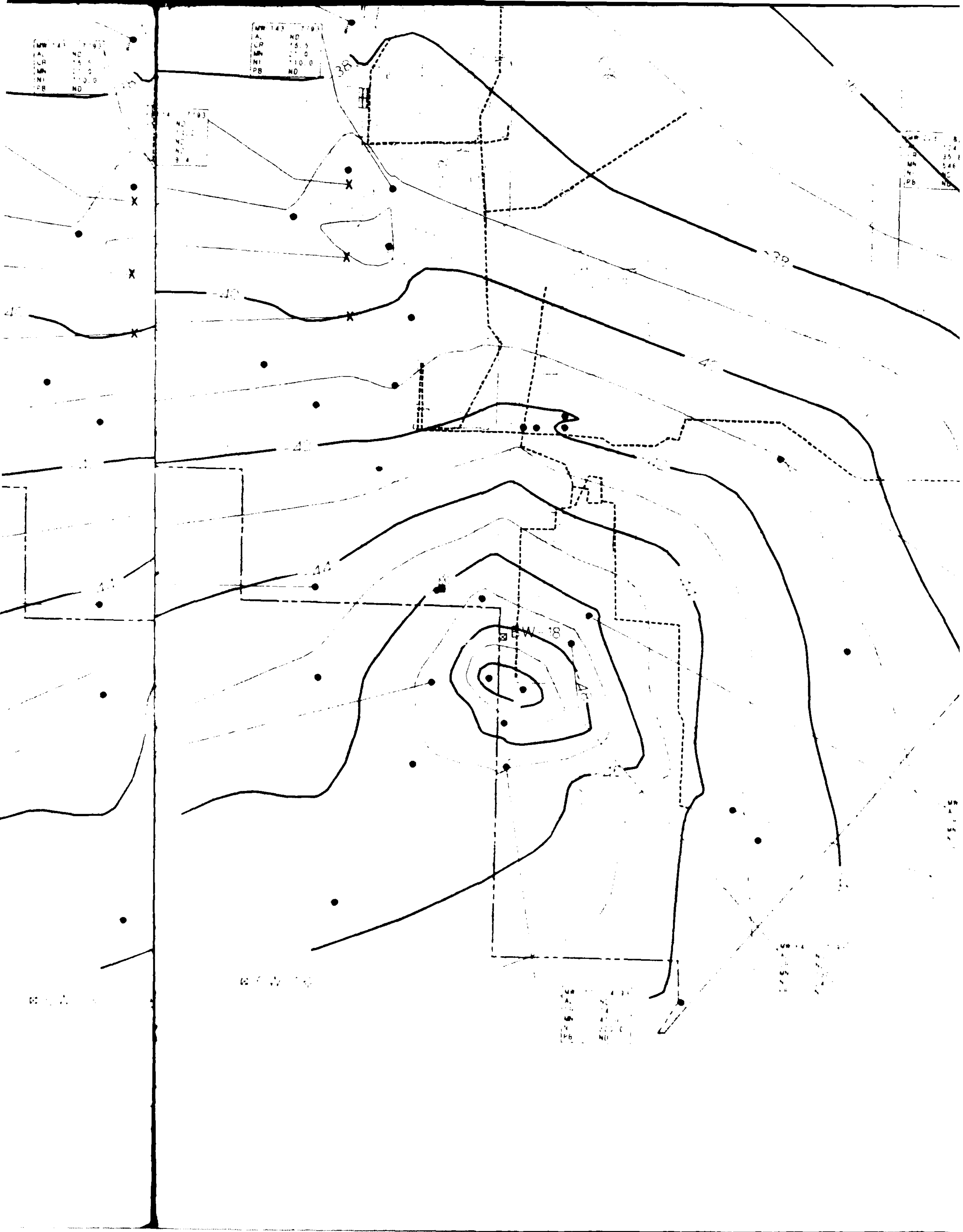


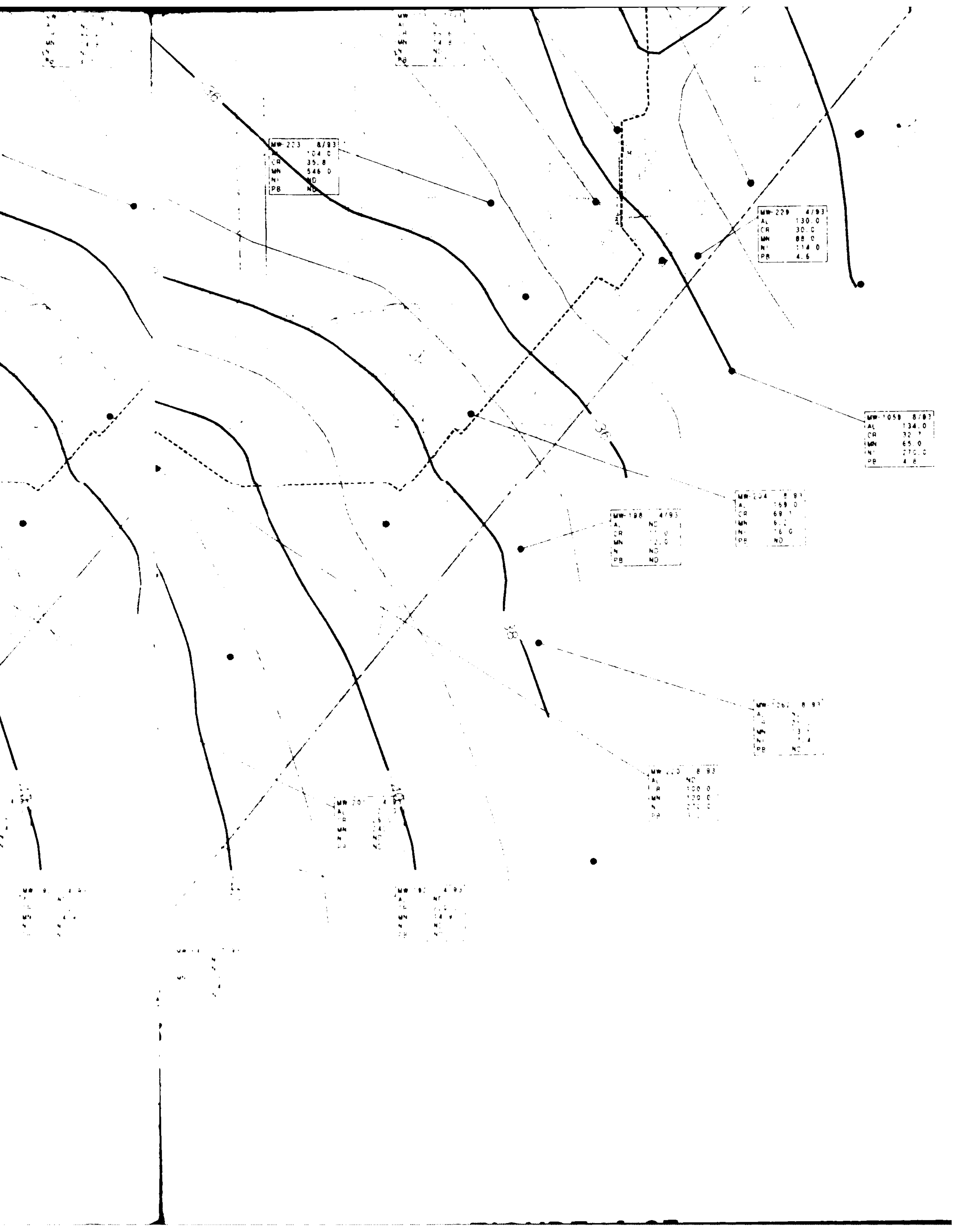
MN 76.0
NI ND
PB ND
MW-53 4/93
AL 66.0
CR 28.0
MN 100.0
NI 180.0
PB 11.0
34
38
MW 189 4/93
AL ND
CR 29.0
PB ND
MW 99 4/93
AL ND
PB ND
MW 225
AL
CR
MN
NI
PB
MW 141 7/93
AL ND
NI 110.0
PB ND
MW 141 7/93
ND
ND
38
MW 223 8/93
CR
MN
PB ND



MW
AL
CR
MN
NI
PB
NO
MW 225 8 93
AL 310.0
CR 24
MN
NI
PB NO
AL 49
CR 30
MN 29.8
NI NO
PB NO
AL NO
MN 9
NI 110.0
PB 3.2
CR 240.0
BW


EW-144 7/
AL ND
CR 14.
MN ND
N ND
PB 9.4
EW-137 7/93
AL ND
CR 9.3
MN 10.1
N ND
PB 10.0
EW-140 7/93
AL ND
CR 12.0
MN ND
NI ND
PB 18.9
MW-1035 4/93
AL ND
CR 8.1
MN 12.7
NI 141.0
PB ND
MW-146 7/93
AL 99.4
CR 22.4
MN 11.6
N 26.0
PB 3.2
MW-1045 4/93
AL ND
CR 51.
MN 108.
NI
PB


MW-143 7/93
AL ND
CR 15.5
MN 21.0
NI 110.0
PB ND
38
38
40
40
42
42
44
44
CW-18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AL 104.0
CR 35.8
MN 546.0
NI ND
PB ND
MW-229 4/93
AL 130.0
CR 30.0
MN 88.0
NI 114.0
PB 4.6
MW-1059 8/93
AL 134.0
MN 65.0
NI 270.0
PB 4.8
MW-204
AL 169.0
CR 69.1
MN 6.2
PB ND
MW-198 4/93
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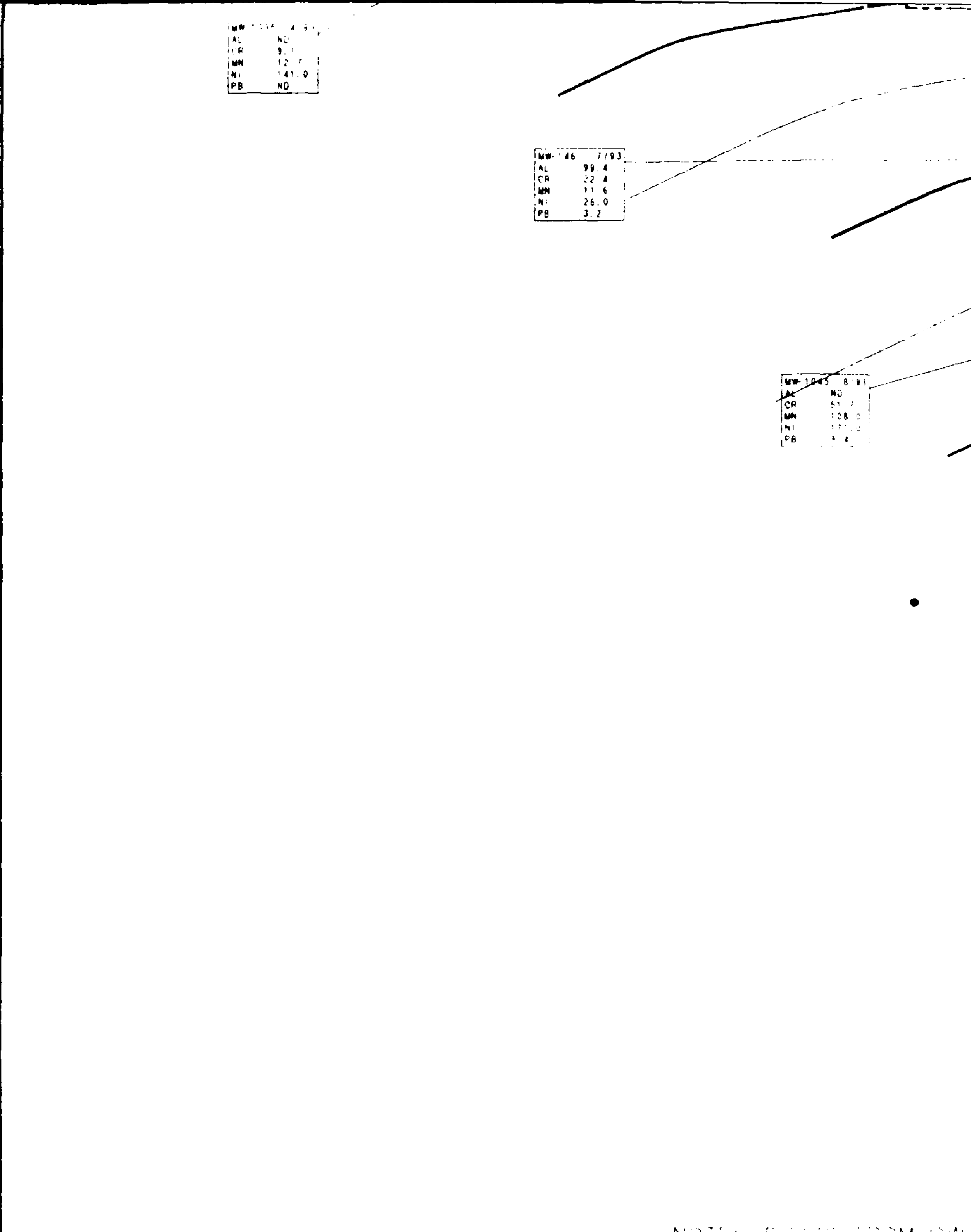

