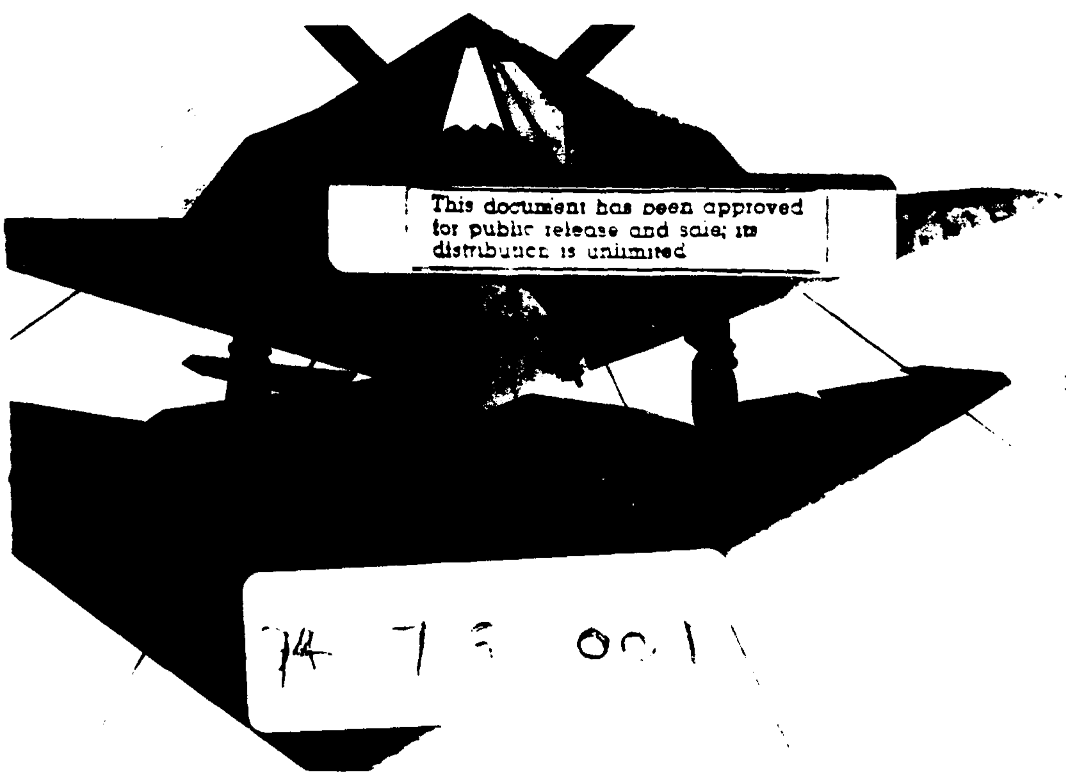
McClellan Air Force Base

Basewide Groundwater Operable Unit

Groundwater Operable Unit Remedial Investigation/ Feasibility Study Report

Delivery Order 5066

Volume 1 of 3



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SACRAMENTO AIR LOGISTICS CENTER (AFMC)
McCLELLAN AIR FORCE BASE, CALIFORNIA

JUN 23 1994

MEMORANDUM FOR SEE DISTRIBUTION

FROM: SM-ALC/EMR
5050 Dudley Blvd, Suite 3
McClellan AFB CA 95652-1389

SUBJECT: Groundwater (GW) Operable Unit (OU) Final Remedial Investigation/Feasibility Study (RI/FS) Document

1. Attached is the GW OU Final RI/FS. This document will be in the repository for public review on 1 Jul 94. The public comment period for the subject document and the GW OU Proposed Plan is 5 Jul - 6 Aug 94. The public meeting to discuss the Proposed Plan is scheduled for 20 Jul 94.

2. If you have any questions or comments, please contact me or Doris Varnadore at (916) 643-0830.

for KENDAL R. TANNER, P.E.
Remedial Program Manager
Environmental Restoration Division
Environmental Management Directorate

Attachment:
GW OU Final RI/FS

cc:
McClellan Admin Record

Accesion For	
NTIS CRA&I	✓
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and / or Special
A-1	

FINAL REPORT DISTRIBUTION LIST

ADDRESS	NUMBER OF COPIES
SM-ALC/EM 5050 Dudley Blvd, Suite 3 McClellan AFB CA 95652-1389	3
U.S. Environmental Protection Agency Office of Superfund Programs Attn: Mr Joe Healy (H-9-1) 75 Hawthorne Street (15th Floor) San Francisco CA 94105	2 (1 bound/1 unbound)
Dept of Toxic Substances Control Senior of Military Team Region I, Site Mitigation Branch Attn: Mr Mark Malinowski Mr John Harris 10151 Croydon Way, Suite 3 Sacramento CA 95827-2106	2
Regional Water Quality Control Board Attn: Mr Alex MacDonald 3443 Routier Road Sacramento CA 95827-3098	1
City of Sacramento Public Works Department Attn: Mr Robert Lee 5730 24th Street, Bldg 4 Sacramento CA 95822	1
Sacramento Metropolitan Air Quality Management District Attn: Mr Jorge' DeGuzman 8411 Jackson Road Sacramento CA 95826	1
State Dept of Health Services Office of Drinking Water Attn: Mr Bert Ellsworth 8455 Jackson Road, Suite 120 Sacramento CA 95826	1
Sacramento County Environmental Management Department Hazardous Materials Division Attn: Mr Mel Knight 8475 Jackson Road, Suite 220 Sacramento CA 95827	1

AS OF: 23 Jun 94

FINAL REPORT DISTRIBUTION LIST (cont'd)

ADDRESS	NUMBER OF COPIES
URS Attn: Mr Dennis Bane 2710 Gateway Oaks Drive Suite 250 North Sacramento CA 95834	1
U.S. Department of Justice Torts Branch, Civil Division Attn: Mr William E. Michaels, Trial Attorney Box 340 Ben Franklin Station Washington DC 20044	1
HQ AFMC/CEV Attn: Mr Alan Waite 4225 Logistic Ave, Suite 8 Wright-Patterson AFB OH 45433-5747	1
Mr Burl Taylor 7449 28th Street North Highlands CA 95660	1
AFGE Local 1857 Attn: Mr Jim Bryant PO Box 1037 North Highlands CA 95660	1
Mr Charles Yarbrough 4919 Raley Blvd Sacramento CA 95838	1
Defense Technical Information Center Cameron Station - DTIC-OCC, Bldg 5 Alexandria VA 22304-6145	1

Groundwater Operable Unit
Remedial Investigation/Feasibility Study Report

Volume 1 of 3

Prepared for

McClellan Air Force Base
Contract No. F04699-90-D-0035

Delivery Order 5066

Line Item 0014

Prepared by

CH2M HILL
2485 Natomas Park Drive, Suite 600
Sacramento, California 95833

SWE28722.66 **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). Because 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 that 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.

Executive Summary

This document presents the Remedial Investigation/Feasibility Study (RI/FS) for the Groundwater Operable Unit (GW OU) at McClellan Air Force Base (McClellan AFB). The RI/FS is one step in the GW OU, which is intended to develop an interim remedial action for groundwater contamination at McClellan AFB.

The preferred interim remedial action for the GW OU is containment of the 10^{-6} risk target volume, treatment using air stripping with vapor phase carbon and LGAC polishing on the east side, the existing GWTP on the west side, and injection of the treated water.

Purpose and Scope of the Groundwater OU

The GW OU encompasses all contaminated groundwater associated with McClellan AFB. It is intended to provide an integrated approach to the investigation and remediation of groundwater contamination at the Base. The principal goals for the GW OU include the following:

- Develop remedial actions that conform to requirements of the federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, also known as "Superfund"), and State of California requirements

- Achieve the objectives of the U.S. Air Force Installation Restoration Program (IRP)

- Integrate groundwater remedial actions with remedial actions for soils and contaminant source areas across the Base

The steps in the GW OU through which these goals will be achieved are:

- The Strawman Record of Decision (ROD) Workshop, held in October 1992

- The GW OU Work Plan, approved in April 1993

- The RI/FS contained in this document

- The Proposed Plan, through which public input will be solicited on the proposed remedial action

- The Interim ROD to be issued for the GW OU in August 1994

The Interim ROD will document the decisions to be made related to the GW OU and will allow McClellan AFB to proceed with implementation of remedial actions. Remedial actions selected prior to the Basewide ROD will be considered interim RODs, and the decisions may be updated in the Basewide ROD.

Under the IRP, 11 separate areas of contamination have been identified as OUs to aid in managing investigation and remediation activities at the Base. The OU boundaries developed at McClellan AFB are presented in Figure 2-1. Ten of the OUs address contaminants in soil associated with different activities at the Base, while there is only a single OU for groundwater. The principal reason for the GW OU is that groundwater contamination is not necessarily associated with the geographical boundaries of operable units or contaminant source areas in soil. The nature of the GW OU requires an integrated Basewide RI/FS and ROD, in terms of evaluation of remedial action alternatives, identification of additional data requirements, integration with existing remedial actions at the Base, and evaluation of the long-term impacts of regional groundwater use.

Nature and Extent of Groundwater Contamination

McClellan AFB has provided maintenance and repair support for aircraft, electronics, and communications systems since 1936. The disposal of hazardous materials used in these activities has resulted in contamination of soil and groundwater at the Base. Three plumes of groundwater contamination have been identified underneath the Base; portions of these plumes have migrated offbase, potentially threatening municipal and private supply wells. The contaminant plumes in groundwater and the contaminant sources in soil have a complex relationship that influences the strategy for groundwater remediation at McClellan AFB.

Contamination is principally confined to the uppermost groundwater zones beneath the Base, but has been detected to a depth of 390 feet. The contaminants detected most frequently, and at the highest concentrations in groundwater, are chlorinated volatile organic compounds (VOCs), principally trichloroethene (TCE) and tetrachloroethene (PCE), which were used for several years as solvents at the Base. Other contaminants of concern in groundwater include 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethene (1,2-DCE), 1,2-dichloroethane (1,2-DCA), vinyl chloride, chloroform, and 1,1,1-trichloroethane (1,1,1-TCA). Chloroform and 1,1,1-TCA also have been used as solvents at the Base, while 1,1-DCE, 1,2-DCE, 1,2-DCA, and vinyl chloride are degradation products of chlorinated VOC solvents. Concentrations of metals have been detected in some samples at levels that are higher than allowed by drinking water standards, typically in unfiltered samples or samples collected soon after well construction. However, it is not certain if these findings are associated with contamination at the Base or background conditions. Several background water quality wells were sampled in October 1993, and these results will be used to resolve the metals issues. Occurrences of organic compounds in groundwater other than VOCs generally have been limited to very small areas at the Base.

General groundwater flow at McClellan AFB has been from northeast to southwest. Withdrawals from Base wells and regional urban and agricultural wells have caused several changes in regional groundwater flow, and have caused groundwater levels to decline over 60 feet in the past 40 years. Evaluation of available sampling and analytical data indicate a slow, continuing vertical migration of contaminants from soil to groundwater in OU A, located on the southeast side of the Base. The highest concentrations of contaminants in groundwater are detected in the shallowest groundwater zones, and concentrations decrease with depth. The vertical and lateral extent of contamination in OU A has not yet been defined, particularly in terms of migration offbase. Groundwater contamination in OUs B and C, located on the west side of the Base, indicates a complex relationship between contaminant sources and groundwater. Shallower groundwater zones at OU C have high levels of contamination, suggesting that vertical migration of contaminants from soils in OU C is likely to be the major cause of groundwater contamination. Groundwater contamination in OUs B and C is partially controlled by a groundwater remedial action involving extraction of groundwater and treatment at the onbase Groundwater Treatment Plant (GWTP). Groundwater contamination under OU D appears to be declining over time, either through biodegradation or in response to remedial actions. Groundwater extraction and treatment are also ongoing at OU D, along with a source remedial action involving soil vapor extraction (SVE) of VOCs in soils and wastes.

In general, groundwater contamination at McClellan AFB is characterized by small areas ("hot spots") with elevated concentrations or non-aqueous phase liquids (NAPL, also known as "free product"), surrounded by larger areas with lower concentrations. This distribution of contamination influenced the development of a groundwater remediation strategy.

Groundwater contamination under McClellan AFB does not represent a significant risk to public health under current conditions. Currently, there are no existing routes of exposure to individuals either onbase or offbase, due to interim remedial actions undertaken by the Base. These remedial actions include an offbase remedial action involving connecting nearby residences (formerly using private wells) to municipal water supplies, and the groundwater extraction and treatment actions described previously. However, contamination under McClellan AFB represents a potential threat to the quality and useability of groundwater as defined by State of California policies, and could potentially represent a significant risk to human health for future use.

Strategy for Groundwater Remedial Action

Groundwater remedial action at McClellan AFB must accomplish several goals. It must achieve remedial response objectives identified for the Base; it must accommodate uncertainties in site conditions; and, it must integrate with other remedial actions being performed at the Base.

The remedial response objectives identified for the GW OU are:

- Contain the contamination by stopping lateral migration offbase and vertical migration to deeper aquifers.
- Apply innovative technologies to reduce the duration and cost of remedial action.
- Protect public health and the environment.

- Achieve compliance with ARARs (Applicable, Relevant and Appropriate Requirements).

Containment of the groundwater contamination, combined with flushing the aquifers and isolating and remediating hot spots, will achieve the remedial response objectives. The volume of contaminated groundwater would be reduced over time when hot spots are isolated. Innovative technologies, such as in situ bioremediation processes, could be applied once hot spots are isolated. Since groundwater would already be hydraulically controlled, the testing and trial implementation of innovative technologies would provide minimal risk to the overall remedial action. This strategy integrates with a Basewide vadose zone and source area remedy, initially being applied at OU D, that addresses continuing sources of VOC contamination in soil. Removal of VOC contamination in soil, and isolation/remediation of NAPLs in hot spots, could significantly reduce the time required to remediate contaminated groundwater. If these sources are allowed to remain in place, then the groundwater remedy would, at best, achieve containment of the contamination.

RI/FS Approach to Remedial Action

A range of remedial action strategies was identified to guide development of remedial action alternatives. These strategies were reflected in the development of the target volumes, or volumes of contaminated ground-water, requiring remedial action. These target volumes represent:

- Hot spots, 500 $\mu g/l$ or greater TCE
- Maximum Contaminant Limit (MCL), 5 $\mu g/l$ TCE (the MCL target volume was determined largely by the extent of TCE in groundwater)
- Health risk, 10^{-6} increased lifetime cancer risk
- Background, 0.5 $\mu g/l$, determined largely by the extent of TCE in groundwater

Note that a hot spot target volume does not strictly reflect a cleanup strategy, but was considered in the RI/FS to better evaluate the relation-ship between contaminant mass removal and remedial action costs. Consensus on these target volumes was obtained between McClellan AFB and the regulatory agencies.

The approach to the FS was developed with the understanding that remedial action alternatives share common elements of groundwater pumping, treatment, and end use, and that there are several options for each of these elements. The development of groundwater containment and extraction options was based on the selected target volumes and the evaluation of the available hydrological data. Screening and selection of treatment technologies were developed in consultation with McClellan AFB and the regulatory agencies. Possible end uses were identified in consultation with local water districts and other interested individuals.

Final screening of all of the different options, and packaging of options into remedial action alternatives, was developed by achieving a consensus between McClellan AFB and the regulatory agencies. Detailed evaluations, involving comparison with the U.S. Environmental Protection Agency's (EPA) evaluation criteria, implementation plans, and budget-level cost estimates were developed for selected remedial action alternatives.

Innovative technologies are new and promising, yet unproven, treatment technologies for site remediation that may offer potential benefits compared with standard technologies. Once groundwater containment, treatment, and end uses are in place, innovative technologies can be incorporated to reduce the treatment burden. In situ processes could be used to treat or accelerate the extraction of contaminant hot spots. Ex situ processes could be used to reduce the costs of treating extracted groundwater. Because the groundwater would already be hydraulically controlled, the testing and trial implementation of innovative technologies would involve minimal risk to the overall remedial action. The evaluation, screening, and development of innovative technologies follows a parallel track to the development of remedial action alternatives (due to their unproven nature, they were not compared directly with standard technologies). Innovative technologies converge with the remedial action alternatives during the development of implementation plans for the remedial action alternatives. The implementation plans identify the bench-, pilot-, or field demonstration-scale testing required to fully evaluate the feasibility of innovative technologies.

Addressing Uncertainties in the Groundwater OU

Decisions for the GW OU will be made under conditions of uncertainty. While collection of additional data could reduce the uncertainty, the effort and expense of such an effort are unrealistic. The objective of the RI/FS process is not the unobtainable goal of removing all uncertainty, but rather to collect sufficient information to make an informed decision about which remedy is most appropriate for a given site. It is recognized that McClellan AFB has collected a considerable amount of data, and the challenge was to provide an approach that would lead to a strategically correct decision given the uncertainties. A five-step process was used in the FS to identify, evaluate, and accommodate the uncertainties that could be encountered during groundwater remediation at McClellan AFB. These five steps are:

- Identify uncertainties
- Define their bounds
- Identify or estimate potential impacts
- Measure outcomes
- Adjust operations during remediation

Accomplishing these steps within the RI/FS was facilitated by using decision analysis. Decision analysis depicted the relationships between decisions to be made in groundwater remediation and the uncertainties, and all possible combinations of decisions and uncertainties were analyzed to aid in selecting an optimal remedial action strategy. The

RI/FS also identified additional data needs that could refine or reduce the extent of the target volumes, and provide for the measurement of the outcomes of remedial action. A data collection and management plan has been developed within the RI/FS to facilitate the verification or adjustment of remedial designs before they are installed. Measurements of performance of the remedial action will then continue to facilitate continuous process improvement.

Selected Remedial Action Alternatives

Six different remedial action alternatives, along with a No-Action Alternative, were evaluated in the RI/FS. These are summarized below in Table FS-1.

Table ES-1
Remedial Action Alternatives

Alternative	Target Volume	Treatment Technology	End Use
1	MCL	Air stripping with catalytic oxidation offgas treatment with carbon polishing—east side; existing groundwater treatment plant—west side	Groundwater injection
2	10^{-6}	Air stripping with catalytic oxidation offgas treatment with carbon polishing—east side; existing groundwater treatment plant—west side	Groundwater injection
3	Background	Air stripping with catalytic oxidation offgas treatment with carbon polishing—east side; existing groundwater treatment plant—west side	Groundwater injection
4	10^{-6}	Air stripping with vapor-phase granular activated carbon offgas treatment with carbon polishing—east side; existing groundwater treatment plant—west side	Groundwater injection
5	10^{-6}	Air stripping with catalytic oxidation offgas treatment—east side; existing groundwater treatment plant—west side	Purvey to local water districts
6	10^{-6}	Liquid-phase granular activated carbon treatment—east side; existing groundwater treatment plant—west side	Groundwater injection
No Action			

Notes: MCL = Maximum Contaminant Limits; 10^{-6} = target volume mapped to a 10^{-6} increased lifetime cancer risk; Background = target volume mapped to limit of detection (0.5 μg/l).

Each alternative has the following baseline requirements:

- Determine the extent of contamination.
- Obtain aquifer parameters.
- Determine the effectiveness of horizontal wells.
- Design the long-term data acquisition system.
- Determine the capacity to inject water as the end use.

- Determine the ability tc maintain containment of the hot spots while injecting treated groundwater to enhance flushing.

- Determine the background concentrations of metals.

- Determine the need for metals removal prior to use of the treated groundwater.

- Design contingency plans for the appropriate offbase wells (currently CW 132 and CW135, but there would be additional wells threatened by OU A contamination).

- Properly abandon Base Well 18 and replace the water supply.

- Properly abandon other Base wells that may serve as conduits for contamination. This is an ongoing program.

- Continue operation of the Groundwater Treatment Plant.

- Contain the groundwater hot spots as they are defined.

- Update the conceptual model at appropriate milestones.

- Continue to monitor water levels and water quality in the existing monitoring wells.

- Identify interim end uses for the water to allow extraction and treatment to begin independent of injection.

In assessing priorities, all the baseline requirements are of high priority because they are either predecessors to achieving containment, or predecessors to major design decisions or activities that could alleviate imminent threats. In the case of the determination of the extent of contamination, there is a subset of priorities, with the highest priorities being:

- Deep plume beneath OUs B and C
- Plume moving south from OU B
- Southern OU A plume
- OU A plume offbase to the east
- OUs G and H plume

Following are the lower priorities for investigation of the extent of contamination:

- Investigation of the extent of contamination west of OU A and east of OU C in the runway area

- Investigation of the presence of groundwater contamination at OUs E, F, G, and H

- Investigation of the low concentration plume west of OU C (offbase)

- Refinement of the OU D plume estimate

Priorities for Containment

The remedy must be implemented in a phased approach because of the need to resolve uncertainties, the magnitude of the potential remedy, and resource constraints. The priorities for containment, and the basis for the priority, are discussed in the following paragraphs.

High priority containment projects include:

- OU A offbase to the east

- OU A southern plume offbase

- OU B offbase plume

- OU B/C deep plume (considerable investigation is needed prior to containment)

- Hot spots in OU A (two hot spots), OU B (two hot spots), and OU C (one hot spot known today)

The OU A and B offbase plumes are high priorities because they are potential threats to offbase water users. The deep plume beneath OUs B and C is a high priority because the contamination is in the more permeable materials subject to pumpage by water users. The hot spots are a high priority because the isolation of the vast majority of contaminant mass can be achieved by containment of the hot spots.

Lower priority containment projects include:

- OU A onbase contamination
- OU B/C onbase contamination
- Low concentration area west of OU C
- OU D expansion (if necessary)
- OUs E, F, G, and H onbase contamination

The onbase contamination is a lower priority because the threat to the public does not exist. The offbase contamination west of OU C is a lower priority because the Air Force has replaced individual water wells with potable supply, thereby removing the threat to the public. In addition, the concentrations are low and much farther from water supply wells than the OU B plume.

All of these remedial action alternatives have similar abilities to protect human health and the environment. All can comply with regulatory requirements and are fully implementable. Alternative 3 is more expensive to implement because it would control and treat a much larger volume of water. Alternatives have similar ranges of costs, ranging from $30 M to $40 M, based on net present value. Innovative technologies would be incorporated into this alternative, including in situ anaerobic biodegradation, SVE with air-sparging, cometabolic biotreatment, and dual-phase extraction. The existing GWTP would remain, and would be upgraded to accommodate higher flows of groundwater contaminants. Base Well 18 (BW-18) would be removed from service and properly abandoned, and its carbon treatment units would be reused in the remedy.

Contingency measures to be included in the remedy are potential metals removal prior to water end use, potential onbase reuse of a portion of the water, and wellhead treatment on offbase supply wells. The contingency measures will only be implemented if necessary.

CONTENTS – Volume 1 of 3

CONTENTS – Volume 1 of 3 (Continued)

CONTENTS – Volume 1 of 3 (Continued)

Figures **Page**

CONTENTS – Volume 1 of 3 (Continued)

Figures (continued) **Page**

CONTENTS – Volume 1 of 3 (Continued)

Figures (continued) **Page**

CONTENTS – Volume 1 of 3 (Continued)

Figures (continued) **Page**

CONTENTS – Volume 1 of 3 (Continued)

Figures (continued) **Page**

Tables **Page**

CONTENTS – Volume 1 of 3 (Continued)

Tables (continued) **Page**

Located in Other Volumes

Volume

Appendixes

Glossary of Terms

AB	Assembly Bill
ADA	Applied Decision Analysis
adsorption	the accumulation of gases, liquids, or solutes on the surface of a solid or liquid
advection	a local change in the properties, such as temperature, of an air mass caused by the horizontal movement of the air mass. Contaminant release is advection-controlled when the rate of contaminant removal rises with increased vapor extraction system flow.
AOP	advanced oxidation process
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
BACT	best available control technology
BDAT	best demonstrated available treatment technology
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
Ca	calcium
CAA	Clean Air Act
CAAQS	California Primary and Secondary Ambient Air Quality Standards
Cal-EPA	California Environmental Protection Agency
CAHs	chlorinated aliphatic hydrocarbons
CARB	California Air Resources Board
CatOx	catalytic oxidation
CCR	California Code of Regulations
CDWR	California Department of Water Resources
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (the Superfund law)
cis-1,2-DCE	cis-1,2-dichloroethene

CLP	Contract Laboratory Program
CO	carbon monoxide
CO_2	carbon dioxide
COCs	contaminants of concern
COD	chemical oxygen demand
cometabolic elements	the elements necessary for cometabolism to occur
cometabolism	the process whereby a "primary substrate" such as toluene, ethyl benzene, or others, induces production of non-specific enzymes that oxidize chlorinated aliphatics such as TCE. This process can "biotransform" contaminants in groundwater to a nonhazardous state.
COPCs	contaminants of potential concern
CS	confirmed site
CT	carbon tetrachloride
CVRWQCB	Central Valley Regional Water Quality Control Board
CWA	Clean Water Act
DCA	dichloroethane
1,1-DCE	1,1-dichloroethene
1,2-DCE	1,2-dichloroethene
desorption	the process of removing an absorbed or adsorbed substance
DHS	State of California Department of Health Services, known as DTSC, Department of Toxic Substances Control
diffusion	the spontaneous intermingling of two or more substances as a result of random thermal motion. Contaminant release is diffusion-controlled when the contaminants migrate into the vapor phase at a relatively slow rate that does not depend on the magnitude of soil vapor extraction system flow.
DNAPL	dense non-aqueous phase liquid
DPE	dual-phase extraction
DPL	Decision Program Language
DREs	destruction and removal efficiencies

DTSC	State of California Department of Toxic Substances Control
dual-phase extraction system	a system designed to simultaneously remove soil gas and water from a single well screened at or above the water table
DWR	(California) Department of Water Resources
EA	Environmental Assessment
EBT	electron beam technology
EC	electrical conductivity
EDB	ethylene dibromide
EE/CA	engineering evaluation/cost analysis
EMR	McClellan AFB's Environmental Management Restoration Division
EPA	U.S. Environmental Protection Agency
FFSRA	Federal Facilities Site Remediation Agreement
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRP	fiberglass-reinforced plastic
FS	feasibility study
GAC	granular activated carbon
gpd	gallons per day
gpm	gallons per minute
GSAP	Groundwater Sampling and Analysis Program
GW OU RI/FS	Groundwater Operable Unit Remedial Investigation/ Feasibility Study
GWTP	groundwater treatment plant
HA	health advisory
HCl	hydrochloric acid
IAG	Interagency Agreement
IC	Investigative Cluster
IRP	Installation Restoration Program

IRPIMS	Installation Restoration Program Information Management System
IWL	Industrial Wastewater Line
IWTPs	industrial wastewater treatment plants
K	potassium
K_{0c}	partition coefficient
LGAC	liquid-phase granular activated carbon
LNAPLs	light nonaqueous phase liquids
McClellan AFB	McClellan Air Force Base
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MicroFem	a steady-state, finite-element computer modeling program used to evaluate capture of contaminants for certain groundwater flow conditions and pumping rates at extraction wells
msl	mean sea level
Na	sodium
NAAQS	National Primary and Secondary Ambient Air Quality Standards
NAPLs	nonaqueous phase liquids
NCP	National Oil and Hazardous Substances Contingency Plan
NOAEL	no observed adverse effect level
NO_x	oxides of nitrogen
NPDES	National Pollutant Discharge Elimination System
NSPS	New Source Performance Standards
NSR	new source review
O&M	operation and maintenance
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.

OSHA	Occupational Safety and Health Act
OU	Operable Unit
PA	Preliminary Assessment
PADRE	Purus adsorption desorption remediation material
PCBs	polychlorinated biphenyls
PCE	perchloroethene or tetrachloroethene
PM10	particulate matter less than 10 microns in diameter
PNAs	polynuclear aromatic compounds (semi-volatile compounds)
POHC	principle organic hazardous constituent
pore volume	volume of all the air in the soil pore spaces within the region of contamination
pore volume exchange	one complete replacement of air in all the pores of soil in a specified area with uncontaminated air
POTW	publicly owned treatment works
ppb	parts per billion
Preliminary GW OU RI (PGOURI)	Preliminary Groundwater Operable Unit Remedial Investigation, a report prepared in 1992 by Radian Corporation
PRG	preliminary remediation goal
PRL	potential release location
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
QC	quality control
RA	remedial action
RAGS	Risk Assessment Guidance for Superfund
RAP	Remedial Action Program
RCRA	Resource Conservation and Recovery Act
RfD	reference dose, usually expressed in units of mg/kg-day

RD/RA	remedial design/remedial action
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
ROD	Record of Decision
RPDs	relative percent differences
RWQCB	Regional Water Quality Control Board
SAP	sampling and analysis plan
SARA	1986 Superfund Amendments and Reauthorization Act
SCS	Soil Conversation Service
SDWA	Safe Drinking Water Act
SIVE	steam injection/vacuum extraction
SMAQMD	Sacramento Metropolitan Air Quality Management District
SO_x	oxides of sulfur
soil gas	gas present in soils
sorbed	attached or held
sorption	the process of sorbing; taking up and holding as by adsorption or absorption
STLC	soluable threshold limit concentration
STRIPR	a computer program designed to calculate design parameters for an air stripping column based on detailed conditions and treatment objectives of the specified site
SVAB	Sacramento Valley Air Basin
SVE	soil vapor extraction
SVOCs	semivolatile organic compounds
SWRCB	State Water Resources Control Board
T-BACT	best available control technology-toxic
TBCs	to-be-considered criteria

1,1,1-TCA	1,1,1-trichloroethane
TCE	trichloroethene
TCLP	toxicity characteristic leaching procedure
TFH	total fuel hydrocarbon
THMs	trihalomethanes
TIS	Technical Information System
TOC	total organic carbon
TPH	total petroleum hydrocarbons
trans-1,2-DCE	trans-1,2-dichloroethene
TSCA	Toxic Substances Control Act
TTLC	total threshold limit concentration
UCL	upper confidence limits
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USDA/SCS	U.S. Department of Agriculture/Soil Conservation Service
UV	ultraviolet
vadose zone	soils above the water table
VCL	vinyl chloride
VLEACH	a computer modeling program designed to simulate the leaching of volatile contaminants through the vadose zone.
VOCs	volatile organic compounds
volatilization	the act of evaporating or causing to be evaporated
WDR	waste discharge requirements
YSAPCD	Yolo/Solano Air Pollution Control District

Chapter 1
Introduction

This Groundwater Operable Unit Remedial Investigation/Feasibility Study (GW OU RI/FS) report has been prepared to support an Interim Record of Decision (Interim ROD) for the selection of a groundwater remedial action at McClellan Air Force Base (McClellan AFB). This section contains:

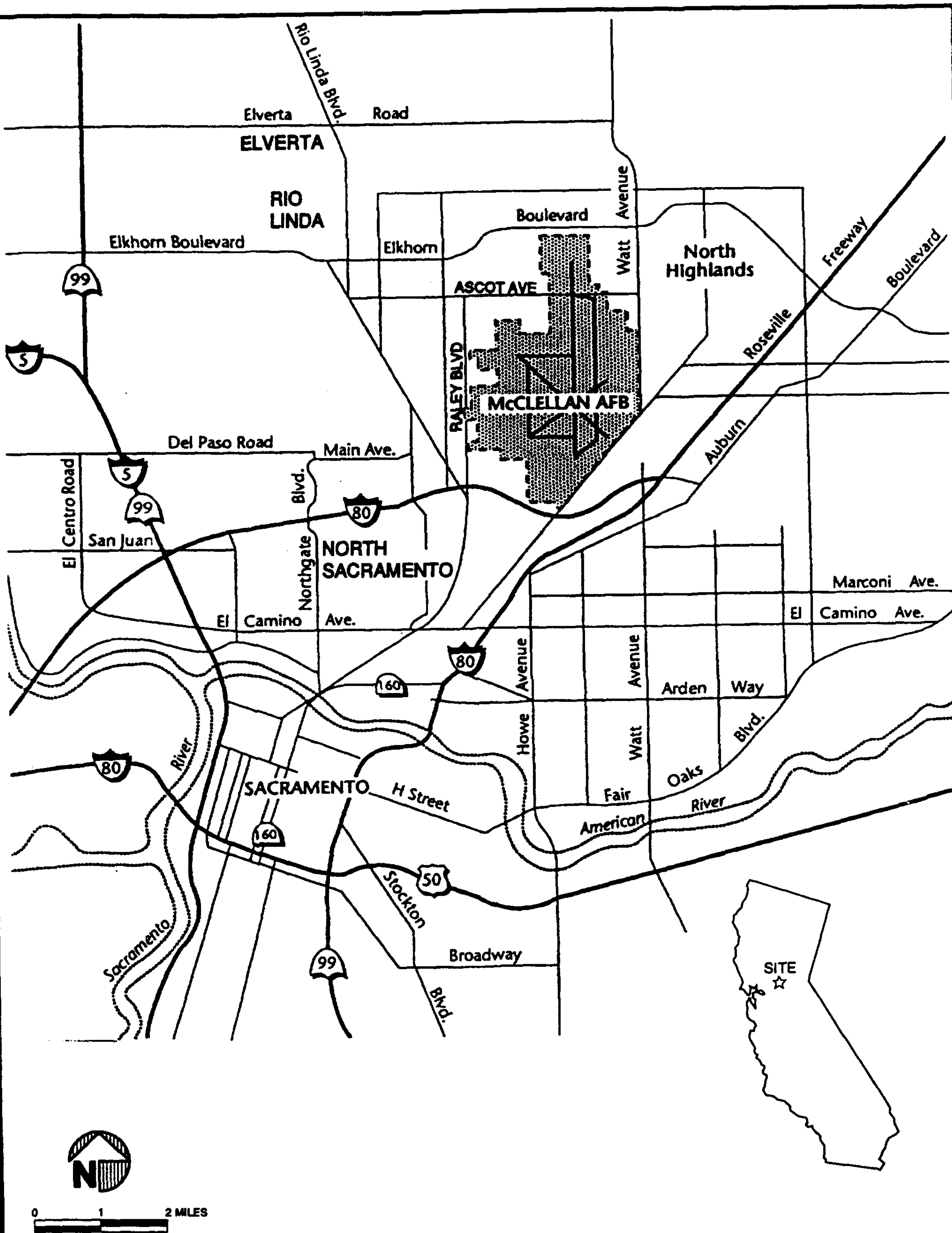
- A site description
- An overview of this document
- An overview of the Superfund RI/FS, Record of Decision (ROD) process, requirements to support an Interim ROD, and the McClellan AFB Installation Restoration Program (IRP)
- The process by which groundwater remedial action priorities and objectives will be established
- The process for making decisions today and in the future
- An explanation of how the existing remedial actions are incorporated into the remediation strategy

1.1 Site Description

McClellan AFB, an Air Force Logistics Command Center, is located approximately 7 miles northeast of downtown Sacramento, California, and is composed of approximately 2,952 acres. The Base property is approximately bounded by Elkhorn Boulevard on the north, Roseville Road on the south, Watt Avenue on the east, and Raley Boulevard on the west. Figure 1-1 shows the Base location.

McClellan AFB currently employs approximately 17,000 people, about 3,500 military and 13,500 civilian employees. Base operations include the management and repair of jet aircraft, electronics, and communications equipment.

Because of its current and past missions, the Base has engaged in a wide variety of operations involving the use, storage, and disposal of hazardous materials, including industrial solvents, caustic cleaners, electroplating chemicals, heavy metals, polychlorinated biphenyls (PCBs), low-level radioactive wastes, and a variety of fuel oils and lubricants. Most of the sites at McClellan AFB were burial pits that were used for disposal and/or burning of wastes.



Source: Radian

FIGURE 1-1
LOCATION OF
McCLELLAN AIR FORCE BASE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1312_132

CH2M HILL

Since 1979, groundwater investigations have identified volatile organic compounds (VOCs) in onbase production wells and offbase residential wells. Groundwater contaminant plumes have been identified in three areas onbase and offbase.

1.2 RI/FS/ROD Process and the Structure of the McClellan AFB Installation Restoration Program

The McClellan AFB IRP is faced with considerable challenges because of the number of sites and the magnitude of the environmental restoration that is necessary. The process of performing an RI/FS and a ROD for a Superfund site is provided in the following section, followed by the tailoring of this process to McClellan AFB.

1.2.1 RI/FS/ROD Process

The purpose of the RI is to collect the data necessary to adequately characterize the site for the purpose of developing and evaluating effective remedial alternatives. The primary objective of the FS is to ensure the appropriate remedial action alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented to a decisionmaker and an appropriate remedy can be selected. The FS culminates in a Proposed Plan for the remedy and undergoes public comment. Following receipt of public comments and any further agency comments, the remedy is selected and documented in a ROD. The ROD, which documents the remedial action plan for a site or operable unit, serves three basic functions:

- It certifies that the remedy selection process was carried out in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), Superfund Amendments and Reauthorization Act of 1986 (SARA), and, to the extent practicable, the National Contingency Plan (NCP).
- It describes the technical parameters of the remedy, specifying the treatment, engineering, and institutional components, as well as the remediation goals.
- It provides the public with a consolidated source of information about the site and the chosen remedy, including the rationale behind the selection.

1.2.2 McClellan AFB Installation Restoration Program

The McClellan AFB IRP is consistent with the EPA Superfund program as described by CERCLA Section 120, amended by SARA, and the NCP. The Base has been divided into operable units (OUs). The principal aims of the environment restoration program at McClellan AFB are as follows:

- Protect human health and the environment.
- Comply with existing statutes and regulations.
- Conduct all IRP activities in a manner consistent with Section 120 of CERCLA as amended by SARA.
- Meet Interagency Agreement (IAG) deadlines and commitments in other agreements, namely the Federal Facility Site Remediation Agreement (FFSRA) concerning the Davis Site and commitments to the Air Force and the California Environmental Protection Agency (Cal-EPA).
- Continue efforts to identify all potential source areas.
- Initiate selected removal actions to control, eliminate, or reduce risks to manageable levels.
- Identify and map the environmental condition of installation property, including areas of no suspected contamination concurrently with remedial investigation (RI) efforts; characterize risks associated with releases of hazardous substances, pollutants, contaminants, or hazardous wastes.
- Complete RIs as soon as practicable for each OU, in order of priority.
- Develop, screen, and select remedial actions (RAs) that reduce risks in a manner consistent with statutory requirements.
- Conduct long-term RAs for groundwater and any necessary 5-year reviews for wastes left onsite.

The GW OU differs from other OUs within the IRP in that it spans the entire Base. The principal reason for this is that groundwater contamination does not recognize geographical OU boundaries. Remedial action alternatives are developed to address Basewide groundwater contaminant problems, rather than those restricted to a particular OU. Finally, the GW OU RI/FS can intake existing remedial actions and integrate them with the Basewide groundwater remedial action. The Groundwater OU also has a role in identifying and prioritizing sources of contaminant release to groundwater in soils within the other OUs. In this manner, the GW OU RI/FS defines priorities for activities within the other OUs related to characterization and remediation of groundwater contaminant sources.

1.3 Overview of the Groundwater OU RI/FS Report

The groundwater contamination at McClellan AFB has been under investigation since 1979. In 1992, Radian Corporation prepared the Preliminary Groundwater Operable Unit Remedial Investigation report (Preliminary GW OU RI). The Preliminary GW OU RI forms the foundation of this GW OU RI/FS report and is referenced often.

This GW OU RI/FS report contains interpretations of the data related to the estimation of the **extent of the remedial action** (risk assessment, target volumes, and future trends) and the **implementation of the remedial action** (regional influences and areas of uncertainty).

It is necessary to understand the overall direction of the IRP at McClellan AFB to appreciate the necessity of the Interim ROD and remedial action for the contaminated groundwater. The McClellan AFB IRP has an overriding goal of reducing risk to public health and the environment. This goal must be met within the CERCLA process, the Air Force IRP protocols, and resource constraints. Risk reduction cannot be achieved without implementation of removal or remedial actions. Removal or remedial actions cannot be designed and implemented without the appropriate decision documents. The appropriate decision documents are action memorandums for removal actions and Records of Decision for remedial actions.

The CERCLA process recognizes the need to take actions that are larger in scope than a removal action prior to full understanding of the extent of contamination and technology performance needed for a final ROD. To fill this need, EPA encourages the use of Interim RODs for the purpose of making as many remedial action decisions as possible at the earliest point in the investigation of the site. A summary of the differences between an Interim ROD and a final ROD is provided in Table 1-1.

The decision documents (action memorandums, Interim RODs, and RODs) are supported by the Administrative Record in general, and by the Proposed Plan, engineering evaluation/cost analysis (EE/CA) or RI/FS in particular. Given the differences in use and content of the decision documents, the content of the supporting documents varies as well. While the overall structure of the documents can be similar to the appropriate guidance documents, there are necessary differences in content. This RI/FS report has been prepared to support an Interim ROD. There is not sufficient information to support a final groundwater ROD.

Given the risk reduction goal of the McClellan AFB IRP and the CERCLA process, the following decision documents have been prepared or are planned:

1. Interim Record of Decision for PCB-, dioxin-, and metals-contaminated soils at OU B1. Completed September 3, 1993.

Table 1-1
Summary of the Checklists for Interim and Final RODs

Heading	Interim ROD – Differences from Final ROD	Final ROD – Differences from Interim ROD
I. DECLARATION		
A. Site Name and Location	None	None
B. Statement of Basis and Purpose	None	None
C. Description of the Selected Remedy	None	None
D. Statutory Determinations	Does not need to use permanent solutions and alternative treatment technologies. Does not need to address reduction of toxicity, mobility, or volume as a principal component.	If the selected remedy satisfies the statutory preference for treatment as a principal element, includes the appropriate standard language: selected remedy is protective of human health and the environment, complies with ARARs or a waiver is justified, and is cost-effective. Uses permanent solutions and alternative treatment or resource recovery technologies to the maximum extent practicable, and satisfies statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element. If the selected remedy does not satisfy the preference for treatment as a principal element, includes the appropriate standard language: "...However, because treatment of the groundwater was not found to be practicable, this remedy does not satisfy the statutory preference for treatment as a principal element." If hazardous substances will remain onsite above health-based level, includes the appropriate standard language: Because the remedy will result in hazardous substances remaining onsite above health-based levels, "a review will be conducted within five years after commencement of the remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment."

Table 1-1
Summary of the Checklists for Interim and Final RODs

Heading	Interim ROD—Differences from Final ROD	Final ROD—Differences from Interim ROD
D. Statutory Determinations (continued)		If hazardous substances will not remain onsite above health-based levels, includes the appropriate standard language: "Because this remedy will not result in hazardous substances onsite above health-based levels, the five-year review will not apply to this action."
II. DECISION SUMMARY		
A. Site Name, Location, and Description	None	None
B. Site History and Enforcement Activities	None	None
C. Highlights of Community Participation	None	None
D. Scope and Role of the Operable Unit Within the Site Strategy	Provides the rationale for taking a limited action. Describes how the response action fits into the overall site strategy. States that the interim action will be consistent with any planned future actions, to the extent possible.	Summarizes the scope of the problems and identifies the contaminated media addressed by the remedial action selected.
E. Summary of Site Characteristics	None	None
F. Summary of Site Risks	Focuses on risks addressed by the interim action.	Extensive requirements for summarizing human health risks and environmental risks.