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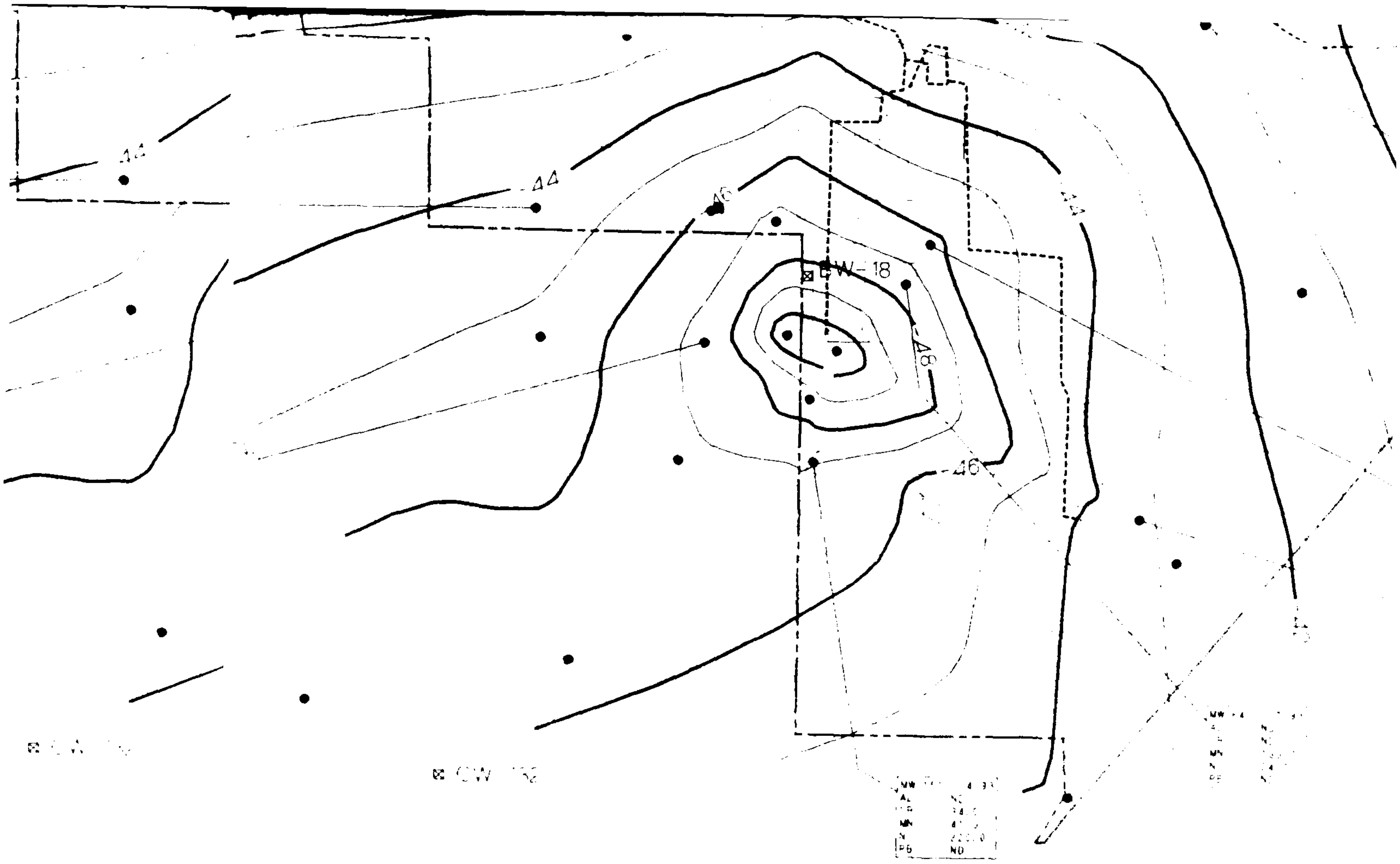

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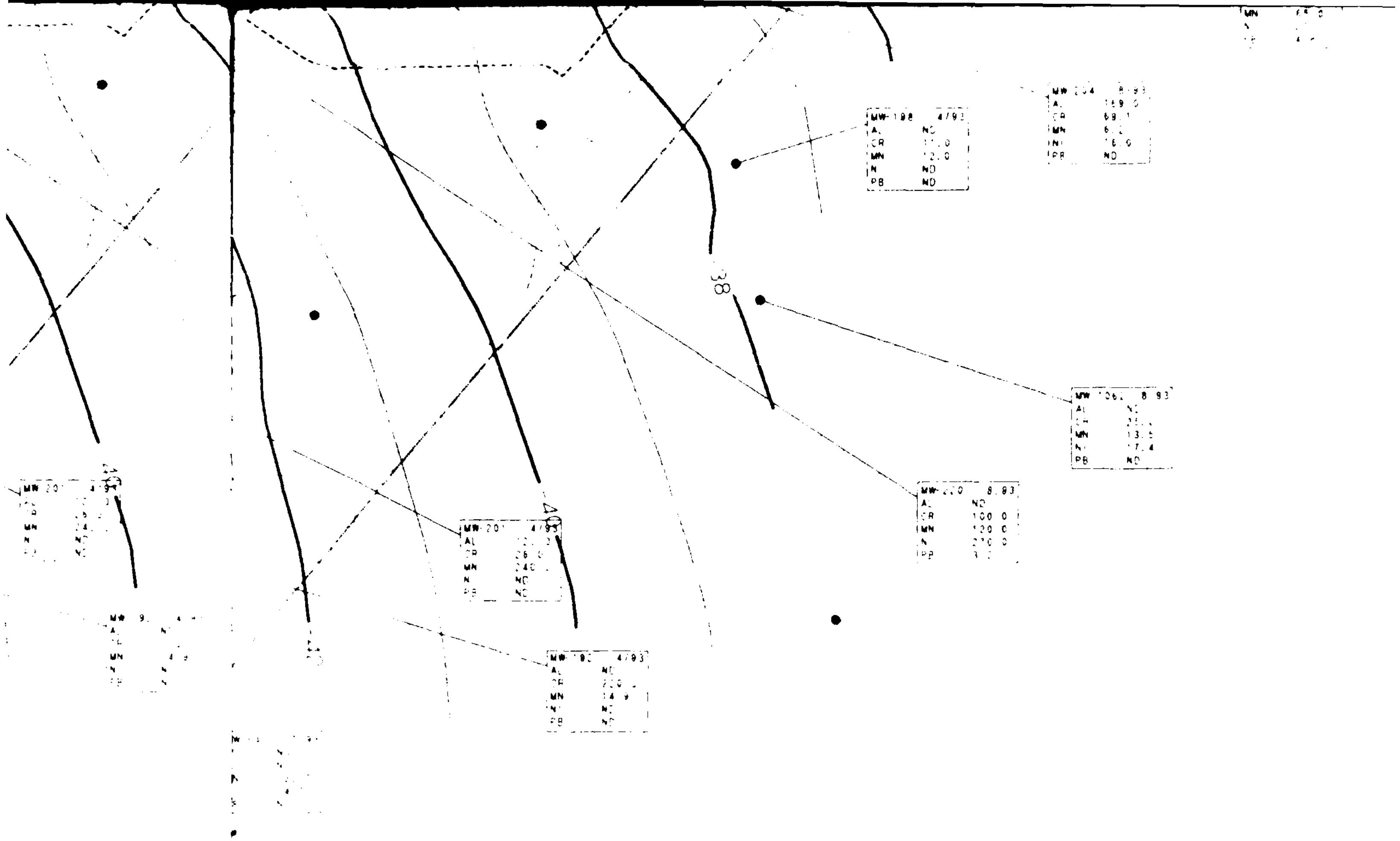


FIGURE 4-27
METALS CONCENTRATIONS IN GROUNDWATER IN THE B ZONE

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Chapter 5
Risk Assessment

Chapter 5
Risk Assessment

The risk assessment evaluated potential exposures and health risks associated with contaminants detected in soil and groundwater under current baseline conditions for the sites at Operable Unit D (OU D). Current baseline conditions are that these sites have undergone remedial actions in the past, such as removal of wastes and placement of imported fill soils (performed prior to 1984). Eight sites were placed under a low permeability cap in 1985 (the Area D cap) to reduce emissions to the air and infiltration of water through contaminated soils and wastes. An offbase remedial action was performed in 1986 to 1987, which involved connecting hundreds of offbase residents to municipal water supply and disconnecting domestic wells impacted or potentially impacted by groundwater contaminants. Groundwater extraction and soil vapor extraction (SVE) remedial actions are ongoing at the sites under the Area D cap. These activities influence the potential for contaminant migration from sites in OU D and the potential exposure pathways that may be present.

The components of the human health risk assessment are as follows:

- Development of a conceptual site model
- Identification of the chemicals of potential concern (COPCs)
- Exposure assessment
- Toxicity assessment
- Risk characterization

These are illustrated in Figure 5-1. The conceptual site model was discussed in Chapter 3.

5.1 Identification of Contaminants of Potential Concern

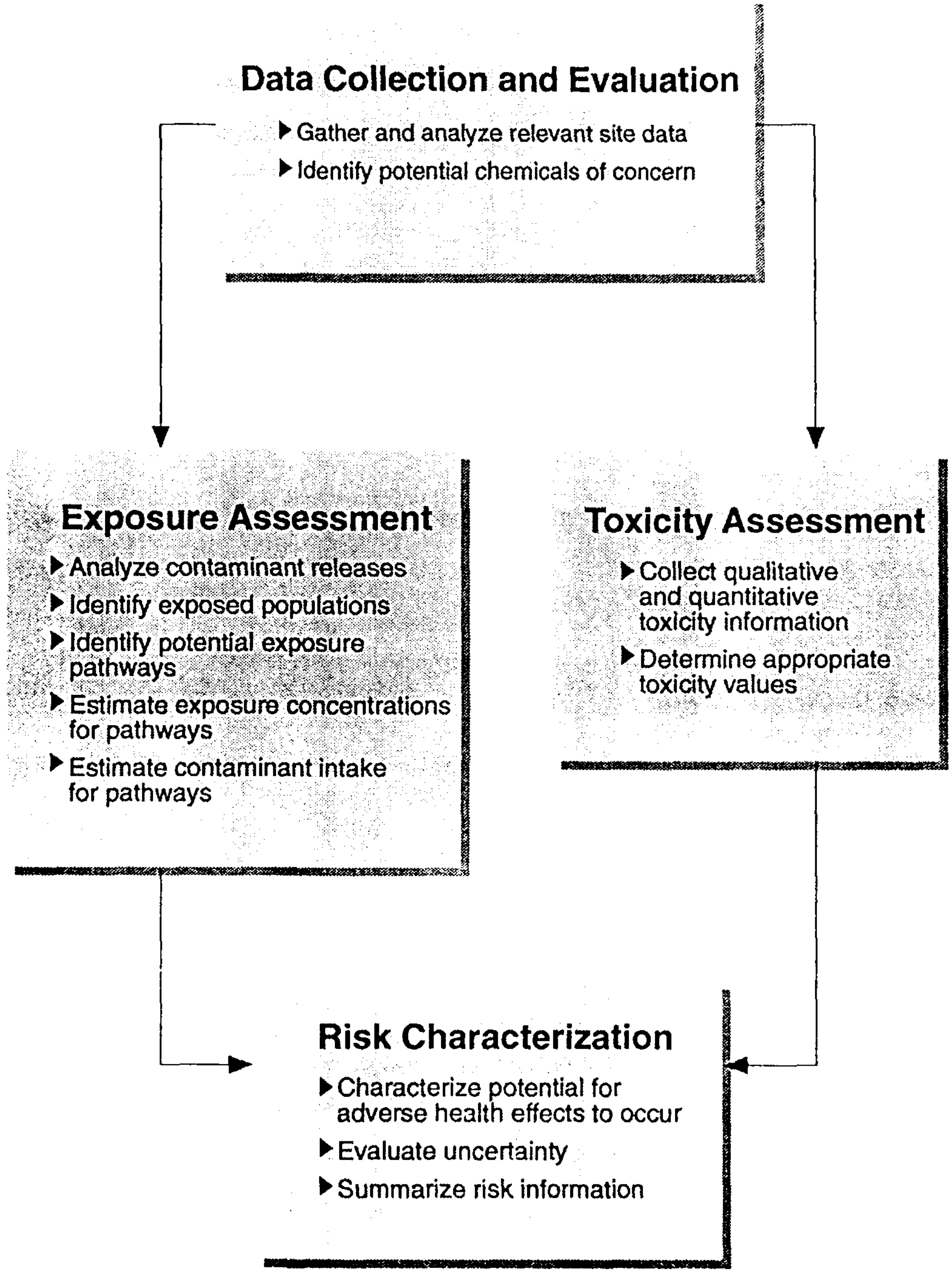
The process involved identifying and selecting for inclusion into the risk assessment those chemicals of greatest potential health concern (*i.e.*, the chemicals that are most toxic, mobile, persistent, or prevalent of those detected at the site) from among the entire set of chemicals associated with OU D. The purpose of identifying chemicals of potential concern (COPCs) is to focus the risk assessment on the most important chemicals (*i.e.*, those chemicals presenting 99 percent of the total risk) detected at the site.

Contaminants of potential are the most toxic, mobile, persistent, or prevalent at t

Factors considered in selecting COPCs for the risk assessment (EPA, 1989a) include the following:

- Evaluation of the analytical methods

- Evaluation of data quality with respect to sample quantitation limits



Data Collection and Evaluation

- Gather and analyze relevant site data
- Identify potential chemicals of concern

Exposure Assessment

- Analyze contaminant releases
- Identify exposed populations
- Identify potential exposure pathways
- Estimate exposure concentrations for pathways
- Estimate contaminant intake for pathways

Toxicity Assessment

- Collect qualitative and quantitative toxicity information
- Determine appropriate toxicity values

Risk Characterization

- Characterize potential for adverse health effects to occur
- Evaluate uncertainty
- Summarize risk information

FIGURE 5-1
ELEMENTS OF RISK ASSESSMENT
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

- Evaluation of data quality with respect to qualifiers and codes
- Evaluation of data quality with respect to blanks
- Evaluation of tentatively identified compounds
- Comparison of potential site-related compounds with background (primarily for inorganic compounds)

Consideration of these factors was modified by site-specific conditions at OU D. For example, semivolatile organic compounds (SVOCs) and metals detected at OU D sites have been found principally under the Area D cap; evaluation of the presence of complete exposure pathways to these contaminants includes consideration of this cap. Much of the data for these sites was collected prior to the development of consistent guidelines for determining data useability. To the extent possible (*i.e.*, for data collected under the 1992 field investigation work plan), evaluation of data for the risk assessment was based on the *EPA Guidance for Data Useability in Risk Assessment* (EPA, 1992a). Generally, earlier data were used "as is" (*i.e.*, as they were presented in the McLaren, 1986 report) in the risk assessment.

Semivolatile organic comp
(SVOCs) detected at OU L
have been found principal.
the Area D cap.

Several of these factors were addressed prior to initiating the risk assessment for OU D. Analytical methods and sample quantitation limits used in the various site investigations have been specified in work plans approved by the appropriate regulatory agencies (CH2M HILL, 1992; 1993; RADIAN, 1992). Prior to use in the risk assessment, data collected under the work plan underwent validation with respect to qualifiers, codes, and blanks; data not meeting data quality objectives specified in the approved work plans were rejected or qualified prior to use in the risk assessment. Collection of surface or shallow soil samples from Sites 6 and 26 was not included in the agency-approved work plans for the OU D RI, which limits the interpretations of the data in the risk assessment. Given the existing data gaps, further discussions of the nature and significance of health risks associated with these two sites are discussed in Section 5.6 (Risk Characterization).

The COPCs were grouped as non-VOCs (SVOCs and metals) and VOCs. The VOCs at the site that were COPCs principally were chlorinated hydrocarbons. The VOCs in fuel hydrocarbons (including benzene) generally did not pose a significant health risk. This distinction is recognized because VOCs have a greater tendency to migrate from the OU D sites and, as the RI data show, pose a greater potential for human exposure.

VOCs have a greater tende
migrate from the OU D sit
as the RI data shows, pose
greater potential for huma
exposure.

Several chlorinated VOCs are COPCs in onbase groundwater. Health risks potentially associated with these contaminants were evaluated using a scenario involving hypothetical use of onbase groundwater in the future. Potential exposure to offbase groundwater contaminants was evaluated for TCE, which has the widest extent of any groundwater contaminant. Several chlorinated and aromatic VOCs have been detected in soil gas underlying OU D, including TCE, PCE, 1,1,1-TCA, 1,1-DCE, Freon 113, benzene, toluene and xylene. These have been identified as COPCs for purposes of evaluating potential onbase worker inhalation exposures and health risks. SVOCs, metals, dioxins and furans have not been identified as COPCs in soil at OU D, at this time. SVOCs in soil generally have been limited to phthalates and selected polynuclear aromatic hydrocarbons (PAHs), including naphthalene and pyrene.

Metals that have been detected in soil above background levels include arsenic, barium, beryllium, cadmium, cobalt, copper, manganese, nickel, lead, and vanadium (see Appendix D). Octachloradibenzo-p-dioxin (OCDD) and total polychlorinated dibenzodioxins (PCDDs) have been detected in soil samples from underneath the cap. However, the cap prevents direct contact with these contaminants in soil, or resuspension of these contaminants in dust. Because there are no complete pathways of exposure to these contaminants, they have not been identified as COPCs in soil under the cap.

Surface and shallow soil samples have not yet been collected from the fill soil covering Sites 6 and 26. Therefore, it is not certain if there are COPCs in soil at these sites. Further discussion of the potential health risks associated with the fill soil covering these sites is presented in the Risk Characterization section.

5.2 Exposure Assessment

This exposure assessment is based on scenarios that define human populations potentially exposed to COPC originating from OU D. The potential pathways of exposure, frequency and duration of potential exposures, rates of contact with air, water and soil and the concentrations of chemicals in air, groundwater, or soil are evaluated in the assessment of human intake of COPCs.

Contaminant intakes and associated risks have been quantified for all exposure pathways considered potentially complete. The steps involved with the exposure assessment are as follows:

- Identification of potentially exposed populations
- Identification of potential exposure pathways and selection of complete exposure pathways
- Evaluation of the environmental fate and transport of chemicals in soil and groundwater
- Development of exposure scenarios

- Estimation of exposure point concentrations used to quantify chemical intakes

- Quantification of chemical intakes for each complete exposure pathway

The exposure scenarios for the baseline risk assessment were based on an estimate of the reasonable maximum exposure (RME). The RME is defined as the highest exposure that is reasonably expected to occur at a site. The RMEs are estimated for individual exposure pathways. If a population is exposed via more than one pathway, the combination of exposures across pathways must also represent an RME. The intent of the RME is to develop a conservative estimate of exposure (*i.e.*, well above the average case) that is still within the range of possible exposures (EPA, 1989a). The exposure scenarios evaluated in the baseline risk assessment are summarized in Table 5-1.

The exposure scenarios baseline risk assessmen based on an estimate o reasonable maximum e (RME).

Certain scenarios were not considered in the risk assessment for OU D. For example, future residential land use in the Area D Cap was not considered, because local ordinances and ARARs would probably prohibit development on an engineered cap. Detailed descriptions of these scenarios are presented in Appendix H.

The chemical intakes calculated in this section are expressed as the amount of chemical at the exchange boundary (*i.e.*, skin, lungs, or gut) and available for absorption. Please note that in keeping with EPA guidance, intake for dermal exposure pathways are estimated in terms of absorbed dose and not quantity of chemical at the exchange boundary. Estimates of chemical intakes in accordance with RME scenarios are presented in this section. Chemical intakes were estimated for both adults and children and for both current and future land use.

Calculations and input parameters used for estimating intake rates through the inhalation, soil ingestion, groundwater ingestion, and dermal contact with soil and groundwater pathways were obtained from EPA (EPA, 1989a; 1990a; 1991a). The calculated intake rates are combined with toxicity criteria values (discussed in Section 5.3) to characterize potential health risks.

The calculations used to estimate exposure or intake from contact with chemicals in soil have the same general components: (1) a variable representing chemical concentration; (2) variables describing the characteristics of the exposed population; and (3) an assessment-determined variable that defines the time frame over which exposure occurs. The general mathematical relationship between these variables and chemical intake in humans is as follows:

Table 5-1
Summary of Exposure Scenarios in the Baseline Risk Assessment for Operable Unit D

Receptor	Location/Media	Exposure Route	Basis for Exposure Concentration
Onsite worker - Building 1093	Shallow soil gas and soil vapor monitoring wells	Inhalation	Maximum VOC concentration in soil gas in samples near Building 1093.
Offbase resident (within offbase Remedial Action Area)	Offbase groundwater	Inhalation (VOCs volatilized from groundwater)	Highest concentration most frequently detected in offbase domestic and monitoring wells.
Hypothetical future onbase resident	Onbase groundwater	Ingestion of groundwater inhalation (VOCs volatilized from groundwater)	Concentrations detected in MW-10, at OU D.
Offbase resident (west of OU D)	Residential crawlspace and ambient air	Inhalation	VOC emissions from soil gas contaminants (migrating from OU D) are not likely to have contributed significantly to concentrations detected in residential and ambient crawlspace air. Chemical intakes and health risks were not calculated for this scenario.

$$I = \frac{C \times CR \times EF \times ED}{AT \times BW} \quad (1)$$

where,

I = Intake (mg/kg-day)

C = Average concentration in the contaminated medium contacted over the exposure period (either mg/kg, mg/l or mg/m^3)CR = Contact rate; the quantity of contaminated medium contacted per unit time (*e.g.*, mg/day))

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

AT = Averaging time; period over which exposure is averaged (days)

BW = Body weight (kg)

The calculated intake rates are combined with toxicity criteria values (discussed in Section 5.3) in order to characterize potential health risks.

5.3 Toxicity Assessment

The toxicity assessment determines the relationship between the magnitude of exposure to a chemical and the adverse health effects. This assessment provides, where possible, a numerical estimate of the increased likelihood and/or severity of adverse effects associated with chemical exposure (EPA, 1989a).

For purposes of the toxicity assessment, the COPCs have been classified into two broad categories: noncarcinogens and carcinogens. This classification has been selected because health risks are calculated quite differently for carcinogenic and noncarcinogenic effects, and separate toxicity values have been developed for carcinogenic and noncarcinogenic effects. These toxicity values represent the potential magnitude of adverse health effects associated with exposure to chemicals, and are developed by EPA and the Department of Toxic Substances Control (DTSC). Toxicity studies with laboratory animals or epidemiological studies of human populations provide the data used to develop these toxicity values. These values represent allowable levels of exposure derived from the results of toxicity studies or epidemiological studies. The toxicity values are then combined with the exposure estimates in the risk characterization process to estimate adverse effects from chemicals potentially originating from OU D.

Noncarcinogenic effects were evaluated using either Reference Doses (RfDs) or Reference Concentrations developed by EPA. The RfD is a health-based criterion, expressed as chemical intake rate in units of mg/kg-day, used in evaluating noncarcinogenic effects. Unless evidence to the contrary exists, if a carcinogenic response occurs at the exposure levels studied (typically high doses), it is assumed that responses will occur at all lower doses. Exposure to levels of a carcinogen is then considered to have a finite risk of inducing cancer. Estimates of cancer are calculated using Slope Factors (SFs), which define the cancer risk caused by continuous constant lifetime exposure to one unit of carcinogen (in units of risk per mg/kg-day).

The toxicity values used to characterize health risks are presented in Appendix H. The characterization of health risks for COPCs at OU D is presented in Section 5.4.

5.4 Risk Characterization

Risk characterization involves estimating the magnitude of the potential adverse health effects under study. This is accomplished by combining the results of the dose response and exposure assessments to provide numerical estimates of potential health effects. These values represent comparisons of exposure levels with appropriate RfDs and estimates of excess cancer risk. Risk characterization also considers the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding such estimates.

Although the risk assessment produces numerical estimates of risk, these numbers do not predict actual health outcomes. The estimates are calculated to overestimate risk, and therefore any actual risks are likely to be lower than these estimates and may even be zero.

The numerical risk estimates are presented in Table 5-2. Appendix H presents summary tables showing the numerical risk estimates for each COPC in each exposure scenario. Generally, EPA considers action to be warranted at a site when cancer risks exceed 1 x 10^{-4}. Action may or may not be required for risks falling within 1 x 10^{-4} to 1 x 10^{-6}. This is judged on a case-by-case basis. A hazard index (the ratio of chemical intake to the RfD) greater than 1.0 indicates that there is some potential for adverse noncancer health effects associated with exposure to the contaminants of concern (EPA, 1991b).

In interpreting the results presented in Table 5-2, it should be noted that these represent likely pathways of exposure to human populations. Health risks would likely be much greater than presented in this risk

Table 5-2

Summary of Estimated Human Health Risks for Complete Pathways of Exposure
McClellan Air Force Base
Operable Unit D[a]

			Cancer Risk Estimates		Noncancer Effects	
Receptor	**Affected Media**	**Exposure Route**	**Increased Lifetime Cancer Risk**[b]	**Chemicals Principally Contributing to Risks**	**Hazard Index**[c]	**Chemicals Principally Contributing to Noncancer Effects**
Onbase worker - Building 1093	Soil gas	Inhalation	8×10^{-7}	Trichloroethylene (TCE) in soil gas	0.08	1,1-Dichloroethylene
Offbase resident - groundwater use for sprinkler irrigation	Groundwater, offbase	Inhalation	1.4×10^{-9}	Trichloroethylene (TCE) in groundwater	Not applicable	Not applicable
Hypothetical future onbase resident - residential groundwater use	Groundwater, onbase	Ingestion Inhalation	8×10^{-4}	1,2-Dichloroethane 1,2-DCA and trichloromethane TCE in groundwater	3.6	1,1-Dichloroethylene
Offbase resident - residential and crawlspace air[d]	Soil gas, ambient air	Inhalation	Not applicable	Risks not calculated for chemicals detected in offbase residential and crawlspace air; concentrations detected in air are not likely to have originated from OU D, and probably represent background level	Not applicable	--

[a] Health risk estimates are based on Reasonable Maximum Exposure (RME) scenarios.

[b] Numerical risk estimates are not predictions of actual health outcomes. These estimates are calculated in a manner that overestimates risk, and therefore any actual risks are likely to be lower than these estimates and may even be zero. The EPA generally considers action to be warranted at a site when cancer risks exceed 1×10^{-4}. Generally, the need for action for risks falling within 1×10^{-4} to 1×10^{-6} is judged on a case-by-case basis. Risks less than 1×10^{-6} generally are not of concern to regulatory agencies.