Table 1-1
Summary of the Checklists for Interim and Final RODs

Heading	**Interim ROD – Differences from Final ROD**	**Final ROD – Differences from Interim ROD**
F. Summary of Site Risks (continued)	Provides the rationale for the limited scope of the action, including facts indicating that temporary action is necessary to stabilize the site or portion of the site, prevent further environmental degradation, or achieve significant risk reduction quickly while a final remedial solution is being developed.	Factors relating to human health include type of current use and potential beneficial use of groundwater; populations at risk, both current and potential; reasonable exposure pathways; concentrations of contaminants of concern; chronic daily intakes; basic toxicity information; summation of pathway-specific carcinogenic risk or non-cancer hazard index; key risk exposure times; results of baseline risk assessment; indication of whether baseline risk is greater than risk range for the site; and a description of significant sources of uncertainty in risk assessment. Factors relating to the environmental evaluation include the reason for performing or not performing an ecological assessment and, if one was performed, a discussion of which media were sampled and whether concentrations of surface-water contaminants were compared to federal, state, or any other stream standard. Also includes a discussion of whether aquatic toxicity tests, bioassays, terrestrial surveys, or stream evaluations were performed; whether critical habitats, endangered species, or wetlands were considered/identified, and if so, what type of effects/risks were identified at the site.
G. Description of Alternatives		
Groundwater Treatment Components	Does not describe the area of attainment. Does not describe the remediation and residual levels to be attained (e.g., 5 ppm) and the basis for the selection of the goal (e.g., ARARs, risk-based levels). Describes implementation requirements and timeframes for **the interim action**. Discusses assumptions, limitations, and/or uncertainties regarding the effectiveness **of the interim action**.	Describes the area of attainment. Describes the remediation and residual levels to be attained (e.g., 5 ppm) and the basis for the selection of the goal (e.g., ARARs, risk-based levels). Describes implementation requirements and timeframes for **restoration**. Discusses assumptions, limitations, and/or uncertainties regarding the effectiveness **of the remedy**.

Table 1-1
Summary of the Checklists for Interim and Final RODs

Heading	Interim ROD—Differences from Final ROD	Final ROD—Differences from Interim ROD
Containment Components	None	None
General Components	Requires no discussion of long-term groundwater monitoring after system shutdown.	Describe provisions for groundwater monitoring once the system is shut off to ensure goals are maintained.
ARARs in the Description of Alternatives	Describes the ARARs for the limited-scope interim action.	Contains more extensive discussion of ARARs; includes TBCs and a discussion of key ARARs and how each alternative's components will or will not comply or invoke a waiver. Requires a discussion of why key ARARs are applicable, relevant, or to be considered. May discuss residuals management, LDRs, Endangered Species Act, Clean Water Act, and State ARARs.
H. Summary of the Comparative Analysis of Alternatives	Briefly describes the evaluation of criteria that are not relevant to the evaluation of the *interim action*.	Discussion of nonrelevant criteria not required.
Threshold Criteria	None	None
Primary Balancing Criteria	Under "Short-Term Effectiveness," discussion includes both the method to achieve protection and the time until protection is achieved. Under "Implementability," addresses technical and administrative feasibility of the alternatives, including institutional controls.	Under "Short-Term Effectiveness," discussion includes both the method to achieve protection and the time until protection is achieved prior to attainment of cleanup levels if any adverse impacts may occur. Also includes discussion of mitigation techniques to minimize any adverse impacts (including institutional controls). Under "Implementability," addresses technical and administrative feasibility of the alternatives and the need for developing appropriate institutional controls.
Modifying Criteria	None	None
I. The Selected Remedy	Addresses uncertainties associated with groundwater extraction and the need to either prevent plume migration or evaluate parameters for final action.	Addresses uncertainties as to remedy, achieving the goals, and, if appropriate, contingency measures. Provides basis for remediation levels for contaminants in each medium and/or each area. Provides risk levels corresponding to cleanup levels.

Table 1-1
Summary of the Checklists for Interim and Final RODs

Heading	Interim ROD – Differences from Final ROD	Final ROD – Differences from Interim ROD
J. Statutory Determinations		
Protection of Human Health and the Environment	States that the interim action protects human health and the environment from the exposure pathway or threat it is addressing and the waste material being managed.	Describes how the selected remedy will eliminate, reduce, or control risks posed through each pathway to each population, through treatment, engineering controls, or institutional controls to ensure adequate protection of human health and the environment. Describes how the selected remedy controls each exposure pathway.
Compliance With ARARs	Focuses only on those ARARs specific to the interim action.	States whether the selected remedy will comply with ARARs and TBCs. Should be organized as chemical-specific, location-specific, and action-specific. Lists and describes federal and state ARARs that will be attained by use of the remedy.
Cost-Effectiveness	None	None
Utilization of Permanent Solutions and Alternative Treatment Technologies or Resource Recovery Technologies to the Maximum Extent Practicable	Indicates that the interim action is not designed or expected to be final, but that the selected remedy represents the best balance of tradeoffs among alternatives with respect to pertinent criteria, given the limited scope of the action.	Describes the rationale for remedy selection. Discusses the criteria that were most critical to the selection decision. Describes the role of the state and community acceptance considerations. States that the selected remedy meets statutory requirements to use permanent solutions and treatment technologies to the greatest extent practicable.
Preference for Treatment as a Principal Element	Notes that the preference will be addressed in the final decision document for the site or final operable unit.	
Documentation of Significant Changes	None	None
III. RESPONSIVENESS SUMMARY		
Community Preferences	None	None

2. Soil vapor extraction (SVE) EE/CA to support Removal Action for areas highly contaminated by VOCs in the vadose zone. Completed November, 1993, with sites added as necessary.

3. Interim ROD for the Basewide Groundwater OU. To be completed by August 1994.

4. Interim ROD for the Basewide Vadose Zone. To be completed in March 1995.

5. Additional Interim ROD for contamination or conditions that do not fit the Interim ROD for the Basewide Groundwater OU or the Interim ROD for the Basewide Vadose Zone.

6. Basewide ROD.

Specific dates beyond 1994 have not been developed and are dependent on the annual priorities for the McClellan AFB IRP resources.

1.4 Priorities

McClellan AFB has clear goals and objectives for the IRP and may be faced with resource constraints. A process for establishing priorities is necessary to resolve the conflict between the goals and the resource constraints. The relationship of the strategy for the remedial action, the implementation of the remedial actions, and the priorities is illustrated in Figure 1-2. Priorities need to be established to balance additional investigation requirements with the control of the contaminant plumes. At a Basewide level, the priorities among the OU investigations, the source remedies, the vadose zone remedies, and the groundwater remedy will be resolved by McClellan AFB and the agencies.

The priorities for the GW OU include:

- Remediation of contamination that has migrated offbase. Prioritization of offbase groundwater contamination remediation will be established with the regulatory agencies. If investigation is a necessary prerequisite to this remedy, it will receive a high priority.
- Control of hot spots.
- Remediation of the contamination between the hot spots and the plume boundary.

In all cases, the remedy will require the appropriate monitoring systems to measure the effectiveness of the remedial actions.

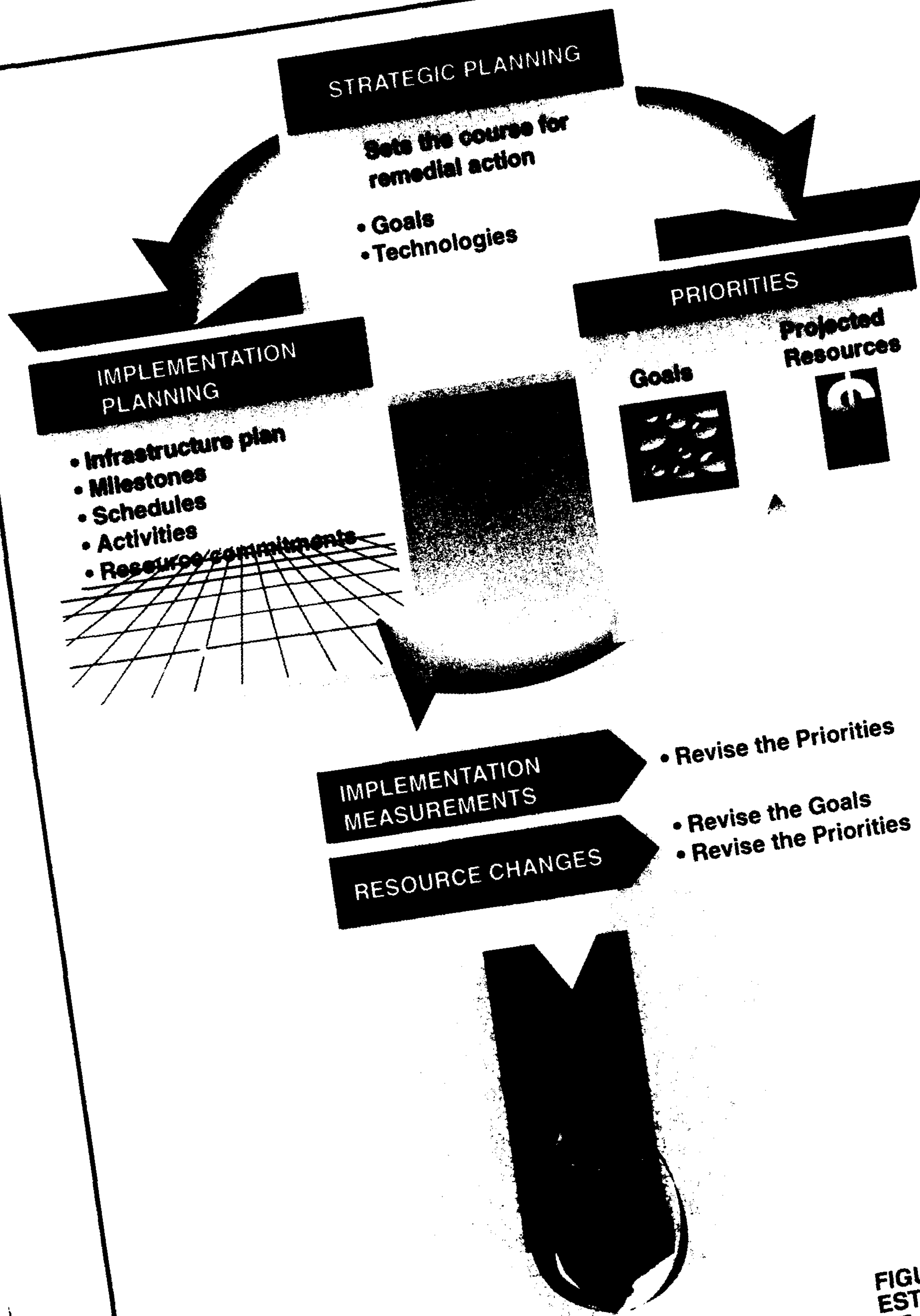


FIGURE 1-2
ESTABLISHMENT OF PRIORITIES

CH2M HILL

RDD1312_18

Future decisions for the GW OU will potentially include the use of new technologies as they become available or when the equipment needs to be replaced, expansion or reduction of the level of protectiveness for the groundwater remediation goals, and balancing resources between the groundwater remedy and other remedies on the Base. The Remedial Project Manager team may be faced with decisions on the priority of remediation versus pollution prevention programs. McClellan AFB developed the Management Action Plan, which provides the overall direction for the IRP at the Base. Several RODs are planned, and the decisionmakers will need to consider the previous decisions in each of the RODs. The process for addressing decisions in the future is similar to the process today, only the baseline conditions will include remedies from previous RODs, and new uncertainties and evaluation factors may need to be included.

As shown in Figure 1-2, strategic planning activities, including the GW OU RI/FS, define the goals for remedial action and identify the technologies to be used in its implementation. The goals will be balanced against projected resources to establish priorities for remedial action. The priorities for containment and additional investigation to refine the interpretation of the extent of contamination are presented in Section 13.1.1 (Chapter 13). These planning and priority-setting activities then support the development of implementation plans that define the infrastructure required for remedial action, milestones, and schedules of activities, and the level of resource commitment. Periodic measurements of the implementation may show site conditions different than those anticipated during the planning process, which then requires a change in the priorities for remedial action.

Changes in resource levels from those anticipated during the planning process may require a change in either the priorities for remedial action, the goals, or both. Addressing this dynamic process is accomplished through a planning process that accounts for uncertainty throughout each step.

1.5 Presumptive Remedies

McClellan AFB is faced with a decision that is common in Superfund sites, that is, how to remediate groundwater contaminated with VOCs. The U.S. Environmental Protection Agency (EPA) has recently advocated using presumptive remedies rather than reconsidering the universe of potential general response actions and technologies. A presumptive remedy approach is possible in instances where there is a remedial action or process option that has repeatedly been shown to work in the range of conditions present at a site, and when 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. When the presumptive remedy approach is used by EPA, the FS report does not evaluate a full range of varied general response actions or technologies. Rather, only the presumed remedy and the No-Action Alternative are evaluated and compared. The FS then describes why it is appropriate to presume the alternative. This is a presumptive remedy FS for the control of groundwater migration by pumping. There are several aspects of the remedy that are not addressed by presuming a remedy, because there is not a single remedy that has been repeatedly selected on similar sites. The components of the remedy that are not addressed by the presumptive remedy approach are the water treatment technologies for treatment capacity beyond the capacity of the existing groundwater treatment plant, water end use, and the innovative technology evaluations. Site-specific conditions lead to the need to evaluate these components in a more traditional fashion.

1.6 Integration of Existing Groundwater Remedial Actions

McClellan AFB currently has several groundwater remedial actions in place. The existing actions are considered part of the baseline conditions in the RI/FS and will become part of the remedy as they currently operate, or possibly be adjusted. Figure 1-3 depicts the integration of the existing remedial actions into the groundwater remedy. This section provides a summary of the existing remedial actions.

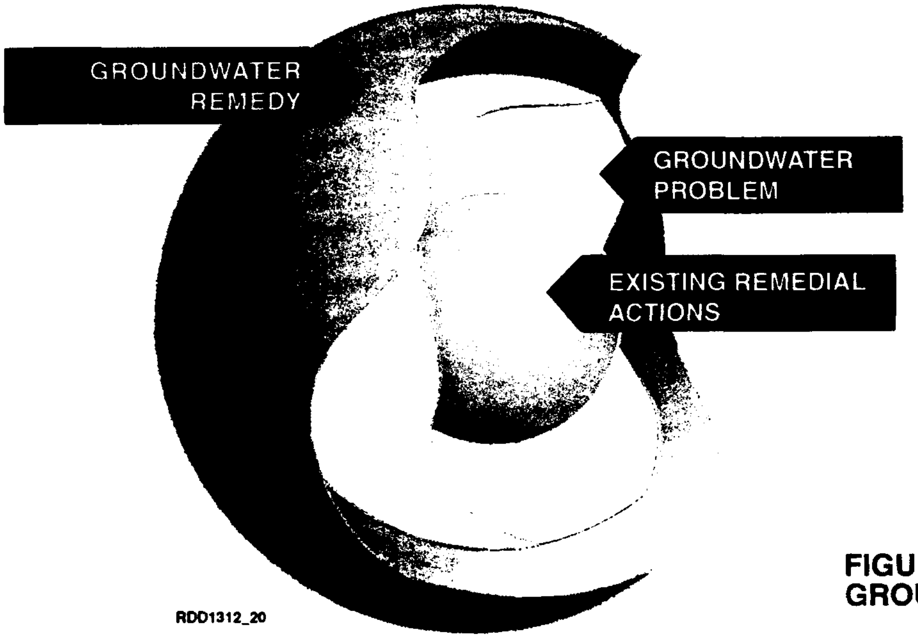


FIGURE 1-3
GROUNDWATER REMEDY

Groundwater extraction is currently taking place in Operable Units B, C, and D to limit offbase subsurface migration. Built in the mid 1980s, the Groundwater Treatment Plant is located on the west side of the Base and receives water from OUs C and D. The plant uses air stripping processes and granular activated carbon-thermal oxidation processes to remediate groundwater and to treat emissions.

There are currently seven extraction wells located within OU B. Two of the wells have been in operation since 1990. They extract approximately

6 to 7 gallons per minute (gpm) from the A zone, and are connected to a portable carbon treatment system. Two additional extraction wells located in northern OU B (EW-140 and EW-141) extract approximately 45 gpm from the B zone and C zone, respectively. Three extraction wells were installed recently, one each in the A, B and C zones, and will be in operation in 1994. BW-18 is a Base supply well located within OU B. It has a radius of influence of approximately 500 to 700 feet in the A and B aquifers, and a slightly higher influence in the C aquifer due to a larger screened interval. The well was out of service from 1981 to 1985 due to detected contaminant concentration; BW-18 currently receives wellhead treatment that has been effective in removing low-level contaminants before releasing the water into the McClellan AFB water supply.

There are currently two extraction wells in operation in OU C (EW-137 and EW-144). These wells are connected to the existing groundwater treatment plant pipeline and pump approximately 30 gpm. Together, the OU B and OU C extraction systems capture approximately 90 gpm from the A, B, and C aquifers. These wells do not totally contain the known groundwater contamination areas. The location of all existing extraction wells at the Base are shown in Figures 4-43 through 4-45.

There are six extraction wells that have been in operation within OU D, all screened in the A/B zone, since July 1987. They extract approximately 60 to 80 gpm of groundwater from the A and B aquifers. Horizontal and vertical capture is achieved within the A, B, and C aquifers beneath the OU D cap. In the spring, C aquifer capture may not be as successful due to increased regional pumping. The current extraction system does not provide capture of all contaminated groundwater; groundwater west of 20th Street appears to flow to the south toward OU C and is not contained by the OU D extraction system. Horizontal extent of containment southeast of OU D is poorly defined due to lack of monitoring wells.

Chapter 2
Study Area Investigations

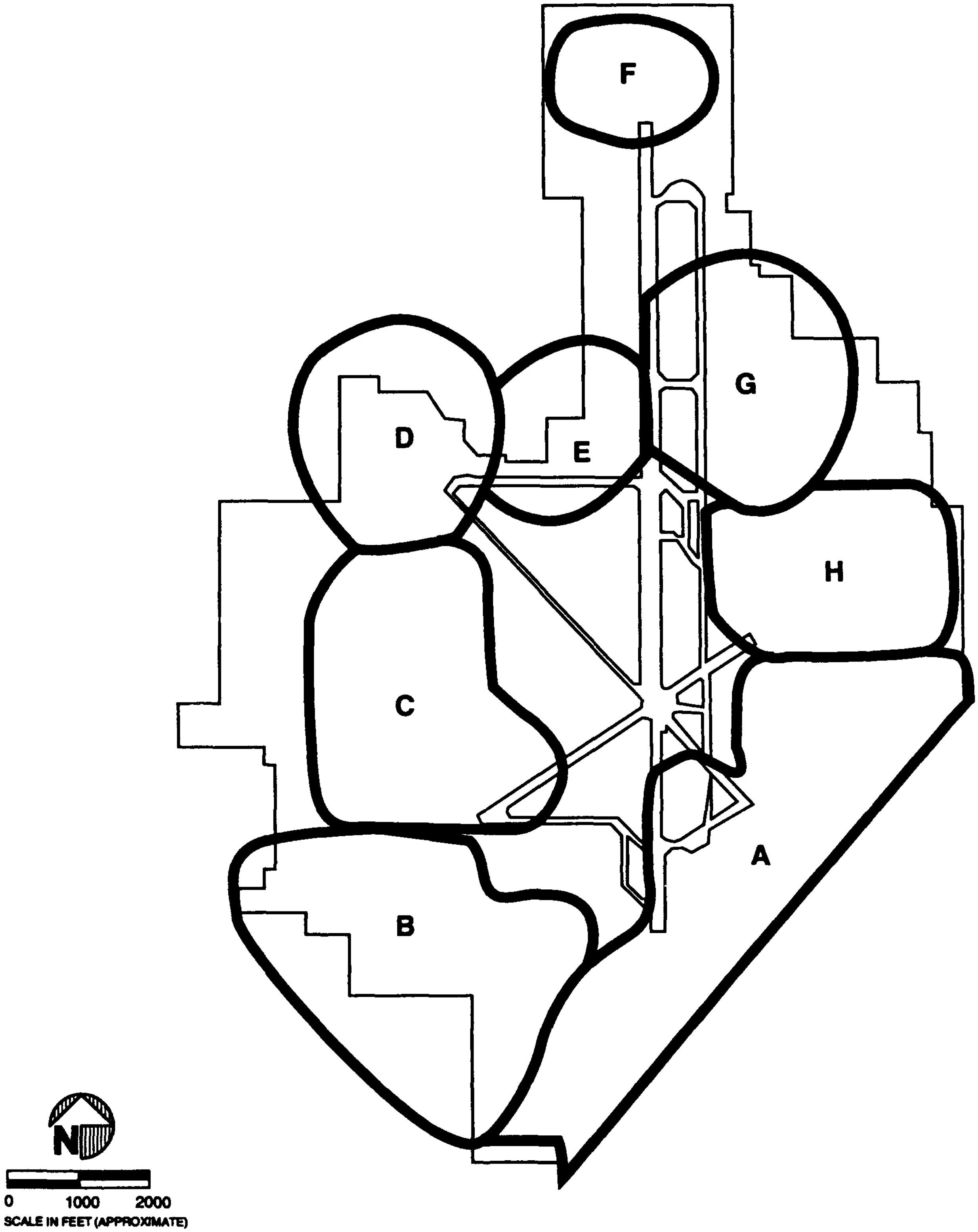
2.1 Site Summary

In 1981, the Department of Defense developed a program to identify and evaluate suspected or potential contamination problems resulting from past hazardous waste disposal practices at 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 CERCLA. The IRP consists of four phases: Phase I involves Installation Assessments (record searches) to identify the potential problem areas, base history, and environmental setting; Phase II is a confirmation of the existence and extent of any contamination; Phase III is a Technology Base Development in which further efforts are made to identify and develop remedial action technology; and Phase IV is the implementation of a recommended remedial action.

In May 1990, the Air Force, U.S. EPA Region IX, and the California Department of Health Services (DHS), now the Cal-EPA, signed an IAG requiring restoration activities to comply with applicable state and federal laws. At the time of the IAG, the Base was divided into 11 OUs. Ten of the 11 OUs have geographic boundaries at the surface and are associated with source areas at the Base. These OUs are A, B, B1, C, C1, D, E, F, G, and H (see Figure 2-1). The eleventh OU is the GW OU.

To date, approximately 253 confirmed sites, potential release locations (PRLs), and other areas that warrant investigation have been identified (Table 2-1). These sites have been grouped into the OUs, each of which corresponds to an area on the Base where specific industrial operations and/or waste management activities have taken place. An OU 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.

VOCs constitute the most widespread and the most common subsurface contamination at McClellan AFB. Compounds with significant concentrations in decreasing order of frequency of detection in soil gas are trichloroethene (TCE), tetrachloroethene (PCE), 1,1-dichloroethene (DCE), 1,1,1-trichloroethane (TCA), and Freon-113. In addition, the following compounds are commonly identified in soil gas, but at lower concentrations: cis-1,2-DCE, 1,1-DCA, trichlorofluoromethane, dichlorodifluoromethane, trans-1,2-DCE, 1,2-DCA, vinyl chloride, carbon tetrachloride, chloroform, methyl benzene, xylenes, and benzene. Of the compounds most frequently reported, TCE and PCE contribute the bulk of the contaminant mass in some areas, but 1,1,1-TCA and 1,1-DCE are as significant in other areas.



LEGEND

BOUNDARIES OF OPERABLE UNITS

McCLELLAN AIR FORCE BASE BOUNDARY

Source: Radian, 1991
RDD1454_802

FIGURE 2-1
APPROXIMATE BOUNDARIES OF OPERABLE UNITS AT McCLELLAN AIR FORCE BASE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	1	LF024	CS 024	CS 24	Landfill	Prip	41,000	1964-1969	CERCLA
	2	LF025	PRL 025	PSPRL 25	Landfill	Unknown	110,000	Late 40s, early 50s	CERCLA
	3	ST034	CS 034	PSPRL 34	Waste sol. storage tanks	Prip	100	--	CERCLA
	4	LF037	CS 037	PSPRL 37	Landfill	Sol, POL	125,000	1940-1957	CERCLA
	5	LF038	CS 038	CS 38	Engine Repair Shop	Sol, Prip, Met	240,000	--	CERCLA
	6	LF039	PRL 039	PSPRL 39	Landfill	Unknown	100,000	Before 1941-1946	NFI, REG-CON
	7	WP040	CS 040	PSPRL 40	Indus. wastewater sludge	Sol, POL	21,000	1943-1972	CERCLA
	8	DP070	PRL B-002	UPRL B-2	Spoil pit/borrow pit	Unknown	189,000	--	NFI, REG-CON
	9	LF071	PRL B-003	UPRL B-3	Landfill	Sol, POL	--	--	NFI, REG-CON
	10	WP072	PRL B-004	UPRL B-4	Sludge drying bed	Sol, Met	2,500	1941	NFI, REG-CON
	11	LF073	CSB-005	UPRL B-5	Empty lot	POLs, Sol	12,500	1962	NFI, REG-CON
	12	WP079	PRL P-003	UPRL P-3	Oil pit	Sol, POL	6,270	1946-1987	CERCLA
	13	WP080	PRL P-004	UPRL P-4	Sump	Sol, POL	3,360	Early 1940s-1989	CERCLA
	14	SD081	CS P-005	UPRL P-5	Open Ditch	Sol, Other	2,200	1940-1965	CERCLA
	15	SD082	CS P-006	UPRL P-6	Open Ditch	Sol, Other	2,200	1943-1989	CERCLA
	16	WP084	PRL P-008	UPRL P-8	Acid and cyanide pit	Acetone, Met	38,000	1955	CERCLA
	17	OT086	PRL S-001	UPRL S-1	Plating shop	Sol, CN, Met	12,000	1944-1957	CERCLA
	18	SS087	PRL S-002	UPRL S-2	Chemical warehouse	Sol	9,400	1943	CERCLA
	19	SS088	PRL S-003	UPRL S-3	Acid storage warehouse	Acetone	5,600	1942-1975	NFI, REG-CON
	20	SS089	PRL S-004	UPRL S-4	Treatment plan/sludge beds	Sol, Met, POL	13,000	1943-1989	CERCLA
	21	WP091	PRL S-006	UPRL S-6	IWTP #1	Sol, Met	4,200	Late 1930s-1989	CERCLA
	22	WP092	CS S-007	UPRL S-7	IWTP #3	Sol, Other	8,100	1940-1989	CERCLA
	23	SS094	PRL S-009	UPRL S-9	Asbestos storage	Asbestos	10,000	Oct-Dec 1987	CERCLA
	24	SD099	PRL S-014	UPRL S-14	Paint shop/spray booths	Sol, POL	8,400	1938-1989	CERCLA
	25	SD101	PRL S-016	UPRL S-16	Sol./paint spray booths	POL, Sol	250,000	1937-1989	CERCLA

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	26	SD102	PRL S-017	UPRL S-17	Repair shop/spray booths	Sol, POL	27,000	1937-???	CERCLA
	27	SD103	PRL S-018	UPRL S-18	Repair shop/clean shop	Sol, POL	27,000	1937-1989	CERCLA
	28	SS104	PRL S-019	UPRL S-19	Entomology storage area	Pesticides	3,600	1940-1970s	CERCLA
	29	SD105	PRL S-020	UPRL S-20	Photo lab	Met, SOL	14,000	1941	CERCLA
	30	SD106	CS S-021	UPRL S-21	Degreaser/spray booths	Sol, POL	28,000	1943-1989	CERCLA
	31	SD107	PRL S-022	UPRL S-22	Repair shop/spray booths	Sol, POL	10,000	Late 1930s	CERCLA
	32	SD108	PRL S-023	UPRL S-23	Plating shop	Sol, Met, CN	14,000	1942	NFI, REG-CON
	33	SD109	CS S-024	UPRL S-24	Depaint washrack	POL, Sol	25,000	1940-1989	CERCLA
	34	SD110	PRL S-025	UPRL S-25	Transformer shop	POL, PCB, Sol	27,000	1943-1989	CERCLA
	35	SD111	CS S-026	UPRL S-26	Mainshop/spray booth	POL, Sol	38,000	1942	CERCLA
	36	SD112	CS S-027	UPRL S-27	Solvent recovery stills	Sol	7,200	1941	CERCLA
	37	SS121	PRL S-036	UPRL S-36	Oil drum storage	Sol, POL	27,000	1943-1989	CERCLA
	38	SS122	PRL S-037	UPRL S-37	Oil drum storage	Sol, POL	27,000	1946-1988	CERCLA
	39	SS123	PRL S-038	UPRL S-38	Drum storage	Sol	15,000	1943-1989	CERCLA
	40	ST131	PRL T-006	UPRL T-6	UST	Sol	3,100	1952-1980	CERCLA
	41	ST132	PRL T-007	UPRL T-7	Sol pit/waste thinner tank	Sol	14,000	1952-1989	CERCLA
	42	ST134	PRL T-010	UPRL T-10	Solvent tank	Sol	56,000	1938-1989	CERCLA
	43	ST136	CS T-012	UPRL T-12	Waste oil/solvent tank	Sol	2,400	1943-1989	CERCLA
	44	ST137	PRL T-015	UPRL T-15	Tank Farm 1	Sol, POL	25,000	1943-1989	UST
	45	ST138	CS T-016	UPRL T-16	Tank Farm 2	Sol, POL	--	Late 40s/Early 50s	UST
	46	ST139	CS T-017	UPRL T-17	Tank Farm 3W	POL	2,800	1943-1987	UST
	47	ST140	PRL T-018	UPRL T-18	Tank Farm 4	POL	5,400	1940-1989	UST
	48	ST141	PRL T-019	UPRL T-19	Tank Farm 5	POL	5,400	Early 40s-Late 60s	UST
	49	ST142	CS T-020	UPRL T-20	Tank Farm 6	Sol, POL	20,000	1941-1989	CERCLA
	50	ST143	CS T-021	UPRL T-21	UST	Sol, POL	10,000	1943-1989	CERCLA

Table 2-1
Summary of Sites Identified at
McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	51	ST144	CS T-030	UPRL T-30	UST	Sol	3,600	1940-1954	CERCLA
	52	ST148	CS T-036	UPRL T-36	UST	Sol	6,700	1943-1989	CERCLA
	53	ST149	CS T-037	UPRL T-37	UST	Sol	6,700	1943-1989	CERCLA
	54	SD156	CS T-047	UPRL T-47	Oil/water separator	POL	6,700	1940-1989	CERCLA
	55	OT159	PRL L-002	--	IWL	Unknown	--	--	CERCLA
	56	OT160	PRL L-003	--	IWL	Unknown	--	--	CERCLA
	57	OT161	PRL L-004	--	IWL	Unknown	--	--	CERCLA
	58	OT169	CS T-057	--	IWL drain at Bldg. 431	Sol, VOC	--	--	CERCLA
	59	ST170	CS T-059	--	UST	Fuel Oil	--	--	UST
	60	ST172	CS T-061	--	UST	Fuel Oil	--	--	UST
	61	ST198	SA 035	--	UST	Diesel	--	1942-1992	UST
	62	SS199	SA 037	--	Motor pool	Unknown	--	--	CERCLA
	63	ST200	SA 038	--	UST	Fuels	--	1938-1991	UST
	64	SS201	SA 040	--	Chemical storage area	Unknown	--	--	CERCLA
	65	SS202	SA 041	--	Metal fabrication	Unknown	--	--	CERCLA
	66	SS203	SA 043	--	Average fluids	Unknown	--	--	CERCLA
	67	WP204	SA 044	--	Sump	Unknown	--	--	CERCLA
	68	SS205	SA 045	--	Soil contamination	Unknown	--	--	CERCLA
	69	ST206	SA 046	--	UST	Diesel	--	1954-1989	UST
	70	SD207	SA 047	--	Washrack 254	Unknown	--	--	CERCLA
	71	ST208	SA 048	--	Warehouse	Paints, Sol	--	--	NFI, REG-CON
	72	ST209	SA 049	--	UST	Diesel	--	1941-1992	UST
	73	ST210	SA 052	--	Blowdown Tanks	Met., Anions	--	1946-1990	CERCLA
	74	WP211	SA 053	--	Washrack	Unknown	--	--	CERCLA
	75	ST212	SA 054	--	Aboveground storage tank	Unknown	--	--	CERCLA

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	76	SS213	SA 055	--	Laboratory	Unknown	--	--	CERCLA
	77	SD214	SA 056	--	Wastewater	Unknown	--	--	CERCLA
	78	SS215	SA 058	--	Chemical storage tank	Unknown	--	--	CERCLA
	79	ST216	SA 059	--	UST	Diesel	--	1952-1988	UST
	80	WP217	SA 060	--	Indus. wastewater drain	Unknown	--	--	CERCLA
	81	SD218	SA 061	--	Solvent spray booth	Unknown	--	--	CERCLA
	82	SS219	SA 064	--	Chemical storage	Unknown	--	--	CERCLA
	83	OT220	SA 065	--	IWL	Unknown	--	--	CERCLA
	84	SS221	SA 066	--	Motor pool	Unknown	--	--	CERCLA
	85	SS222	SA 067	--	Soil contamination	Unknown	--	--	CERCLA
	86	SS223	SA 068	--	Spills	Unknown	--	--	CERCLA
	87	WP224	SA 069	--	Steam Fac./UST	Met/Fuels	--	1942-1993	UST
	88	OT225	SA 070	--	IWL	Unknown	--	--	CERCLA
	89	SS226	SA 071	--	Hazardous mat. storage	Unknown	--	--	CERCLA
	90	WP227	SA 073	--	Sump	Unknown	--	--	CERCLA
	91	ST228	SA 074	--	AGT, UST	Diesel	--	1943-1989	UST
	92	OT229	SA 075	--	IWL	Unknown	--	--	CERCLA
	93	SS230	SA 076	--	Hazardous mat. storage	Unknown	--	--	CERCLA
	94	ST231	SA 077	--	Aboveground storage tank	Unknown	--	--	CERCLA
	95	SD232	SA 078	--	Locomotive washrack	Unknown	--	--	CERCLA
	96	ST233	SA 079	--	Fuel Test Fac.	Sol	--	--	CERCLA
	97	SS234	SA 080	--	Contractor staging	Unknown	--	--	CERCLA
	98	ST235	SA 081	--	Fuel lines	Unknown	--	--	CERCLA
	99	OT236	SA 084	--	Spray booth	Unknown	--	--	CERCLA
	100	WP237	SA 085	--	Oil/water separator	Sol	--	--	CERCLA

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	101	WP238	SA 086	--	Engine Test/UST	Sol, VOC	--	--	CERCLA
	102	ST239	SA 087	--	UST	POL	--	1944-1986	UST
	103	SS240	SA 088	--	Soil contamination	Unknown	--	--	CERCLA
	104	SS241	SA 089	--	Open storage area	Unknown	--	--	CERCLA
	105	SD242	SA 090	--	Washrack	Unknown	--	--	CERCLA
	106	SS243	SA 091	--	Soil contamination	Unknown	--	--	CERCLA
	107	RW244	SA 093	--	Radionuclide	Unknown	--	--	CERCLA
	108	ST245	SA 094	--	Open storage area	Unknown	--	1964-???	CERCLA
	109	ST246	SA 095	--	UST	Fuel Oil	--	1946-1957	UST
	110	WP247	SA 096	--	UST	Unknown	--	1943-???	CERCLA
	111	SD248	SA 097	--	Tank farm	Unknown	--	--	CERCLA
	112	SS249	SA 098	--	Spray booths	Unknown	--	--	CERCLA
	113	ST250	SA 099	--	Sewage treat./UST	Sewage, Diesel	--	1950-	UST
	114	ST251	SA 100	--	Doc. destruct./UST	Sol, Diesel	--	1973-	UST
	115	WP252	SA 101	--	Sump	Unknown	--		CERCLA
	116	SS253	SA 103	--	Soil contamination	Unknown	--	--	CERCLA
	117	SS254	SA 105	--	Laboratory	Unknown	--	--	CERCLA
	118	ST255	SA 106	--	Salvage yard/UST	Sol, Diesel	--	--	UST
	119	SS256	SA 107	--	Soil contamination	Unknown	--	--	CERCLA
	120	SD257	SA 108	--	Aircraft fluids	Unknown	--	--	CERCLA
	121	SD258	SA 109	--	Magpie Creek contam.	Unknown	--	--	CERCLA
B	122	LF023	CS 023	CS 23	Landfill	Prip	24,000	1966-1989	CERCLA
	123	DP030	CS 030	PSPRL 30	Radio/chem lab/landfill	Sol, Met	39,000	1957-1988	CERCLA
	124	OT031	CS 031	PSPRL 31	Incinerate ash burial pit	Met, POL	53,000	1963-1968	CERCLA
	125	SS036	CS 036	PSPRL 36	Open storage area	Sol, CN	30,000	1958-1980	CERCLA

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
B	126	OT045	CS 047	CS 47	Abandoned plating shop	Sol, Met	44,000	1957-1982	CERCLA
	127	WP046	CS 048	CS 48	Abandoned IWTP	Unknown	--	--	CERCLA
	128	OT066	--	--	Base Well 18	Unknown	--	--	CERCLA
	129	DP035	PRL 035	PSPRL 35	Scrap metal burial pit	Unknown	35,000	World War II	NFI, REG-CON
	130	LF069	PRL B-001	UPRL B-1	Landfill	Unknown	109,200	--	NFI, REG-CON
	131	LF076	PRL B-009	UPRL B-9	Landfill	Unknown	50,400	--	NFI, REG-CON
	132	SD078	PRL P-002	UPRL P-2	Waste pond	POL, Sol	18,820	1962-???	CERCLA
	133	SD085	PRL P-009	UPRL P-9	Open drainage ditch	Sol, Met	1,700	1956 to mid-1960s	CERCLA
	134	WP090	PRL S-005	UPRL S-5	Abandoned IWTP	Unknown	5,900	--	CERCLA
	135	SS097	PRL S-012	UPRL S-12	PCB storage	Unknown	20,000	Mid 1940s	NFI, REG-CON
	136	SS098	PRL S-013	UPRL S-13	Open storage	Sol	120,000	1955-1989	CERCLA
	137	SS113	PRL S-028	UPRL S-28	Oil/paint storage	POL	5,000	1968-1987	CERCLA
	138	SS114	PRL S-029	UPRL S-29	PCB storage	PCB	190,000	--	CERCLA
	139	SD115	PRL S-030	UPRL S-30	Depaint washrack	Sol, POL	15,000	1951-???	CERCLA
	140	SS118	PRL S-033	UPRL S-33	Hazardous mat. storage	Sol, Other	84,000	1953	CERCLA
	141	SD119	PRL S-034	UPRL S-34	Degreaser/paint booth	Other, Sol	35,000	--	CERCLA
	142	SD120	PRL S-035	UPRL S-35	Solvent spray booth	Sol, Other	25,000	1946-49;. 1965	CERCLA
	143	SD126	PRL S-041	UPRL S-41	MAT K storage	Jet Fuel	125,000	1955-1989	NFI, REG-CON
	144	OT162	PRL L-005	--	Indus. wastewater line	Unknown	--	--	CERCLA
	145	OT163	PRL L-006	--	Indus. wastewater line	Unknown	--	--	CERCLA
	146	ST133	PRL T-008	UPRL T-8	Fuel tank	Unknown	16,000	--	CERCLA
	147	SD154	PRL T-045	UPRL T-45	Oil/water separator	POL, TCE, PCE	3,600	--	UST
	148	SD155	PRL T-046	UPRL T-46	Defuel fac. tanks	POL, TCE, PCE	6,700	Before 1968-???	CERCLA/UST
	149	SD157	PRL T-048	UPRL T-48	Oil/water separator, UST	POL, TCE, PCE	6,700	1968-Present	CERCLA/UST
	150	ST171	PRL T-060	--	UST	POL	--	--	UST

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
B	151	WP179	SA 001	--	Surface disposal	Unknown	--	--	NFI, REG-CON
	152	SS180	SA 002	--	Laboratory	Unknown	--	--	CERCLA
	153	SD181	SA 003	--	Washrack	Unknown	--	--	CERCLA
	154	SS182	SA 004	--	Paint shop	Unknown	--	--	CERCLA
	155	SS183	SA 005	--	Paint storage	Unknown	--	--	CERCLA
	156	ST184	SA 006	--	Gas station	MOGAS	--	1954-1991	UST
	157	SD185	SA 007	--	Washrack	Unknown	--	--	CERCLA
	158	ST186	SA 008	--	UST	POL	--	--	UST
	159	SS187	SA 009	--	Hazardous mat. storage	VOC	--	--	NFI, REG-CON
	160	SS188	SA 010	--	Sump	Herbicides	--	--	CERCLA
	161	ST189	SA 011	--	UST	Diesel	--	--	UST
	162	SS191	SA 013	--	Chemical storage area	Unknown	--	--	CERCLA
	163	SD192	SA 014	--	Storm water drainage	Unknown	--	--	CERCLA
	164	SS193	SA 015	--	NW corner lot 10 spill	Unknown	--	--	CERCLA
	165	SD194	SA 016	--	Chemical storage area	Unknown	--	--	CERCLA
	166	SS195	SA 017	--	Oil storage yard	Unknown	--	--	CERCLA
	167	SS196	SA 018	--	Oil storage yard	Unknown	--	--	CERCLA
	168	SD197	SA 019	--	Spray booth	Unknown	--	--	CERCLA
B1	169	OT029	PRL 029	PSPRL 29	Landfill	Unknown	120,000	1950s-1960s	CERCLA
	170	SS190	SA 012	--	DRMO storage area	Unknown	--	--	CERCLA
C	171	SD007	CS 007	CS 7	Sludge/oil pit	Prip, Sol, PCB,	35,000	--	CERCLA
	172	LF008	PRL 008	PSPRL 8	Sludge refuse/landfill	POL	59,000	--	CERCLA
	173	LF009	PRL 009	PSPRL 9	Landfill	Prip, Sol, POL	30	--	CERCLA
	174	LF010	CS 010	CS 10	Landfill	Unknown	32,000	--	CERCLA
	175	LF011	CS 011	CS 11	Landfill	PCB, Prip	32,000	--	CERCLA
						Prip			

Table 2-1
Summary of Sites Identified at
McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
C	176	LF012	CS 012	CS 12	Landfill	Prip	55,000	--	CERCLA
	177	LF013	CS 013	CS 13	Landfill	Prip	54,000	--	CERCLA
	178	LF014	CS 014	CS 14	Landfill	Prip	54,000	--	CERCLA
	179	DP015	PRL 015	PSPRL 15	Sodium valve trench	Unknown	30	--	CERCLA
	180	DP016	PRL 016	PSPRL 16	Sodium valve trench	Unknown	30	--	CERCLA
	181	LF017	PRL 017	PSPRL 17	Landfill	Sol	40,000	--	CERCLA
	182	LF018	PRL 018	PSPRL 18	Landfill	Unknown	40,000	1957-1959	CERCLA
	183	LF019	PRL 019	PSPRL 19	Landfill	Unknown	40,000	1957-1959	CERCLA
	184	DP020	PRL 020	PSPRL 20	Sludge/oil pit	Sol, POL	50,000	1956-1957	CERCLA
	185	DP021	PRL 021	PSPRL 21	Sludge/oil pit	VOC, Sol	50,000	1956-1957	CERCLA
	186	DP028	PRL 028	PSPRL 28	Sludge pit	Prip	3,000	--	CERCLA
	187	SS032	PRL 032	PSPRL 32	Rad./hazardous wastes	Prip	160	1955-1974	CERCLA
	188	LF043	CS 043	CS 43	Burn pit	Prip	20,000	--	CERCLA
	189	LF047	PRL 049	PSPRL 49	Landfill	Unknown	45,000	Before 1971	CERCLA
	190	WP048	PRL 050	PSPRL 50	Settling pond	Unknown	11,000	1946-1971	CERCLA
	191	WP049	PRL 051	PSPRL 51	Holding pond	Unknown	180,000	1982-1989	CERCLA
	192	DP050	CS 052	CS 52	Burn pit	Prip	20,000	--	CERCLA
	193	WP051	PRL 053	PSPRL 53	Settling pond	Sol	96,000	1958???	CERCLA
	194	SS052	PRL 054	PSPRL 54	Storage area	Unknown	6,300	Circa 1970	CERCLA
	195	SS053	PRL 055	PSPRL 55	Acid storage area/landfill	Sol	900	1951-1989	CERCLA
	196	SS054	PRL 056	PSPRL 56	Storage area	Unknown	100,000	1957-1974	CERCLA
	197	LF055	PRL 057	PSPRL 57	Landfill	Unknown	29,000	1956	CERCLA
	198	WP056	PRL 060	PSPRL 60	Holding pond	Unknown	80,000	--	CERCLA
	199	WP057	PRL 061	PSPRL 61	Chemical waste pit	Unknown	900	Early 1950s	CERCLA
	200	WP058	PRL 062	PSPRL 62	Chemical waste pit	Unknown	500	Early 1950s	CERCLA