[c] Hazard index greater than one indicates that there is some potential for adverse noncancer health effects associated with exposure to the contaminants of concern.

[d] Health risks not calculated for this exposure pathway. Available information indicates that detected concentrations in residential crawlspace and ambient air resemble background and are largely unrelated to sites at OU D.

Table 5-3
Comparison of Agency for Toxic Substance and Disease Registry Health Assessment Findings and Operable Unit D Baseline Risk Assessment Results

Public Health Issue	Health Assessment	Operable Unit D Risk Assessment
Private well exposure pathway	There are 550 homes connected to municipal water supply. Some domestic wells *may still be used for non-potable uses*, such as irrigation. It is possible that some residents may have reconnected their wells for potable water use. Individuals using water for irrigation could become exposed by inhaling contaminants from droplets of water spray and ingesting biota that have accumulated contaminants.	No current exposure pathways from domestic water use since the offbase remedial action (connection of residences with municipal water). No data on whether any domestic well water use has resumed in the remedial action area, which represents an uncertainty in the risk assessment. Potential exposures associated with sprinkler irrigation do not represent a significant health risk. Contaminants in groundwater are not expected to accumulate into biota (crops or livestock) on the basis of physical/chemical properties (log k_{ow} coefficients).
Onbase surface soil exposure pathway	The only data available are from OU B. Surface soil sampling data from other OUs are lacking, preventing full assessment of the pathway.	There is no current direct contact or fugitive dust inhalation exposure pathway from sites under the Area D cap. Future pathways are also prevented as long as the cap remains in place. Available information for sites not under the cap (Sites 6 and 26) indicate that wastes have been excavated and imported fill soil placed over the site. Available sampling and analytical data at depth suggest that surface soil is not a contaminant source. There is not likely to be exposure pathways from surface soil at Sites 6 and 26.
Onbase subsurface soil exposure pathway	Elevated concentrations of contaminants of concern have been found in soil samples at OUs A, B, C, and D. The ATSDR has no information that there has been human exposure to contaminants in onbase soils. Construction workers moving or removing soils could be exposed to contaminants in subsurface soils; subsurface soil is considered a potentially complete exposure pathway because no data confirm such exposure. Subsurface soil contamination has not yet been fully characterized at *many sites* at the base.	There is no current direct contact or fugitive dust inhalation exposure pathway from sites under the Area D cap. Future pathways are also prevented as long as the cap remains in place. Available sampling data from soil borings and soil gas samples from Sites 6 and 26 do not suggest that contamination is present within the excavation zone. The VOCs detected in deep soil borings and soil vapor monitoring wells probably represent lateral migration through soil gas from sites under the Area D cap. There are not likely to be exposure pathways from subsurface soil at Sites 6 and 26.
Onbase inhalation exposure pathway of soil gas contaminants	No information.	Contaminants migrating laterally from sites under the Area D cap could potentially be emitted from surface soil underneath nearby buildings (Building 1093). Potential exposures associated with indoor air inhalation, on the basis of currently measured VOC concentrations in soil gas, do not pose a significant health risk.

Table 5-3
Comparison of Agency for Toxic Substance and Disease Registry Health Assessment Findings
and Operable Unit D Baseline Risk Assessment Results

Public Health Issue	Health Assessment	Operable Unit D Risk Assessment
Offbase surface soil exposure pathway	At the request of ATSDR, McClellan AFB performed offbase surface soil sampling from residences adjacent to OU D. The contaminants PCBs, dioxins/furans, and SVOCs were not detected in these samples. Pesticides detected were all at concentrations consistent with the agricultural use of the properties. Elevated concentrations of lead and arsenic detected in single samples were considered to be associated with localized sources and not associated with migration from McClellan AFB. Elevated concentrations of thallium are anomalous; these may be laboratory artifaces. Analysis of surface soils at the residences have not detected any contaminants emanating from McClellan AFB that are at levels of public health concern. This pathway was eliminated from consideration in the Health Assessment.	No additional data were collected. The finding from the Health Assessment was incorporated into the risk assessment.
Offbase residential crawlspace and ambient air inhalation exposure pathway	Contaminants have been detected in air by monitoring residential crawlspaces and ambient air, fenceline ambient air, private well airspaces, and offbase soil gas monitoring wells adjacent to OU D. Some VOCs, such as benzene and methylene chloride are present in Sacramento ambient air. Certain elevated levels, such as methylene chloride and 1,1,1-TCA, may be due to industrial activities at McClellan AFB or residential activities. Other VOCs measured in crawlspaces and ambient samples correspond to high levels of gases near OU D (TCE and 1,1-DCE). To further define this pathway, crawlspace samples should also be analyzed for methane to evaluate the potential physical hazard.	Contaminants detected in shallow soil gas near the residences, which due to proximity to human receptors would be anticipated to provide the strongest emissions source, appear to provide a very small contribution to the VOC concentrations detected in ambient air near the residences. The presence of the same VOCs in nearby background air samples, and in emissions from permitted onbase industrial sources, suggests that contaminants in soil gas near OU D sites are not the source of the VOCs detected in the residential crawlspace and ambient air samples. As shown by the data collected during the RI, the VOCs detected in the residential crawlspace and ambient air samples are considered to represent typical background ambient air conditions and not an impact related to OU D. Concentrations of methane detected in crawlspace samples are well below the lower explosive limit.

assessment if there were complete pathways of exposure to contamination in soil and soil gas at the sites under the Area D cap and the groundwater under the cap. In the subsequent section, Prioritization of Sites for Further Action, health risks were evaluated with the assumption that complete pathways of exposure existed to these contaminants. This evaluation supports prioritization of sites with OU D along with other sites at McClellan AFB, and does not represent the potential magnitude of health risks associated with contaminants migrating from sites in OU D. The existing remedial actions at OU D, including the Area D cap, groundwater extraction and treatment, and soil vapor extraction have a significant role in reducing health risks associated with sites at OU D.

Health risks would likely be muc greater than presented in this ris assessment if there were complet pathways of exposure to contamination detected in soil an soil gas at the sites under the Area D cap and the groundwater under the cap.

The results from the risk assessment were compared with the findings from the Health Assessment for McClellan AFB prepared by the Agency for Toxic Substances and Disease Registry (ATSDR). In preparation of the Health Assessment, ATSDR collected and reviewed relevant health and environmental data for activities across the entire Base. The findings from the ATSDR as they relate to specific features in OU D, along with the specific results from the risk assessment, are summarized in Table 5-3.

Chapter 6
Problem Definition

Chapter 6
Problem Definition

This chapter identifies the contaminants and media that will require remedial action. The areas of the site that will require remedial action are determined by comparing the site data to the applicable or relevant and appropriate requirements (ARARs) and risk-based criteria. As illustrated in Figure 6-1, the problem areas are defined to be those areas where site contamination exceeds the ARARs or risk criteria. The ARARs or risk criteria for each COC are summarized in Table 6-1.

The areas of the site that will
require remedial action are
determined by comparing the
data to the applicable or relev
and appropriate requirements
(ARARs) and risk-based criter

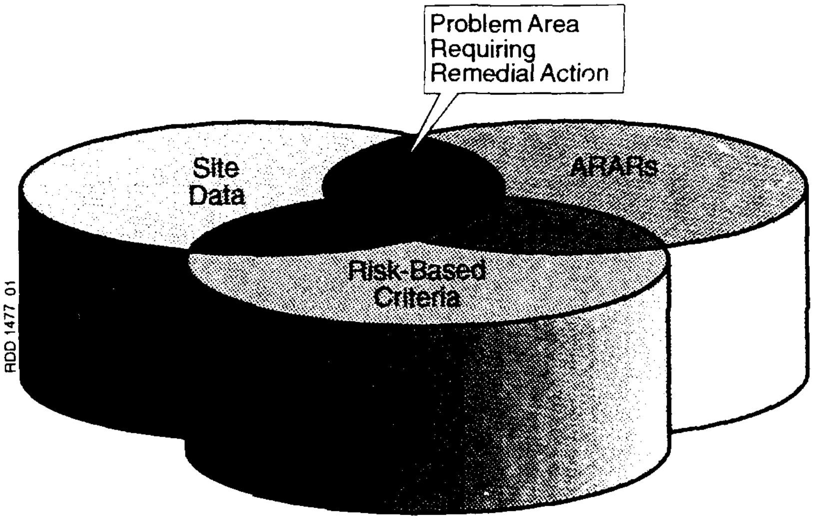


FIGURE 6-1
CONCEPTUAL
REPRESENTATI
OF PROBLEM A
OPERABLE UNIT D
McCLELLAN AIR FORCE
SACRAMENTO, CALIFO

Target volumes are developed for the groundwater and vadose zone at Operable Unit D (OU D). The purpose of the target volume is to establish a volume for developing and evaluating remedial action alternatives in the Feasibility Study (FS). Target volumes are determined from the understanding of the site conceptual model (Chapter 3). They are the most probable representation of the problem areas and may or may not coincide with the true volume of contaminated media. The target volume is representative of the type and magnitude of problem requiring remedial action. The conceptual differences of the extent of contamination, the problem area, and the target volume are illustrated in Figure 6-2. Target volumes may be refined during the Vadose Zone FS.

The purpose of the target vol
to establish a volume for dev
and evaluating remedial acti
alternatives in the Feasibility

Table 6-1
Proposed Criteria for Contaminants of Concern
Based on ARARs and Risk Assessment

Contaminant of Concern	Soil[a] (mg/kg)	Soil Gas[b] (μg/l)	Groundwater (μg/l) Federal MCL	State MCL
Trichloroethylene	25	1.3	5	5
1,1-Dichloroethylene	0.12	2.4	7	6
Vinyl Chloride	0.016	1	2	0.5
Tetrachloroethylene	56	1.5	5	5
1,1,1-Trichloroethane	300	1.9	200	200
1,2-Dichloroethane	1.4	1	5	0.5
Freon 113	410	17.7	--	--
Bis(2-ethylhexyl) phthalate	200	--	--	--
1,2-Dichlorobenzene	230	--	600	--
Naphthalene	--	--	28[c]	
Pyrene	--	--	210[c]	

[a] From the Region IX Preliminary Remediation Goals for Industrial Soil (TBC criteria).
[b] Calculated levels to protect groundwater assuming a porewater concentration at the bottom of a 2-meter thick capillary fringe equal to 0.5 μg/l.
[c] From the U.S. EPA Integrated Risk Information System Reference Dose as water quality criterion.
-- = Not available or estimated.

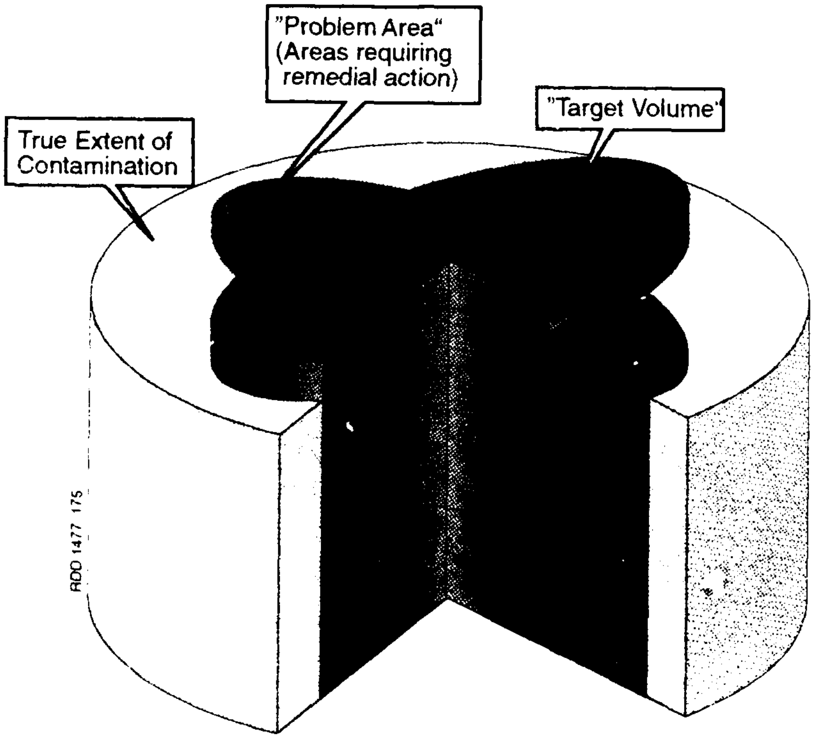


FIGURE 6-2
CONCEPTUAL
REPRESENTATION OF E
OF CONTAMINATION, PR
AREA, AND TARGET VOL
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

In defining the problem areas, the future use of OU D must be considered. McClellan Air Force Base (McClellan AFB) intends to maintain the Area D cap and use the land within OU D for industrial purposes. In particular, it is not anticipated that the land overlying the capped waste pits will ever be used for residential purposes.

6.1 Volatile Organic Compounds in the Vadose Zone

The ARARs analysis presented in Appendix I concludes that there are currently no enforceable soil cleanup standards. The Preliminary Remediation Goals established by EPA Region IX are non-legally binding to-be-considered (TBC) criteria. The results of the risk assessment indicate that current human health risks associated with vadose zone contamination at OU D are less than 1 x 10^{-6}. The results of the contaminant transport modeling indicate that the VOC contamination in the vadose zone may continue to be a source of contamination to the groundwater for many years into the future. Since contaminant concentrations in the vadose zone must be protective of groundwater quality, active remediation of the vadose zone will be required to control the spread of contamination and reduce the threat to groundwater.

Active remediation of the v
zone will be required to co
spread of contamination an
the threat to groundwater.

The area identified for remedial action is represented by the target volume shown on Figure 6-3. The target volume encompasses the extent of vadose zone contamination as defined by the available soil and soil gas VOC data and extends to the groundwater. In areas where data are limited (i.e., to the west of the McClellan AFB property boundary and to the northeast of Building 1093), the boundaries of the target volume are extended to the maximum extent of VOC migration as indicated by the contaminant transport modeling (500 feet from the edge of the cap). It should be noted that the estimated maximum extent of VOC contamination occurs near the groundwater, as depicted in Figure 3-6. The extent of shallow soil gas contamination is likely to be smaller than the area shown on Figure 6-3 (see Figures B-3, B-4, and B-5 in Appendix B).

6.2 Nonvolatile Organic Compounds in the Vadose Zone

As with the VOCs, there are currently no enforceable soil cleanup standards for the nonvolatile organic compounds (non-VOCs) in the vadose zone. The results of the risk assessment indicate that no complete exposure pathway exists for the non-VOCs, and therefore they are not posing a human health risk. The non-VOCs in the vadose zone are generally confined to the areas beneath the Area D cap. Some pthalates and metals have been detected in borings outside the capped area (see Chapter 4 and Appendix D); however, they are relatively isolated and not thought to represent a consistent source to groundwater. Although some of the non-VOC contaminants have migrated to groundwater in the past (as evidenced by detectable concentrations of semivolatile organic

The extent of non-VOC co
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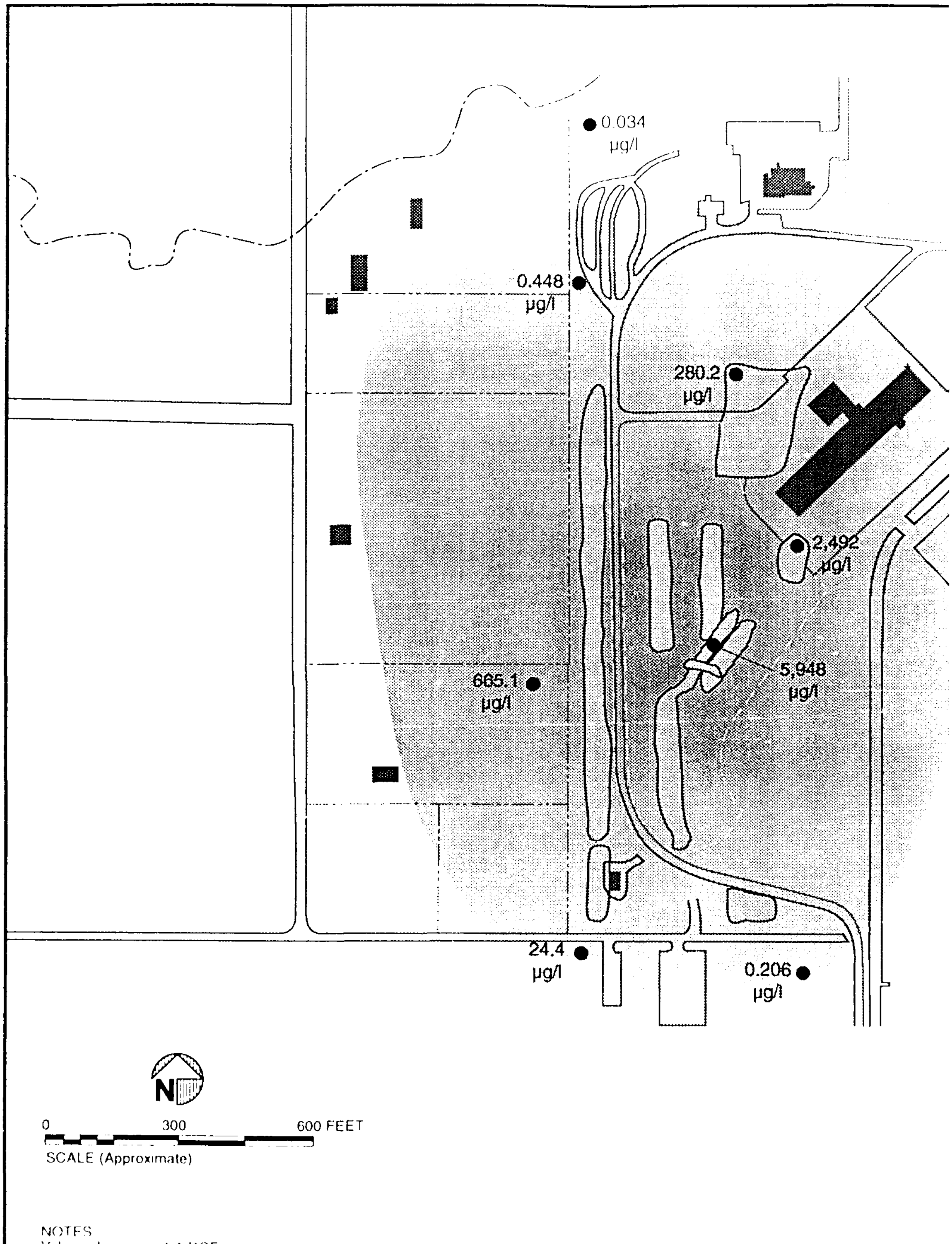

NOTES
Values shown are 1,1-DCE concentrations in the deep vadose zone from samples collected June 1993

FIGURE 6-3
TARGET VOLUME BOUNDARY
FOR VOCs IN THE VADOSE ZON
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

compounds (semi-VOCs), pesticides, and metals in the groundwater), migration is limited by the presence of the Area D cap. Additionally, the extent of non-VOC contamination in the vadose zone is within the capture zone of the groundwater extraction system. Non-VOC contaminants that might enter the groundwater would be contained. As long as the existing remedial actions are continued, additional source actions for the non-VOC contamination will probably not be required. Development of a target volume for the non-VOCs is appropriate because contamination exists and may impact human health or the groundwater if the existing remedial actions were stopped. The target volume is presented in Figure 6-4 and encompasses the area where non-VOC contaminants have been detected at concentrations above the Region IX Preliminary Remediation Goals (EPA, 1993a) because they are TBCs. This target volume is believed to represent the area posing the greatest threat to groundwater. The methodology for quantifying groundwater impacts of non-VOC contaminants will be presented in the Basewide RI. This methodology will be applied to OU D as part of the FS evaluation to verify the target volume presented in Figure 6-4.

As long as the existing reme
actions are continued, addit
source actions for the non-V
contamination are probably
required.

6.3 Volatile Organic Compounds in Groundwater

The ARARs analysis and risk assessment for the groundwater beneath OU D have been conducted as part of the Groundwater OU FS. As a result, four target volumes have been identified for the VOCs in the A Zone. The largest target volume encompasses the area where VOC contaminants are above background (considered as the detection limit). The second largest target volume includes the areas where groundwater concentrations exceed a 1×10^{-6} excess cancer risk. The third largest target volume includes the areas where contaminants exceed the maximum contaminant levels (MCLs). The smallest target volume encompasses the "hot spot" which is characterized by the area where trichloroethylene (TCE) concentrations are greater than 500 μg/l. The target volumes are presented in the Groundwater OU RI/FS Report.

6.4 Nonvolatile Organic Compounds in Groundwater

The extent of non-VOCs (semi-VOCs, pesticides/PCBs, and metals) in groundwater is within the area captured by the groundwater extraction system. Non-VOC compounds have been detected in some of the extraction wells, but when combined with the flow from other extraction wells, the concentrations to the treatment plant are within the levels that the treatment plant can address and not exceed discharge requirements. The target volume for the non-VOCs in groundwater is within the VOC target volume and is presented in the Groundwater OU RI/FS Report.

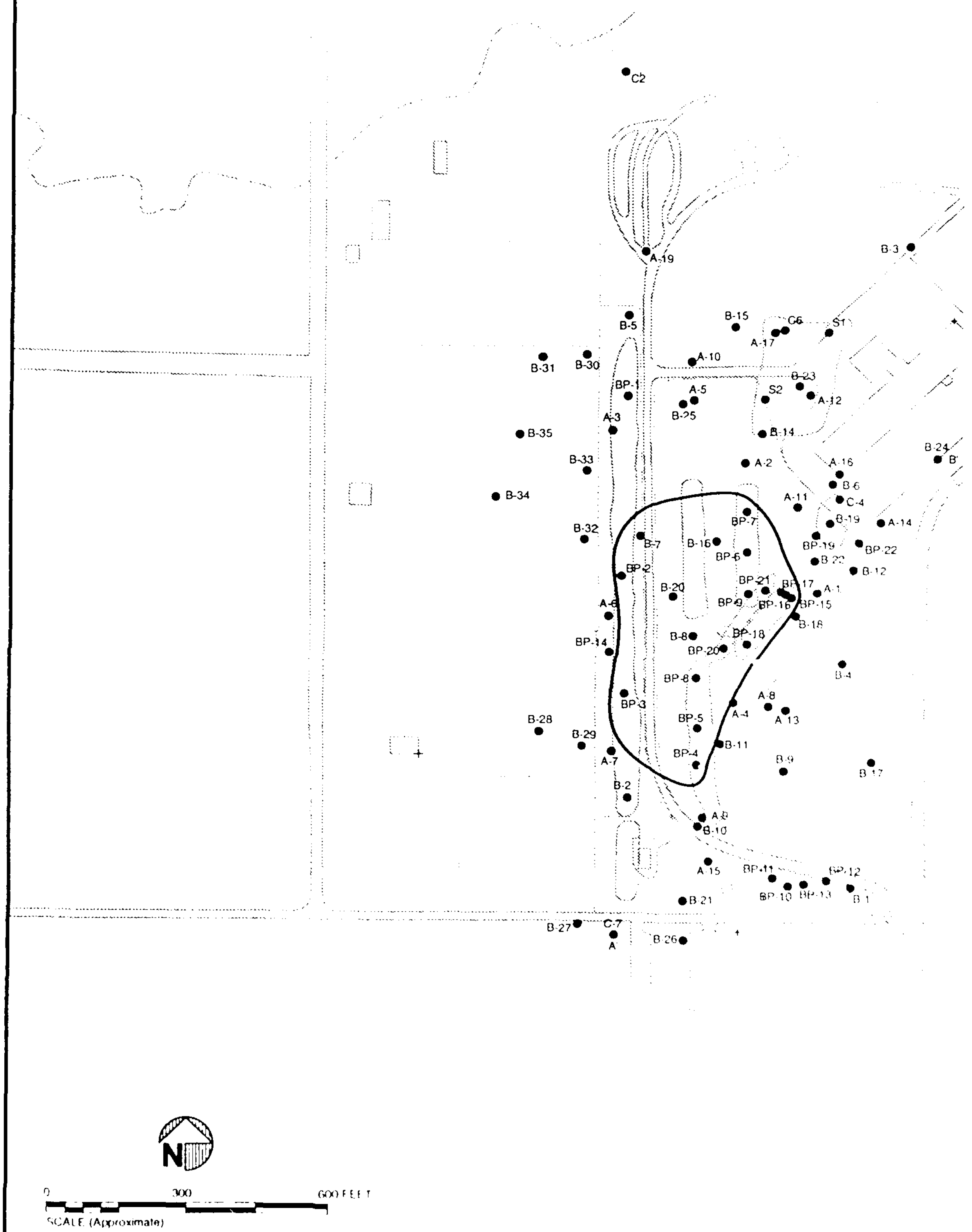

FIGURE 6-4
TARGET VOLUME BOUNDARY NON VOCs IN THE VADOSE ZO

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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6.5 Volatile Organic Compounds in Ambient Air

From data collected during the RI, the OU D risk assessment found that the VOCs detected in the residential crawlspace and ambient air samples are considered to represent typical background ambient air concentrations and not an impact related to OU D. The presence of VOCs in the nearby background air samples and emissions from permitted onbase industrial sources suggests that the contaminants in the soil gas near OU D may not be the source of the VOCs detected in the residential crawlspace and ambient air samples.

VOCs detected in the reside crawlspace and ambient ai are considered to represent background ambient air co tions and not an impact rel OU D.

Because the VOC contaminants detected in the residential crawlspace and ambient air sampling appear to be consistent with background concentrations, they do not warrant any specific remedial action. The remedial actions for the vadose zone and groundwater will provide an indirect benefit to the air by reducing the potential sources of contamination. Nonetheless, McClellan AFB is continually monitoring the residential crawlspaces and ambient air and have a Contingency Plan in place should the concentration levels become a threat.