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
C	201	SD059	PRL 063	PSPRL 63	Unlined ditch	Unknown	20,000	--	CERCLA
	202	SD060	PRL 064	PSPRL 64	Unlined ditch	Unknown	--	--	CERCLA
	203	LF061	PRL 065	PSPRL 65	Landfill	Unknown	--	--	CERCLA
	204	WP062	PRL 066	PSPRL 66	Ditches and pond	Unknown	--	1946-1989	CERCLA
	205	WP063	CS 067	CS 67	Landfill	Prip, POL	40,000	--	CERCLA
	206	WP068			Groundwater treat. plant	Unknown	--	--	CERCLA
	207	SS096	PRL S-011	UPRL S-11	BCE/PCE storage	PCB, POL, Sol	47,000	1941-1989	CERCLA
	208	SD116	PRL S-031	UPRL S-31	Aircraft paint hangar	Paints, POL, Sol	47,000	1968-1989	CERCLA
	209	SS117	PRL S-032	UPRL S-32	Paint storage area	Paints, POL, Sol	10,080	1968-1989	CERCLA
	210	SD165	PRL P-010	--	Magpie Creek	VOC	--	--	CERCLA
	211	OT166	PRL S-046	--	Unknown	Unknown	--	--	CERCLA
	212	OT168	PRL S-048	--	W of Bldg. 720	Unknown	--	--	CERCLA
C1	213	LF022	CS 022	CS 22	Burn pit/landfill	Prip, Sol, PCB,	40,000	1946-1968	CERCLA
	214	LF041	PRL 041	PSPRL 41	Landfill	POL	106,000	--	CERCLA
	215	LF042	CS 042	CS 42	Oil storage/landfill	Prip	11,000	1946-1960S	CERCLA
	216	WP064	PRL 068	PSPRL 68	Sludge ponds	Prip, PCB, POL	13,000	--	CERCLA
	217	DP065	CS 069	CS 69	Burn pit	Prip	--	--	CERCLA
	218	OT164	PRL L-007	--	Indus. wastewater line	Prip Unknown	--	--	CERCLA
D	219	LF001	CS 001	CS 1	Landfill	Prip	10,500	--	OSD/NVZ
	220	LF002	CS 002	CS 2	Sludge/oil pit	POL, Prip, Sol	20,000	--	OSD/NVZ
	221	LF003	CS 003	CS 3	Sludge/oil pit	Prip	50,700	--	OSD/NVZ
	222	DP004	CS 004	CS 4	Sludge/oil pit	Prip, Sol, POL	15,000	--	OSD/NVZ
	223	DP005	CS 005	CS 5	Sludge/oil pit	Prip	15,600	--	OSD/NVZ

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
D	224	DP006	CS 006	CS 6	Oil burn pit	Sol, Met, POL	7,500	--	OSD/NVZ
	225	LF026	CS 026	CS 26	Sludge/oil burn pit	Sol, Met	40,000	--	OSD/NVZ
	226	DP027	PRL 027	PSPRL 27	Sodium valve trench	Unknown	100	Late 40s-Early 50s	OSD/NVZ
	227	WP003	PRL 033	PSPRL 33	IWTP sludge landfarm	Sol	2,000,000	1972	NFI, REG-CON
	228	SD083	PRL P-007	UPRL P-7	Open ditch	POL, Sol	5,000	--	CERCLA
D	229	ST135	PRL T-011	UPRL T-11	Bldg. 1093	Sol	1,000	--	CERCLA
	230	DP151	CS A	CS A	Sludge disposal pit	Sol, Met, Prip	--	--	OSD/NVZ
	231	DP152	CS S	CS S	Fuel/solvent/oil burn pit	Sol, POL, Prip	9,200	--	OSD/NVZ
	232	DP153	CS T	CS T	Fuel/solvent sludge pit	Sol, POL, Prip, Met	8,400	--	OSD/NVZ
	233	DP178	--	--	Vadose zone contam.	VOC	600 acres	Late 40s-Early 50s	CERCLA
E	234	LF044	PRL 045	PSPRL 45	Paint waste landfill	Unknown	150,000	--	CERCLA
	235	SS095	PRL S-010	UPRL S-10	Storage area	Sol, Rad	63,000	--	CERCLA
F	236	LF074	PRL B-006	UPRL B-6	Waste area	Unknown	627,200	--	CERCLA
G	237	SD127	PRL S-042	UPRL S-42	Hobby shop/washrack	Sol, POL	8,100	--	CERCLA
	238	SD128	PRL S-043	UPRL S-43	Aircraft washrack	POL, Sol	49,000	--	CERCLA
	239	SD129	PRL S-044	UPRL S-44	Aircraft maintenance area	Sol, POL	275,000	--	CERCLA
	240	ST145	PRL T-031	UPRL T-31	UST	Sol	12,500	--	CERCLA
	241	ST146	PRL T-032	UPRL T-32	UST	Sol	12,500	--	CERCLA
	242	ST147	PRL T-033	UPRL T-33	UST	Sol	12,500	--	CERCLA
	243	ST150	PRL T-044	UPRL T-44	Stoddard solvent tank	Sol	10,000	--	CERCLA
	244	OT158	PRL L-001	--	Indus. wastewater line	Unknown	--	--	CERCLA
	245	ST173	PRL T-062	--	UST	Unknown	--	--	CERCLA

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
H	246	LF075	PRL B-007	UPRL B-7	Spoil area	Unknown	627,200	1943-1989	CERCLA
	247	SD077	PRL P-001	UPRL P-1	Drainage ditch/ponds	Sol, POL	56,400	1943-1964	CERCLA
	248	OT093	PRL S008	UPRL S-8	Electorplating shop	Sol, CN, Met	35,000	--	CERCLA
	249	SD100	PRL S-015	UPRL S-15	Degreaser/spray booths	Sol, POL	290,000	--	CERCLA
	250	OT124	PRL S-039	UPRL S-39	New museum site	Sol	94,000	--	CERCLA
	251	OT125	PRL S-040	--	S-40 Troop Issue area	Unknown	19,000	1946-1968	CERCLA
	252	SD130	PRL S-045	UPRL S-45	Aircraft maintenance area	POL, Sol	615,000	1941-???	CERCLA
	253	OT167	PRL S-047	--	Unknown	Unknown	--	--	CERCLA
--	254	OT067	--	--	Offbase wells, Raley Blvd.	Unknown	--	--	CERCLA
--	255	OT174	--	--	Davis	Unknown	--	--	AF IRP
	256	ST175	--	--	Lincoln	Unknown	--	--	AF IRP
	257	LF176	--	--	Wilson Park	Unknown	--	--	NFI
	258	ST177	--	--	Camp Kohler	Unknown	--	--	AF IRP

[a]This site number is just a means of sequencing this listing. If new sites are found, the sequencing would change.

[b]Work Information Management System-Environmental Subsystem (WIMS-ES) identification number. The first two letters denote the type of site (e.g., LF=landfill), while the three digits represent a sequencing from 001 to several hundred (in the case of McAFB). The numerical portion is unique at each AFB; for example, there is only on 034 representation; in this case it is preceded by an ST as a descriptor. Thus there is no LF034 or WP034. Other alpha codes are as follows:

DP = Disposal pits
OT = Other, ordnance, burn areas, buildings
SD = Surface runoff, ditches, wash racks, oil/water separators
ST = Underground tanks, above ground tanks, POL lines
FT = Fire training areas
RW = Radioactive wastes
SS = Spills, storage areas
WP = Waste pits, sumps, lagoons, waste treatment, evaporation pits

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]	Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]

[c]Some sites have several identifying numbers from different studies or documents. The first column represents those numbers used in the 1992 Comprehensive CERCLA Work Plan (CCWP) while the numbers in the second column are from Attachment A in the 1990 IAG.

CCWP Terminology			IAG Terminology		
CS	=	Confirmed Site	CS	=	Confirmed Site
PRL	=	Potential Release Location	PSPRL	=	Partially Studied PRL
SA	=	Study Area	UPRL	=	Unstudied PRL

[d]
PCB = Polychlorinated Biphenyl
IWL = Industrial Waste Line
IWTP = Industrial Wastewater Treatment Plant
MAT K = Maintenance Apron Terminal No. K
UST = Underground Storage Tank

[e]
CN	=	Cyanide	Prip	=	Primary Pollutant
Met	=	Metals	Sol	=	Solvents
PCE	=	Perchloroethylene (or Tetra)	TCE	=	Trichloroethylene
POL	=	Petroleum, Oil, and Lubricants			

[f]Area in square feet (unless otherwise noted)

Table 2-1
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]	Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]

[g]**Status**--Generally speaking, the status (stage) of sites on base is taken as RI/FS, with most off-base sites in the PA/SI stage (however, Davis is in RI/FS). Exceptions to this rule ar those 16 sites which are NFI (no further investigation) with regulatory concurrence (REG-CON). OSD/NVZ, which applies to 11 sites, indicates and old site designation, now included in the Vadose Zone site (DP-178).

Regulatory Mechanism--All of the 253 on-base sites are being addressed under CERCLA. Twenty-four UST sites containing POL or fuels have been identified for transfer to the UST program under RCRA, Title I, pending regulatory concurrence. Two other sites that need further investigation of contaminants to determine whether CERCLA or UST prevails are listed under the heading CERCLA/UST. Five sites are off-base. One of the off-base sites is being handled under CERCLA, while the other four sites are non-CERCLA, but subject to standard AF IRP procedures.

Source: McClellan AFB Management Action Plan, July, 1993.

Most of these compounds have also been detected in groundwater at various locations underneath the Base (McClellan AFB, 1993).

Results of groundwater samples collected on and in the vicinity of McClellan AFB confirm the presence of a variety of contaminants, principally VOCs and metals. Local residents have historically used groundwater for irrigation purposes; however, the Air Force has provided public water to these residents in response to the contamination problem, reducing the reliance on individual domestic wells in areas to the west and southwest of the Base.

This section focuses on the purpose of investigations conducted both in the past and present at McClellan AFB and a summary of the findings that affect characterization of groundwater contamination at the Base. Description of all investigative activities will be provided in the Basewide RI report. A summary of major investigations at McClellan AFB is given in Table 2-2.

2.2 Source Area Investigations, Geological Investigations, and Soil and Vadose Zone Investigations

In 1981, CH2M HILL conducted Phase I of the IRP and investigated the historic waste handling and disposal practices to determine the potential for migration of hazardous materials offbase. A search of records was performed to identify and prioritize past activities that may have contaminated groundwater. Results of the search discovered that organic solvents were detected in the groundwater underlying the Base and that PCBs were contained in the soil in a small area at the northwest corner of the runway clear zone. Recommendations were made to implement an expanded monitoring program to determine the geographic extent of organic compounds in the groundwater.

In 1986, McClaren Environmental Engineering began a shallow exploration program at McClellan AFB as part of the IRP implemented in 1981. Soil borings were drilled to further define the extent of contamination of sites identified during IRP Phase I. The study area consisted of Areas A, B, C, and Other Sites not defined by specific boundaries. The results from these investigations identified those sites which required further study.

2.2.1 Operable Unit A

Jacobs Engineering Group has been conducting an RI at OU A since 1992, with a draft report to be issued in 1996. While conclusions from the RI are not yet available, preliminary findings have identified several releases to soil representing potential sources of groundwater contamination. On the basis of the available information, these potential release sources include leaks from the Industrial Wastewater Line (IWL), underground storage tanks and fuel distribution lines, spills from hazardous

Table 2-2
Summary of Major Investigations at McClellan AFB

Year	Contractor	Scope	Conclusions
1981	CH2M HILL	IRP Phase I—Initial assessment of contamination	Past disposal sites in all areas of the Base were identified.
1983	Engineering Science	IRP Phase II—Definition and quantification of contamination; implementation of a monitoring program to determine the extent of groundwater contamination	Base production wells could be serving as conduits for contamination to migrate to deeper aquifers.
	Ludorff & Scalmanini	Review of previous investigations	Aquifers are not separated from one another and provide a natural path for contaminant migration.
1984	Radian Corporation	Determination of the nature and extent of contamination in wells offbase	Public health hazards were identified and remedial alternatives assessed.
1985	McLaren Environmental Engineering, Inc.	Drilling of soil borings to further define the extent of contamination at sites identified during IRP Phase I	Some sites required further investigation; others did not.
1986	Radian Corporation	Groundwater Sampling and Analysis Program	The presence and concentration of contaminants was determined and migration over time was evaluated.
1988	Idaho National Engineering Laboratory	Characterization of the industrial wastewater collection system	Samples were collected and compared to hazardous waste criteria. Also, the integrity of the collection system piping was evaluated.
1989	Radian Corporation	Engineering Evaluation/Cost Analysis-Environmental Assessment	Three plumes exist in the southwest part of the Base. Removal actions were recommended.
1989	Radian Corporation	Area B Groundwater Operable Unit Investigation	Hydrogeologic characteristics of the southwest portion of the Base were characterized; the horizontal and vertical extent of groundwater contamination were evaluated.
1991	Radian Corporation	Preliminary Groundwater Operable Unit Investigation	A conceptual model of the hydrogeology was developed and the extent of groundwater contamination at McClellan AFB was investigated.
1992	CH2M HILL	Operable Unit D Remedial Investigation	A remedial investigation was performed to collect enough data to reduce the uncertainty in contaminant type and distribution at OU D. In addition, a risk assessment was conducted. Further action to determine the extent was recommended.
1993	U.S. Department of Health and Human Services	Public Health Assessment for McClellan AFB	Several health actions are necessary for the site.

materials storage areas, and wastewater spills. Specific source areas for groundwater contaminants have not yet been identified in OU A.

Areas of suspected or confirmed releases to soil are as follows:

- Site 38 (Building 475)—engine repair facility: VOCs, oil and grease (detected to a depth of 30 feet in soil)
- Site 24—former storage area and burn pit: VOCs detected to a depth of 79 feet in soil
- Site S-24 (Building 375)—aircraft washrack: chemical storage
- Industrial Wastewater Treatment Plant (IWTP) No. 3 (Site S-7)
- Tank Farm 2 (T-16)—aromatic VOCs detected to a depth of 25 feet in soil
- Building 431 (T-57)—former fire test area, engine test facility

2.2.2 Operable Unit B

Radian Corporation has been conducting an RI since 1991, with a draft report to be issued in June 1994. While conclusions from the RI are not yet available, preliminary findings indicate that VOCs in soil are the principal contaminants of concern at OU B. Highest concentrations in VOCs measured in soil gas at McClellan AFB have been detected in two principal areas in OU B:

- Investigative Cluster (IC) 1, which includes Sites 36, 47, and 48, and PRL L-5D.
- IC 7, which includes PRL S-34, PRL L-6, PRL S-5, Site S-35, and PRL P-9.

These two ICs are considered to represent major source areas for potential VOC contamination to groundwater. Interim remedial actions have been initiated at these two ICs through the Basewide SVE EE/CA developed by CH2M HILL. Other sources of VOC contamination in subsurface soil may be associated with potential leaks from the portion of the IWL in OU B. Lower concentrations of VOCs in soil gas have been detected at several other sites within OU B.

2.2.3 Operable Unit B1

In 1993, Radian Corporation completed an RI/FS for OU B1. Results of the study show that the principal pathways of exposure at OU B1 were associated with PCBs and dioxins/furans in surface soil. Contaminants in soil at OU B1 were not considered to represent significant sources of groundwater contamination.

2.2.4 Operable Unit C

In 1993, CH2M HILL performed a Preliminary Assessment (PA) of OU C at McClellan AFB as part of Phase I of the IRP. The PA consisted of the following: (1) a review of existing data; (2) literature searches, including collection of data generated by previous investigations, review of documents at McClellan AFB, regulatory agencies, and other governmental agencies; and (3) interviews of McClellan AFB employees to gather information regarding past and present hazardous materials and waste management practices within OU C. Limited additional investigation at many of the sites (41 of the 43 total sites in OU C) was recommended to evaluate potential risk to workers on the Base. At these sites, available information does not support the conclusion that hazardous materials pose a threat to human health or the environment. However, because some uncertainty remains, limited additional sampling was recommended.

On the basis of the results of the PA, Radian Corporation developed an RI Sampling and Analysis Plan (SAP). The SAP outlines field procedures, sample collection points, analytical methods, data handling and analysis, and decisionmaking criteria for the RI. A draft RI report for OU C is to be issued in 1998.

2.2.5 Operable Unit C1

OU C1 was identified as a separate OU in 1992 because of soil contamination that potentially represented a significant source of groundwater contamination. Jacobs Engineering Group is presently conducting the RI for OU C1, with a draft report to be issued in mid-1994. Interim remedial actions undertaken at OU C1 include the SVE EE/CA, and a treatability study investigating the use of steam injection/vapor extraction (SIVE). Air permeability and surface VOCs emissions flux testing are scheduled to be performed at OU C1 in 1994.

In addition to the ongoing RI, CH2M HILL designed a Phase III pilot-scale treatability investigation of SIVE at Site 22. Site 22 is one of six waste disposal sites identified in OU C1. Originally intended for installation in the vadose zone at Site 22, a preliminary assessment determined that it was more economically feasible for use in the saturated zone. This project is currently on hold because of funding restrictions.

2.2.6 Operable Unit D

In 1984, 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 the 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 1992, an RI was performed by CH2M HILL to collect enough data for OU D to reduce the uncertainty in contaminant type and distribution to a level that is acceptable for the Feasibility Study (FS) so that remedial alternatives could be fairly evaluated and selected. Components of the

RI included Resident Crawlspace and Ambient Air Sampling; Soil Vapor Monitoring Well Sampling; Shallow Soil Gas Survey; Soil Borings and Well Installations; and Monitoring Well Sampling. In addition, a risk assessment was conducted to identify the contaminants posing the greatest threat and to evaluate potential exposures and adverse effects to human health. As a result of this investigation, further action to determine the extent was recommended. The recommendations were split into three categories: (1) Feasibility Study; (2) Remedial Design/Remedial Action; and (3) Additional Data Collection and Evaluation to support (1) and (2).

In addition to the RI, CH2M HILL is currently operating a SVE pilot treatment system at Site S, a previously activated waste pit used for disposal of solvents and fuel. The SVE system consists of a network of soil gas extraction wells set at various depths in the vadose zone. The extracted offgas flow rate and chemical composition are monitored, and the emissions are treated using an onsite catalytic oxidation system and a hydrochloric acid scrubber. In addition to evaluating the applicability of SVE at OU D and at the Base in general, other objectives of the investigation include evaluating offgas emission control systems and evaluating the degree of bioremediation at the site. Two innovative offgas treatment systems have been demonstrated at the site: Zappit electron beam irradiation and the Purus Padre resin adsorption system.

2.3 Groundwater Investigations

2.3.1 Earlier Studies

As part of the IRP Phase II, Engineering Science performed a study of groundwater monitoring well installation and designed a sampling program to quantify the magnitude and extent of contamination onbase. Conducted in 1983, the results of the study indicated organic compounds and trace metals were present in shallow wells throughout the Base. It concluded that the first water-bearing zone in the aquifer (shallow water-bearing zone) was contaminated. Deeper water-bearing units had contaminant levels at or below detection levels.

In 1983, Ludorff & Scalmanini reviewed previous investigations to determine if any wells served as conduits for water to move from one aquifer to another. The study identified base production and monitoring wells that provided potential vertical conduits for contaminant migration. Results suggested that shallow aquifers are not totally separated from deep aquifers, but that confining layers are discontinuous and form natural paths for potential contaminant migration.

Reconnaissance borings and an inventory of private wells offbase were performed by Radian Corporation in 1984 to determine contamination of groundwater and geologic information offbase. Data were gathered for the purpose of guiding the placement of new monitoring wells onbase and offbase. Results from the analysis of groundwater samples identified the presence of contamination in several areas near the Base boundary.

In 1983, the McClellan AFB Groundwater Task Force established a quarterly sampling and analysis program that involved 240 private wells located primarily west and south of McClellan AFB. In June 1985, the Air Force contracted Radian Corporation to sample domestic wells. The total number of wells sampled each quarter had grown from approximately 30 in mid-1983 to more that 120 wells. Results from the first year's quarterly sampling program were used to evaluate the extent of offbase contamination and as a basis for providing bottled water to owners of contaminated wells. In the spring of 1986, McClellan AFB performed an offbase remedial action to provide municipal drinking water hookups to approximately 550 residences that used private wells for drinking water supplies in the area west of the Base. Monitoring of offbase residential wells was discontinued following completion of the offbase remedial action.

In 1986, Radian Corporation began quarterly groundwater sampling and analysis of monitoring wells onbase and offbase. Conducted each quarter since October 1986, this Groundwater Sampling and Analysis Program (GSAP) has provided data to better determine the presence and concentration of contaminants in groundwater and has evaluated contaminant migration over time. In addition, water levels in wells both onbase and offbase have been determined. The GSAP is currently ongoing. Data from the GSAP have been used in the risk assessment (see Chapter 5) and the conceptual model (see Chapter 4) to evaluate the nature and extent of groundwater contamination at McClellan AFB.

2.3.2 Preliminary Groundwater Operable Unit Remedial Investigation

In 1991, Radian Corporation conducted a preliminary RI of the groundwater OU titled the Preliminary GW OU RI. The purpose of Preliminary GW OU RI was to develop a conceptual model of hydrology and to further define the extent of groundwater contamination. Data collected in the Preliminary GW OU RI form the basis for the conceptual model presented in Chapter 4 of this RI/FS report.

The following eight contaminants have been consistently detected in groundwater at levels above federal drinking water standards:

- Benzene
- 1,1-dichloroethene
- Carbon tetrachloride
- 1,2-dichloroethene
- Trichloroethene
- 1,2-dichloroethane
- Vinyl chloride
- Tetrachloroethene

Seven other contaminants are consistently detected at levels below federal drinking water standards: acetone, bromodichloroethane, 2-butanone, 1,1-DCA, 4-methyl-2 pentanone, toluene, and trichlorofluoromethane.

The contaminant having the greatest spatial extent is TCE. Approximately 400 acres are underlain by groundwater plumes having TCE concentrations above the federal drinking water standard of 5 μg/l, or parts per billion (ppb).

Using concentrations of TCE above 1 ppb, groundwater contaminant plumes underlay about 520 acres, or about 18 percent of the total area of the Base. The TCE plume also extends to cover an additional 70 acres offbase.

Forty-four organic compounds have been detected in groundwater samples from wells at McClellan AFB. Of these 44, 18 have been detected consistently; the other 26 are believed to have been detected as a result of either field or laboratory contamination, or have been detected at or near method detection limits.

In OUs A, B, and C, higher concentrations of VOCs are consistently detected in samples from wells located near branches of the IWL. The suite of VOCs detected in groundwater from these wells and their concentrations vary from location to location. Cracks, breaks, and contaminated soils have been found at locations along the IWL. If wastewater in the IWL had been discharged through cracks or breaks over a period of years, the leaking water may have provided a means to carry dissolved contaminants downward through the unsaturated zone to groundwater.

Intended to be a component of the Preliminary GW OU RI, the Area B GW OU RI was given priority and started prior to initiation of the Preliminary GW OU RI. The Area B GW OU RI has since been renamed the OU B GW RI. The Area B GW OU RI assessed the potential for migration of groundwater contaminants to offbase areas southwest of McClellan AFB and further defined the horizontal and vertical extent of groundwater contamination in those areas. An EE/CA-Environmental Assessment (EA) was developed to initiate removal actions for contaminated groundwater. Three contaminant plumes were identified in the EE/CA-EA in the southwest part of the Base.

The following 17 recommendations were presented in Chapter 6 of the Preliminary GW OU RI (Radian, 1992):

- Conduct an investigation of soil or groundwater contamination from leakage in IWL
- Sample and analyze groundwater in PZ-38
- Install monitoring wells to define the direction of flow and extent of contamination near NW-17
- Conduct an investigation to locate an extraction system in the southwestern onbase portion of Sector C
- Evaluate the effectiveness of EW-144 in removing contaminated groundwater from the A and B zones

- Conduct an investigation of the source of deep zone contamination by, in part, installing monitoring wells adjacent to ponds and settling basins in Sector C
- Install B and C zone monitoring wells at, and A and B zone wells downgradient of, MW-1053
- Install a monitoring well cluster between the cluster at MW-150, MW-151, and MW-152 and BW-13
- Install vapor extraction system as a pilot treatability study at MW-172, MW-224, MW-181, PZ-28, or MW-190
- Install an extraction well close to EW-140 and EW-141
- Evaluate the feasibility of using BW-18 to control hydraulic gradient and contaminant movement
- Evaluate the pumping of NW-14 and its potential to induce migration of contaminated groundwater offbase
- Evaluate the pumping rates and schedules of BW-10 and BW-29 to determine their effect on groundwater flow
- Coordinate with local water purveyors within 2 miles of McClellan AFB
- Add all Preliminary GW OU RI wells to the GSAP, and reevaluate the objectives of the GSAP
- Adopt the use code for each monitoring well concerning its suitability for use in water level measurements
- Adopt one groundwater operable unit agreed upon by the Air Force and agencies

2.3.3 Industrial Wastewater Line

In 1988, EG&G Idaho conducted a study of the IWL. The purpose of the study was to obtain measurements of wastewater flows and the chemical constituents of the wastewater, investigate the system's integrity, determine the compatibility of the system to the wastewater constituents, and study possible system alternatives.

Previous investigations have estimated that 950 gallons per day (gpd) leaked from the IWL prior to 1988. The recommendations of the EG&G study completed in 1988 focused on piping integrity. Sections of the underground pipe were recommended for replacement, and repairs were made where possible. The compatibility of the pipe construction materials with the wastewater was determined to be adequate.

Radian Corporation stated in 1991 that all piping had been repaired, and recommended that the nature and extent of contamination resulting from the IWL be evaluated more completely.

2.3.4 Interim Remedial Measures

The major influence on groundwater flow in OU B is the pumping of BW-18. At a continuous pumping rate of 720,000 gpd or more, BW-18 would capture a portion of the groundwater containing contaminants in OU B.

In OU C, the highest concentration of contaminants are detected in Monitoring Zone A. In late August 1988, the OU C interim groundwater extraction system was put into operation. The extraction system is controlling the movement of contaminated groundwater in some zones. The effectiveness of the system could be improved by the addition of a well in the A zone.

In OU D, contamination is detected most frequently in groundwater from wells screened in Monitoring Zones A and B. The McClellan AFB IRP Task Force recommended a groundwater contamination containment system that included a cap over OU D and the installation of a groundwater extraction and treatment system. The cap was designed to keep rainwater from percolating into the subsurface and further mobilizing contaminants. This umbrella effect will restrict future contaminant migration in the unsaturated zone beneath the pits. The cap was completed in 1986. The six-well extraction system is effectively controlling groundwater flow in the zones known to contain contamination in this OU.

2.4 Health Assessments

In 1993, a Public Health Assessment for McClellan AFB was prepared by the Agency for Toxic Substances and Disease Registry (ATSDR). The Public Health Assessment, which was prepared as required under Section 104 of CERCLA, evaluated relevant health and environmental data for all activities at McClellan AFB. According to the Public Health Assessment, the ATSDR categorized McClellan AFB as a public health hazard, primarily on the basis of the existence of past exposures to contaminants in groundwater and the potential for future exposures (ATSDR, 1993). The results from the Public Health Assessment are discussed in further detail in the risk assessment presented in Chapter 5.

2.5 Ecological Assessment

The U.S. EPA (Region IX) performed a preliminary ecological survey of McClellan AFB to meet requirements set forth by the CERCLA remedial action program. Two surveys were conducted during the fall of 1992. The site surveys identified four critical habitats that have the potential to be impacted by site discharge and/or disposal practices onsite. Further study including site surveys, and surface-water and sediment sampling was recommended. Subsurface groundwater remediation needs to be assessed as the discharge of treated groundwater and/or the change of the water table may impact the critical habitats. Impacts caused by hazardous waste have yet to be defined in these areas.

Chapter 3
Physical Characteristics of the Study Area

3.1 Surface Features

McClellan AFB is located in the Great Valley Physiographic Province, which extends north 120 miles to Redding and approximately 400 miles south to Bakersfield (California Department of Water Resources [CDWR], 1974). The Great Valley Province is approximately 40 miles wide and consists of the Sacramento Valley to the north and the San Joaquin Valley to the south (CDWR, 1974; 1978). The Sacramento Valley is bordered by the Sierra Nevada to the east and the Coast Range Mountains to the west.

McClellan AFB is located on the east side of the Victor Plain, an alluvial plain lying along the eastern side of the Sacramento Valley. The Victor Plain was created by accumulation of sediments eroded from the Sierra Nevada and alluvium originating from several local sources. It is nearly flat and is dissected by numerous westerly flowing streams draining the Sierra Nevada (CDWR, 1978).

The land surface at the Base slopes gently to the west. Elevations range from 75 feet above mean sea level (msl) on the east side of the Base to approximately 50 feet msl on the west side, yielding a ground surface with low topographic relief.

The major drainages in the vicinity of the Victor Plain are the Sacramento and American Rivers. The Sacramento River originates on the slopes of Mount Shasta in Northern California; downstream of Shasta Lake it is fed predominantly by the Feather, Yuba, and Bear Rivers from the east before reaching its junction with the American River near Sacramento. The Sacramento River collects drainage from the Cascade Range and the Sierra Nevada. It flows approximately 6 miles west of McClellan AFB. The American River originates in the Sierra Nevada east of the Base. It consists of three forks flowing westerly and converging east of Sacramento. The American River is located approximately 7 miles south of the Base. These features are shown in Figure 3-1.

3.2 Surface Water

Surface-water in the Sacramento Valley originates in the Cascade Range and Sierra Nevada to the north and east, and from the east side of the Coast Ranges to the west. The Sacramento and American Rivers are the major drainages in the vicinity of the Base.

LEGEND

Q	Quaternary alluvium deposits
1	Mine and dredge tailings
Qa	Levee and channel deposits
Qb	Basin deposits *(alluvium)*
Qm	Modesto Formation *(alluvium)*
Qm	Lower Member of Modesto Formation
Qr	Riverbank Formation *(alluvium)*
Qmr	Modesto-Riverbank Formations *(arkosic alluvium)*
Qtl	Turlock Lake Formation *(sand, silt, and gravel)*
Tl	Laguna Formation *(consolidated alluvial deposits)*
Tm	Mehrten Formation *(andesitic conglomerate, sandstone, and breccia)*
Tvs	Valley Springs Formation *(rhyolitic tuff and sedimentary rocks)*
Ti	Ione Formation *(quartzose sandstone and kaolinitic clay)*
	Salt Springs Slate
	Copper Hill Volcanics
	Gopher Ridge Volcanics

SOURCE: Geologic Map of the Sacramento Quadrangle, California, 1:250,000; 1981

SAC28722.66.FS

FIGURE 3-1
REGIONAL GEOLOGY IN THE VICINITY OF McCLELLAN AIR FORCE BASE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Surface-water drainage in the vicinity of the Base occurs predominately through Magpie, Don Julio, Robla, Rio Linda, and Arcade Creeks. These creeks are fed by the McClellan AFB storm drainage system, which is a network of storm drains and channels that collect runoff from streets and runways. Runoff is directed into the storm drainage system and leaves the Base via Magpie Creek, which then discharges into the Natomas East Drainage Canal west of the Base. The Canal flows south and west until it discharges into the Sacramento River, just east of the confluence of the American and Sacramento Rivers.

The drainage patterns of some of these creeks have been modified within the Base boundary for building, runway, and road construction. Magpie Creek has undergone the most extensive changes since the Base opened.

Magpie Creek has been an industrial ditch since McClellan AFB began operating in the 1930s. Water in Magpie Creek was diverted to a skimming basin in 1945 and two oxidation ponds in 1959 prior to leaving the Base to the west.

Over the years, Magpie Creek's creek bed lying within the Base boundary has been partially channelized and diverted several times. Between 1943 and 1945, the original streambed was routed to accommodate runway expansion. In 1953, the southwestern portion of Magpie Creek was routed north. The portion of creek bed near Building 694 was rerouted in 1972 when the flight air terminal was constructed east of Building 694. The last change to Magpie Creek occurred in 1989 when the extension to Building 783 was constructed, and Magpie Creek was moved to the north.

Once lined with tules and weeds growing in and along the banks, the slopes of Magpie Creek were later paved with concrete, and the bottom was lined with corrugated metal pipe starting near Building 737 and ending near Building 790A. A section of creek upstream of Building 737 was unlined until 1969. Asphalt and concrete chunks and construction debris were used to stabilize the sides, but the bottom remains unlined.

Don Julio Creek, located near PRL 50, discharged to properties west of the Base until 1957 when it was connected to the skimming basin in Magpie Creek. Another tributary located in an open field behind Test Stands 772 through 774 has also been connected to the portion of Don Julio Creek that is off base since operations began in the 1940s (on the basis of aerial photographs of OU C). This tributary is not lined now and does not appear to have been lined in the past.

3.3 Meteorology

McClellan AFB is located in the Sacramento Valley Air Basin (SVAB). The SVAB encompasses several counties extending north from Sacramento County to Shasta County and is bounded by the Sierra Nevada to the east and the Coastal Ranges to the west. Prevailing winds are usually oriented along the major axis of the Sacramento Valley, approximately following a southeast-northwest pattern.

In the winter, northerly and southerly flow patterns are predominant during the day; calm conditions predominate during the late evening and early morning. During spring and summer, the predominant flow pattern is the delta or sea breeze. Northerly winds and the sea breeze predominate in the fall. Full sea breeze conditions occur 29 percent of the year; northerly winds occur 20 percent of the year (California Air Resources Board [CARB], 1984).

Climate in the SVAB is moderate, with mild winters and hot, dry summers. Average daily maximum temperatures range from 53° to 54°F in January to 93° to 98°F in July (University of California, Berkeley, undated). Mean annual precipitation from 1875 to 1975 in the SVAB was approximately 24 inches (Kahrl, 1978). Approximately 90 percent of the rainfall occurs between November and April with little or no precipitation from late spring to early fall. Most of the rainfall is associated with Pacific storms, which are frequent in winter (National Oceanic and Atmospheric Administration [NOAA], 1989).

3.4 Geology

3.4.1. Regional Geology

McClellan AFB is centrally located within the Great Valley geomorphic province, a wedge-shaped accumulation of sediments, bounded on the west by the Coast Range and on the east by the Sierra Nevada. The Great Valley is approximately 400 miles long, running from Redding in the north to Bakersfield in the south. The Sacramento River drains the northern portion of the valley, and the San Joaquin River drains the southern portion. The wedge of sediments that comprises the Great Valley was accumulated in a downwarped "trough" between late Mesozoic to late Cenozoic time (from approximately 144 million to 10,000 years ago). This trough now assumes an asymmetrical shape because of uplifting of the Sierra Nevada along the eastern edge. The greatest thickness of sediments is in the western portion of the Great Valley (estimated to be 20,000 feet thick) and generally thins to the east, in the Sierra Nevada foothills (Norris, 1990).

The Great Valley is unusual for a lowland valley because it is a relatively undeformed valley bounded by highly deformed rock units in the Coast Range and in the western Sierra Nevada. Because the entire valley lacks topographic relief, rock exposures are poor. Most of the valley subsurface has been inferred from well records from oil, gas, and groundwater wells. The valley and the area where McClellan AFB is located in particular consist of sediments and rock units derived from alluvial, fluvial, flood, and deltaic deposits of the Sacramento and San Joaquin Rivers, and from alluvial fan accumulations at the base of the Sierra Nevada foothills. The specific rock units that are exposed at the ground surface in the vicinity of McClellan AFB are shown on Figure 3-1.

The Great Valley persisted as a shallow marine embayment during the late Mesozoic and early Cenozoic (144 million to 50 million years ago). During this time, sediments were deposited with saline connate water (original interstitial water), forming the salt-bearing Chico Formation that overlies much of the Sierran basement rock underlying the valley (Norris, 1990; CDWR, 1974). Because there are no surface exposures of the Chico Formation in the area shown in Figure 3-1, it is not included in the legend.

The Ione Formation represents a time of transition between marine and nonmarine deposits, including sandstone and peat-rich clay beds. The Ione Formation is believed to have been deposited during the Eocene (an epoch spanning approximately 55 million to 38 million years before present.) The Ione Formation is generally thought to be nonwater-bearing, but contains water of brackish quality, indicative of saltwater diluted by freshwater.

The overlying Valley Springs Formation consists of ash deposits that have weathered to form low permeability clay with some sand and gravel. The Valley Springs Formation is also considered nonwater-bearing and is believed to have been deposited between 24 to 19 million years ago (Radian, 1992). Below McClellan AFB the Chico, Ione, and Valley Springs Formations are generally grouped as "pre-Mehrten" sediments. These units are thought to underlie the site at depths exceeding 600 feet below ground surface (bgs) (CDWR, 1974).

The Mehrten Formation is generally divided into two units: a nonwater-bearing, low permeability, tuff breccia, or "lava," and the water-bearing andesitic "black sands." These units are Mio-Pliocene in age. (Mio-Pliocene refers to the transition from the Miocene to Pliocene, approximately 6 to 5 million years before present.) The black sand unit is known for producing large quantities of good to excellent quality groundwater (CDWR, 1978). According to well data, this unit is believed to underlie the site at a depth of approximately 200 feet bgs (Radian, 1992).

Three units overlie the Mehrten Formation in the vicinity of McClellan AFB: the Laguna, Turlock Lake and Riverbank Formations (formerly referred to as the Mehrten, Fair Oaks and Victor Formations, respectively) (Radian 1992). The Laguna Formation is thought of as the transition from volcanic to continental deposits and consists of feldspathic silt, clay, and sand deposits with occasional hardpan deposits. The feldspar has typically weathered to clay. The tan or "white" clay or micaceous layers serve as marker beds for this formation.

The Turlock Lake Formation is similar to the underlying Laguna Formation, except feldspars tend to be less weathered. The contact between the two is thought to be an erosional unconformity indicating up to 30 feet of relief at the time of deposition (Radian, 1990); however, the two units are often difficult to distinguish. They are considered to be of Pliocene age (The Pliocene epoch occurred between 5 to 1.6 million years ago.) The Riverbank Formation is composed of feldspathic sediments deposited in a fluvial or alluvial environment, during the Pleistocene epoch (the Pleistocene epoch occurred approximately 1.6 million to 11,000 years ago.) Typically, the Riverbank Formation has better water-bearing characteristics than the Laguna or Turlock Lake Formations, making it an important unit for shallow irrigation wells.

For a more detailed description of regional geology, the reader is referred to the Preliminary GW OU RI (Radian, 1993). The remainder of this section pertains to geologic conditions specific to the Base.

3.4.2 Site Geology

Introduction

The lithology below the Base is dominated by coalescing deposits from two depositional sources, alluvial and fluvial. These deposits consist primarily of sand, silt, and clay in various combinations with localized occurrences of gravel. These deposits were frequently transported and redeposited by local streams. The general direction of streamflow was southwest to west. This trend is in agreement with the overall trend for Great Valley deposits. Erosion and redeposition of sediments makes distinction between units difficult, especially when the basis for distinction is soil samples or geophysical logs from boreholes. In addition, meandering and abandonment of channels has produced complex site stratigraphy dominated by lenses of material with little lateral or vertical continuity.

The stratigraphy of Monitoring Zones A through E reflects changes that have occurred in the depositional setting and variations in meteorological conditions. During deposition of the C, D, and E zones, the vertical relief between the young Sierra foothills and the Base was greater than exists under current conditions. The steep gradient produced high energy streams capable of carrying coarse-grained sediments over relatively large distances. Relative to the A and B zones, these deposits have extensive vertical and lateral extent. As erosion decreased the elevation of the foothills, the resulting sedimentation increased the elevation of the valley floor. This reduction in vertical relief produced finer grained deposits with reduced lateral and vertical extent. In addition, the low energy environment increased the sinuosity of the stream system, resulting in a meandering system prone to frequent course changes. This depositional setting contributed to the extreme heterogeneity typical of the younger deposits below the Base.

The stratigraphy is also influenced by flooding, glacial melting, drought, and other meteorological events. Events that result in increased surface runoff and velocities are reflected by an increase in grain size Basewide. Conversely, periods of reduced surface runoff are indicated by an overall reduction of grain size at that stratigraphic interval. Because the site is under the influence of two depositional systems (alluvial and fluvial), variations in stratigraphy may also reflect fluctuations in these systems.

Deposits generally show a greater degree of heterogeneity in the north-west portion of the Base, with some deposits showing extreme variation over distances less than 25 feet (Radian, 1993). Deposits in the southeast portions of the Base are more persistent in both vertical and lateral extent. Gravel occurs primarily in the C, D, and E zones in the southern portion of the Base and is rare in most other locations.

Approach for Developing Cross Sections

The purpose of presenting geologic cross sections is to illustrate how variations in the site's depositional history produced existing subsurface conditions. In cases of extreme heterogeneity, selection of the location and orientation of cross sections are critical. A thorough understanding of subsurface conditions is required prior to location selection to effectively demonstrate the relationship between stratigraphy, hydrogeology, and contaminant transport. Because of the complexity in Basewide geologic data, previous presentations of Basewide stratigraphy generally consist of aquifers' zone designation based on geophysical data, with little or no interpretation of site stratigraphy. To provide an initial interpretation of site stratigraphy, the classification of soils was reduced to the following three units:

1. **Fine-grained** materials include silt, clay, sandy silt or clay, and gravelly silt or clay (Also includes lean and fat clay, although these qualifiers are rarely used.) If the soil is classified in accordance with the Unified Soil Classification System (USCS), these materials should have greater than 50 percent silt or clay, indicating a low energy depositional environment and minimal permeability within the existing system. (Classifications such as silty clay or clayey silt are not include in the USCS; however, these materials are obviously included within this unit.)

2. **Medium-grained** materials include silty or clayey sand or gravel. These materials have less than 50 percent clay or silt, but greater than 12 percent. They are indicative of a medium energy depositional environment, or a transition from low to high energy (such as when a channel shifts laterally.) These materials should exhibit moderate permeability within the existing setting.

3. **Coarse-grained** materials include poorly graded or well-graded sand or gravel (as defined in the USCS, it has less than 5 percent silt or clay.) These materials indicate a relatively high energy environment and therefore are indicators of stream channels. These materials will tend to have the greatest permeability within the existing system (all other variables being equal.)

Prior to preparation of the cross sections, these three units were mapped in plan view in 10-foot elevation increments using available well logs. Because this area was relatively level over the period of deposition and has undergone little subsequent structural or tectonic disturbance, this approach is valid. These incremental plan view maps of lithology were used to evaluate subsurface conditions and to select cross-section locations. The level of detail as well as the precision of these logs is highly variable; however, the simplification to three units has produced comparable lithology in most cases.

In most cases, the lithology within well clusters shows reasonable agreement, although some clusters show much variation. Where discrepancies were found between logs for wells within a cluster, lithology was based on geophysical logs from the pilot hole.

Cross Section Interpretation

The eight cross sections are shown on Figures 3-2 through 3-8 (located at the end of this chapter). Along several of the sections, the well spacing is quite variable. Distances between wells range from almost negligible to over 2,000 feet. When a number of closely spaced wells coincide along a section, one well representative of site conditions was selected; however, all wells in the vicinity were considered while developing stratigraphic relationships. Layers with a thickness of 2 feet or less are not shown in the cross sections. Monitoring wells with elevated VOC concentrations and wells that extend to the C, D, and E zones were included on sections, whenever possible. The extent of contamination in Monitoring Zones A, B, and C is shown where contamination has been detected. The interpretation of the extent of contamination is presented in Chapter 4.

The cross sections are intended to provide a general understanding of stratigraphic relationships, to improve understanding of contaminant transport, and to provide guidance for future investigations. In most cases, there is a great deal of uncertainty in evaluating how specific units are linked The actual conditions between well locations is undoubtedly more complex than is shown. Nevertheless, the relationships shown are consistent with the modes of deposition and show agreement with intersecting sections. These sections also compare favorably with the cross sections presented in the Preliminary GW OU RI (Radian, 1993). In areas of the Base where geologic data are available with reduced space between sites, such as OU D, a more precise interpretation can be provided. As additional information is incorporated into the cross sections, the interpretation of stratigraphy will be modified to reflect actual conditions.