McClellan AFB is continua monitoring the residential crawlspaces and ambient a

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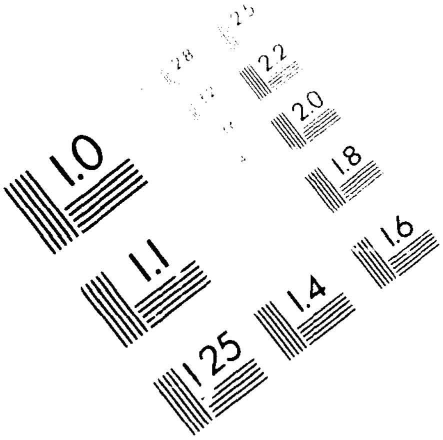

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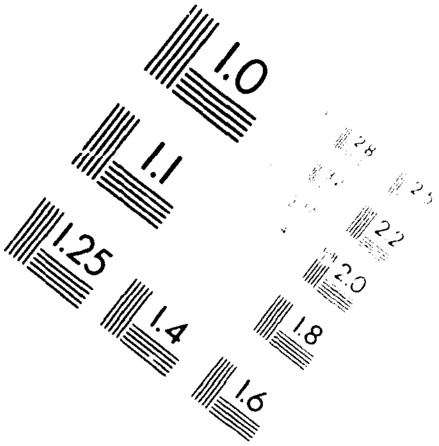

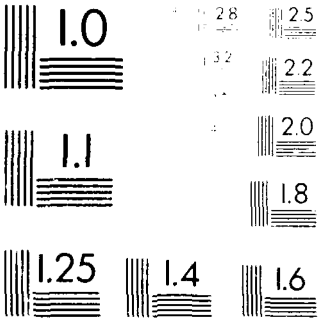

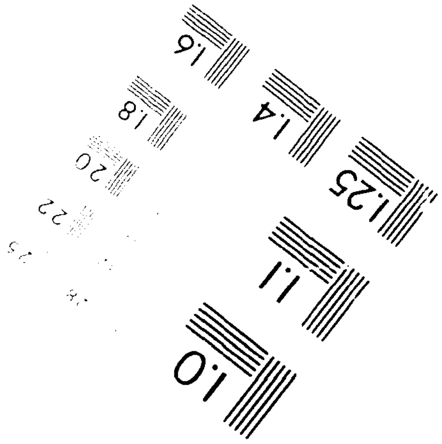

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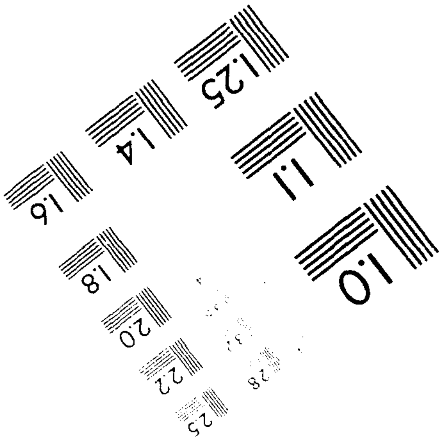


Chapter 7
Existing Remedial Actions

Chapter 7
Existing Remedial Actions

The existing remedial actions at Operable Unit D (OU D) consist of excavation and capping, placing local residents on city water, the groundwater extraction system, and the soil vapor extraction (SVE) system. The locations of these remedial actions are shown in Figure 7-1.

7.1 Excavation and Capping

By 1985, three of the CSs: CSs 4, 6, and 26, had been excavated and backfilled to remove the contaminated soil within these sites. In 1985, the Area D Cap was placed over eight of the CSs to prevent infiltration from precipitation and to control offgas emissions.

The Area D cap has been effective at reducing infiltration and therefore has limited the migration of the less mobile contaminants (i.e., metals, pesticides/polychlorinated biphenyls (PCBs), dioxins, and semivolatile organic compounds (semi-VOCs). The Area D cap has probably had a smaller effect on the more mobile contaminants, volatile organic compounds (VOCs), which are more subject to diffusive and advective transport.

The Area D cap has been effective at reducing infiltration and therefore has limited the migration of the less mobile contaminants.

7.2 Municipal Water Hookup

In 1986 and 1987, 500 offbase residences were connected to the municipal water supply system. The switch to the municipal water system was initiated when the contaminated groundwater plume under OU D was found to have migrated offbase.

The municipal hookups have effectively eliminated the risks to offbase residents from contaminated groundwater by eliminating the exposure pathway. It is possible that some residents may still be using domestic wells for nonpotable uses.

The municipal hookups have effectively eliminated the risks to offbase residents from contaminated groundwater by eliminating the exposure pathway.

7.3 Groundwater Extraction and Treatment

The groundwater extraction system was established in 1987. The groundwater is pumped from OU D and treated in the groundwater treatment plant located south of OU D. The extraction system was installed to control contaminant migration and remove the contaminated groundwater from beneath OU D.

Groundwater from six extraction wells in OU D is flowing into the groundwater treatment plant at a flow rate of 80 gallons per minute (gpm). The groundwater treatment plant consists of an influent tank, heat exchangers, an air-stripping column, activated carbon vessels, an incinerator, and a scrubber. The OU D groundwater flows into the influent tank where it is combined with groundwater from other OUs and effluent that is recycled to maintain the minimum influent flow into the air stripper. The water from the influent tank passes through two heat exchangers to increase the water temperature and thereby increase the stripping efficiency of the air stripper. The water then proceeds down through the air stripper where contaminants are transferred to the airstream. The water then proceeds to the activated carbon vessels where any residual contaminants are stripped out. The contaminated airstream from the stripper is treated as the air passes through the incinerator and the scrubber.

It appears that the existing groundwater extraction system is effectively controlling the migration of contaminants in both the A and B Zones. The lateral extent of the capture zones are shown in Figure 7-2, along with groundwater target volumes. The development of the target volumes presented in Figure 7-2 is addressed in the Groundwater Operable Unit RI/FS Report.

The existing OU D extraction system is controlling the areas of groundwater contamination in both the A and B Zones. The groundwater treatment plant effectively removes contaminants and achieves the effluent requirements.

Target volumes were not delineated in the C or D Zones because monitoring wells are not screened within the C or D Zones.

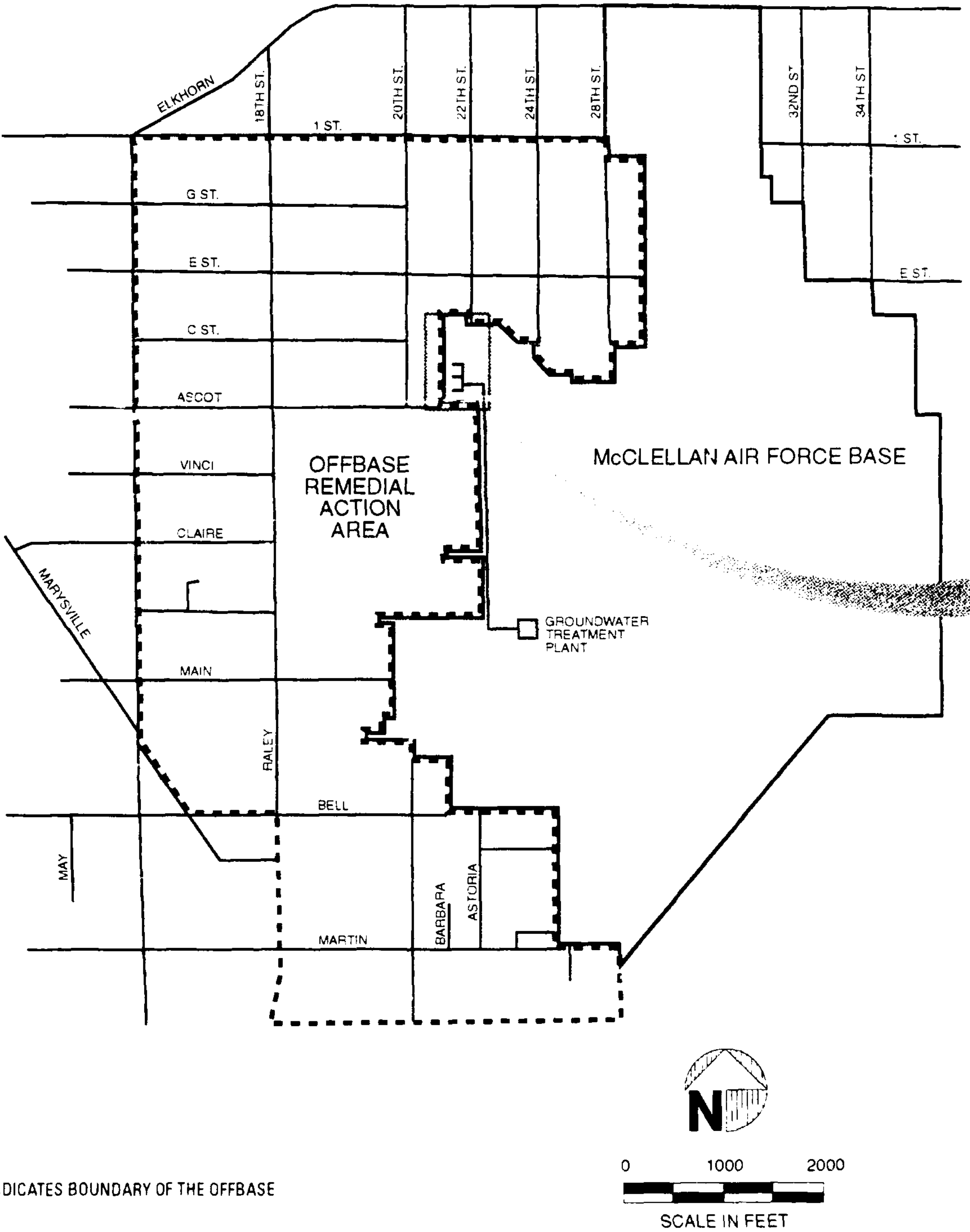
Operation of the system has also resulted in an upward flow of groundwater from the B Zone to the A Zone (refer to Figure 4-23), controlling the downward migration of contaminants. The extraction system effectively controls the spread of contaminants from the known source areas underlying the OU D low-permeability cap. Areas of contamination not within the capture zone of the present system are not extracted and treated. These outlying areas of contamination may be the result of historical contaminant transport from the source areas before operation of the extraction system. Alternatively, the contaminants may have originated from other unknown onbase and/or offbase sources.

Following extraction, the groundwater treatment plant effectively removes contaminants and satisfies the effluent requirements of the National Pollution Discharge Elimination System (NPDES) permit.

The groundwater treatment plant has removed approximately 10,000 lbs of VOCs from OU D during its 6-year operation period from 1987 to 1993. Initially, the influent concentrations were relatively high, and the mass per unit time removed was significantly greater than it has been recently (CH2M HILL, 1993b). Recent operations data compiled for 1992 indicate that the cost per pound of VOC removed and treated is $2,400. Initially when contaminant removal rates were high, the operational cost was approximately $80 per pound of VOC removed.

7.4 Soil Vapor Extraction

The SVE system was constructed within Site S in 1992 and in operation in 1993. The SVE system was installed as a treatability study to determine its effectiveness in removing VOC contaminants and less mobile



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▪ ▪ ▪ INDICATES BOUNDARY OF THE OFFBASE

NOTE

RESIDENTS WITHIN THE REMEDIAL ACTION AREA
HAVE BEEN SUPPLIED WITH MUNICIPAL WATER HOOKUPS.