Cross Sections 1, 2, and 3 are oriented perpendicular to the predominantly southwestern flow direction of depositional channels. These sections illustrate the lateral migration of channels over time. Cross Sections 4 and 5 are approximately parallel to the channel flow direction and perpendicular to Cross Sections 1, 2, and 3.

Cross Section 6, parallel to Cross Sections 4 and 5, crosses through the southern portion of OU B. This area appears to represent an area of little or no fluvial interaction between the eastern and western stream systems. Cross Section 7 bridges hot spots in OU C and OU B. It is oriented roughly perpendicular to the direction of deposition in its northern extent and approaches parallel in its southern extent. Cross Section 8 extends from OU D to OU B, generally parallel with the present-day groundwater flow direction.

The following descriptions of stratigraphy will generally move from the ground surface downwards. When a well cluster location is specified along a section, it will be referred to by the A-zone well. For example, on Cross Section 1, Monitoring Wells MW-178, MW-179, and MW-180 constitute a well cluster for the A, B, and C zones. For any stratigraphic reaturess discussed at this cluster location, the well referred to will be MW-178.

Cross Section 1

The migration of a stream system with several dominant channels can be traced through Cross Section 1. A northern channel migrates north then south between Elevations 60 to 20, 20 to -40, and -40 to -120, below which two channels appear to join and form a single channel. A southern channel follows a similar pattern on the southern half of the section. Another significant feature in this section is the fine-grained unit that is deposited on the southern shore of the northern migrating channel. The formation surrounding MW-179 is predominantly clay with relatively few channel crossings, whereas MW-224 is surrounded with an abundance of coarse-grained layers because of numerous channel crossings.

Cross Section 2

The migration of the northern channel and the presence of the fine-grained unit described above can also be traced in Cross Section 2. It is clear from the pattern of channel migration that factors that affected channel migration in Cross Section 1 have had a similar affect in Cross Section 2. The coarse-grained units in the C zone in MW-222 suggest small-scale channel migrations. As described previously, these coarse-grained units have increased lateral and vertical extent in the deeper zones.

As in Cross Section 1, a persistent fine-grained unit is deposited on the southern shore of this channel. The unit of medium- grained material that occurs between the coarse and fine units is common in migratory channel deposits.

Cross Section 3

Cross Section 3 is located to the south of Cross Sections 1 and 2 and is slightly skewed to the north. Cross Section 3 includes the southern channel shown on the periphery of Cross Sections 1 and 2. The southern channel moves from north to south between Elevations 40 to -30, -30 to -80, and -80 to -110, below which the southern channel merges with the northern channel.

The channel migration depicted in Cross Sections 1, 2, and 3 can also be observed in the Preliminary GW OU RI Cross Sections H-H', J-J', K-K', and R-R'.

Cross Section 4

Cross Section 4 is crossed by both the northern and southern channels shown in Cross Sections 1, 2, and 3. Most wells on this section are crossed by both channels, which makes distinguishing channel migration directions somewhat difficult. In general, the channel follows the same trends shown on Cross Sections 1, 2, and 3. These migrations are shown in Figure 3-3.

The large singular channel shown on Cross Sections 1, 2, and 3 is located between Wells MW-186 and MW-203 in the C zone (on this section). The distinct difference in the grain size and the vertical extent of layers below Monitoring Zone B indicate a change in the hydraulic regime. The abundance of coarse-grained material is likely associated with glacial melting, whereas the A and B zone deposits indicate a moderate- to low-energy fluvial environment.

The northern portion of Cross Section 4 is in agreement with the units presented in Section I-I' from the Preliminary GW OU RI (Radian, 1993). The southern extent is not included in the Preliminary GW OU RI sections.

Cross Section 5

Cross Section 5 is parallel to Cross Section 4 and lies offbase southeast of OU A. All wells in the cross section are traversed by the southern channel, which follows the same pattern previously described. This section consists primarily of medium- to fine-grained deposits that are also shown in the southern portions of Cross Sections 1 and 2.

Cross Section 5 compares favorably with Cross Section O-O' from the Preliminary GW OU RI (Radian, 1993).

Cross Section 6

Cross Section 6 is roughly parallel to Cross Sections 4 and 5 crossing the southern portion of OU B. This section is dominated by fine-grained to medium-grained materials between the ground surface and the C zone, indicating this area represents a depositional divide between western and eastern stream systems at the Base. The occurrence of isolated coarse-grained units originate during periods of high energy deposition, when streams from either west or east breach this divide. These lenses occur sporadically throughout the section. Because they appear to lack lateral continuity, the permeability of these layers may be greatly reduced.

The large coarse-grained deposit within the C zone appears to coincide with the lower channel presented in Cross Sections 1 through 4. This deposit also occurs in Cross Section 7. The alignment of units with coarse-grained units at similar elevations suggests a channel flowing east or southeast, shifting between Monitoring Wells 206 and 1054.

Cross Section 6 can be favorably compared with portions of Cross Sections F-F', K-K', and M-M' from the Preliminary GW OU RI (Radian, 1993).

Cross Section 7

Cross Section 7 appears to be oriented at a skewed angle from the direction of channel flow in its northern extent and approximately aligned with the flow direction in its southern extent. Within the C zone, the large channel observed in Cross Sections 3 and 6 crosses the section at a sharp angle to the direction of flow. This occurrence of one coarse-grained unit overlying another at an approximate right angle is a significant deviation from the typical depositional mode of gradual channel migrations.

This apparent anomaly can be explained through examination of lithology of wells in this vicinity at similar elevations and comparison with geophysical logs. During the deposition of the D and E zones, an influx of fine-grained alluvium transported from the south or southeast began to accumulate along the southern portion of the Base. The alluvium may represent basin deposits. The present-day American Basin is likely a vestigial relict corresponding to these ancient basin deposits. Periodically, this influx of alluvium exceeded the capacity of the fluvial system, forcing the streams northward in response.

The deposit of fine-grained material formed a barrier to channels exiting along the southern boundary of the Base. As the fluvial system migrated northward, channels exited along the eastern portion of the Base. These channels moved as far north as Monitoring Well MW-206 at least twice during deposition of the C and D zones. Periodically, the influx of alluvium began to subside, the fluvial system received an increase in source material, and stream flows increased. During episodes of high energy deposition, the channel eroded through this southern barrier and reasserted its original course. This form of erosional break occurred at least twice in the vicinity of Monitoring Well MW-1047, the first time was between Elevation -250 and Elevation -260 and the second between Elevation -180 and Elevation -190. These events are illustrated in Cross Section 7.

The vestigial deposits of alluvium that remained when the channel breached the alluvial deposit constitute the thick accumulations of fine-grained material shown in Cross Sections 1 through 4. This material also forms fine- to medium-grained depositional divide shown in Cross Section 6 and provides an explanation for the apparent scarcity of channel exits in the southern and southeastern portions of the Base.

The A and B zones in the southern portion of Cross Section 7 (south of MW-120) are dominated by channels flowing south that exit the Base generally between MW-145 and MW-217, but rarely crossing the divide indicated by Cross Section 6. Channels may have crossed the divide eastward north of Cross Section 6; however, there is currently insufficient information in this area. The A and B zones in the northern portion of the section (generally north of MW-121) consist of several small channels deposited with a southwest trend. The deposits along Cross Section 7 in Zones A and B are primarily fine- to medium-grained, indicating small-scale features with little lateral continuity. These features should be mapped in detail to ascertain detailed information regarding site conditions.

This history can also be observed in portions of Cross Sections D-D', F-F', H-H', J-J' and M-M', but is illustrated most clearly in Cross Section L-L' in the Preliminary GW OU RI (Radian, 1993).

Cross Section 8

Cross Section 8 illustrates the features described above, but from a different orientation. The northern portion of the section, through OU D, does not differ appreciably from that shown in Section 7, although more coarse grained deposits are apparent in Section 8. The Southern portion of the section illustrates the dynamic channel transitions that have occurred in response to variations in fluvial and alluvial influxes. The migration of fluvial deposits shown in Cross Sections 1, 2, and 3 can be recognized in this cross section near and south of MW-139.

This finding is supported in Cross Section B-B' (Radian, 1993) as well as those listed above for Cross Section 7.

3.5 Hydrogeology

The groundwater system in the vicinity of McClellan AFB has been divided into two zones: an upper zone composed of the Fair Oaks, Laguna, and Victor Formations and a lower zone composed of the Mehrten Formation and underlying water-bearing formations (CDWR, 1974). The two zones are separated by a buried erosional surface of moderate to high relief.

In the vicinity of the Base, groundwater occurs predominantly in the Fair Oaks, Laguna, and Mehrten Formations. Most groundwater production wells in the area are screened in the Mehrten Formation (Engineering Science, 1983). Groundwater recharge in the eastern portion of the Sacramento Valley occurs as a result of leakage from streams and rivers, percolation of precipitation and irrigation water through soils, and migration of runoff along fracture zones and formation contacts in the foothills of the Sierra Nevada. The upper water-bearing zone in the Sacramento Valley is recharged predominantly through percolation of water from the ground surface. This process is generally inhibited by the presence of hardpan throughout much of the valley. Therefore, groundwater recharge to the upper zone occurs predominantly through past and present stream channels consisting of permeable sands and gravel that allow percolation of surface waters into the saturated zone. According to the CDWR (1974), the permeable buried stream channels interlayered with less permeable sediments have resulted in a network of tabular, shallow aquifers throughout the county. Hardpan locally restricts downward migration of water to the deeper aquifers.

Groundwater discharge in the Sacramento Valley occurs predominantly through pumping. Since the turn of the century, the extraction of groundwater for irrigation, industrial, municipal, and domestic use has substantially altered the groundwater levels and gradients. Presently the regional groundwater flow in the vicinity of Sacramento is in a southerly direction toward a pumping trough south of Sacramento.

Where saturated, the Victor Formation has only moderate hydraulic conductivity and generally yields little water to wells unless stream channel deposits are penetrated. The Fair Oaks and Laguna Formations have generally low to moderate hydraulic conductivity except where coarse-grained channel deposits are present. In the more permeable materials, well yields may reach 3,500 gallons per minute (gpm) with drawdowns of approximately 30 feet, yielding a specific capacity of about 120 gpm per foot of drawdown (CDWR, 1974). The black sands of the Mehrten Formation generally have a specific capacity of approximately 45 gpm per foot. Specific capacities as high as 100 gpm per foot have been noted in the Mehrten Formation (CDWR, 1974).

The water table in the vicinity of the Base is typically 90 to 110 feet below ground surface (bgs). Variations in the depth to water depend predominantly on local topography and locations of cones of depression from high-capacity extraction wells.

Deeper water-bearing zones are semiconfined or confined and are believed to be locally interconnected with the unconfined zone because of the absence of continuous confining layers. Lateral discontinuity and facies changes within confining layers allow for local vertical groundwater movement between the various water-bearing zones.

The water table in the vicinity of the Base fluctuates as much as 2 feet per year. The annual mean water level is declining as a result of groundwater extraction for private, public, industrial, and domestic purposes. The water table declined by 0.9 to 1.7 feet each year between 1955 and 1985 (Radian, 1986). Groundwater levels are expected to continue declining in future years because of overdrafting of the local groundwater aquifers.

Extensive groundwater pumping near McClellan AFB has also altered the flow direction of the local groundwater system. In 1955, groundwater flow was generally to the southwest toward a pumping depression southwest of the Base. By 1965, this depression had deepened, and a second pumping depression developed directly south of the base as a result of the operation of production wells located near the Base boundary. Flow directions were therefore altered as groundwater on the Base began to flow to the south and groundwater west of the Base began to flow in an east-southeast direction in the late 1950s or early 1960s (Radian, 1986).

As previously discussed, the geologic environment beneath the Base is a complex series of alluvial deposits that were laid down, eroded, and redeposited by actions of streams, rivers, and floods. The alternating layers of unconsolidated sand, silt, clay, and gravel form a single groundwater system. The geologic and hydrologic properties of the aquifer formation vary over short distances, but the aquifer is laterally and vertically interconnected by permeable sand and gravel lenses. The shallow aquifer system is characterized as leaky, with the potential for vertical migration of contaminants found in the shallow sediments to deeper portions of the aquifer. The hydraulic conductivity of the aquifers is variable but is as high as 0.01 cm/s (Radian, 1991).

The aquifer system at McClellan AFB has been divided into a series of monitoring zones for investigative purposes. The monitoring zones are layers that together act as preferential pathways for horizontal groundwater flow within the aquifer system. The monitoring zones are not hydraulically independent; groundwater can flow vertically between zones. Previous investigations had also defined monitoring zones. The PGOURI had refined those zones to better define the potential for contaminants to migrate horizontally or vertically. The monitoring zones are designated A through F, from shallowest to deepest. Generally, the zones thicken and dip from east to west, following the geologic sequence. However, it is entirely possible for two adjacent wells screened at different depths to be screened within the same zone, or for two wells screened at similar depths to be screened in different zones. These local variations in zone depths are due to the heterogeneity of the deposits beneath McClellan AFB, and to the relative abilities of different deposits to conduct water. At some locations, isolated or intermediate zones were identified between the monitoring zones, especially in OU D. In OU A, the portion of the current A monitoring zone that is saturated consists of the fine-grained layers that probably once formed the aquitard between the now dry, historical A zone above and the B zone below. When it was fully saturated, the historical A zone had lateral continuity and provided a conductive pathway for groundwater flow, as it still does in OUs B, C, and D.

Water level maps presented in the PGOURI indicated that groundwater in each zone flows in a generally south-southwest direction, toward OU B of McClellan AFB, and the regional pumping depression to the south.

Groundwater flow beneath McClellan AFB is also controlled by the pumping of wells. Thirteen water supply wells in the vicinity of McClellan AFB, both on and off base, affect the groundwater flow beneath several OUs, and the extraction systems in OUs D and C exert hydraulic control in the A and B monitoring zones in those OUs. The supply wells include (on base) Base Well (BW) 10 in OU A, BW-29 in OU E, and BW-18 in OU B; and (off base) Northridge Water District Well (NW) 17 and Arcade Water District Well (AW) 16, which are east of OU E, and NW-14, south of OU A.

3.6 Soils

This discussion describes the soil types that occur at McClellan AFB. Soil, as defined here, represents the alluvial material that extends to the base of the vegetative root zone. Soil permeabilities at McClellan AFB range from 0.6 to 2.0 inches per year depending on local amounts of clay and hardpan. The local soils are generally classified as San Joaquin fine sandy loam, Fiddyment fine, sand loam, or San Joaquin-Xeralfic

Arents complex. These soils have a low shrink-swell potential, a slight erosion potential, and a low available water capacity of approximately 0.10 to 0.14 inch per inch.

3.7 Populations and Land Uses

McClellan AFB is surrounded by three communities that include residential, commercial, and industrial zones. They include Rio Linda and Elverta to the northwest, North Sacramento to the west and southwest, and North Highlands to the east. All of these communities are in Sacramento County. Rio Linda and North Highlands are unincorporated.

The population of the surrounding communities as determined by the 1980 census was 107,822. A summary of population by community and tract number and projected populations in the year 2005 are presented in Table 3-1.

The communities in the vicinity of McClellan AFB receive water from private wells and municipal water supplies. Most of the water for North Highlands is supplied by the Arcade Water District, with smaller amounts from the Rio Linda Water District and the Northridge Water District. North Sacramento receives water from the City of Sacramento Water Department. Many private wells are still in use in the area north of El Camino Boulevard in North Sacramento.

Rio Linda and Elverta receive water from the Rio Linda Water District and from private wells. In 1986, the Rio Linda Water District and the City of Sacramento Water Department began connecting Rio Linda, Elverta, and North Sacramento residences in nearby areas to the west of the Base to municipal water supplies. The residents in this area previously used private wells to meet their water needs. The connection of the residences to municipal water supplies was a remedial action initiated by McClellan AFB.

Land use in the vicinity of McClellan AFB is a combination of military, industrial, commercial, residential, and agricultural uses.

Much of the land around the Base is zoned residential. In the Rio Linda area northwest of the Base, most of the land is categorized as agricultural-residential. This land category identifies acres reserved for large-lot, rural residential uses where animals may be kept and crops raised for recreational use, educational use, personal consumption, or supplemental income purposes (Sacramento County, 1985). Many of these residences use private well water for nonpotable uses.

Several Rio Linda lots near the Base have been zoned as industrial-intensive. This land category identifies areas reserved for research, manufacturing, processing, and warehousing activities. Necessary public services, such as sewer and water systems, are available in industrial intensive areas.

Most of the land to the southwest and east of the Base consists of low density residential zones. These areas are reserved for a planned population density range of 5 to 30 persons per acre or a housing density range of 1 to 12 dwelling units per acre. Some of these residences may have private wells, but the majority have municipal water supplies.

Table 3-1
Population Data and Projections for the Communities Surrounding McClellan AFB

Tract Community	1980 Population	Projected 2005 Population
Rio Linda and Elverta	3,689	
	3,547	
	6,737	
Subtotal	13,973	26,529
North Highlands	1,541	
	6,207	
	4,451	
	3,511	
	7,044	
	7,959	
	9,819	
	7,262	
	11,010	
Subtotal	58,804	118,861
North Sacramento	1,613	
	3,578	
	4,514	
	3,406	
	4,621	
	7,365	
	5,644	
	4,304	
Subtotal	35,045	52,682

Source: Sacramento County, 1985.

To the southwest and east of McClellan AFB are parcels designated for commercial and office use, including shopping centers, large office complexes, and major concentrations of strip commercial development.

Del Paso Park, designated as a recreational area, is within 1 mile of the southeast edge of the Base. Additional recreational/agricultural-recreational reserve areas are located along Dry Creek, approximately 2 miles west of the Base.

3.8 Plants and Wildlife

Grasslands are the predominant plant community at the Base and most of the surrounding undeveloped region. Small riparian forests and vernal pools also occur within the general area. A field survey of fauna present on the Base was conducted in April 1981 (CH2M HILL, 1981). During the survey, one fish, one amphibian, one reptile, two mammal, and 24 bird species were sighted. The black-tailed hare was the largest mammal permanently residing onbase. Muskrats were also observed at a number of locations along Magpie Creek. Game bird species, such as pheasant, mourning dove, and California quail, were common onbase. Mallards were observed in Magpie Creek.

The vertebrate fauna of Magpie Creek are limited primarily to mosquitofish, waterfowl, muskrats, and amphibians. A 1973 study (Pauls and Doane) documented the macroinvertebrate fauna of the creek. Density and diversity were limited in the portions of the creek lined with concrete where little natural substrate was available. Sludge worms (Tubiflex) were the only species found upstream of McClellan AFB where the San Six Wastewater Treatment Plant provides most of the flow. Farther downstream, damselfly (*Ischnura*), *Psychoda* fly, and mosquito larvae were prevalent.

Only two endangered plant species are known to occur within Sacramento County: the Sacramento orcutt grass (*Orcuttia viscida*), *which occurs in the vicinity* of Phoenix Field, and Boggs Lake hedge hyssop (*Gratiola heterosepala*) which is found in the vicinity of Rio Linda (CH2M HILL, 1981).

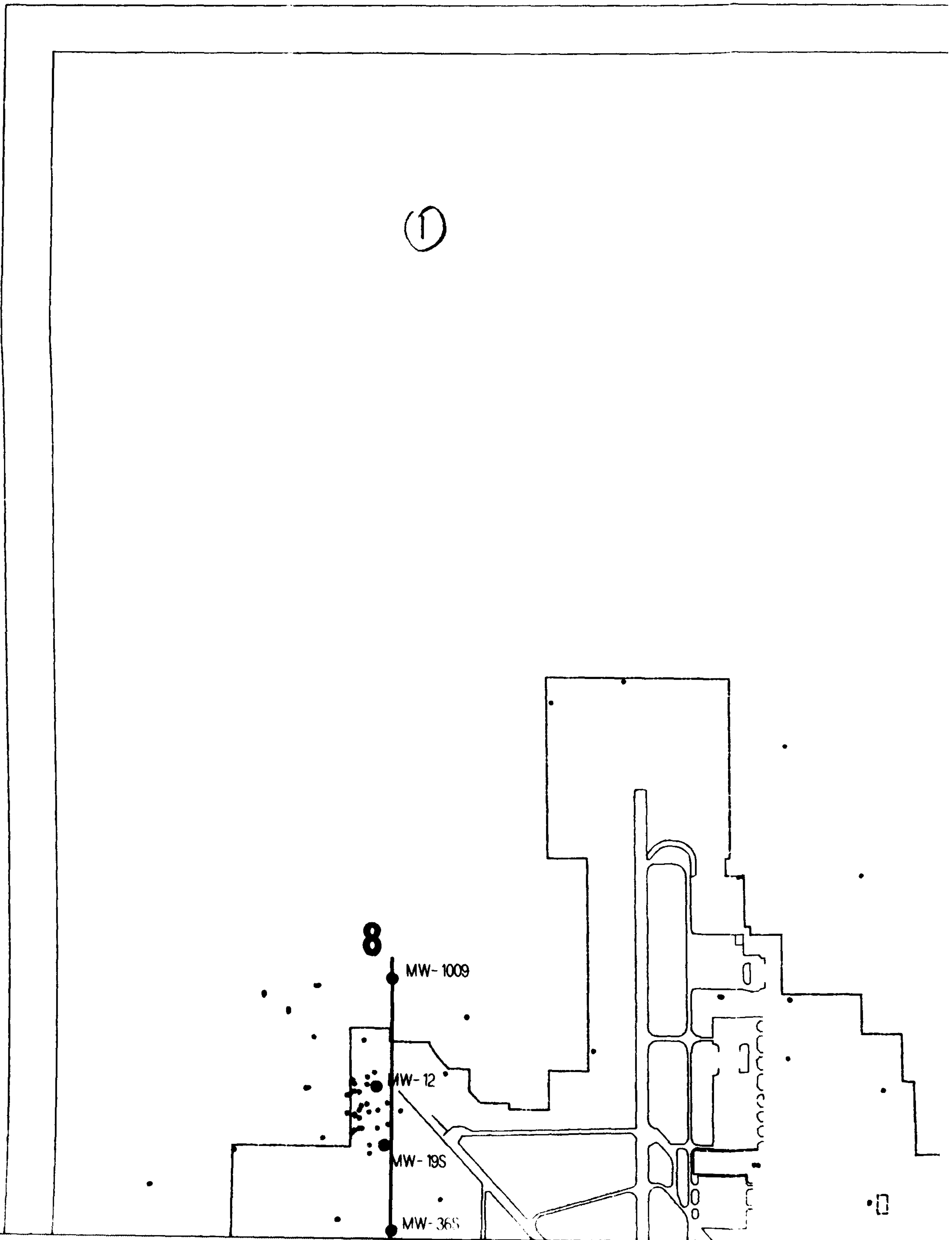
Only three endangered wildlife species are expected to occur within 25 miles of the Base: the bald eagle, the peregrine falcon, and the giant garter snake. The nearest eagle nest sites are near Lake Pillsbury (Mendocino County) and in the vicinity of Chico (Butte County) (CH2M HILL, 1981). However, juvenile or nonbreeding eagles occasionally pass through the Sacramento area. Peregrine falcons regularly migrate through Sacramento County, and it is possible that some may reside in the area. The giant garter snake is confined to sloughs, marshes, and other permanent freshwater areas. The nearest known location of the giant garter snake is in rivers and associated wetlands in North Natomas.

Most undeveloped grassland areas on the Base have been disturbed in the past. Much of Magpie Creek has been cleared of former riparian vegetation and channelized. Some of the vernal pool areas of the creek have been drained or filled. Most of these actions took place years ago, however, and vegetation growing on the unimproved areas of the Base is generally healthy, vigorous, and supporting the appropriate fauna.

In addition to its physical modification, Magpie Creek has been affected by the effluent from the San Six County Wastewater Treatment Plant north of the Base. In 1977, a fish kill of 100 to 150 minnows in Magpie Creek was traced to high chlorine residual originating from the treatment plant. This problem has since been corrected. The San Six County

Wastewater Treatment Plant is no longer operational and has not discharged to Magpie Creek in more than a decade.

The historical use of persistent and later nonpersistent pesticides for mosquito control on the Base affected the natural invertebrate fauna of Magpie Creek and the vernal pools. However, this impact is considered minor as CH2M HILL found no evident stress on biota resulting from the use and disposal of waste pesticides at McClellan AFB.



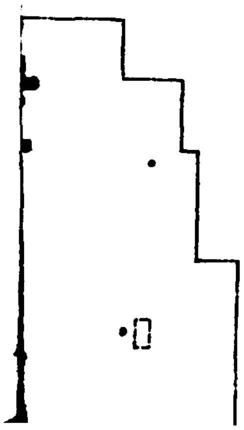
(1)
8
MW-1009
MW-12
MW-19S
MW-36S

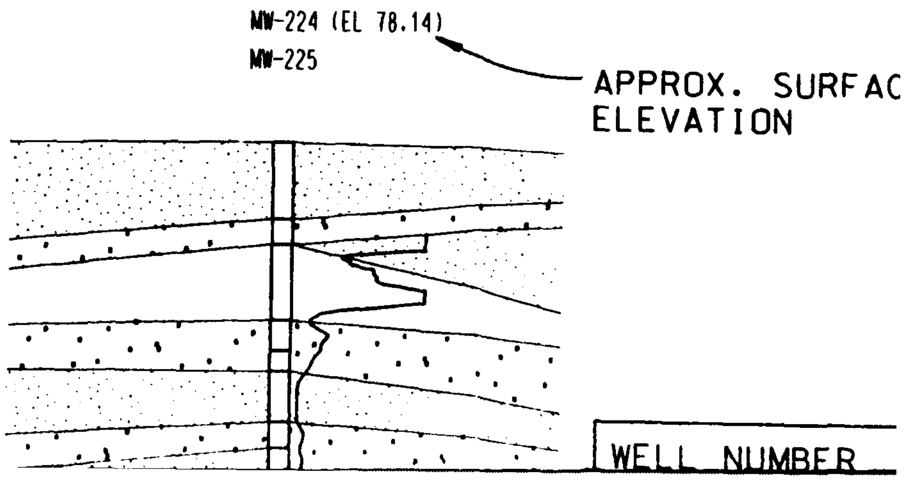
LEGEND

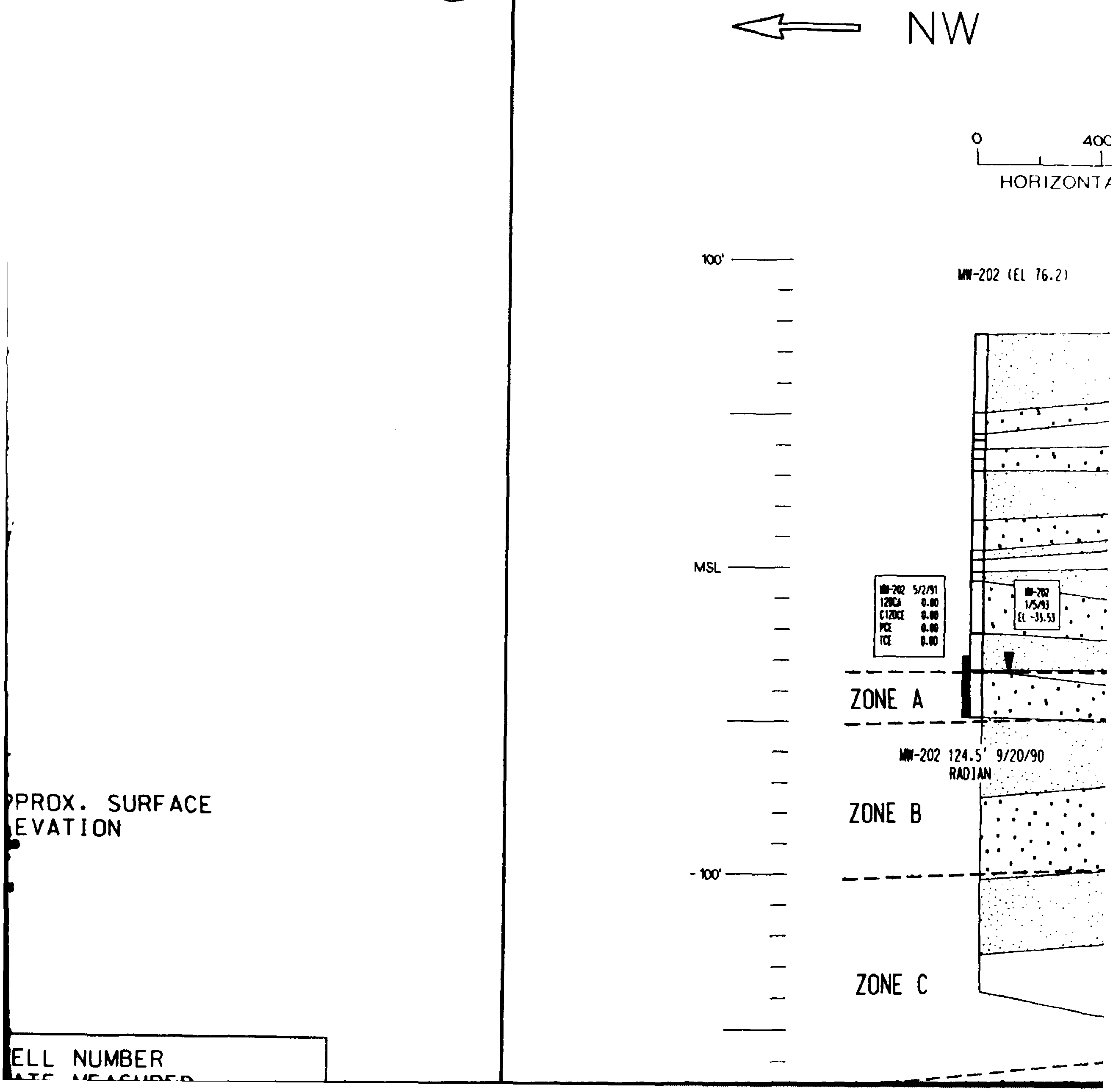
FINE-GRAINED MATERIALS INCLUDE SILT, CLAY SANDY SILT OR CLAY, GRAVELLY SILT OR CLAY, LEAN AND FAT CLAY, SILTY CLAY, AND CLAYEY SILT

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

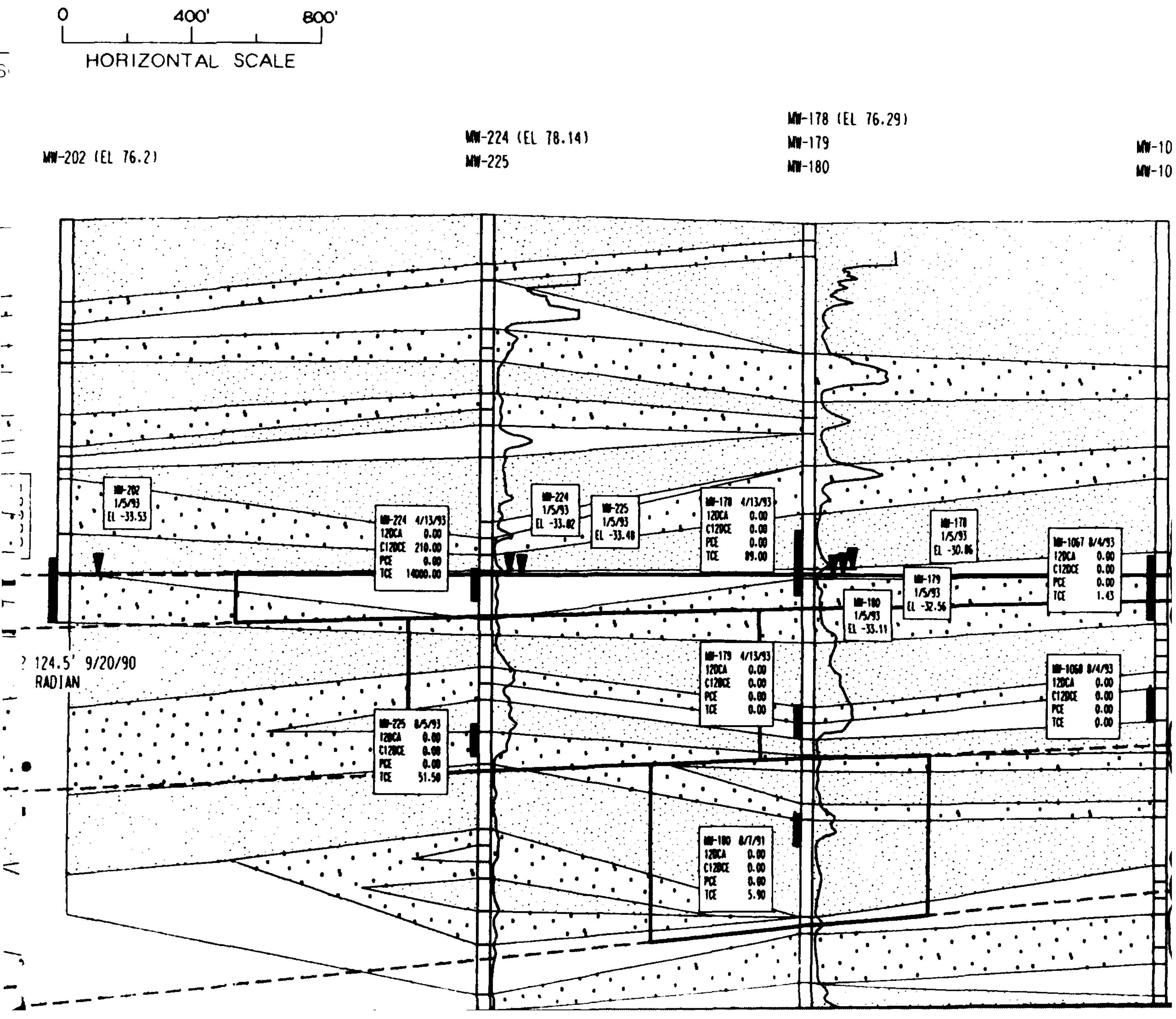




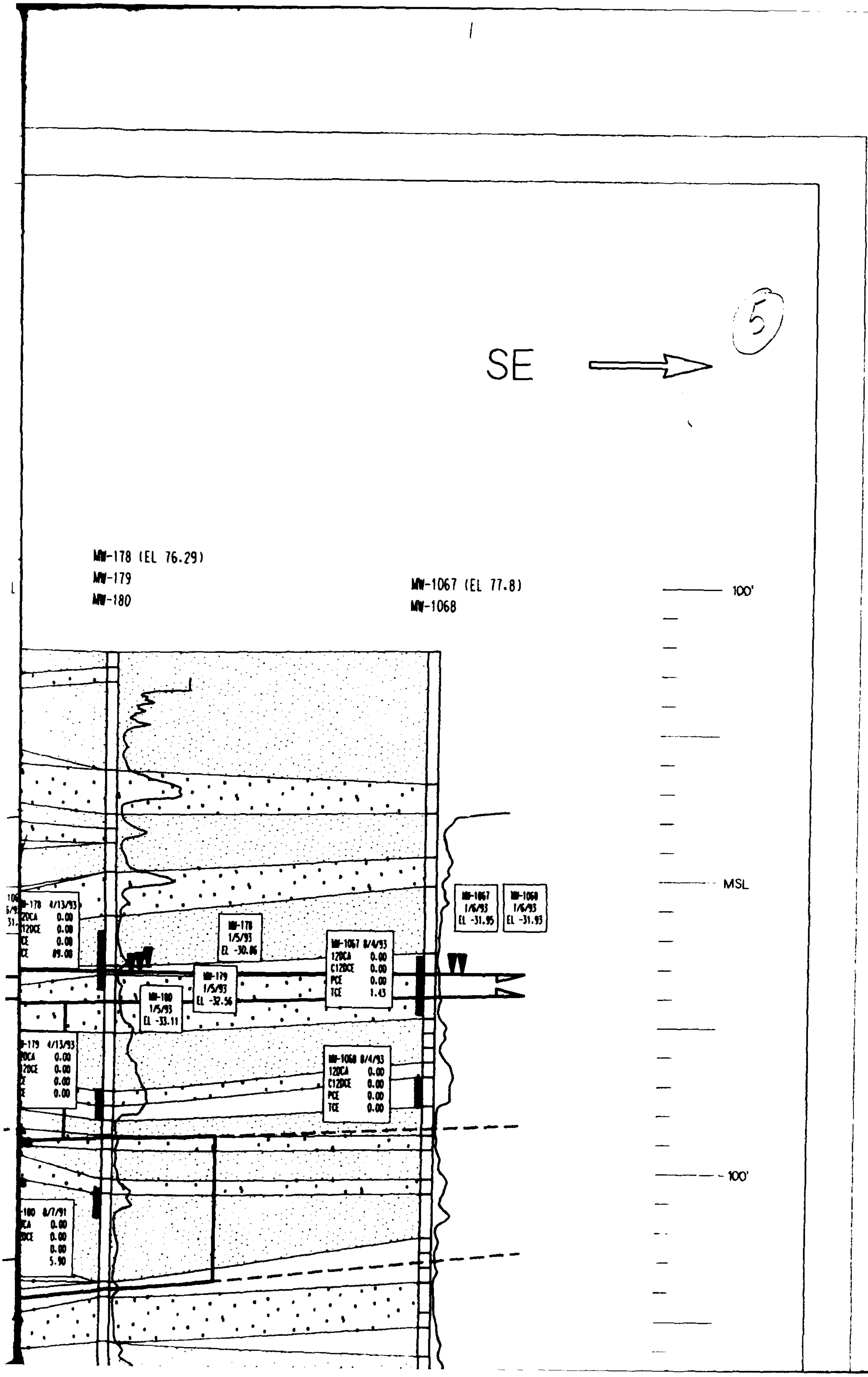

NW
0
HORIZONT
100'
MW-202 (EL 76.2)
MSL
MW-202 5/2/91
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-202
1/5/93
EL -33.53
ZONE A
MW-202 124.5' 9/20/90
RADIAN
ZONE B
-100'
ZONE C
PPROX. SURFACE
EVATION
ELL NUMBER

JW

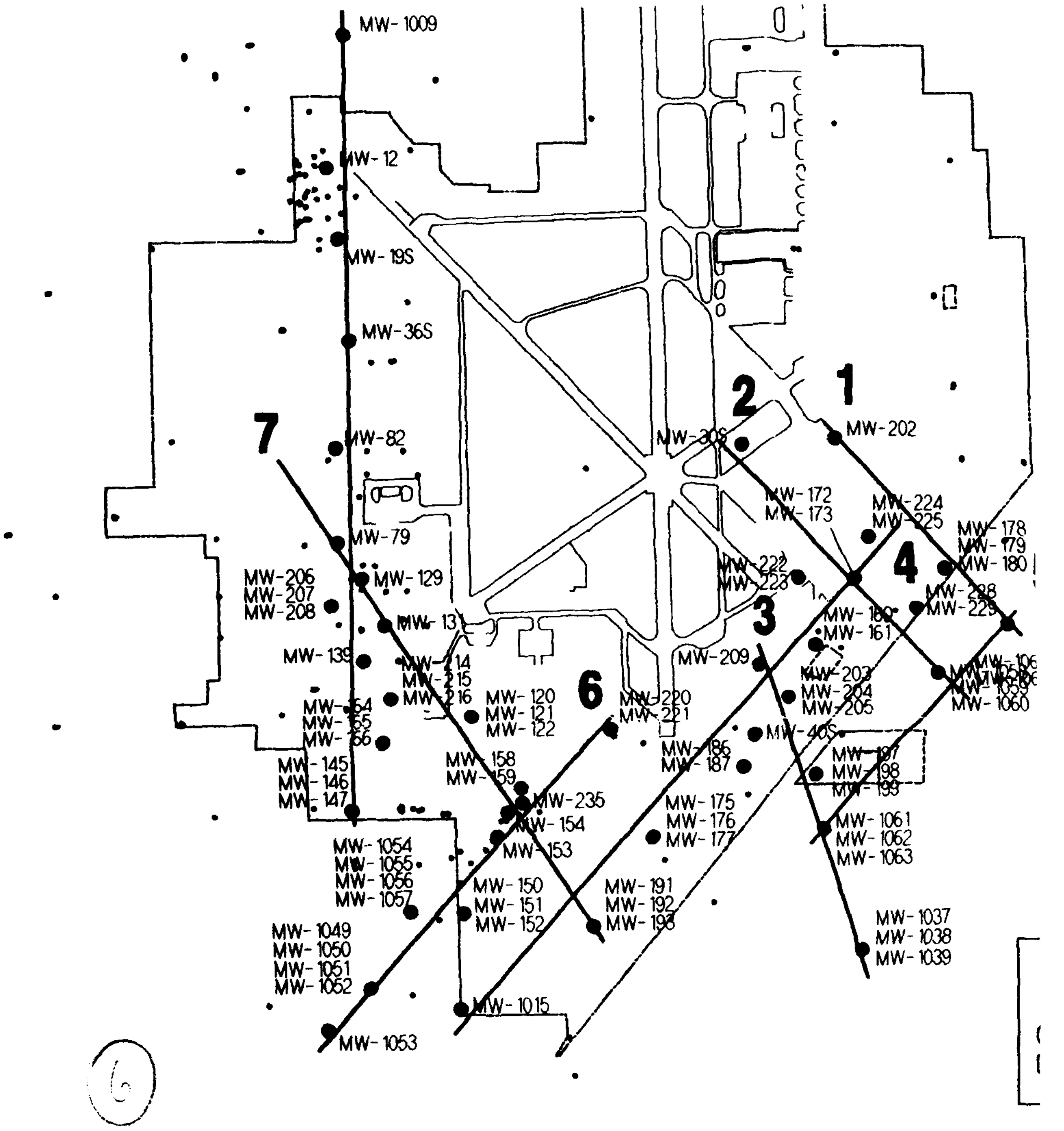
4



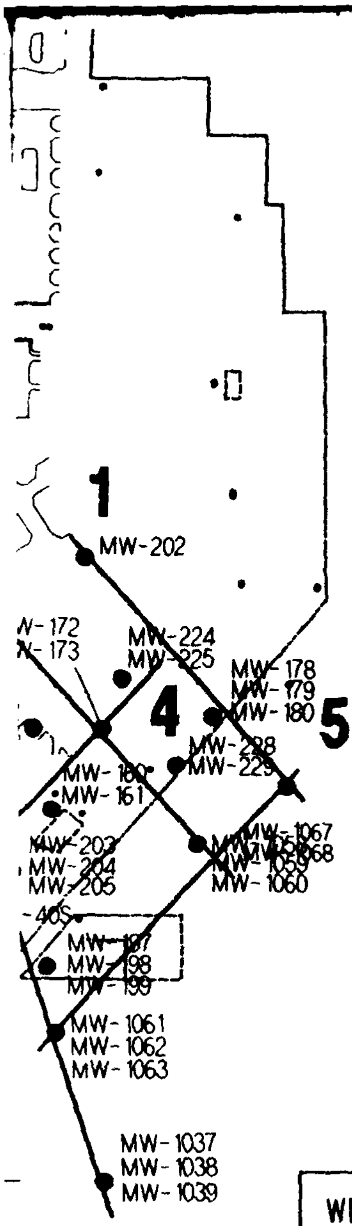
0
400'
800'
HORIZONTAL SCALE
MW-202 (EL 76.2)
MW-224 (EL 78.14)
MW-225
MW-178 (EL 76.29)
MW-179
MW-180
MW-10
MW-10
MW-202 1/5/93 EL -33.53
MW-224 4/13/93 12DCA 0.00 C12DCE 210.00 PCE 0.00 TCE 14000.00
MW-224 1/5/93 EL -33.02
MW-225 1/5/93 EL -33.48
MW-178 4/13/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 89.00
MW-178 1/5/93 EL -30.06
MW-1067 8/4/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 1.43
MW-179 1/5/93 EL -32.56
MW-180 1/5/93 EL -33.11
? 124.5' 9/20/90
RADIAN
MW-179 4/13/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-1068 8/4/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-225 8/5/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 51.50
MW-180 8/7/91 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 5.90



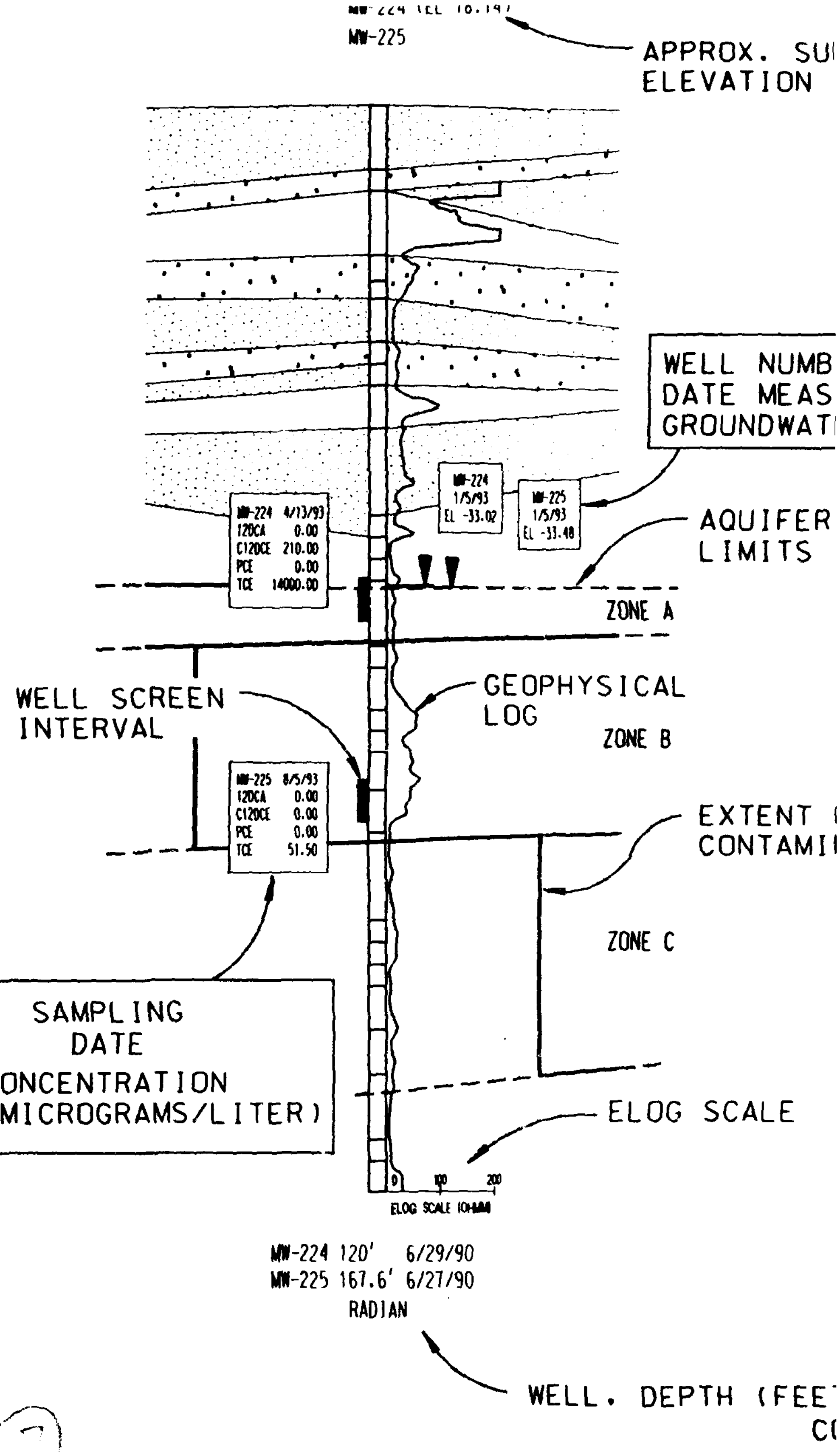
SE
MW-178 (EL 76.29)
MW-179
MW-180
MW-1067 (EL 77.8)
MW-1068
100'
MSL
100'
MW-1067 1/6/93 EL -31.95
MW-1068 1/6/93 EL -31.93
MW-178 1/5/93 EL -30.86
MW-179 1/5/93 EL -32.56
MW-180 1/5/93 EL -33.11
MW-1067 8/4/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 1.43
MW-1068 8/4/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00


MW-1009
MW-12
MW-19S
MW-36S
MW-82
MW-79
MW-129
MW-206
MW-207
MW-208
MW-13
MW-139
MW-214
MW-215
MW-216
MW-120
MW-121
MW-122
MW-154
MW-155
MW-156
MW-145
MW-146
MW-147
MW-158
MW-159
MW-235
MW-154
MW-153
MW-1054
MW-1055
MW-1056
MW-1057
MW-150
MW-151
MW-152
MW-1049
MW-1050
MW-1051
MW-1052
MW-1053
MW-1015
MW-191
MW-192
MW-193
MW-175
MW-176
MW-177
MW-186
MW-187
MW-220
MW-221
MW-209
MW-40S
MW-197
MW-198
MW-199
MW-1061
MW-1062
MW-1063
MW-1037
MW-1038
MW-1039
MW-203
MW-204
MW-205
MW-160
MW-161
MW-222
MW-223
MW-172
MW-173
MW-30S
MW-202
MW-224
MW-225
MW-178
MW-179
MW-180
MW-228
MW-229
MW-1059
MW-1060
1
2
3
4
6
7
N
0
2000
4000
FEET

SITE MAP



1
MW-202
MW-172
MW-173
MW-224
MW-225
4
MW-178
MW-179
MW-180
5
MW-228
MW-229
MW-160
MW-161
MW-203
MW-204
MW-205
MW-1067
MW-1068
MW-1059
MW-1060
MW-197
MW-198
MW-199
MW-1061
MW-1062
MW-1063
MW-1037
MW-1038
MW-1039



MW-225
APPROX. SU
ELEVATION
WELL NUMB
DATE MEAS
GROUNDWAT
MW-224 1/5/93 EL -33.02
MW-225 1/5/93 EL -33.48
MW-224 4/13/93
12DCA 0.00
C12DCE 210.00
PCE 0.00
TCE 14000.00
AQUIFER
LIMITS
ZONE A
WELL SCREEN
INTERVAL
GEOPHYSICAL
LOG
ZONE B
MW-225 8/5/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 51.50
EXTENT
CONTAMI
ZONE C
WELL NUMBER
SAMPLING
DATE
CONTAMINANTS
OF CONCERN
CONCENTRATION
(MICROGRAMS/LITER)
ELOG SCALE
0 100 200
ELOG SCALE (OHMM)
MW-224 120' 6/29/90
MW-225 167.6' 6/27/90
RADIAN
WELL. DEPTH (FEE
C

APPROX. SURFACE
ELEVATION

WELL NUMBER
DATE MEASURED
GROUNDWATER ELEVATION

AQUIFER ZONE
LIMITS

A

AL

B

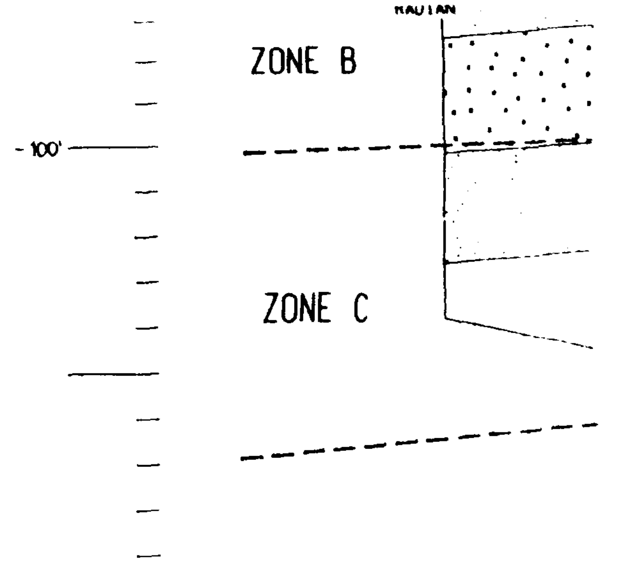
EXTENT OF
CONTAMINATION

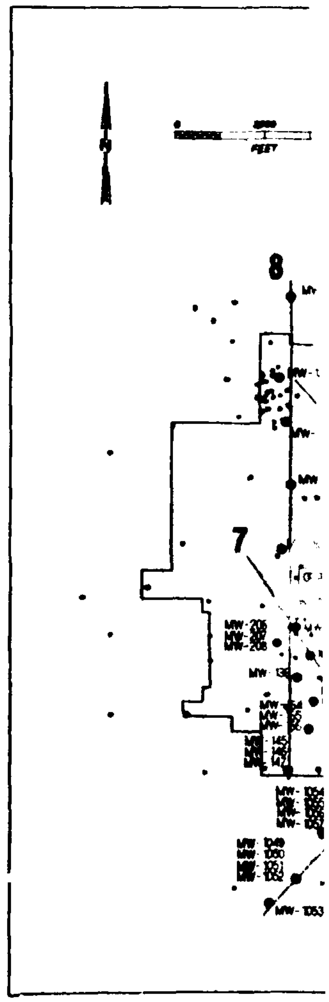
C

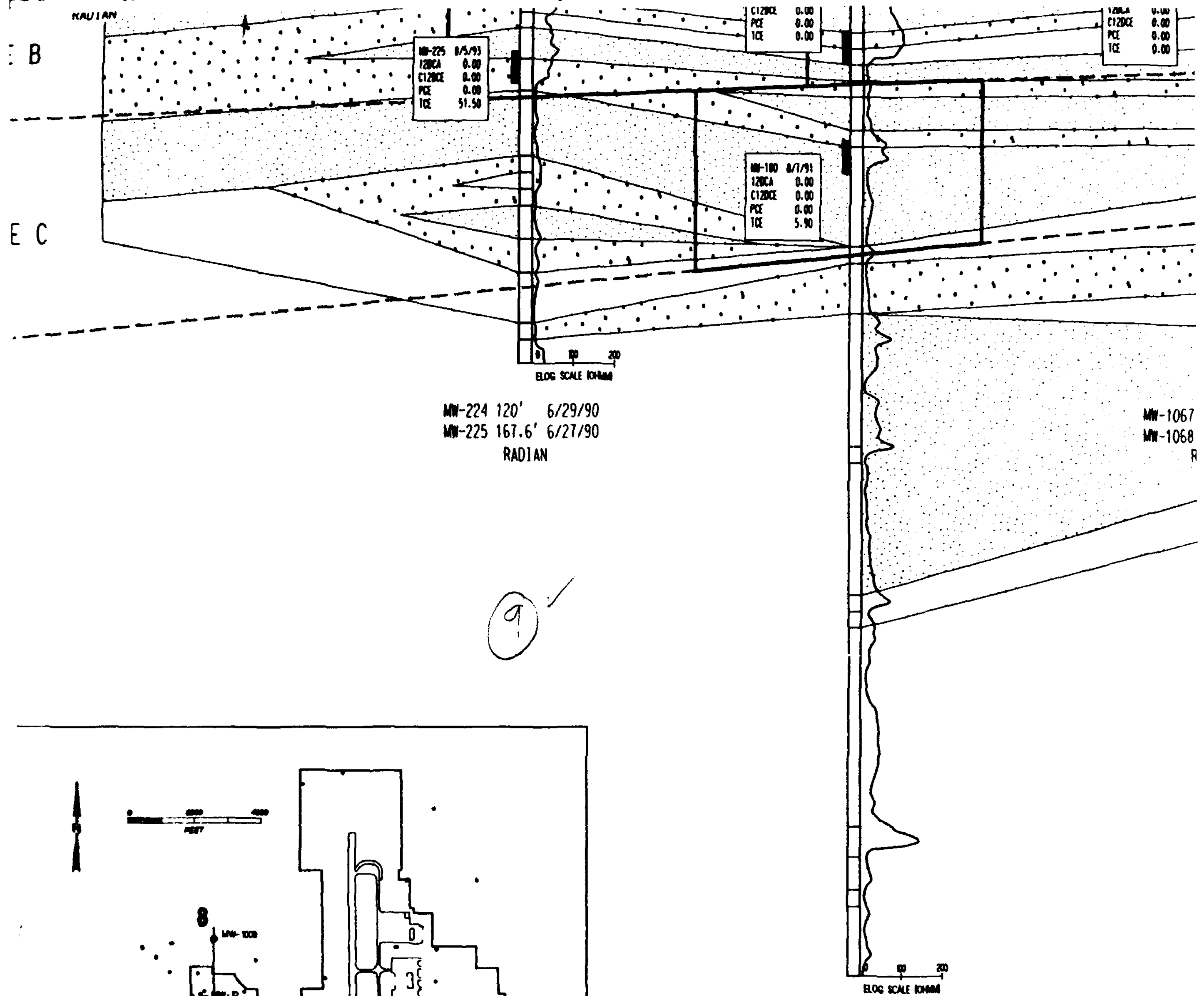
)G SCALE

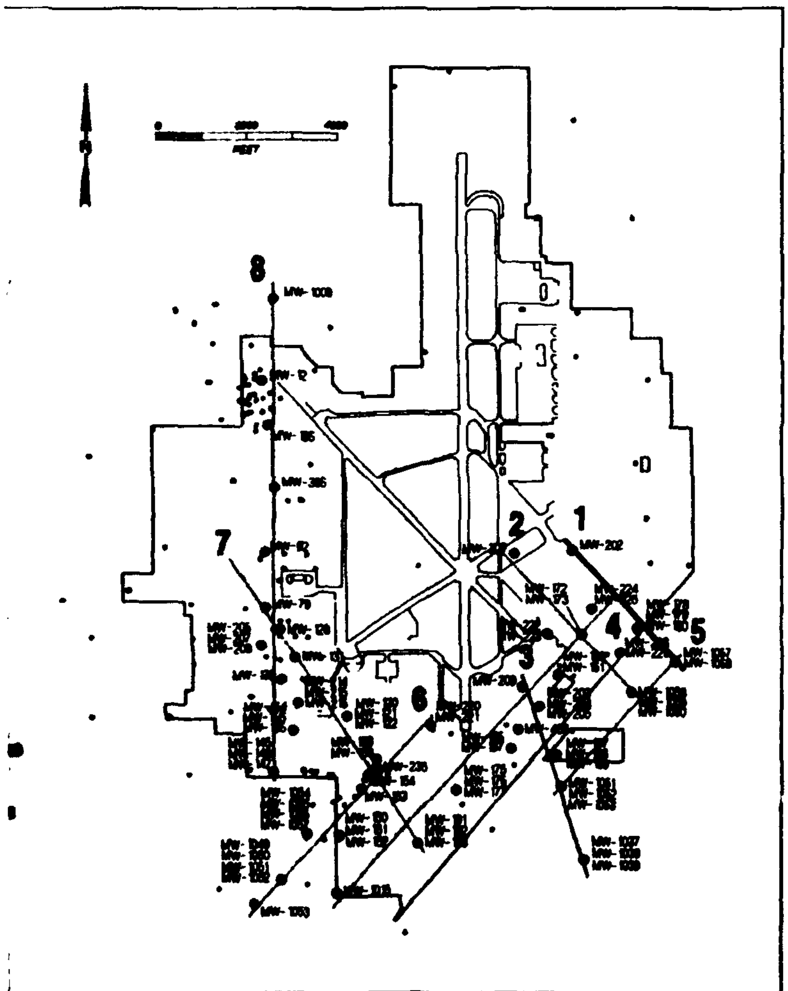
EPTH (FEET BGS), DATE DRILLED
CONTRACTOR

(8)









SITE MAP

LEGEND

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

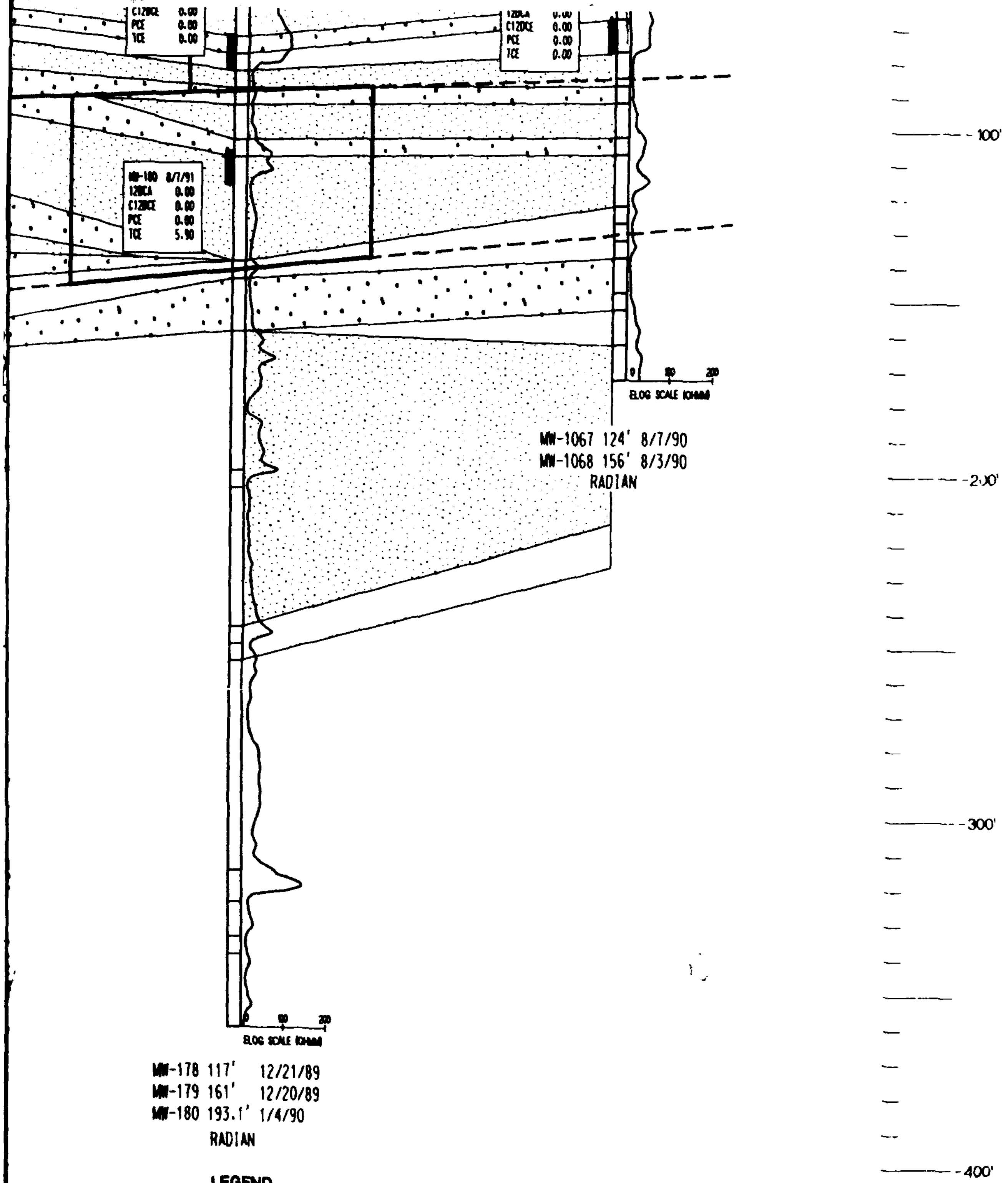
MEDIUM-GRAINED MATERIALS INCLUDE S OR CLAYEY SAND OR GRAVEL

COARSE-GRAINED MATERIALS INCLUDE P GRADED OR WELL GRADED SAND OR GRAV LESS THAN 5% FINES

NOTES:

1. Flow direction of depositional channels is approxima cross section. Groundwater generally follows the cours but is strongly influenced by regional pumping south of

2. Groundwater levels in MW-225 and MW-1068 have



LEGEND

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

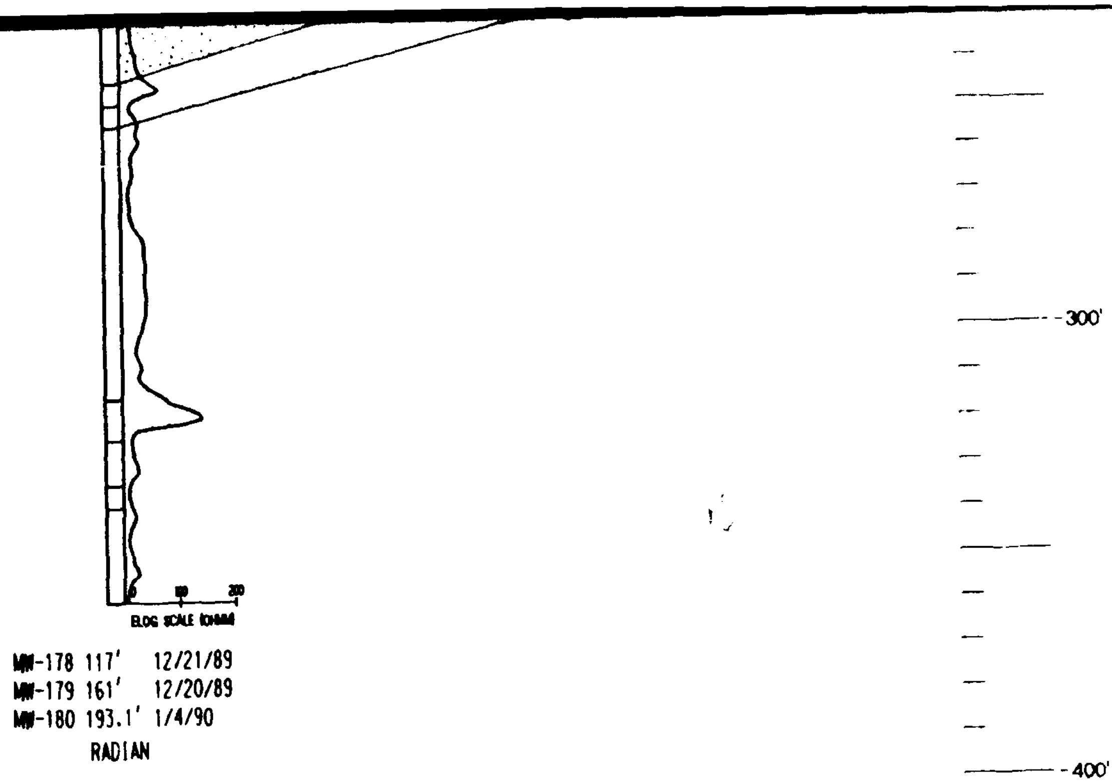
MEDIUM-GRAINED MATERIALS INCLUDE SILTY OR CLAYEY SAND OR GRAVEL

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

NOTES:

1. Flow direction of depositional channels is approximately perpendicular to the cross section. Groundwater generally follows the course of the channel deposits, but is strongly influenced by regional pumping south of the Base.

2. Groundwater levels in MW-225 and MW-1068 have dropped more than 30 feet between first and third quarter measurements, while other wells in the cross



LEGEND

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

NOTES:

1. Flow direction of depositional channels is approximately perpendicular to the cross section. Groundwater generally follows the course of the channel deposits, but is strongly influenced by regional pumping south of the Base.

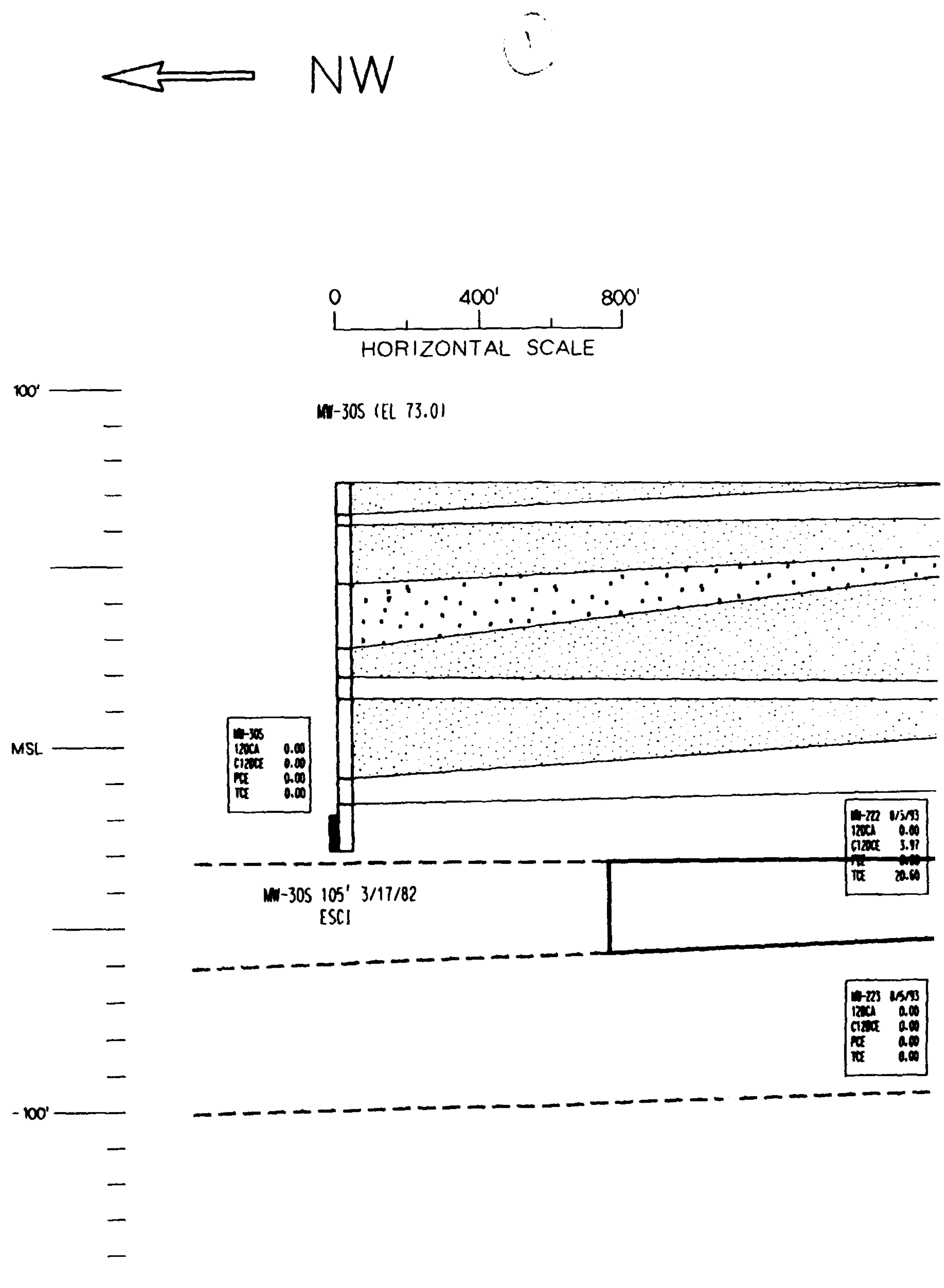
2. Groundwater levels in MW-225 and MW-1068 have dropped more than 30 feet between first and third quarter measurements, while other wells in the cross section have dropped less than ten feet over the same period. MW-178, MW-179, and MW-180 show little variation over the same period, due to the concentration of fines in the vicinity of this cluster.

FIGURE 3-2

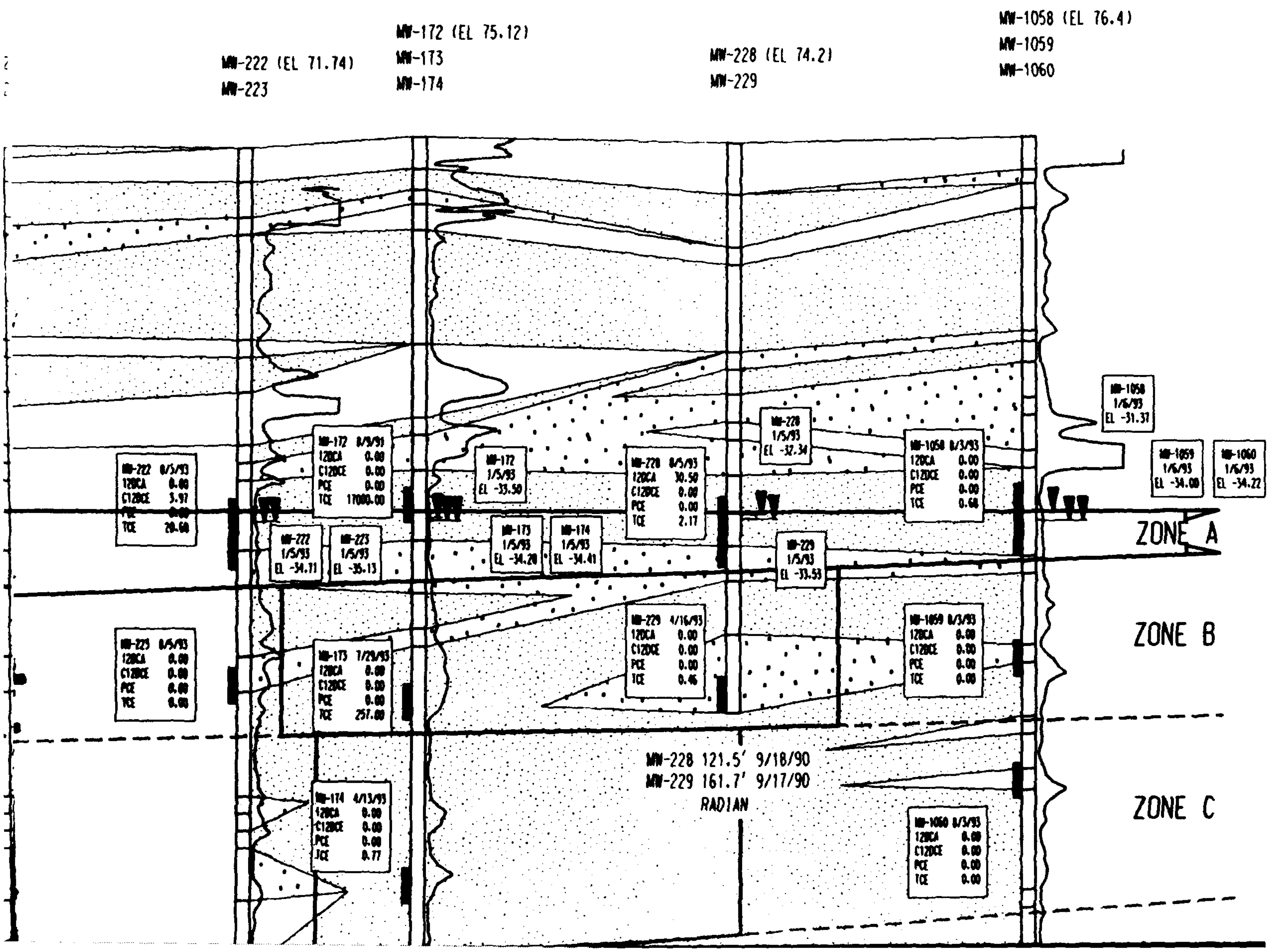
CROSS SECTION 1

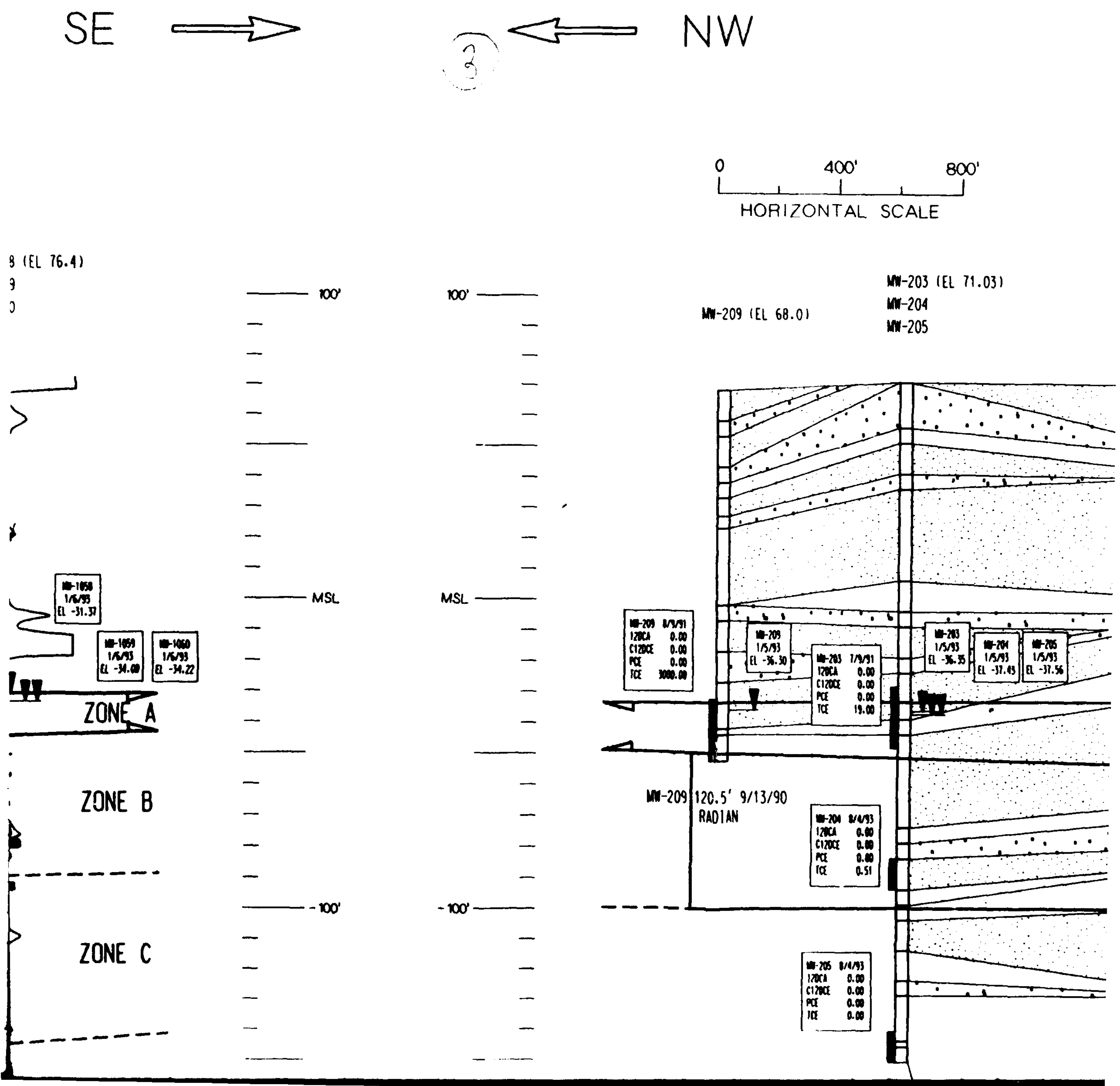
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


NW
0
400'
800'
HORIZONTAL SCALE
100'
MW-30S (EL 73.0)
MSL
MW-30S
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-30S 105' 3/17/82
ESCI
TCE 20.60
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
-100'

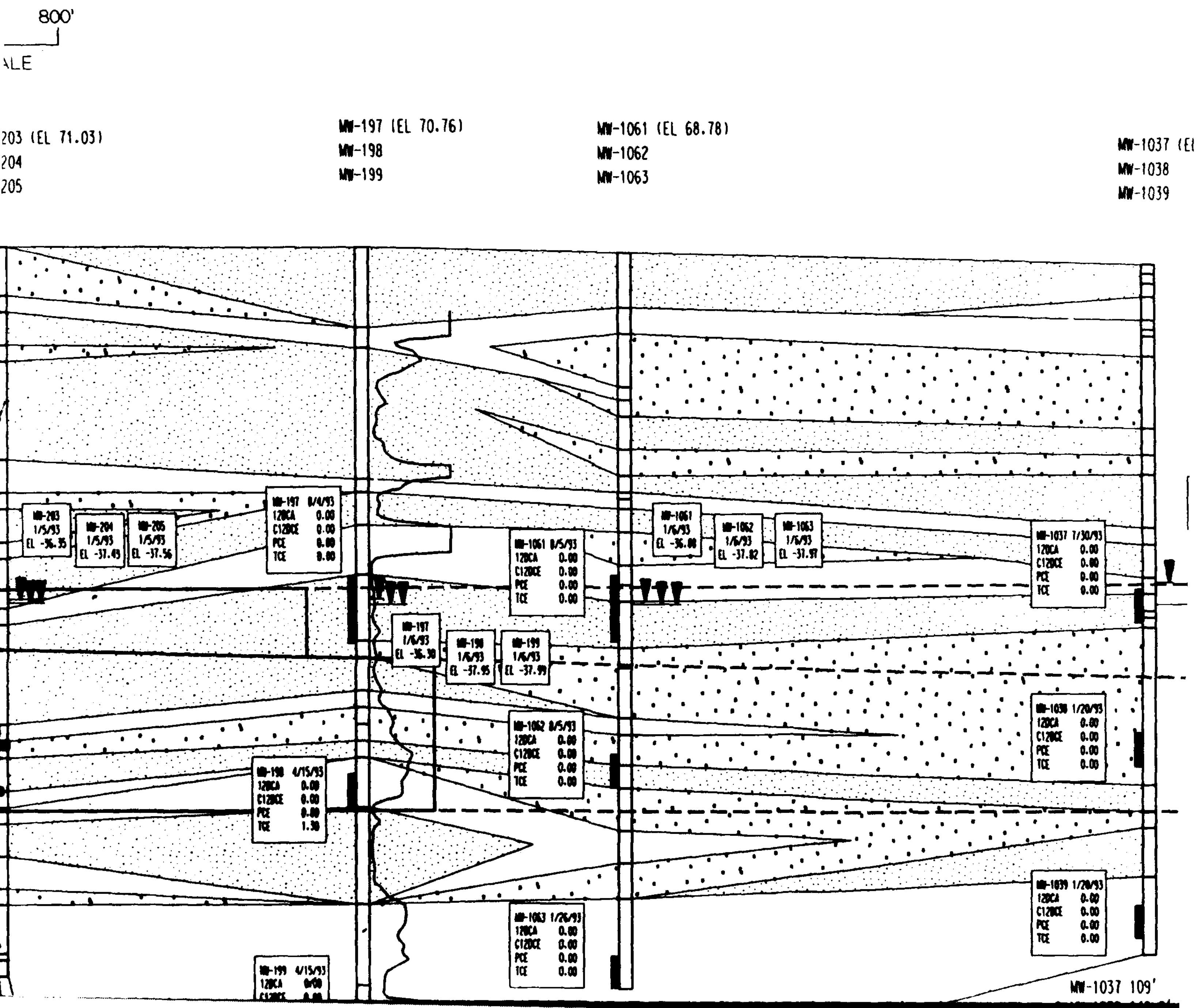
SE


MW-222 (EL 71.74)
MW-223
MW-172 (EL 75.12)
MW-173
MW-174
MW-228 (EL 74.2)
MW-229
MW-1058 (EL 76.4)
MW-1059
MW-1060
MW-222 8/5/93
12DCA 0.00
C12DCE 3.97
PCE
TCE 20.60
MW-172 8/9/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 17000.00
MW-172
1/5/93
EL -33.50
MW-222
1/5/93
EL -34.71
MW-223
1/5/93
EL -35.13
MW-173
1/5/93
EL -34.20
MW-174
1/5/93
EL -34.41
MW-228 8/5/93
12DCA 30.50
C12DCE 0.00
PCE 0.00
TCE 2.17
MW-228
1/5/93
EL -32.34
MW-229
1/5/93
EL -33.53
MW-1058 8/3/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.68
MW-1058
1/6/93
EL -31.37
MW-1059
1/6/93
EL -34.00
MW-1060
1/6/93
EL -34.22
ZONE A
MW-223 8/5/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-173 7/29/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 257.00
MW-229 4/16/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.46
MW-1059 8/3/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
ZONE B
MW-228 121.5' 9/18/90
MW-229 161.7' 9/17/90
RADIAN
MW-174 4/13/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.77
MW-1060 8/3/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
ZONE C

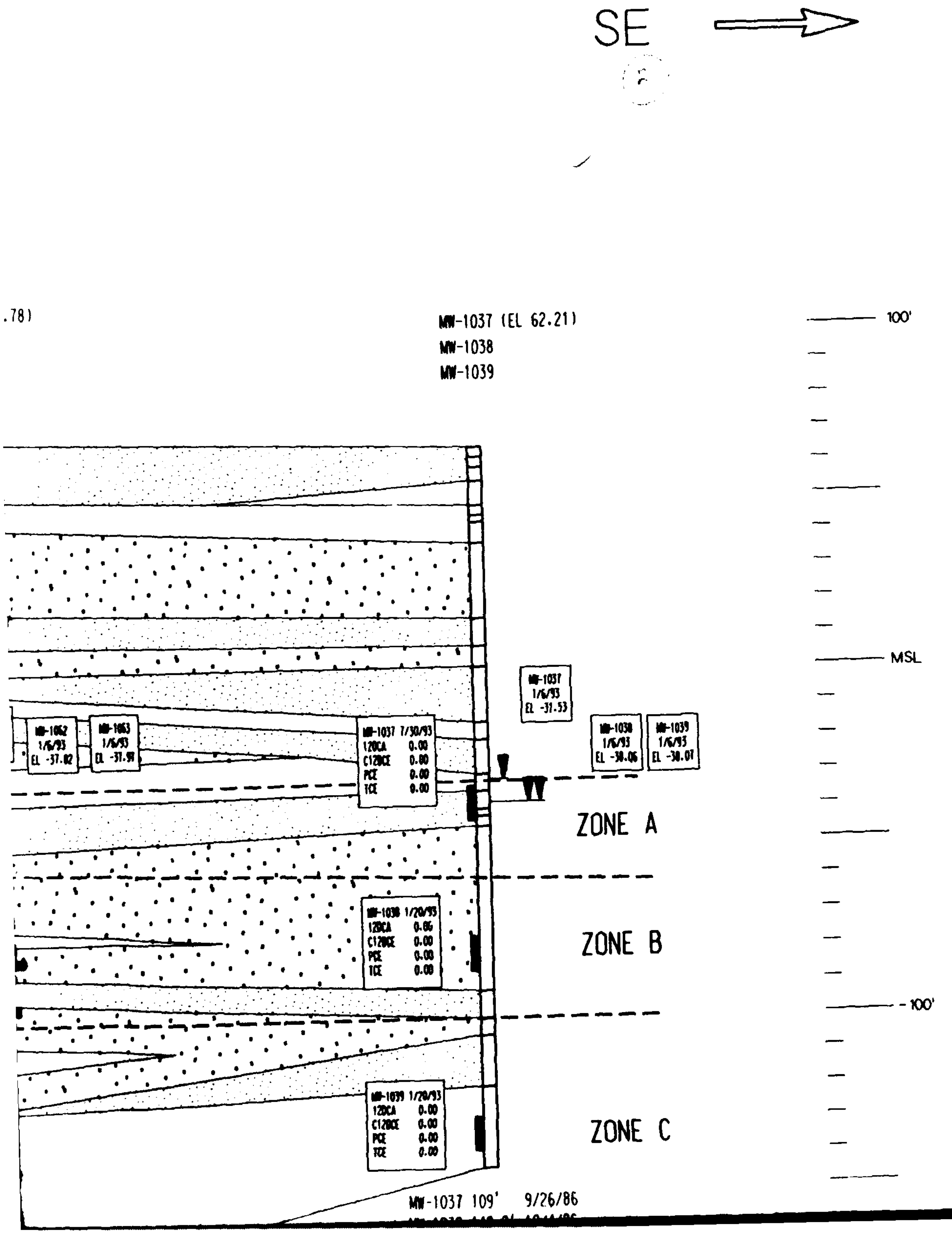


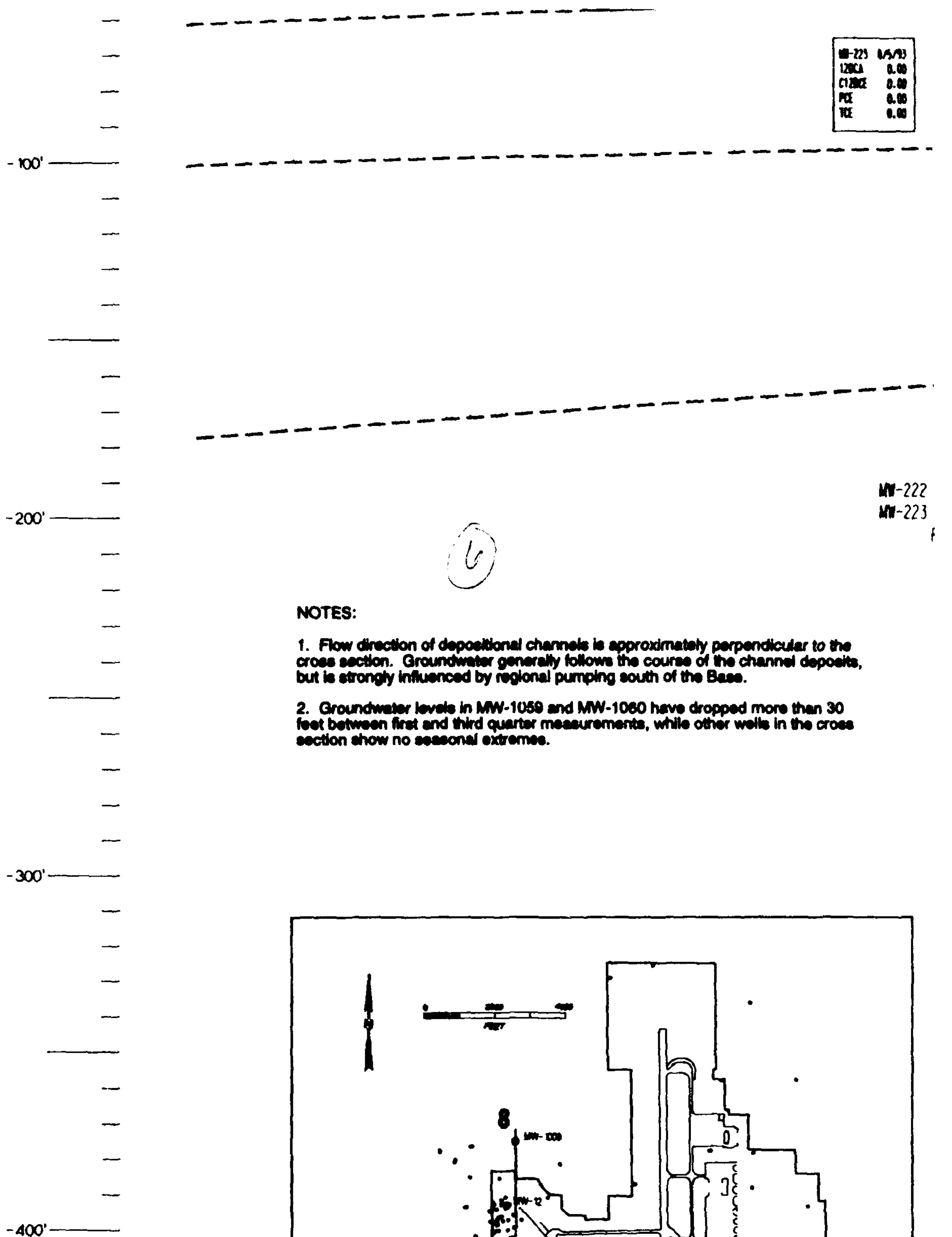
SE
NW
0
400'
800'
HORIZONTAL SCALE
8 (EL 76.4)
9
0
100'
100'
MSL
MSL
-100'
-100'
MW-209 (EL 68.0)
MW-203 (EL 71.03)
MW-204
MW-205
MW-1058
1/6/93
EL -31.37
MW-1059
1/6/93
EL -34.00
MW-1060
1/6/93
EL -34.22
ZONE A
ZONE B
ZONE C
MW-209 8/9/91
120CA 0.00
C120CE 0.00
PCE 0.00
TCE 3000.00
MW-209
1/5/93
EL -36.30
MW-203 7/9/91
120CA 0.00
C120CE 0.00
PCE 0.00
TCE 19.00
MW-203
1/5/93
EL -36.35
MW-204
1/5/93
EL -37.43
MW-205
1/5/93
EL -37.56
MW-209 120.5' 9/13/90
RADIAN
MW-204 8/4/93
120CA 0.00
C120CE 0.00
PCE 0.00
TCE 0.51
MW-205 8/4/93
120CA 0.00
C120CE 0.00
PCE 0.00
TCE 0.00