Source: Radian, 1990
CH2M HILL, 1993

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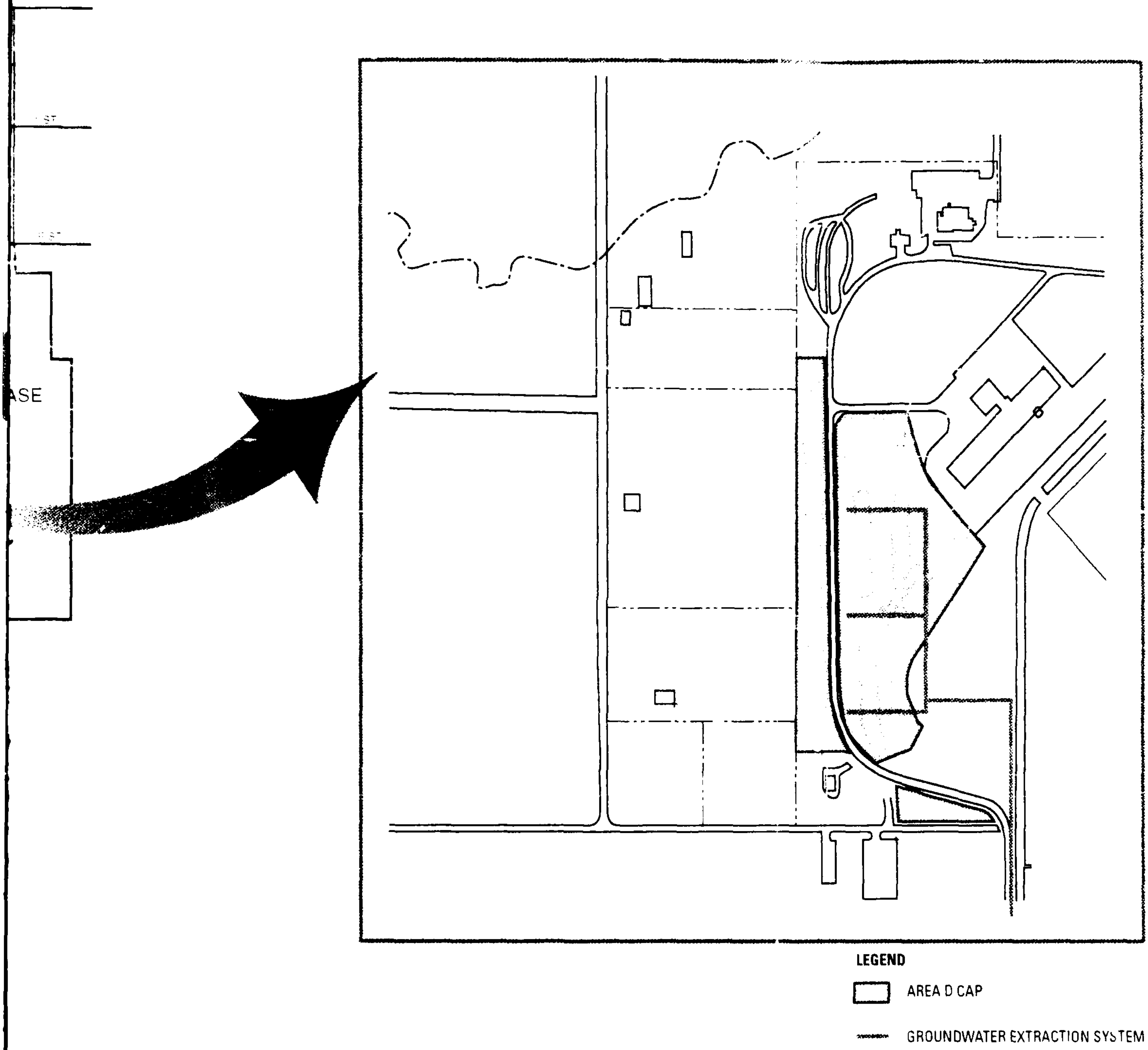
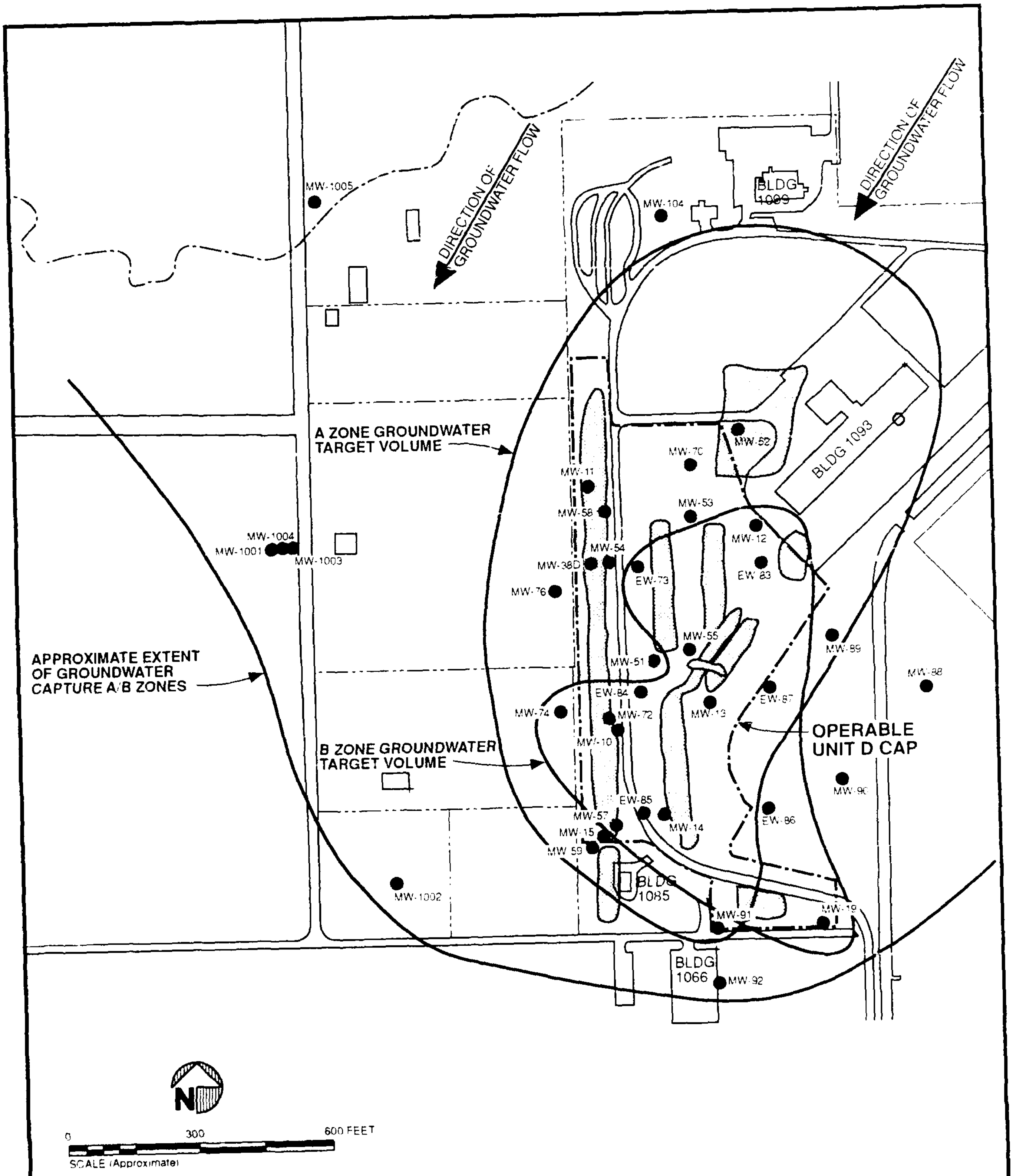


FIGURE 7-1
EXISTING REMEDIAL ACTIO
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



LEGEND

● GROUNDWATER MONITORING WELLS

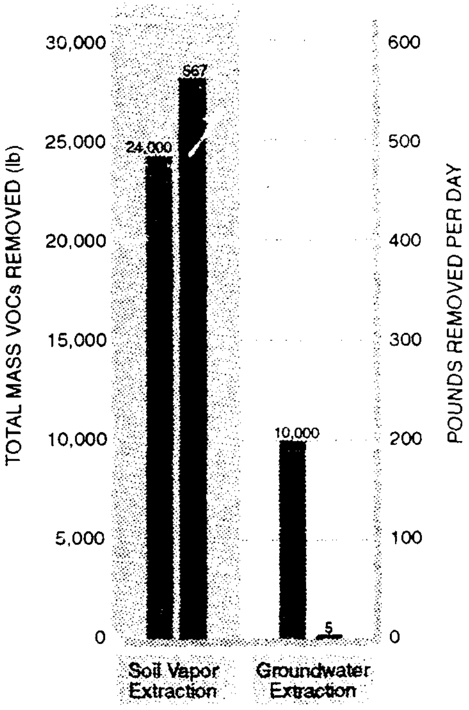
REFERENCE GROUNDWATER OPERABLE UNIT RI/FS, MARCH 1993

FIGURE 7-2
GROUNDWATER EXTRACTION SYSTEM CAPTURE ZONE AND TARGET VOLUME BOUNDARIES FOR A AND B ZONES

OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

compounds from waste pits and the native soil. The SVE system consists of 17 vapor extraction wells, manifold piping, an air/water separator, blowers, and a catalytic oxidation treatment unit. Alternate treatment methods are also being pilot tested. The SVE system is currently not a full-scale remedial action; it will be considered for expansion in the Basewide Vadose Zone Plug-in Feasibility Study (FS). The SVE system has been very effective at removing VOCs from the vadose zone within and around Site S. The estimated area of influence of the SVE system is shown in Figure 7-3 along with the VOC target area. The area of influence was qualitatively estimated from observations at MW-7 (i.e., increased oxygen and decreased vinyl chloride concentrations, refer to Appendix C) located approximately 400 feet from Site S near the edge of the cap. These observations suggest that the SVE system may be influencing the capped area. Determining the actual area influenced by the system is an objective of the next phase of the Treatability Investigation. During a relatively short 6-week operating period in March and April 1993, approximately 24,000 pounds of VOCs were removed and treated. The cumulative mass removed is shown in Figure 7-4. The total speciated VOC concentrations increased to approximately 2,500 ppmv during the operation period. Individual VOC concentrations generally increased, except for vinyl chloride, which reached a peak concentration of 85 ppmv after 3 days of operation then steadily decreased to less than 10 ppmv. The vinyl chloride behavior is typical of that observed at other SVE sites. Since vinyl chloride is very mobile in the gas phase and only produced in anaerobic environments, its removal from the vadose zone is rapid. As the subsurface is changed to aerobic conditions because of operation of the SVE system, vinyl chloride is no longer produced.



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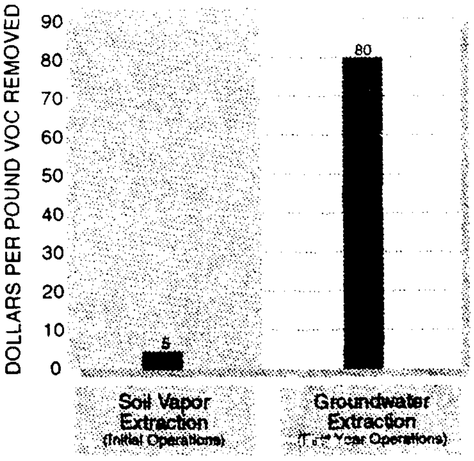
The approximate operational cost per pound of VOC removed is $5. This cost does not include construction and setup costs which would bias the cost high since the operation period is so short. The cost per pound removed should increase over time as the contaminant concentrations decline. However, compared to the cost per pound for the groundwater extraction and treatment system, SVE still looks economical. The SVE system provides a greater benefit in terms of mass of contaminants removed than groundwater extraction.



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7.5 Need for Additional Actions

It appears that the Area D cap is effectively addressing the non-VOC contamination in the vadose zone, and, as long as it is maintained, additional actions may not be necessary. The Basewide Vadose Zone Plug-in FS will evaluate potential remedial actions against the Area D cap to determine if continued maintenance of the cap is the best remedial alternative.

Although SVE is very effective at removing the VOCs from the vadose zone, the current system was not designed to (nor does it) completely address all the VOC contamination. The Basewide Vadose Zone Plug-in FS will evaluate SVE as a presumptive remedy and develop alternatives for full-scale implementation.