21



800'
ALE
203 (EL 71.03)
204
205
MW-197 (EL 70.76)
MW-198
MW-199
MW-1061 (EL 68.78)
MW-1062
MW-1063
MW-1037 (E
MW-1038
MW-1039
MW-203 1/5/93 EL -36.35
MW-204 1/5/93 EL -37.43
MW-205 1/5/93 EL -37.56
MW-197 8/4/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-1061 1/6/93 EL -36.80
MW-1062 1/6/93 EL -37.02
MW-1063 1/6/93 EL -37.97
MW-1061 8/5/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-1037 7/30/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-197 1/6/93 EL -36.30
MW-198 1/6/93 EL -37.95
MW-199 1/6/93 EL -37.99
MW-1038 1/20/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-1062 8/5/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-198 4/15/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 1.30
MW-1039 1/20/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-1063 1/26/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-199 4/15/93 12DCA 0/00
MW-1037 109'

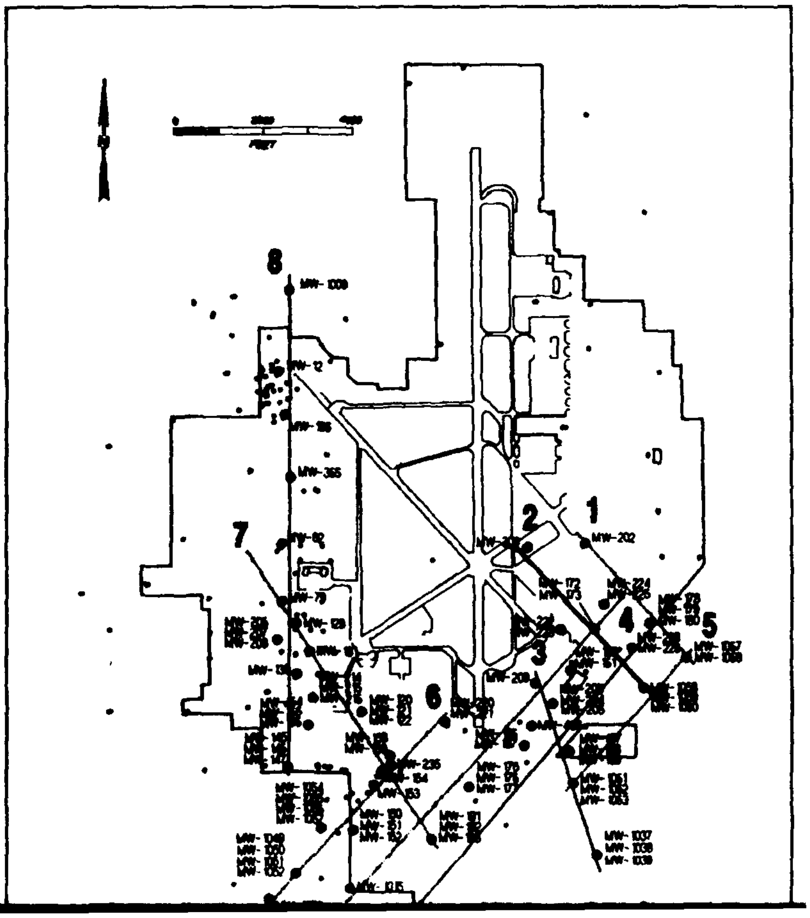

SE
.78)
MW-1037 (EL 62.21)
MW-1038
MW-1039
100'
MSL
-100'
MW-1037
1/6/93
EL -31.53
MW-1062
1/6/93
EL -37.82
MW-1063
1/6/93
EL -37.99
MW-1037 7/30/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1038
1/6/93
EL -30.06
MW-1039
1/6/93
EL -30.07
ZONE A
MW-1038 1/20/93
12DCA 0.06
C12DCE 0.00
PCE 0.00
TCE 0.00
ZONE B
MW-1039 1/20/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
ZONE C
MW-1037 109' 9/26/86

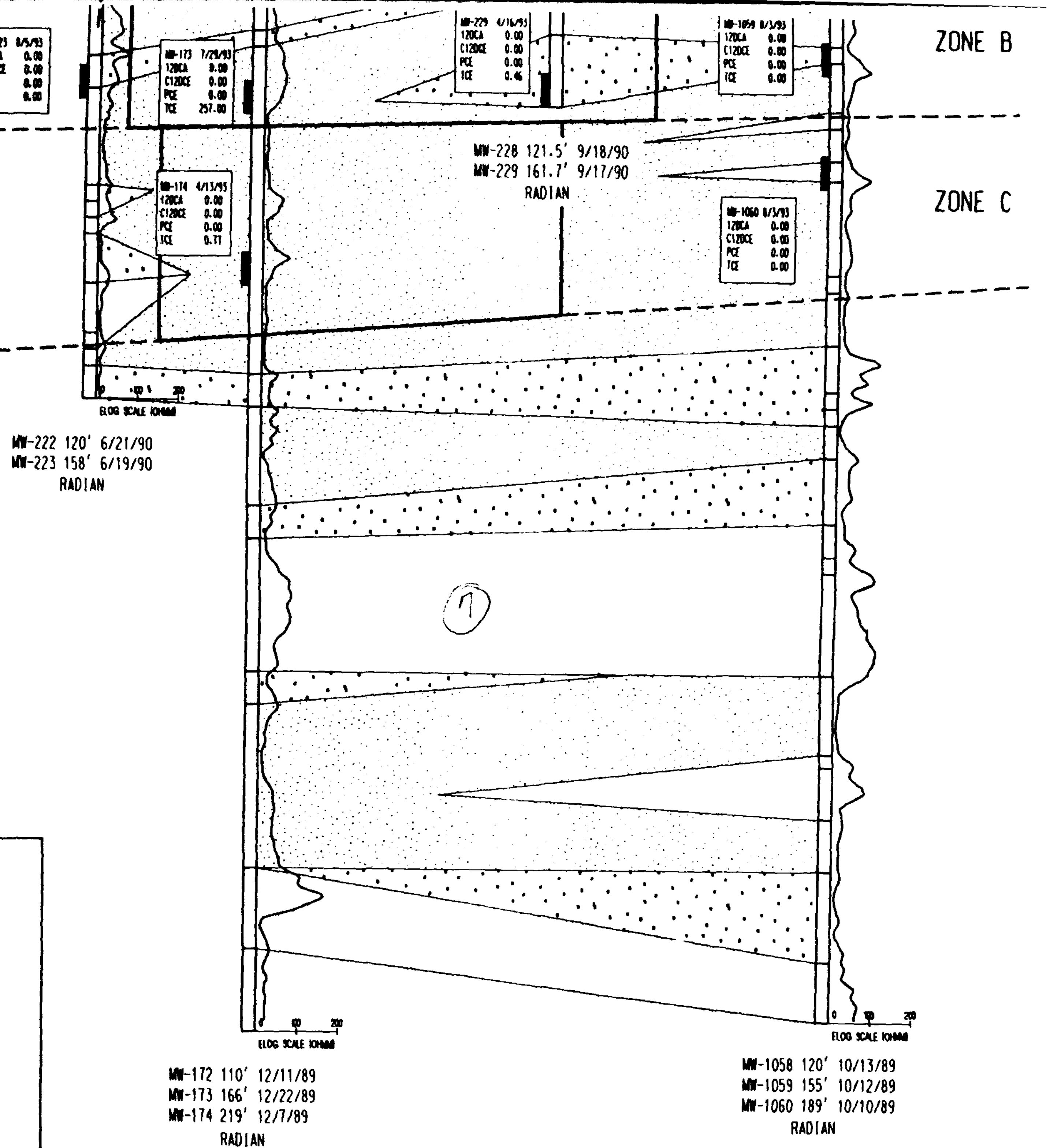


NOTES:

1. *Flow direction of depositional channels is approximately perpendicular to the cross section.* Groundwater generally follows the course of the channel deposits, but is strongly influenced by regional pumping south of the Base.

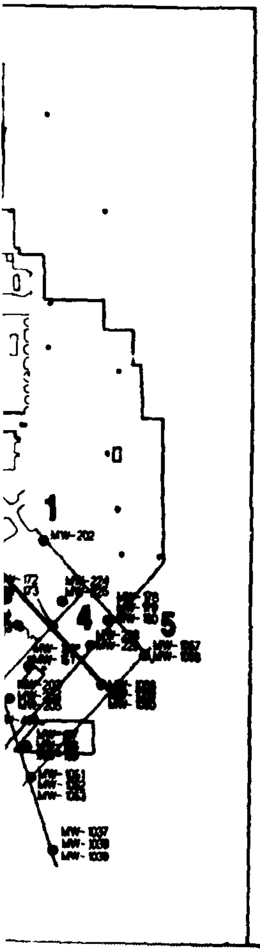
2. Groundwater levels in MW-1059 and MW-1060 have dropped more than 30 feet between first and third quarter measurements, while other wells in the cross section show no seasonal extremes.

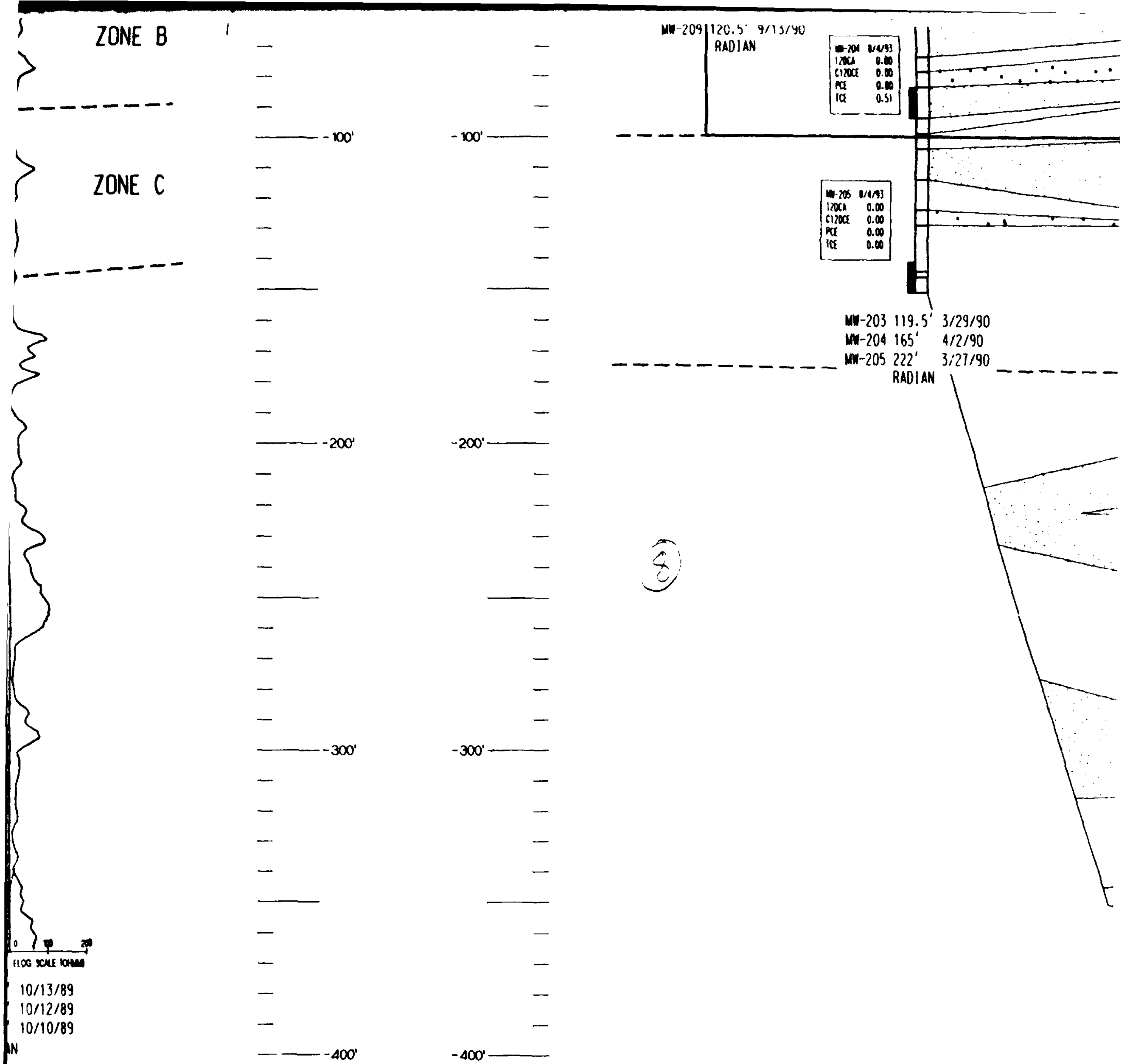




perpendicular to the
the channel deposits,
Base.

pped more than 30
er wells in the cross



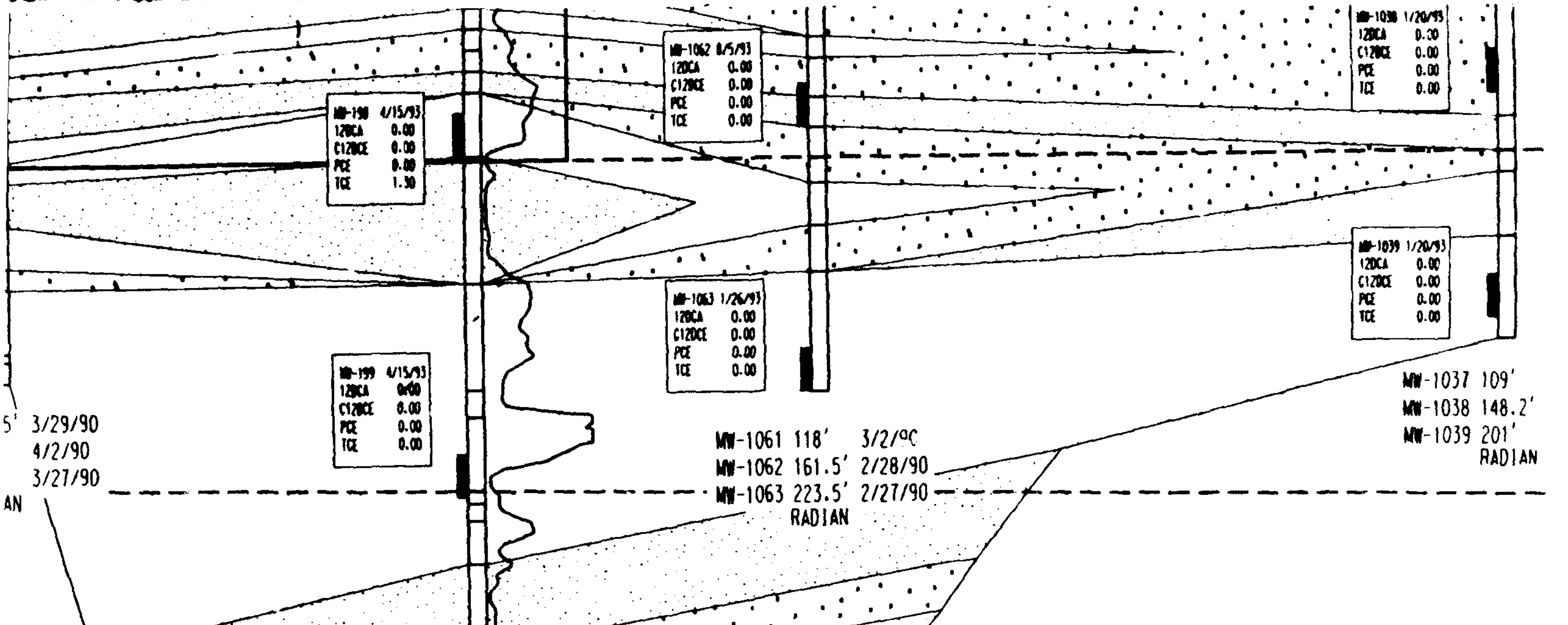


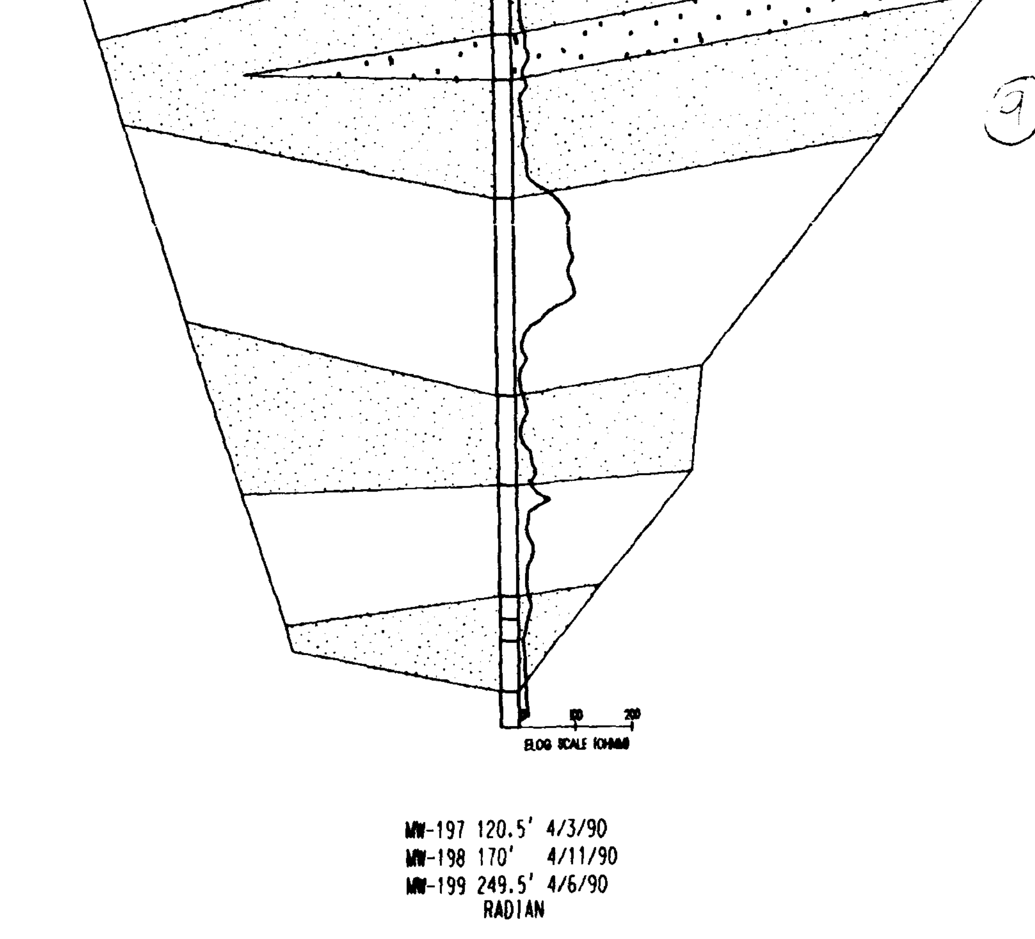
LEGEND

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

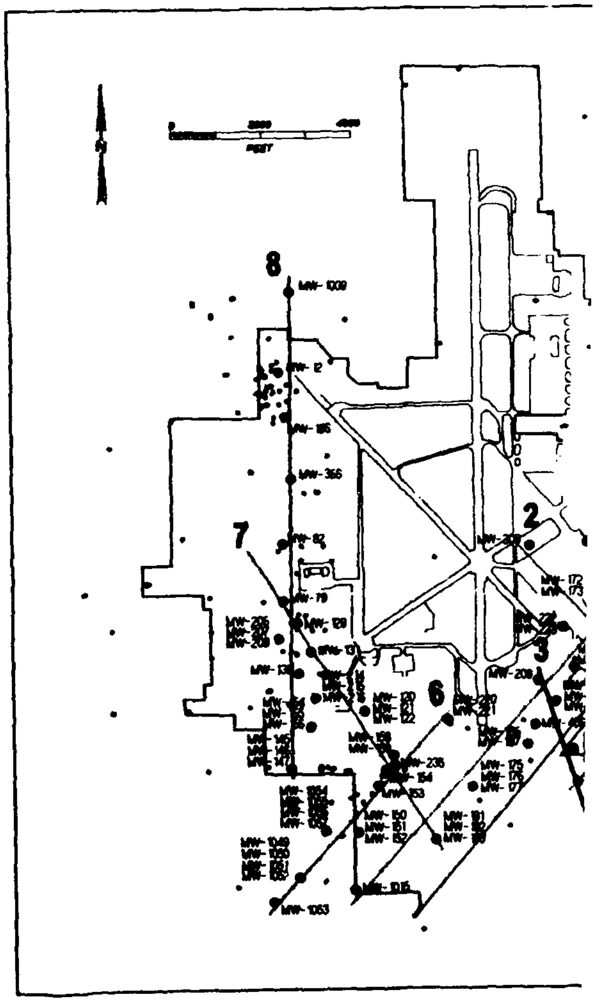




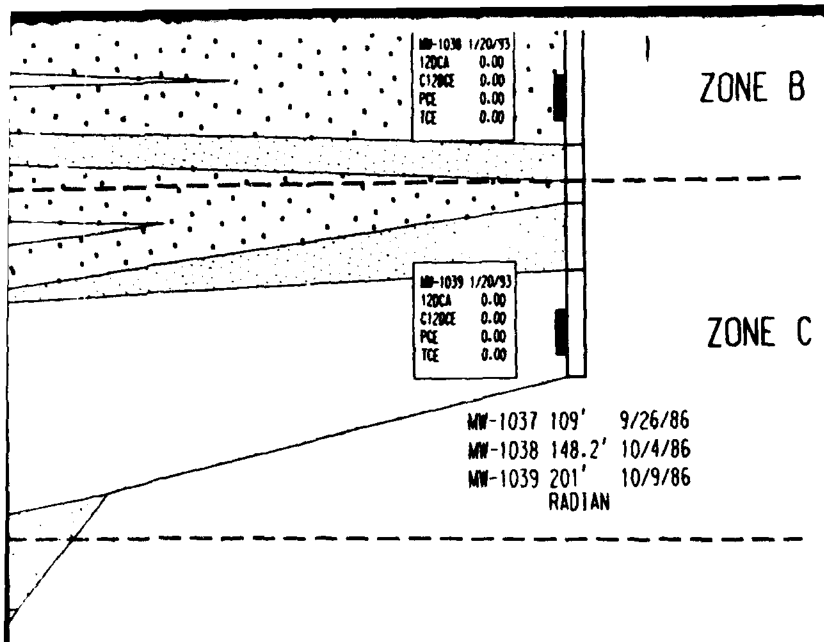
NOTES:

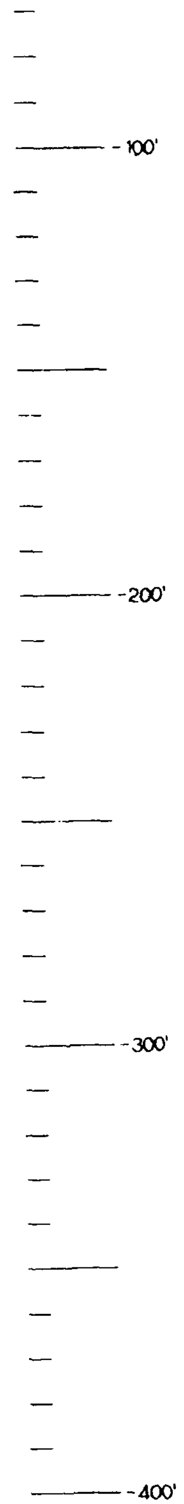
1. Flow direction of depositional channels is approximately p
cross section. Groundwater generally follows the course of t
but is strongly influenced by regional pumping south of the B

2. Groundwater levels in MW-198, MW-199, MW-1062, MW-
have dropped more than 30 feet between first and third quart
while other wells in the cross section show no seasonal extre



SITE MAP

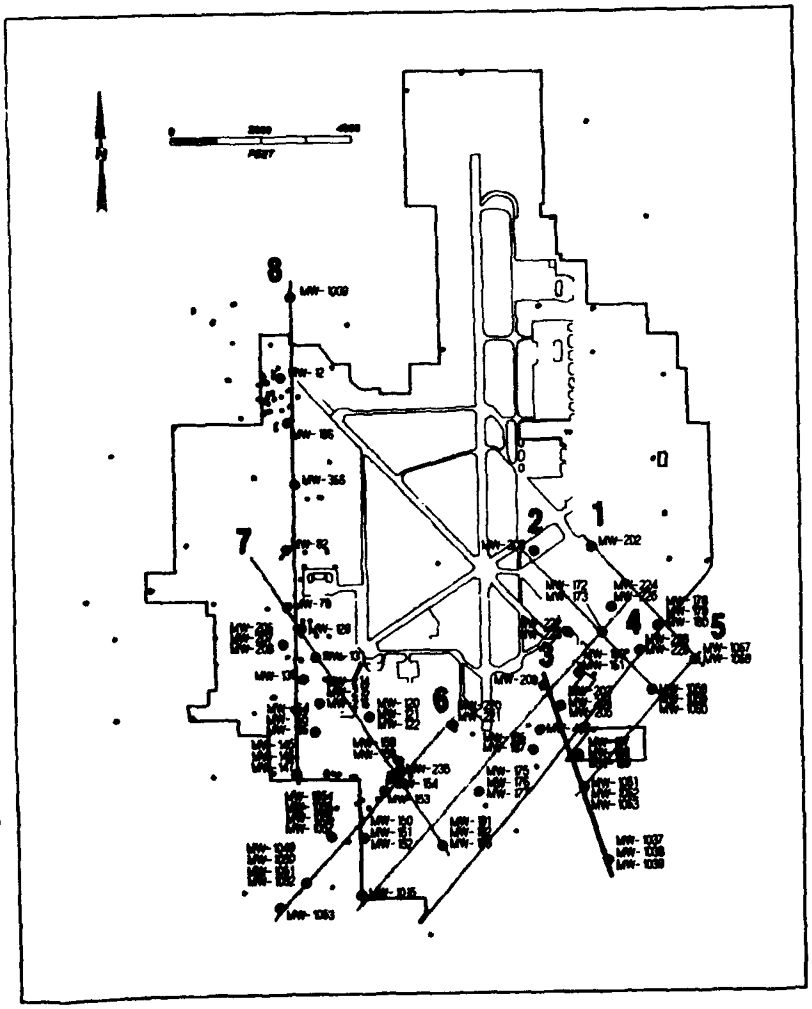




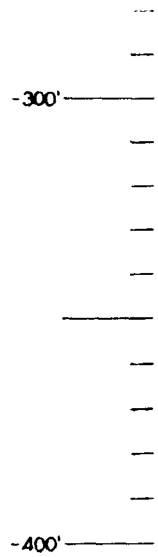
NOTES:

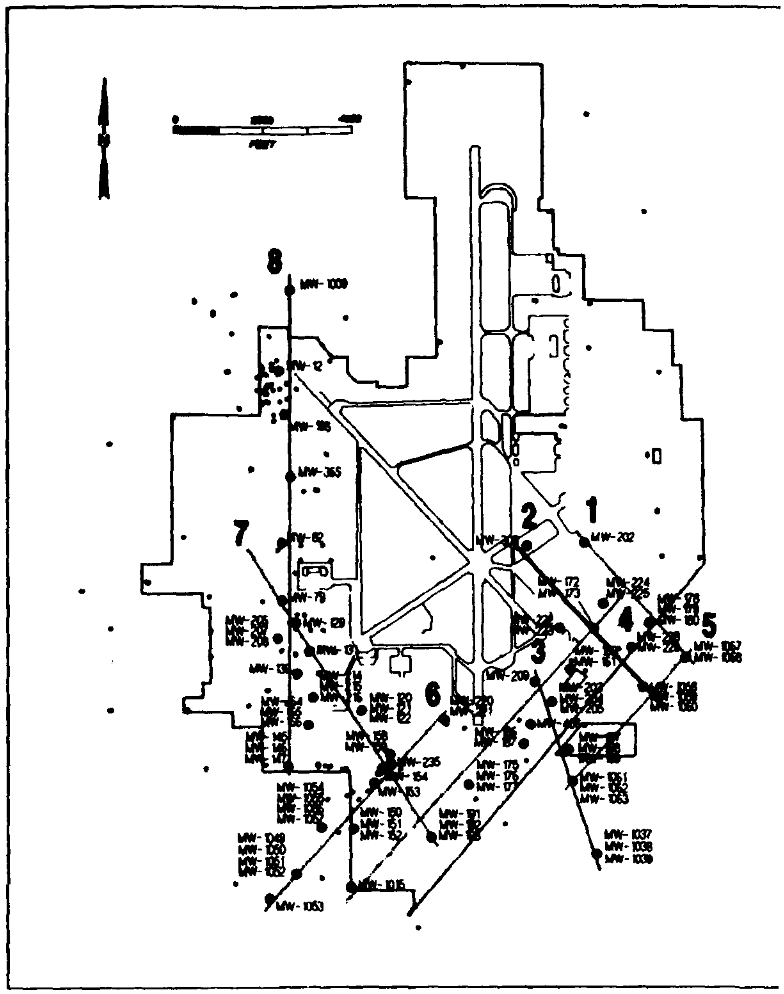
1. Flow direction of depositional channels is approximately perpendicular to the cross section. Groundwater generally follows the course of the channel deposits, but is strongly influenced by regional pumping south of the Base.

2. Groundwater levels in MW-198, MW-199, MW-1062, MW-1063, and MW-1038 have dropped more than 30 feet between first and third quarter measurements, while other wells in the cross section show no seasonal extremes.

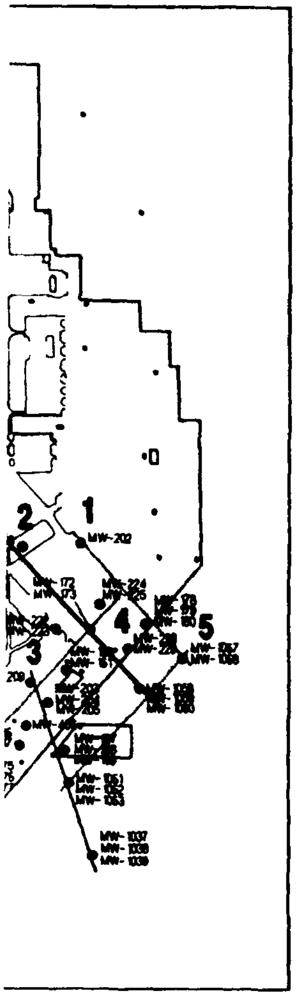


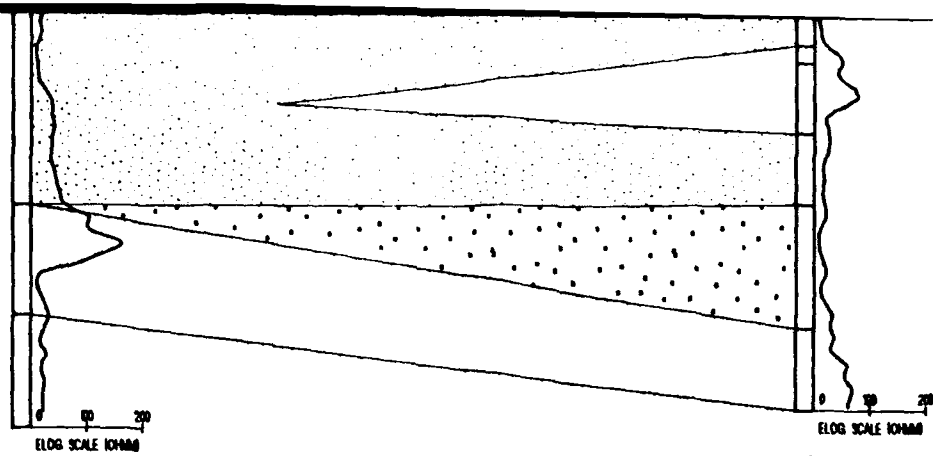
SITE MAP


-300'
-400'


8
7
6
5
4
3
2
1
MW-1009
MW-12
MW-355
MW-202
MW-209
MW-1053
MW-1015

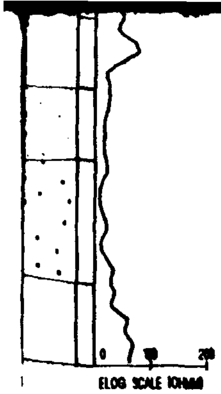
SITE MAP





MW-172 110' 12/11/89
MW-173 166' 12/22/89
MW-174 219' 12/7/89
RADIAN

MW-1058 120' 10/13/89
MW-1059 155' 10/12/89
MW-1060 189' 10/10/89
RADIAN



058 120' 10/13/89
059 155' 10/12/89
060 189' 10/10/89
RADIAN

-300' -300'

-400' -400'

LE

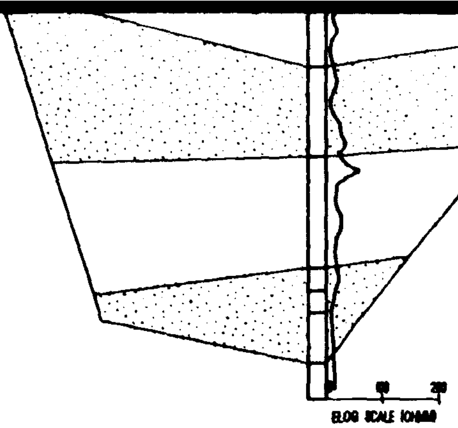
LEGEND

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

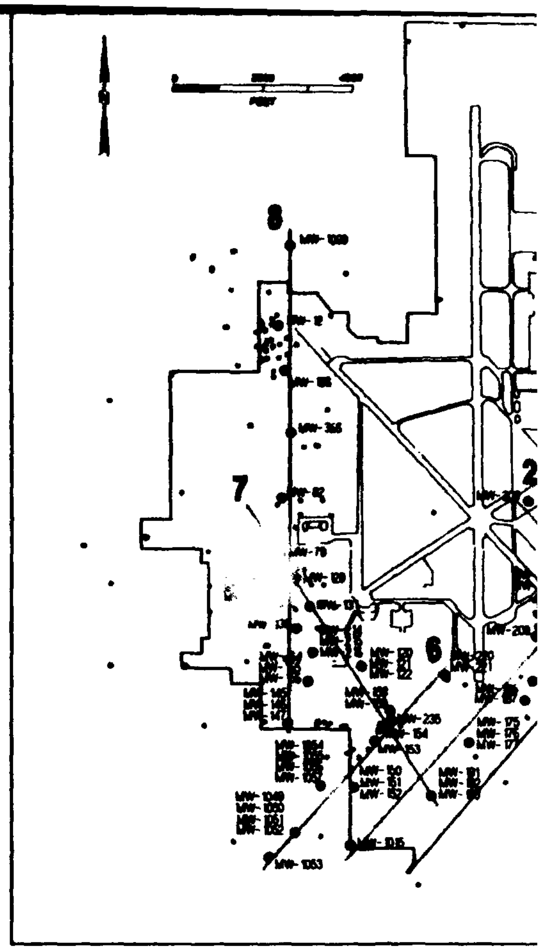
MEDIUM-GRAINED MATERIALS INCLUDE SILTY OR CLAYEY SAND OR GRAVEL

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

13



MW-197 120.5' 4/3/90
MW-198 170' 4/11/90
MW-199 249.5' 4/6/90
RADIAN

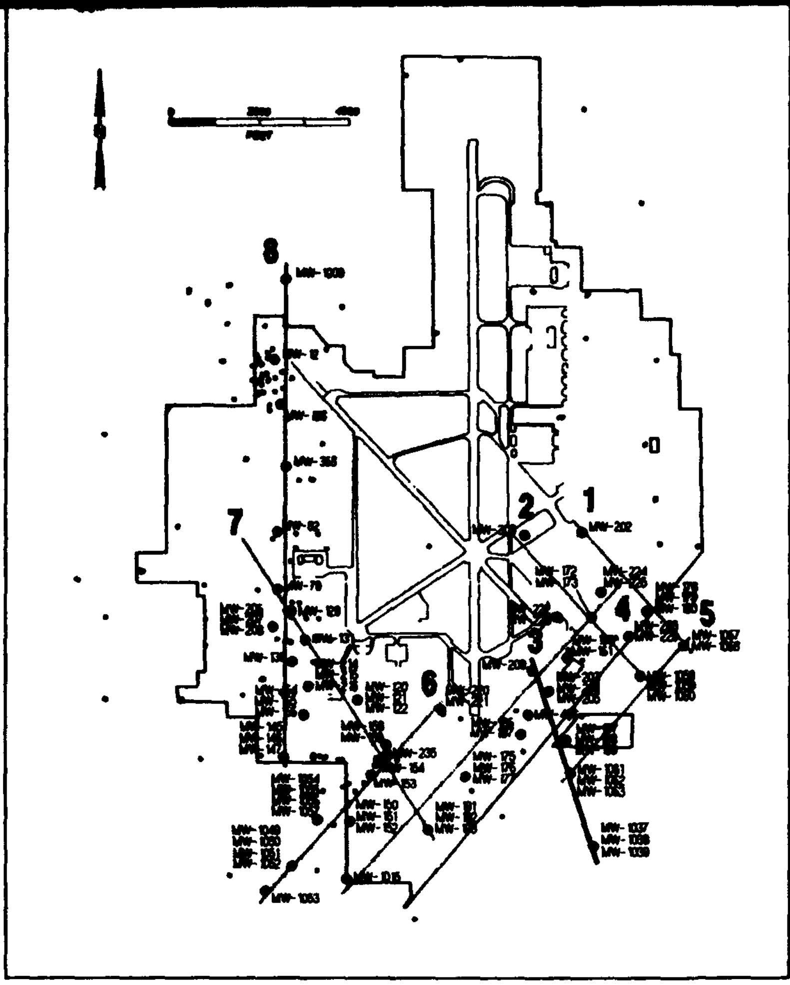


SITE MAP

FIGURE 3-3
CROSS S
GROUNDWATE
McCLELLAN A
SACRAMENTO,

-300'

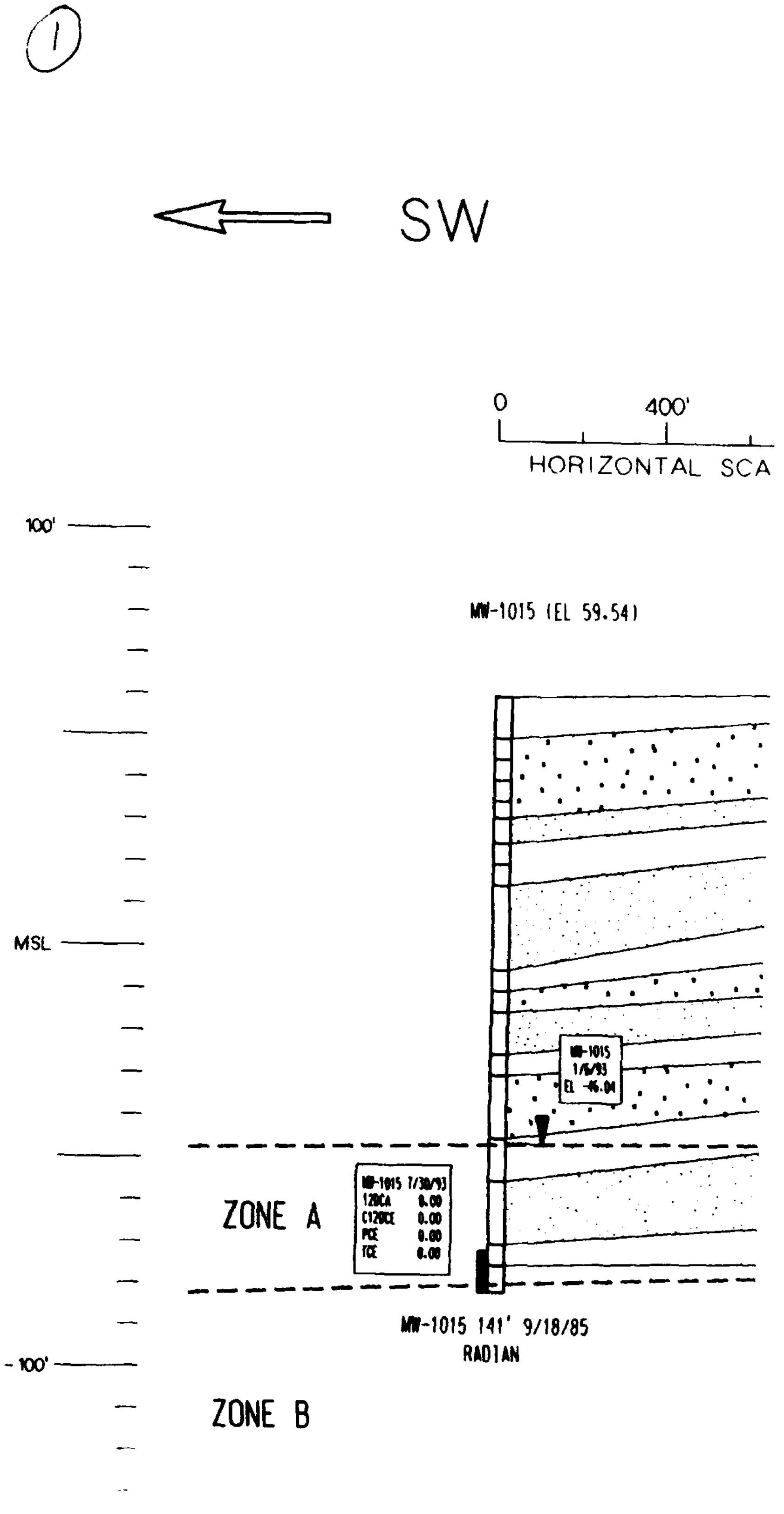
-400'