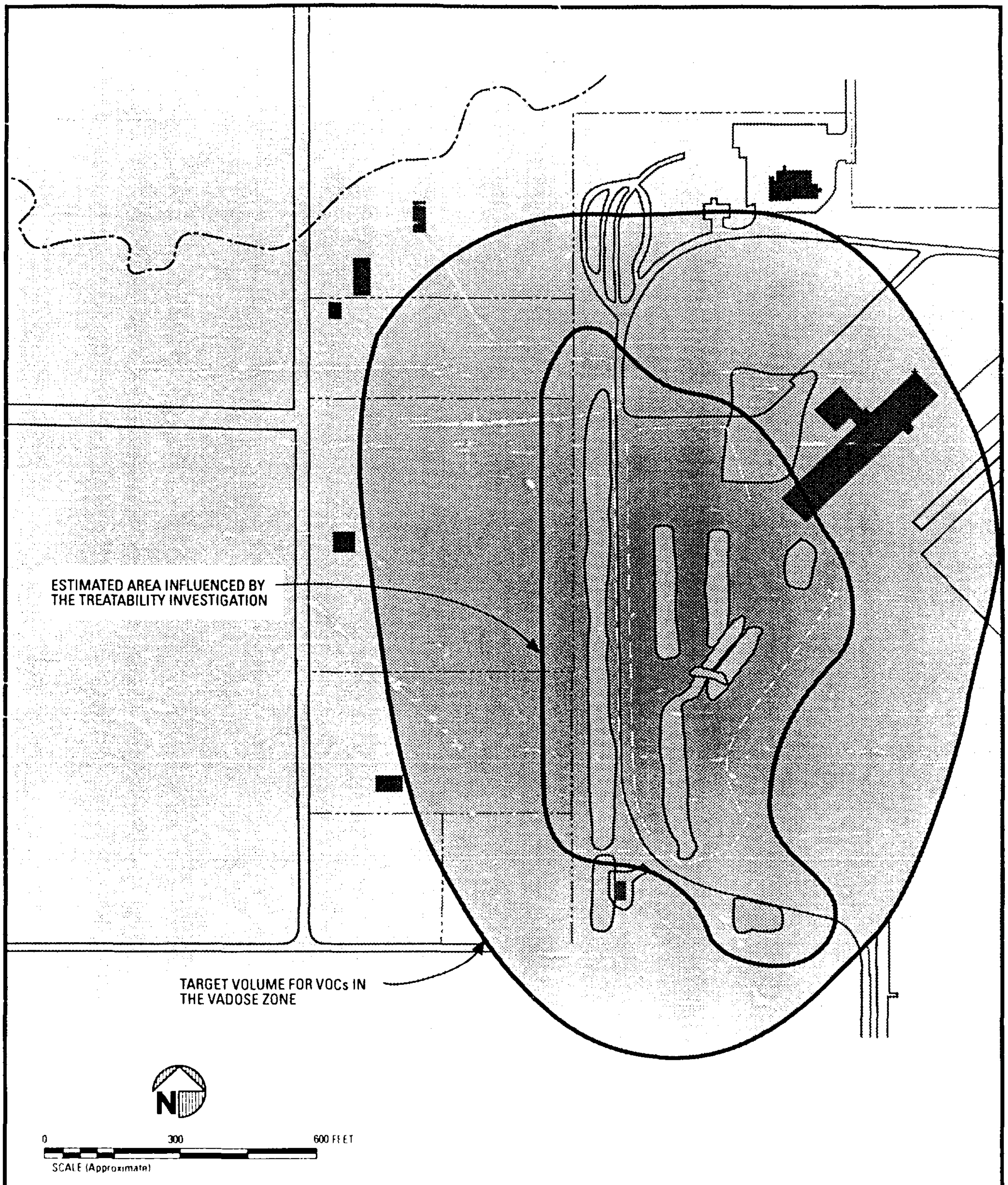

FIGURE 7-3
ESTIMATED VOC TARGET VOLUME AND AREA INFLUENCED BY THE SVE TREATABILITY INVESTIGATION
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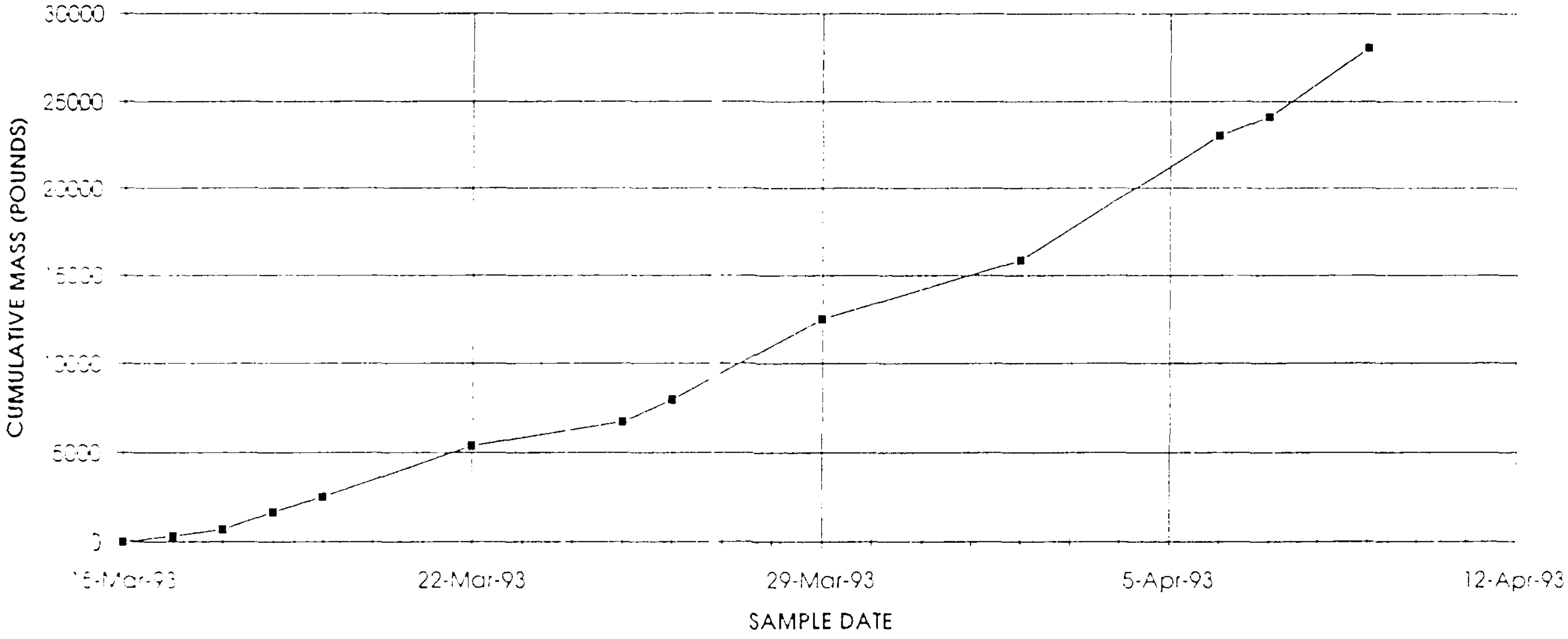

FIGURE 7-4
TOTAL SPECIATED VOCs
CUMULATIVE MASS
OPERABLE UNIT D
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SACRAMENTO, CALIFORNIA
CH2M HILL

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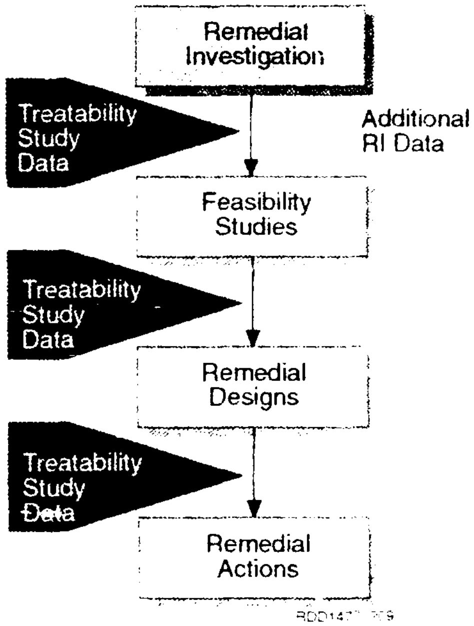
The groundwater extraction and treatment system is effectively addressing the groundwater contamination at OU D. Potential enhancements to the extraction and treatment system are evaluated in the Groundwater OU FS. Continued monitoring is necessary to verify that the contamination is effectively controlled and treated.

Chapter 8
Potential Future Actions

Chapter 8
Potential Future Actions



This remedial investigation report has been prepared to summarize and provide interpretations of investigation data obtained to date from Operable Unit D (OU D). A rational question that should be posed by persons interested in the eventual fate of OU D is: What next? Now that the available data have been obtained and analyzed for OU D, what will be done with the information in the future to address the contamination problems created by OU D?

This chapter is a discussion of the future activities that will be needed for OU D to achieve adequate remediation of the contamination. Future activities needed may be grouped into three categories: (1) Feasibility Study (FS); (2) Remedial Design/Remedial Action (RD/RA) activities; and (3) Additional Data Collection and Evaluation to support the Feasibility Study and RD/RA. Each of these categories are discussed individually in this chapter.

8.1 Feasibility Study Activities

A single FS is planned to address basewide vadose zone contamination. The FS will be written to address volatile organic compound (VOC) contamination, and nonvolatile organic compound contamination (i.e. semi-VOCs and metals). The final feasibility study is scheduled to be completed by November 1994. The final ROD is scheduled for completion by March 1995.

The approach for the vadose zone VOC contamination component of the FS will be an innovative one that employs the *presumptive remedy* and *plug-in* concepts. The presumptive remedy concept will be used for VOCs in the vadose zone. The presumptive remedy will be soil vapor extraction (SVE). The plug-in concept will be used for both VOCs and non-VOCs. The plug-in concept will allow the ROD for contamination in the vadose zone to be written to support remediations at all locations at McClellan Air Force Base (McClellan AFB), and not just at OU D. Chapter 2 provides more detailed definitions of these two concepts.

8.2 Remedial Design/Remedial Action Activities

After the FS is completed and the proposed plan has been developed, subjected to public comment, and the final ROD has been signed, the RD/RA phase of work at OU D will begin. The RD/RA progress will be strongly dependent on the site characterization data obtained during this RI, as well as on the alternative evaluations that will be performed for the FS.

Data from other sources will also be needed to support the RD/RA effort. These include information from the SVE treatability study regarding subsurface airflow characteristics under the cap, mass and type of contaminants removed, destruction efficiencies of the offgas treatment system, operational cost information with recommendations for ways to reduce the cost of a full-scale system, and other information or experience that would improve the design and implementation of a full-scale SVE system (the presumed remedy for VOCs in the vadose zone).

For the design of a system to remediate non-VOCs in the vadose zone, data may be needed from the solidification/stabilization treatability study at OU C. Treatability data may also be needed from the Ex Situ Bioremediation Treatability Study. It is not known at this time what the remedial action for non-VOCs in the vadose zone will be

8.3 Additional Data Collection and Evaluation

To further refine knowledge regarding the extent of contamination at OU D, additional information may be needed to support the FS and RDs/RAs. Figure 8-1 is a plot showing how the knowledge on the extent of contamination (as measured by target volume accuracy) should increase as expenditures increase on the project. The increases in cost may be partially attributed to the evaluation and use of existing data, and partially to the collection and evaluation of new data that has not been obtained at the time of this report.

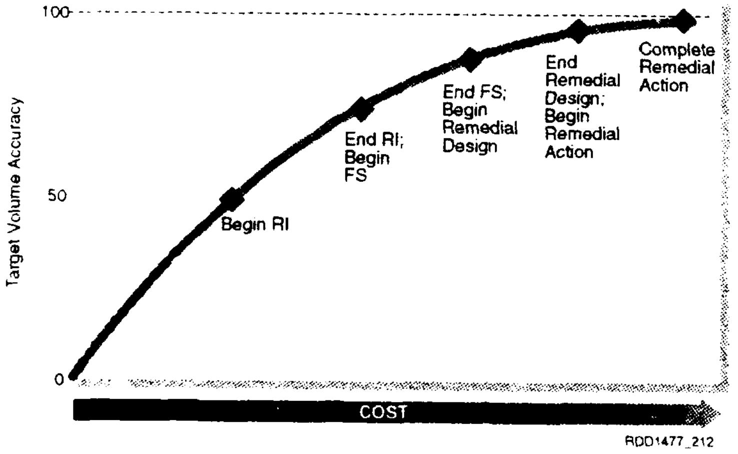


FIGURE 8-1
TARGET VOLUME ACCURACY AS A FUNCTION OF COST
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

The following data collection efforts are currently planned to provide more data regarding contamination at OU D and to provide additional support to the FS:

1. Install three additional soil vapor monitoring wells (C1, C5, and C8) on residential properties to the west of OU D–These wells will be used to help better define the boundaries of the VOC target volume in the vadose zone. Soil samples will be obtained during drilling of the borings to provide metals, semi-VOC, and VOC data; downhole soil gas sampling will also be conducted. The locations of these wells are shown in Figure D-2 in Appendix D. The wells will be completed and sampled according to the Final Work Plan for OU D (CH2M HILL, 1993a).

2. Install one new groundwater monitoring well–This well will serve as a replacement well for MW-1005, and should provide more information on the extent of groundwater contamination to the northwest of OU D. The location of this well is shown in Figure D-4.

3. Conduct air permeability testing–One air permeability test is planned. The test will consist of monitoring the apparent radius of influence of the existing SVE pilot plant. Pressure measurements will be taken at selected vadose zone monitoring wells as the SVE plant is operating under a steady-state condition of air flow. The pressure measurements will be combined with soil gas chemistry and correlated with the horizontal distances from the extraction wells and airflow rate to evaluate the air permeability of differing lithologies at varying depths and directions.

4. Perform quarterly sampling–Quarterly sampling of the SVMWs will continue to provide information on the migration of the soil gas contamination in the vadose zone. Chemical data and air pressure data will be collected to monitor the effectiveness of the Site S SVE system and to design the expansion of the SVE system.

5. Expansion of the Site S SVE system–An additional 13 extraction wells and monitoring wells will be installed within the waste pits and surrounding soils as part of the SVE expansion under the Basewide EE/CA. Additional characterization data will be collected to improve mass estimates and adjust the SVE design and operations.

The above data will be used to reduce the total uncertainty regarding the subsurface characteristics and the extent of contamination that resides within the subsurface. However, the site characteristics will never be known with absolute certitude; the heterogeneities and discontinuities in the subsurface are far too complex to be understood in their entirety before implementing remedial action. There will be a point of diminishing returns where the incremental investigation cost will be too high to justify the small increase in site understanding. This concept is illustrated in Figure 8-2, where a point is shown of "acceptable uncertainty". This is the point where the investigation can stop, and RD/RA can begin despite some remaining unknowns.

There will be a point of diminishing returns where the incremental investigation cost will be too high to justify the small increase in site understanding.

One of the functions of the FS will be to characterize the remaining unknowns and to quantify their possible impacts on the evaluated remedial alternatives.

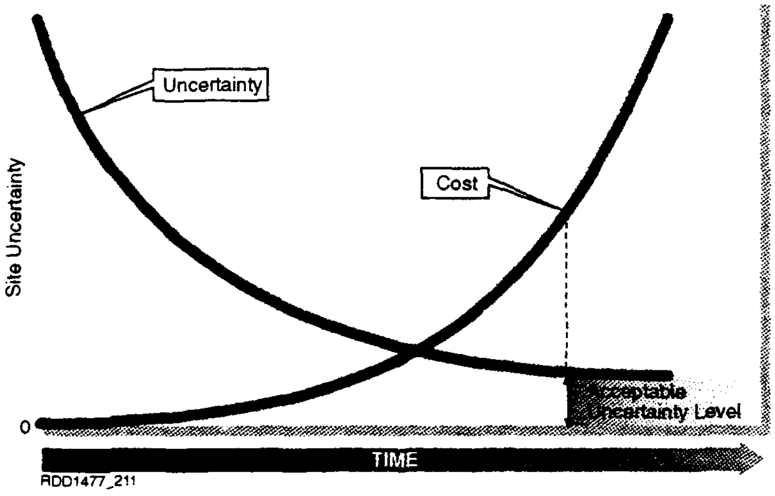


FIGURE 8-2
UNCERTAINTY AND COST AS A FUNCTION OF TIME
OPERABLE UNIT D
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Chapter 9
Works Cited

Chapter 9

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