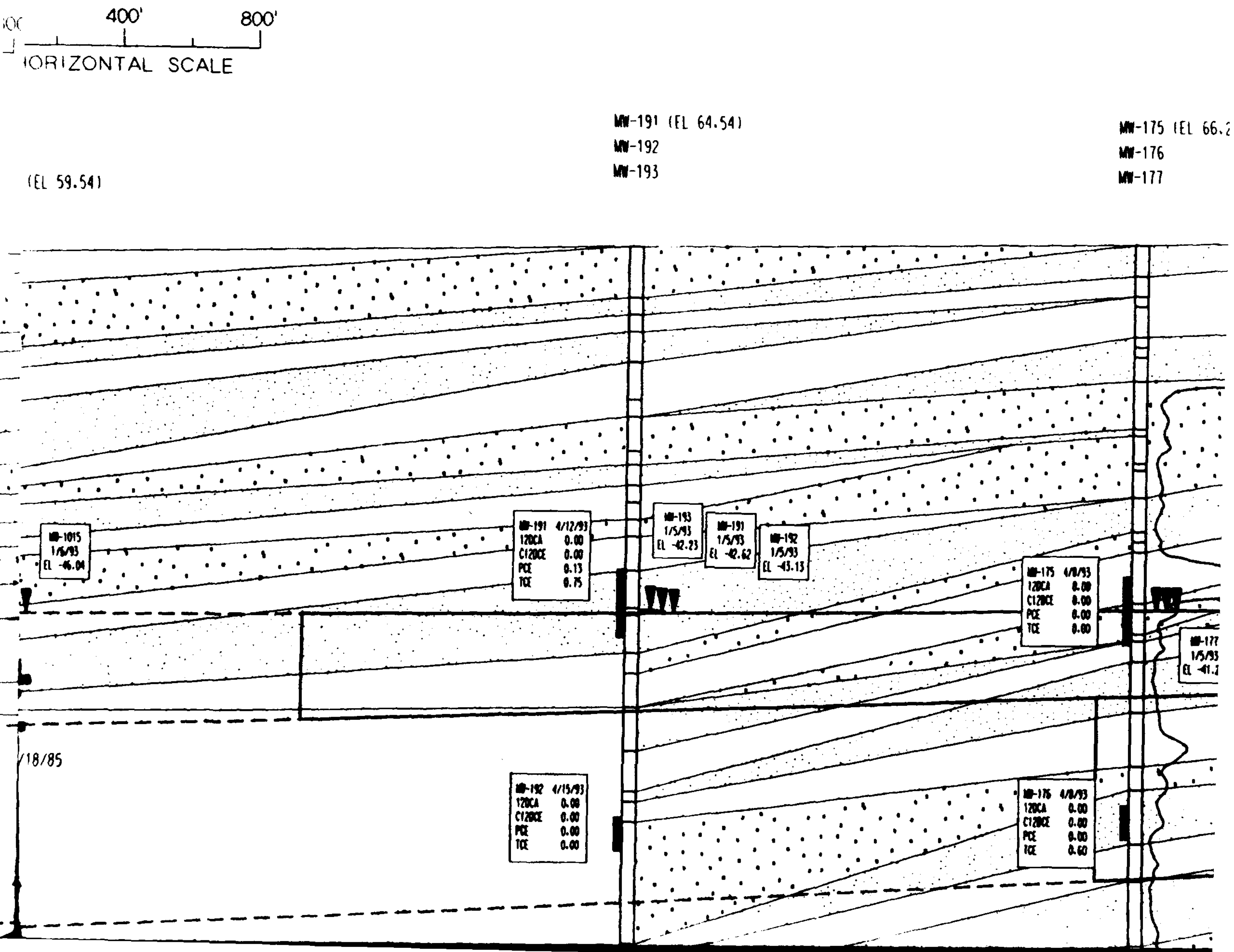
SITE MAP

FIGURE 3-3
CROSS SECTIONS 2 AND 3
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

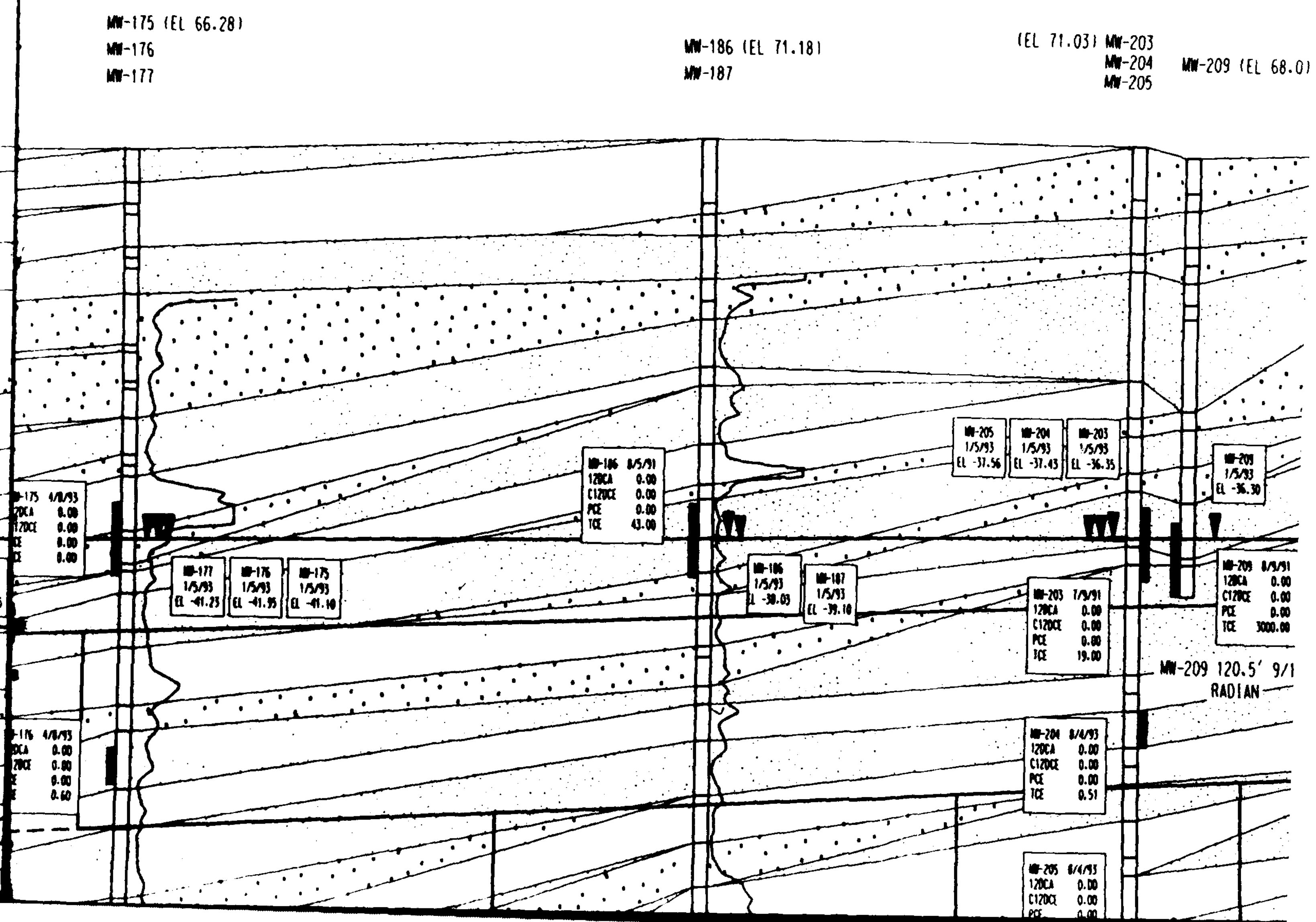
CH2M HILL



SW
0
400'
HORIZONTAL SCA
100'
MW-1015 (EL 59.54)
MSL
MW-1015
1/6/93
EL -46.04
ZONE A
MW-1015 7/30/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1015 141' 9/18/85
RADIAN
-100'
ZONE B



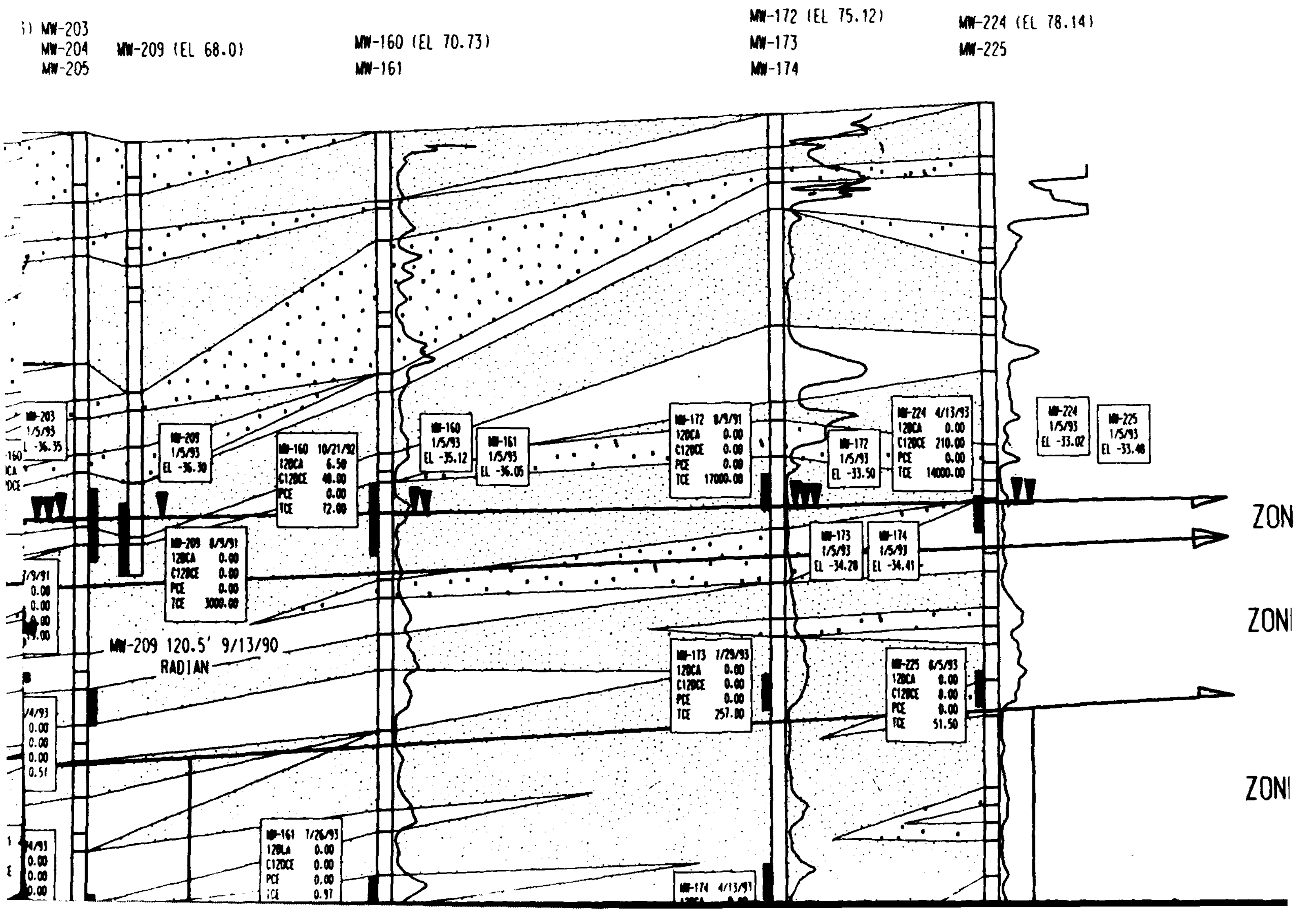
400'
800'
HORIZONTAL SCALE
MW-191 (EL 64.54)
MW-192
MW-193
MW-175 (EL 66.
MW-176
MW-177
(EL 59.54)
MW-1015 1/6/93 EL -46.04
MW-191 4/12/93
12DCA 0.00
C12DCE 0.00
PCE 0.13
TCE 0.75
MW-193 1/5/93 EL -42.23
MW-191 1/5/93 EL -42.62
MW-192 1/5/93 EL -43.13
MW-175 4/8/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-177 1/5/93 EL -41.
/18/85
MW-192 4/15/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-176 4/8/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.60

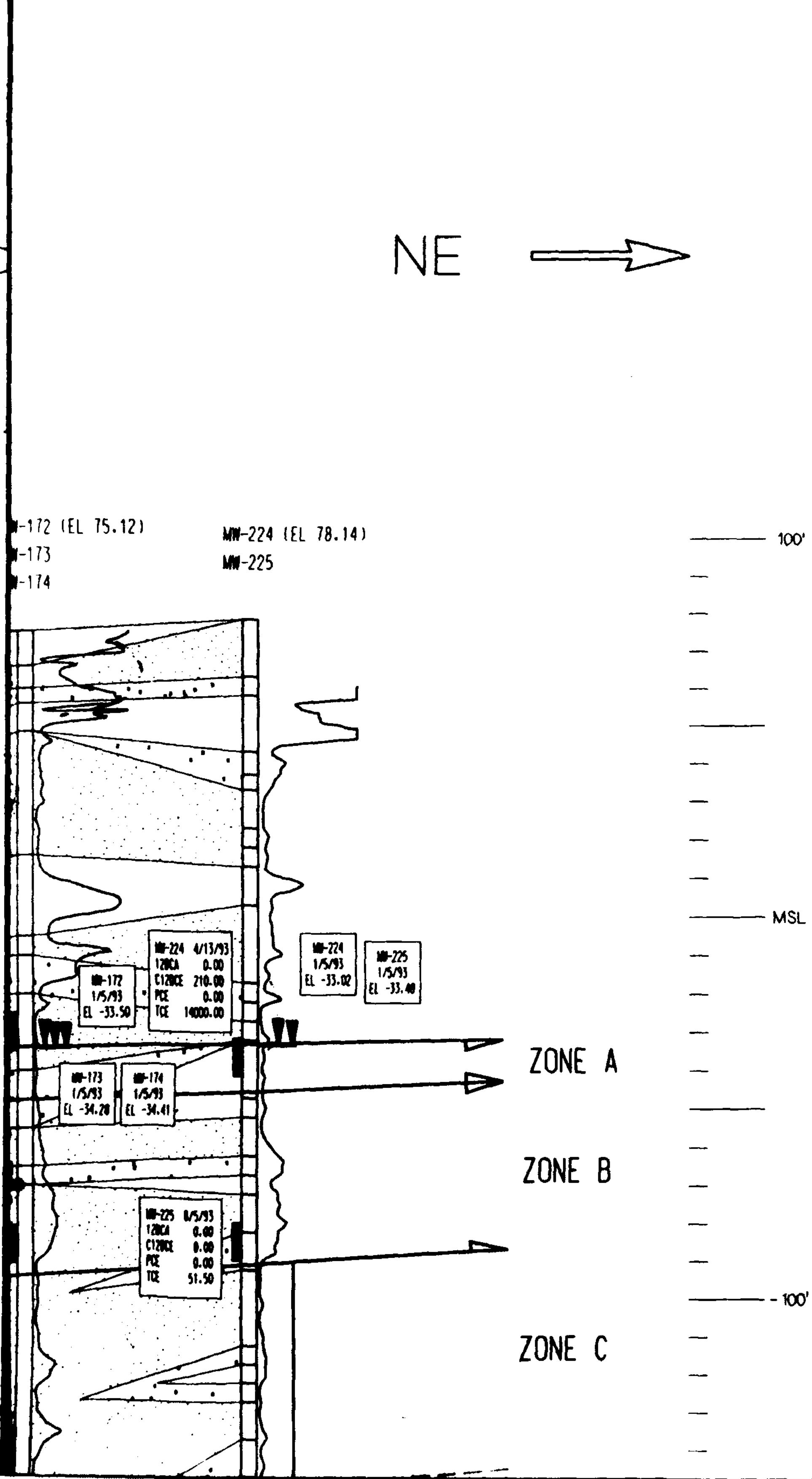


MW-175 (EL 66.28)
MW-176
MW-177
MW-186 (EL 71.18)
MW-187
(EL 71.03) MW-203
MW-204
MW-205
MW-209 (EL 68.0)
MW-186 8/5/91
120CA 0.00
C120CE 0.00
PCE 0.00
TCE 43.00
MW-177 1/5/93 EL -41.23
MW-176 1/5/93 EL -41.95
MW-175 1/5/93 EL -41.10
MW-186 1/5/93
MW-187 1/5/93 EL -39.10
MW-205 1/5/93 EL -37.56
MW-204 1/5/93 EL -37.43
MW-203 1/5/93 EL -36.35
MW-209 1/5/93 EL -36.30
MW-203 7/9/91
120CA 0.00
C120CE 0.00
PCE 0.00
TCE 19.00
MW-209 8/9/91
120CA 0.00
C120CE 0.00
PCE 0.00
TCE 3000.00
MW-209 120.5′
RADIAN
MW-204 8/4/93
120CA 0.00
C120CE 0.00
PCE 0.00
TCE 0.51
MW-205 8/4/93
120CA 0.00
C120CE 0.00

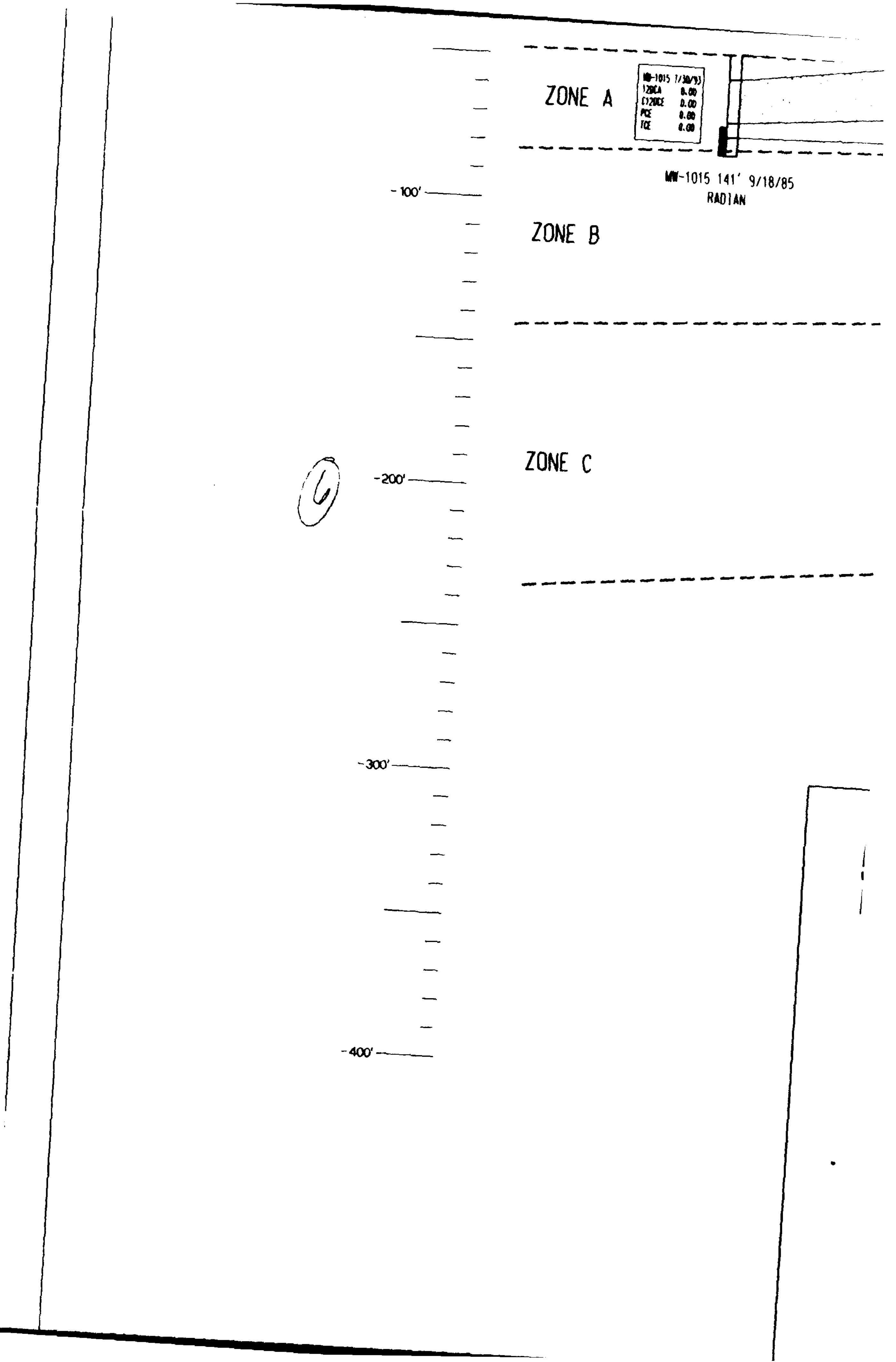
(4)

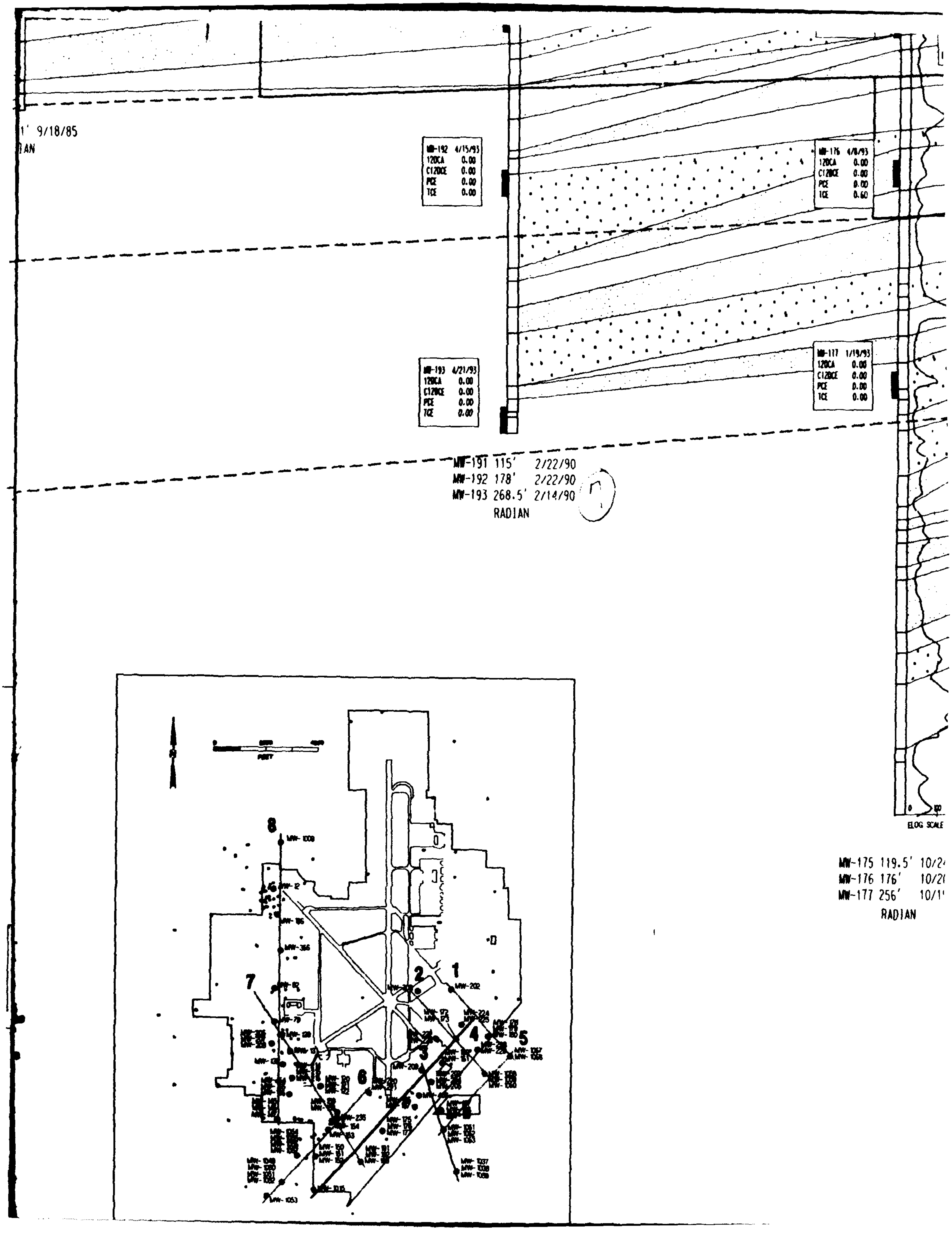
NE


MW-203
MW-204
MW-205
MW-209 (EL 68.0)
MW-160 (EL 70.73)
MW-161
MW-172 (EL 75.12)
MW-173
MW-174
MW-224 (EL 78.14)
MW-225
MW-209 120.5' 9/13/90
RADIAN
MW-209 1/5/93 EL -36.30
MW-160 10/21/92 12DCA 6.50 C12DCE 40.00 PCE 0.00 TCE 72.00
MW-160 1/5/93 EL -35.12
MW-161 1/5/93 EL -36.05
MW-209 8/9/91 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 3000.00
MW-172 8/9/91 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 17000.00
MW-172 1/5/93 EL -33.50
MW-224 4/13/93 12DCA 0.00 C12DCE 210.00 PCE 0.00 TCE 14000.00
MW-224 1/5/93 EL -33.02
MW-225 1/5/93 EL -33.48
MW-173 1/5/93 EL -34.28
MW-174 1/5/93 EL -34.41
MW-173 7/29/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 257.00
MW-225 8/5/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 51.50
MW-161 7/26/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.97
MW-174 4/13/93
ZON
ZONI
ZONI

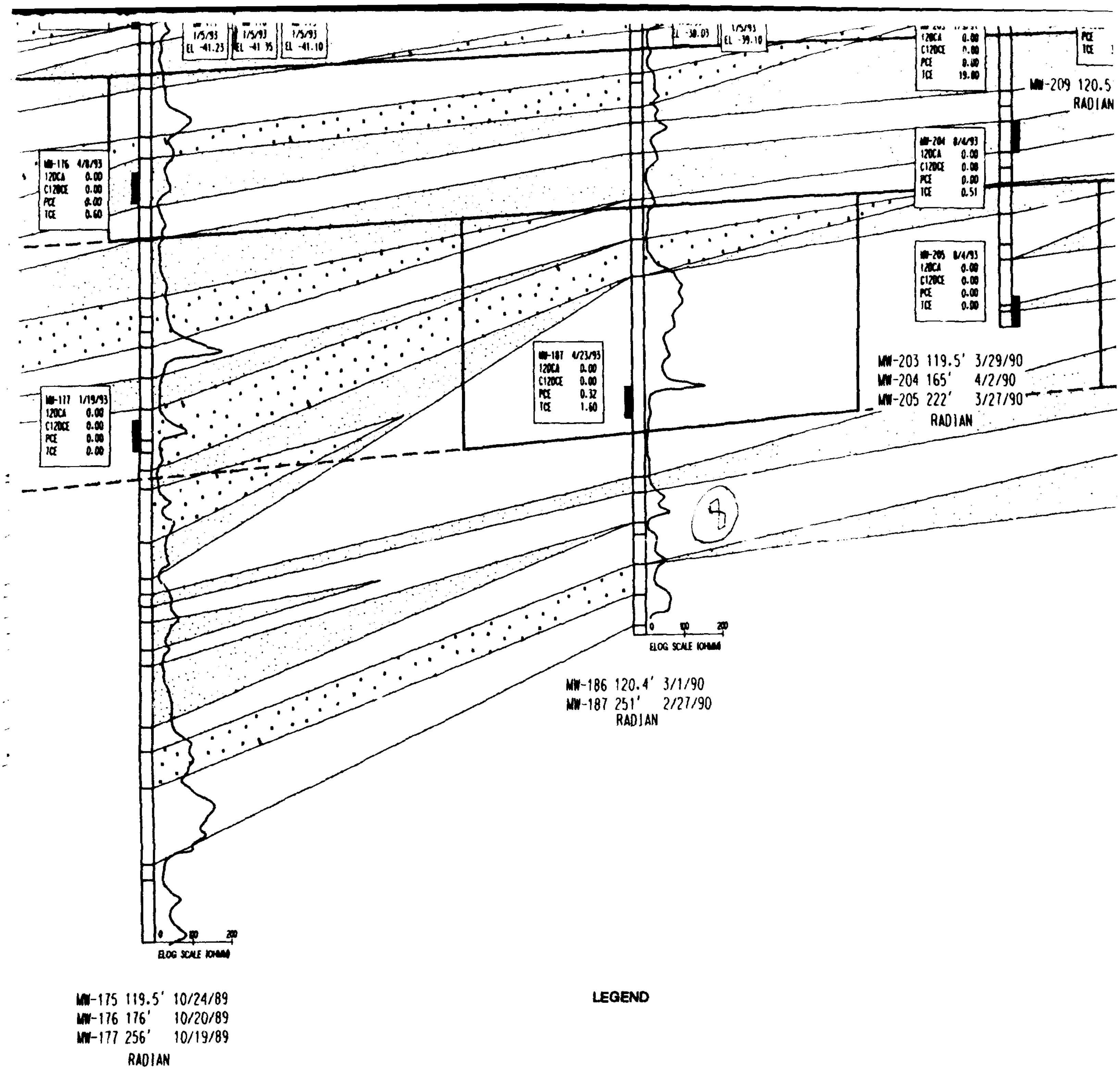


5
NE
-172 (EL 75.12)
-173
-174
MW-224 (EL 78.14)
MW-225
100'
MSL
-100'
MW-224 4/13/93
12DCA 0.00
C12DCE 210.00
PCE 0.00
TCE 14000.00
MW-172
1/5/93
EL -33.50
MW-224
1/5/93
EL -33.02
MW-225
1/5/93
EL -33.40
MW-173
1/5/93
EL -34.28
MW-174
1/5/93
EL -34.41
MW-225
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 51.50
ZONE A
ZONE B
ZONE C


ZONE A
1015 7/30/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1015 141' 9/18/85
RADIAN
-100'
ZONE B
ZONE C
-200'
-300'
-400'

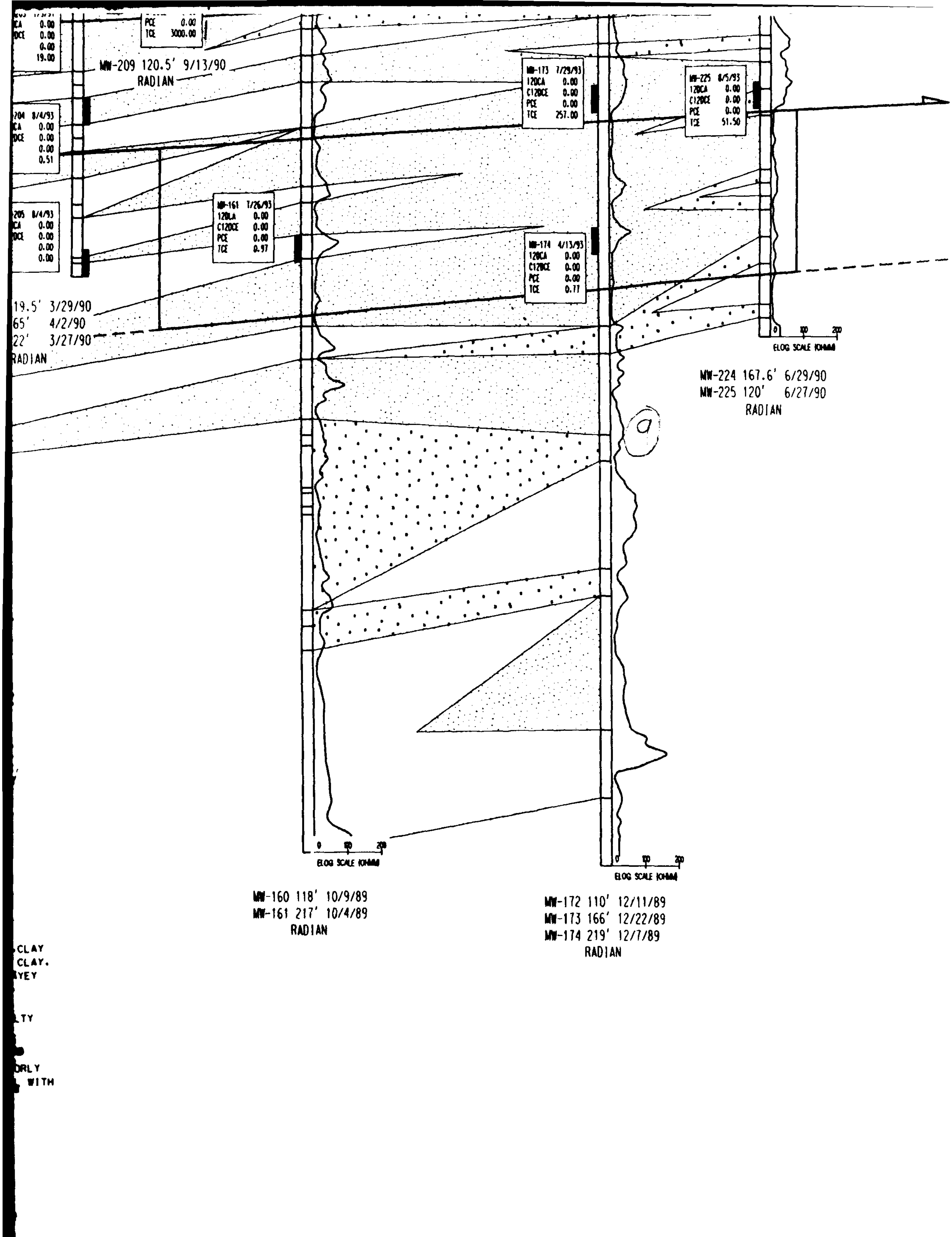


1' 9/18/85
IAN
MW-192 4/15/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-176 4/8/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.60
MW-193 4/21/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-177 1/19/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-191 115' 2/22/90
MW-192 178' 2/22/90
MW-193 268.5' 2/14/90
RADIAN
ELOG SCALE
MW-175 119.5' 10/2
MW-176 176' 10/2
MW-177 256' 10/1
RADIAN
8
7
6
5
4
3
2
1
MW-1009
MW-202
MW-1053



LEGEND

(fine-grained pattern)	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 pattern)	MEDIUM-GRAINED MATERIALS INCLUDE SILTY OR CLAYEY SAND OR GRAVEL
(coarse-grained pattern)	COARSE-GRAINED MATERIALS INCLUDE POORLY GRADED OR WELL GRADED SAND OR GRAVEL WITH LESS THAN 5% FINES



PCE 0.00
TCE 3000.00
0.00
0.00
0.00
19.00
MW-209 120.5' 9/13/90
RADIAN
0.00
0.00
0.00
0.51
0.00
0.00
0.00
0.00
MW-161 7/26/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.97
MW-173 7/29/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 257.00
MW-174 4/13/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.77
MW-225 8/5/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 51.50
19.5' 3/29/90
65' 4/2/90
22' 3/27/90
RADIAN
0 100 200
ELOG SCALE (OHMS)
MW-224 167.6' 6/29/90
MW-225 120' 6/27/90
RADIAN
a
MW-160 118' 10/9/89
MW-161 217' 10/4/89
RADIAN
MW-172 110' 12/11/89
MW-173 166' 12/22/89
MW-174 219' 12/7/89
RADIAN
CLAY
CLAY.
YEY
TY
RLY
WITH

FIGURE 3-4

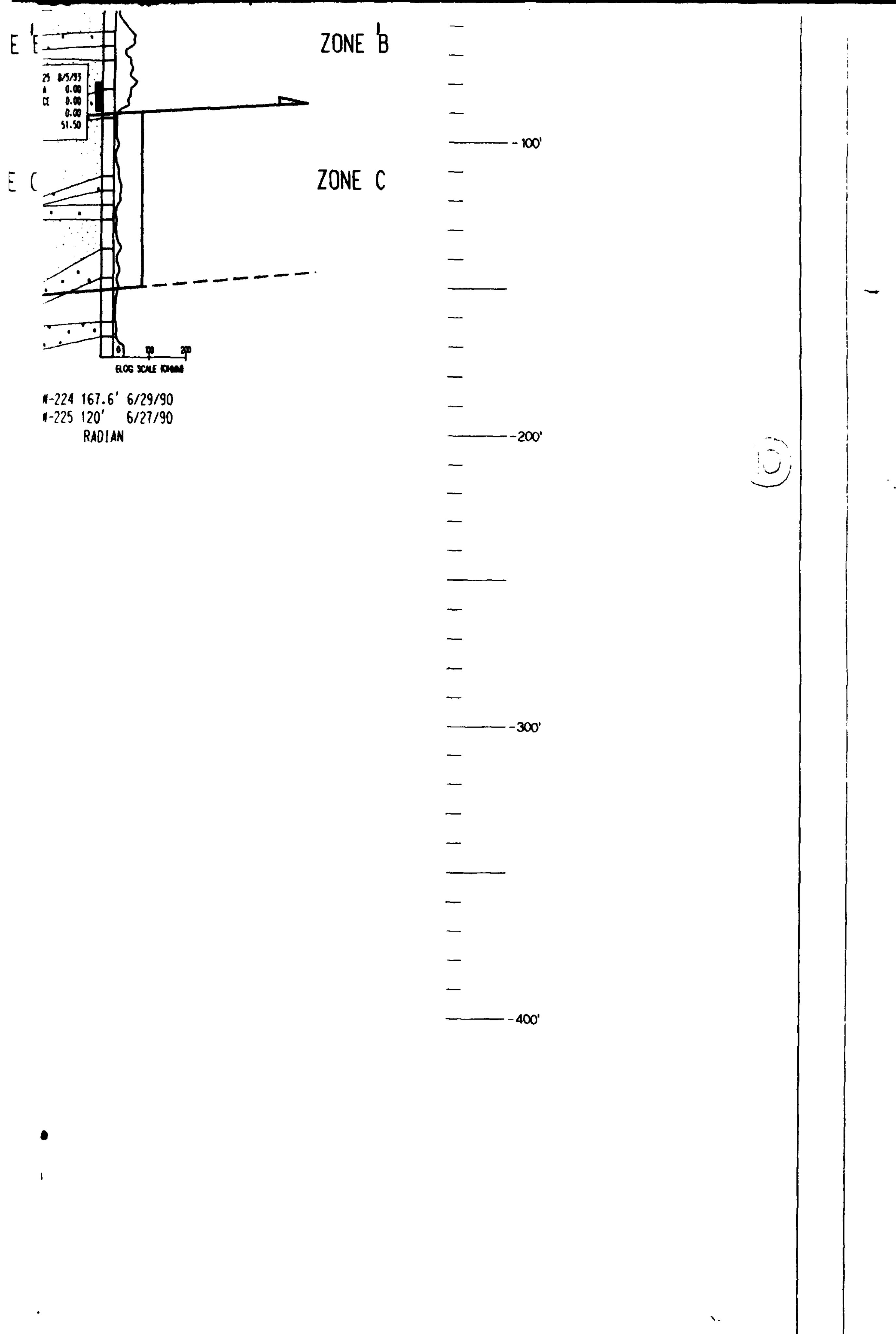
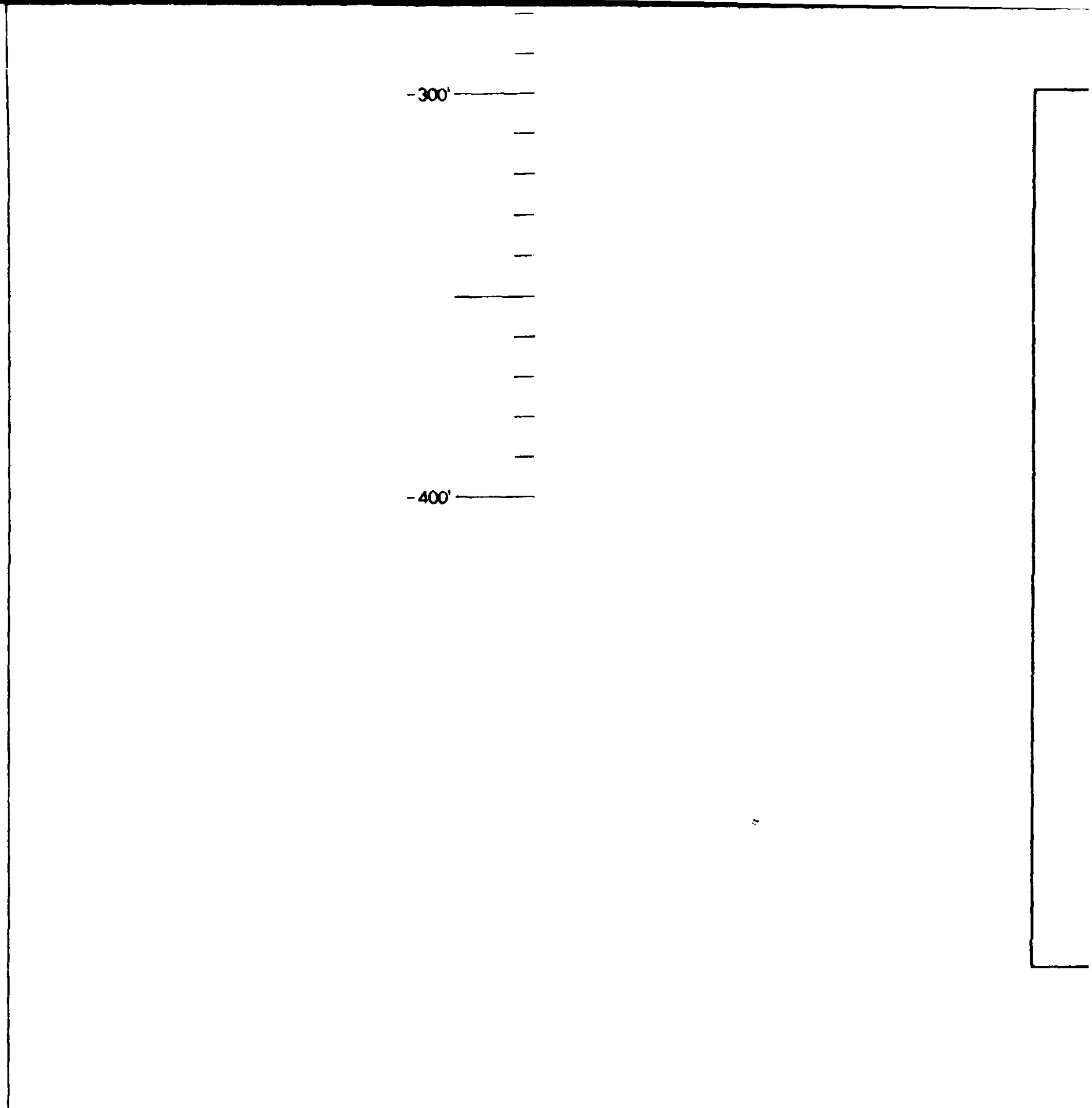
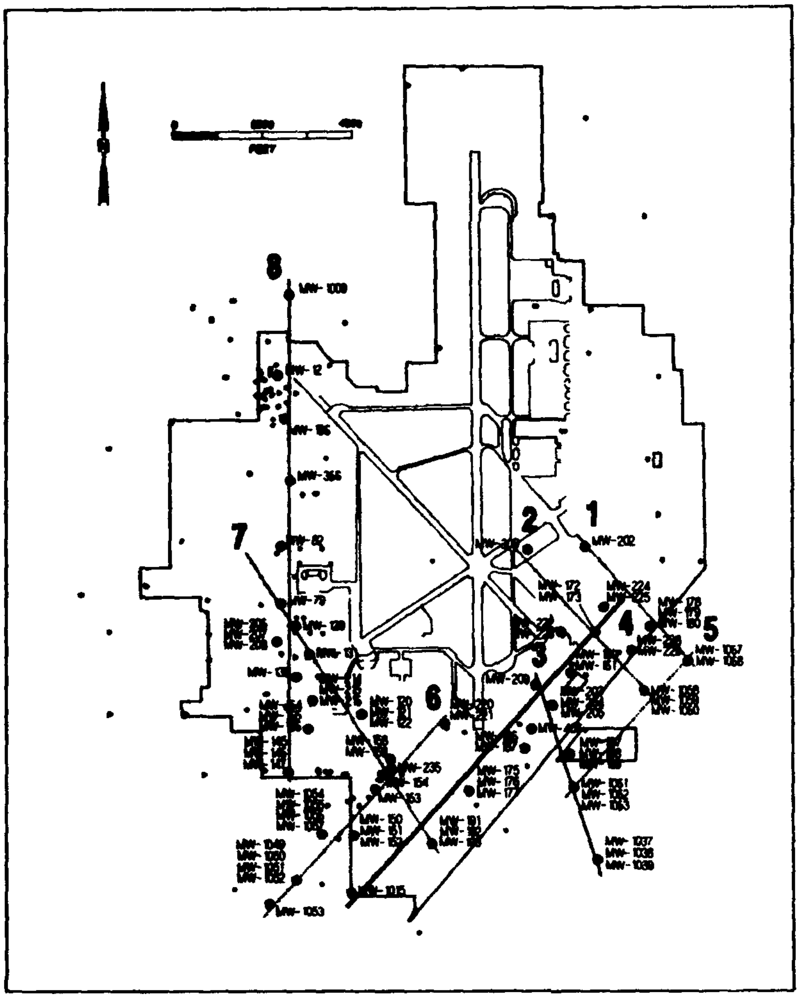

ZONE B
ZONE C
-100'
-200'
-300'
-400'
ELOG SCALE (OHMS)
#-224 167.6' 6/29/90
#-225 120' 6/27/90
RADIAN

FIGURE 3-4


-300'
-400'



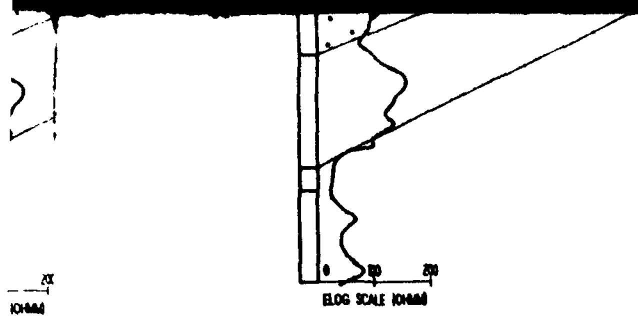
SITE MAP

MW-175 119.5

MW-176 176'

MW-177 256'

RADI



4/89 MW-175 119.5' 10/24/89
0/89 MW-176 176' 10/20/89
9/89 MW-177 256' 10/19/89

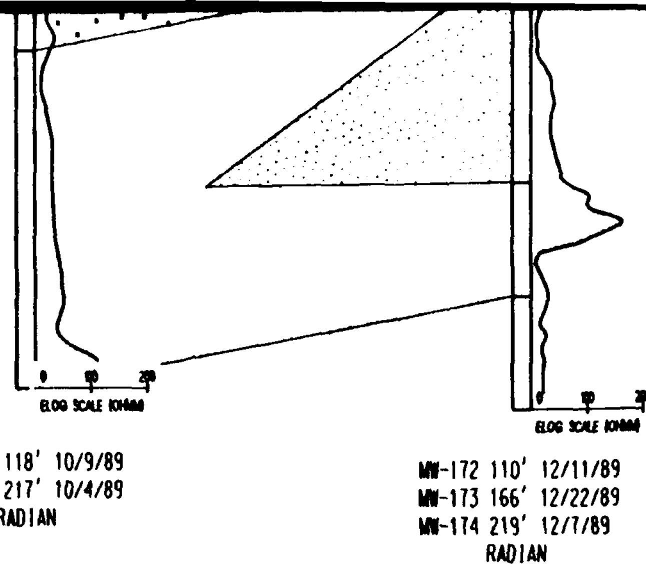
RADIAN

LEGEND

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



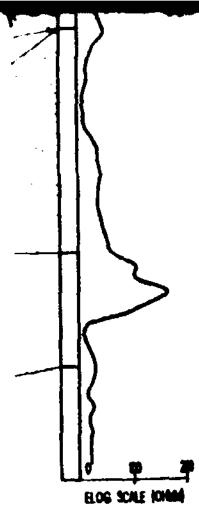
LUDE SILT.CLAY
Y SILT OR CLAY.
AY.AND CLAYEY

NCLUDE SILTY

NCLUDE POORLY
OR GRAVEL WITH

FIGURE
CROSS
GROUNDW
McCLELL
SACRAME

(14)



'2 110' 12/11/89
'3 166' 12/22/89
'4 219' 12/7/89
RADIAN

-300'

-400'

SI
TE
I /
TO

FIGURE 3-4

CROSS SECTION 4

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

LEGEND

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

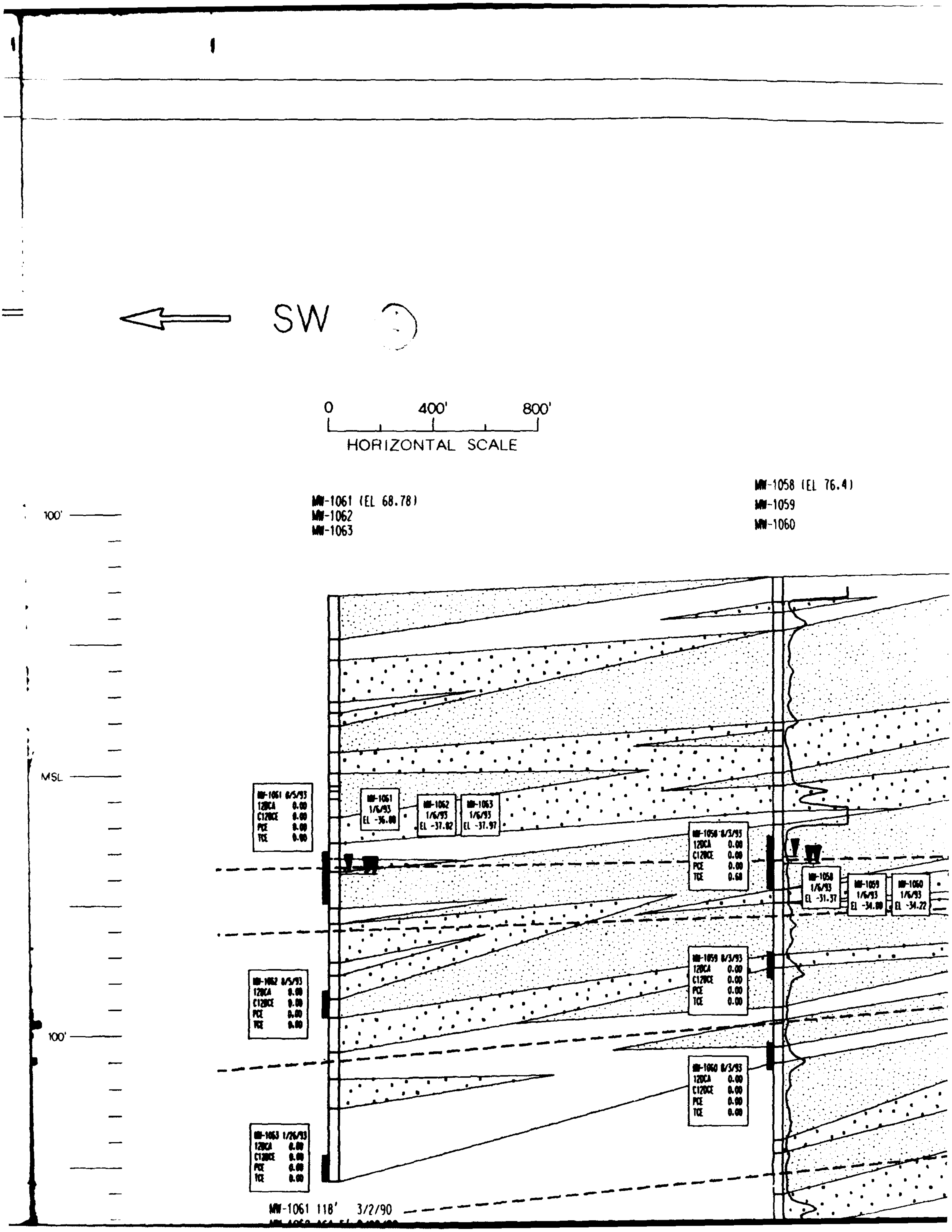
MEDIUM-GRAINED MATERIALS INCLUDE SILTY OR CLAYEY SAND OR GRAVEL

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

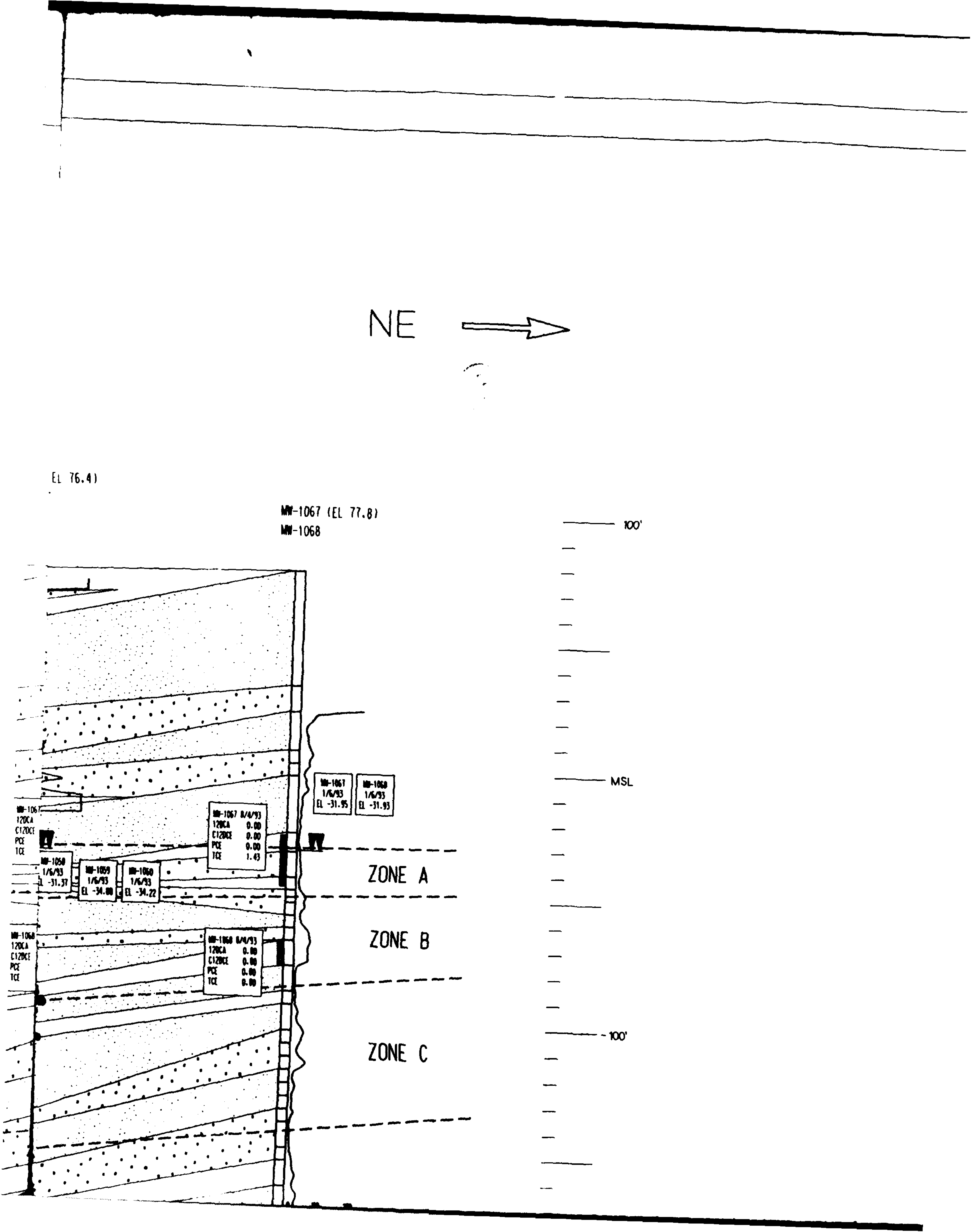
NOTES:

1. Flow direction of depositional channels is approximately parallel to the cross section. Groundwater generally follows the course of the channel deposits, but is strongly influenced by regional pumping south of the Base.

2. Groundwater levels in MW-1059, MW-1060, MW-1061, MW-1062, and MW-1066 have dropped more than 30 feet between first and third quarter measurements, while other wells in the cross section have dropped less than ten feet over the same period.



SW
0
400'
800'
HORIZONTAL SCALE
MW-1061 (EL 68.78)
MW-1062
MW-1063
MW-1058 (EL 76.4)
MW-1059
MW-1060
100'
MSL
100'
MW-1061 8/5/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1061
1/6/93
EL -36.00
MW-1062
1/6/93
EL -37.02
MW-1063
1/6/93
EL -37.97
MW-1058 8/3/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.68
MW-1058
1/6/93
EL -31.37
MW-1059
1/6/93
EL -34.00
MW-1060
1/6/93
EL -34.22
MW-1059 8/3/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1062 8/5/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1060 8/3/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1063 1/26/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1061 118' 3/2/90



NE
EL 76.41
MW-1067 (EL 77.8)
MW-1068
100'
MSL
100'
MW-1067 1/6/93 EL -31.95
MW-1068 1/6/93 EL -31.93
120CA 0.00
C12DCE 0.00
PCE 0.00
TCE 1.43
ZONE A
ZONE B
ZONE C

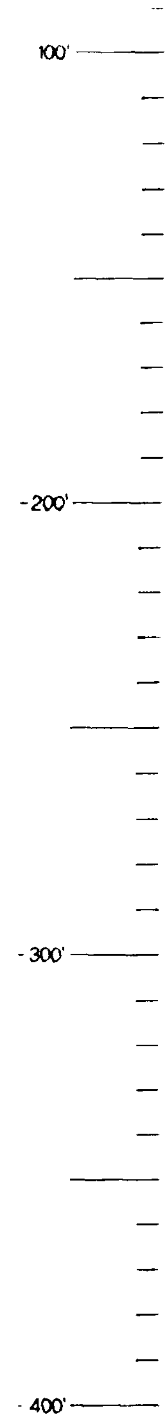
OR CLAYEY SAND OR GRAVEL

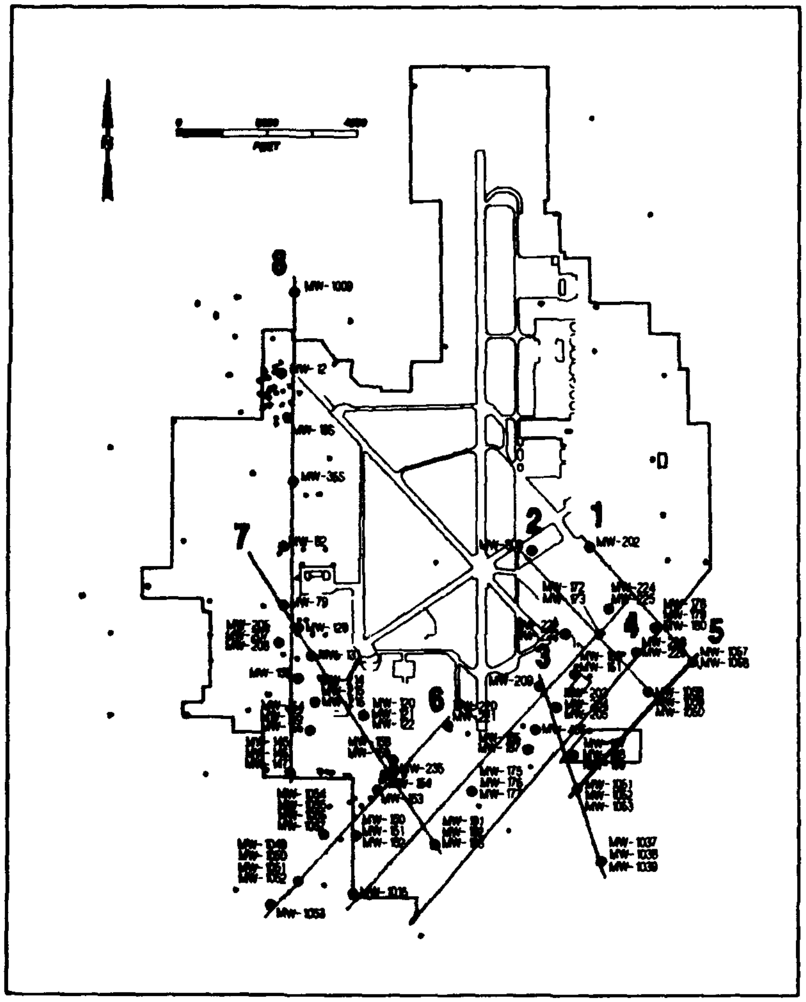
COARSE-GRAINED MATERIALS INCLUDE POORLY GRADED OR WELL GRADED SAND OR GRAVEL WITH LESS THAN 5% FINES

NOTES:

1. Flow direction of depositional channels is approximately parallel to the cross section. Groundwater generally follows the course of the channel deposits, but is strongly influenced by regional pumping south of the Base.

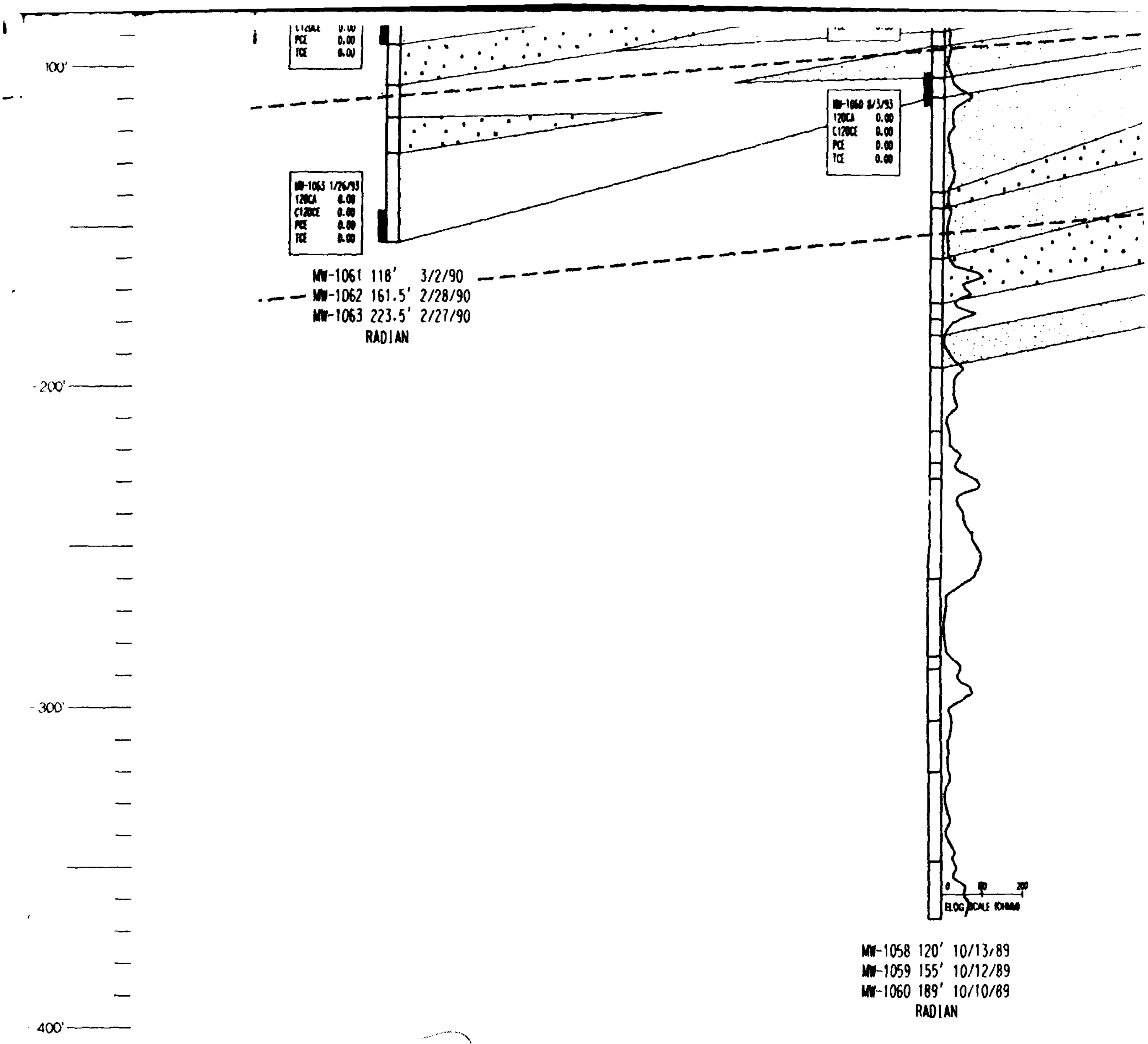
2. Groundwater levels in MW-1059, MW-1060, MW-1061, MW-1062, and MW-1068 have dropped more than 30 feet between first and third quarter measurements, while other wells in the cross section have dropped less than ten feet over the same period.





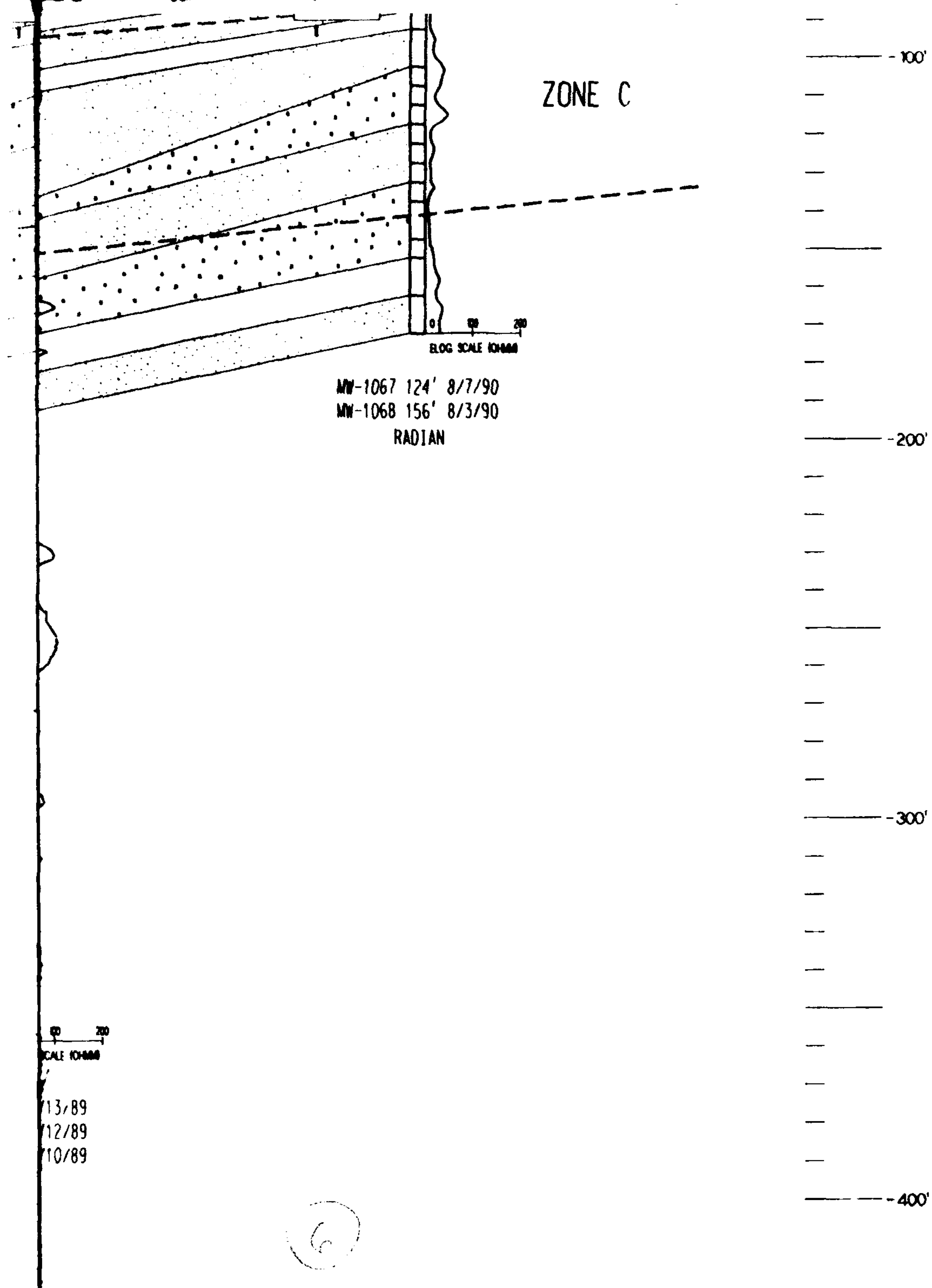
SITE MAP

(4)



PCE 0.00
TCE 0.00
100'
MW-1060 8/3/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1063 1/26/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1061 118' 3/2/90
MW-1062 161.5' 2/28/90
MW-1063 223.5' 2/27/90
RADIAN
-200'
-300'
0 100 200
ELOG SCALE (OHMS)
MW-1058 120' 10/13/89
MW-1059 155' 10/12/89
MW-1060 189' 10/10/89
RADIAN
400'

5



ZONE C
0
100
200
ELOG SCALE (OHMS)
MW-1067 124' 8/7/90
MW-106B 156' 8/3/90
RADIAN
-100'
-200'
-300'
-400'
/13/89
/12/89
/10/89

FIGURE 3-5

-200'

-300'

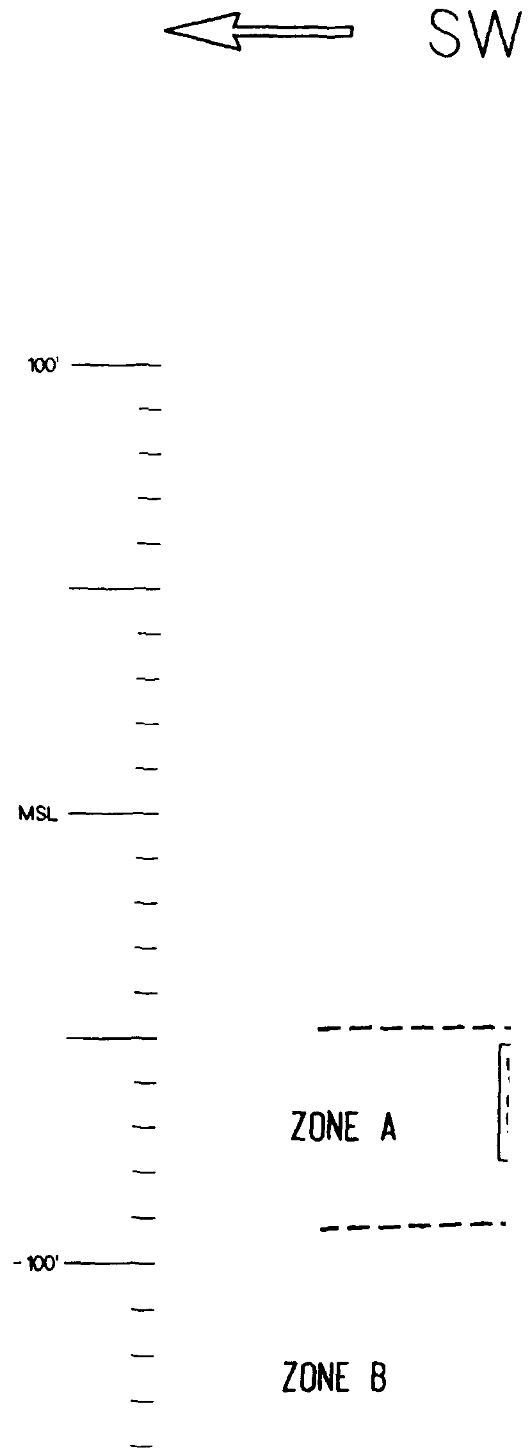
-400'

FIGURE 3-5

CROSS SECTION 5

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

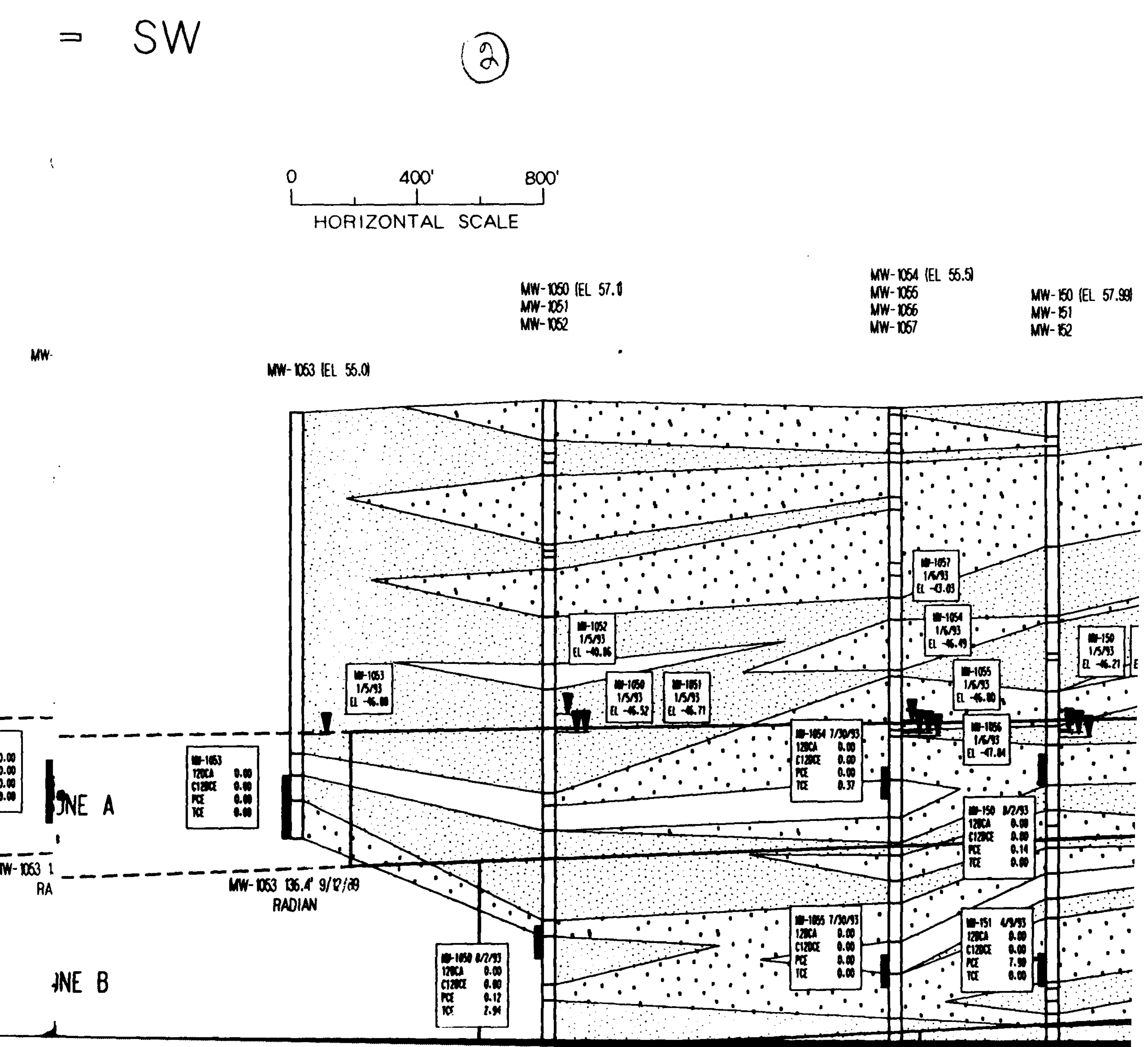


LEGEND

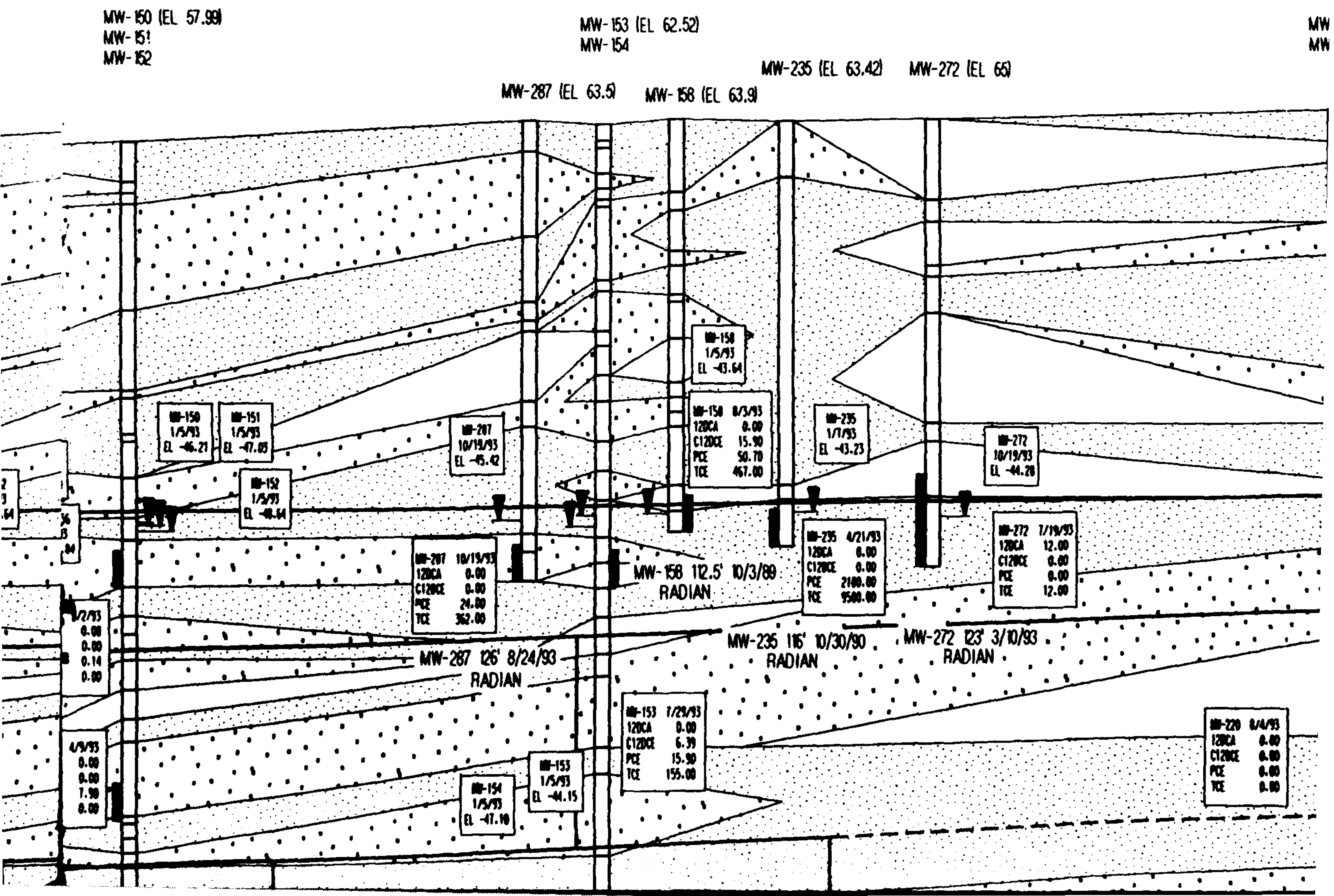
FINE-GRAINED MATERIALS INCLUDE SILT, CLAY SANDY SILT OR CLAY, GRAVELLY SILT OR CLAY, LEAN AND FAT CLAY, SILTY CLAY, AND CLAYEY SILT

MEDIUM-GRAINED MATERIALS INCLUDE SILTY OR CLAYEY SAND OR GRAVEL

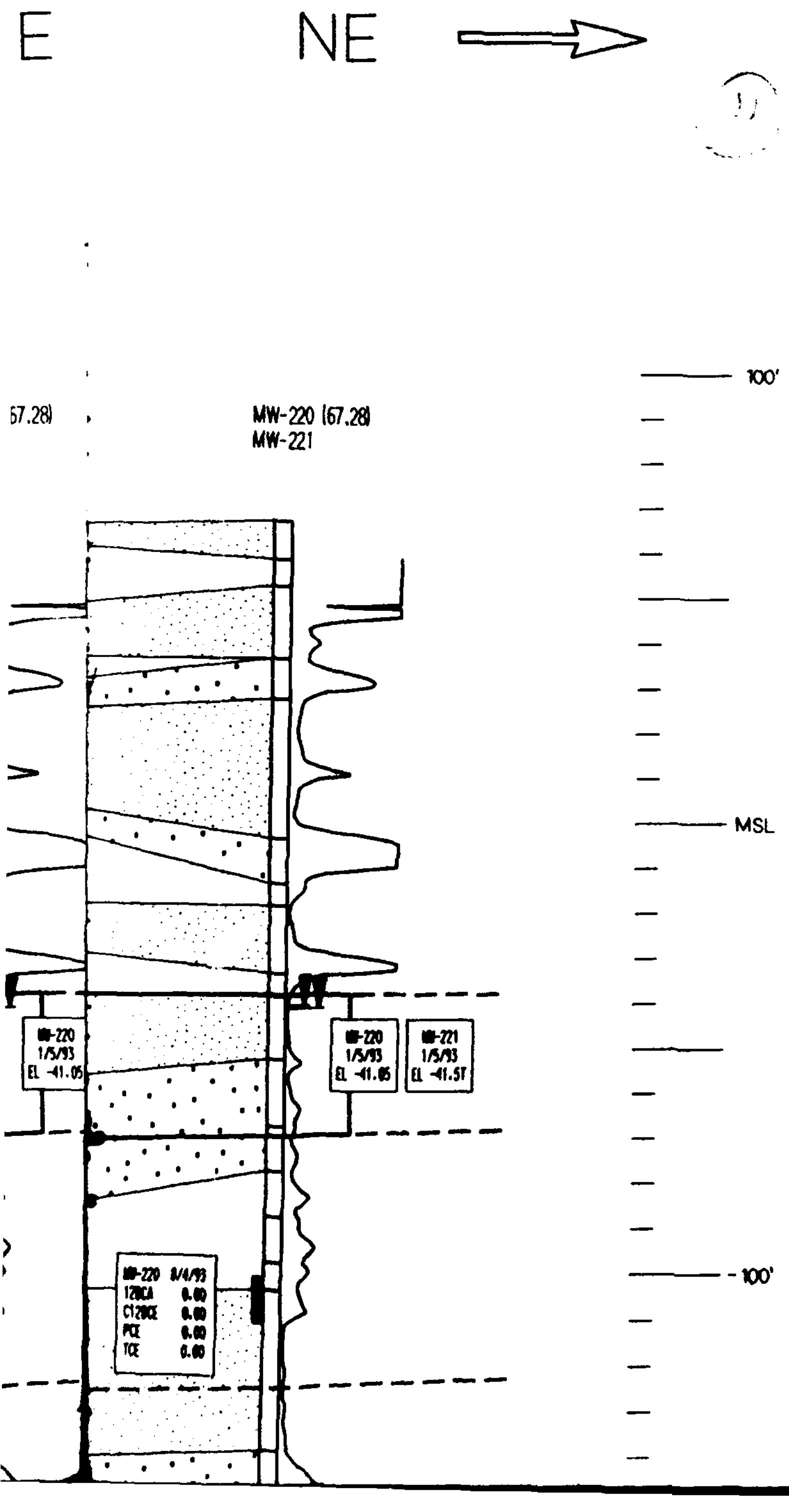
COARSE-GRAINED MATERIALS INCLUDE POORLY GRADED OR WELL GRADED SAND OR GRAVEL WITH LESS THAN 5% FINES


SW
0
400'
800'
HORIZONTAL SCALE
MW-1050 (EL 57.0)
MW-1051
MW-1052
MW-1054 (EL 55.5)
MW-1055
MW-1056
MW-1057
MW-150 (EL 57.99)
MW-151
MW-152
MW-1053 (EL 55.0)
ZONE A
MW-1053 136.4' 9/12/89
RADIAN
ZONE B
MW-1053
120CA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1054 7/30/93
120CA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.37
MW-150 8/2/93
120CA 0.00
C12DCE 0.00
PCE 0.14
TCE 0.00
MW-1055 7/30/93
120CA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-151 4/9/93
120CA 0.00
C12DCE 0.00
PCE 7.90
TCE 0.00
MW-1050 8/2/93
120CA 0.00
C12DCE 0.00
PCE 0.12
TCE 2.94

3



MW-150 (EL 57.99)
MW-151
MW-152
MW-153 (EL 62.52)
MW-154
MW-235 (EL 63.42)
MW-272 (EL 65)
MW-287 (EL 63.5)
MW-158 (EL 63.9)
MW-150 1/5/93 EL -46.21
MW-151 1/5/93 EL -47.05
MW-152 1/5/93 EL -48.64
MW-287 10/19/93 EL -45.42
MW-158 1/5/93 EL -43.64
MW-158 8/3/93 120CA 0.00 C12DCE 15.90 PCE 50.70 TCE 467.00
MW-235 1/7/93 EL -43.23
MW-272 10/19/93 EL -44.28
MW-287 10/19/93 120CA 0.00 C12DCE 0.00 PCE 24.00 TCE 362.00
MW-158 112.5' 10/3/89
RADIAN
MW-235 4/21/93 120CA 0.00 C12DCE 0.00 PCE 2100.00 TCE 9500.00
MW-272 7/19/93 120CA 12.00 C12DCE 0.00 PCE 0.00 TCE 12.00
MW-287 126' 8/24/93
RADIAN
MW-235 116' 10/30/90
RADIAN
MW-272 123' 3/10/93
RADIAN
MW-153 7/29/93 120CA 0.00 C12DCE 6.39 PCE 15.90 TCE 155.00
MW-153 1/5/93 EL -44.15
MW-154 1/5/93 EL -47.10
MW-220 8/4/93 120CA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00



E
NE
100'
67.28)
MW-220 (67.28)
MW-221
MW-220 1/5/93 EL -41.05
MW-220 1/5/93 EL -41.05
MW-221 1/5/93 EL -41.57
MSL
MW-220 8/4/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
-100'

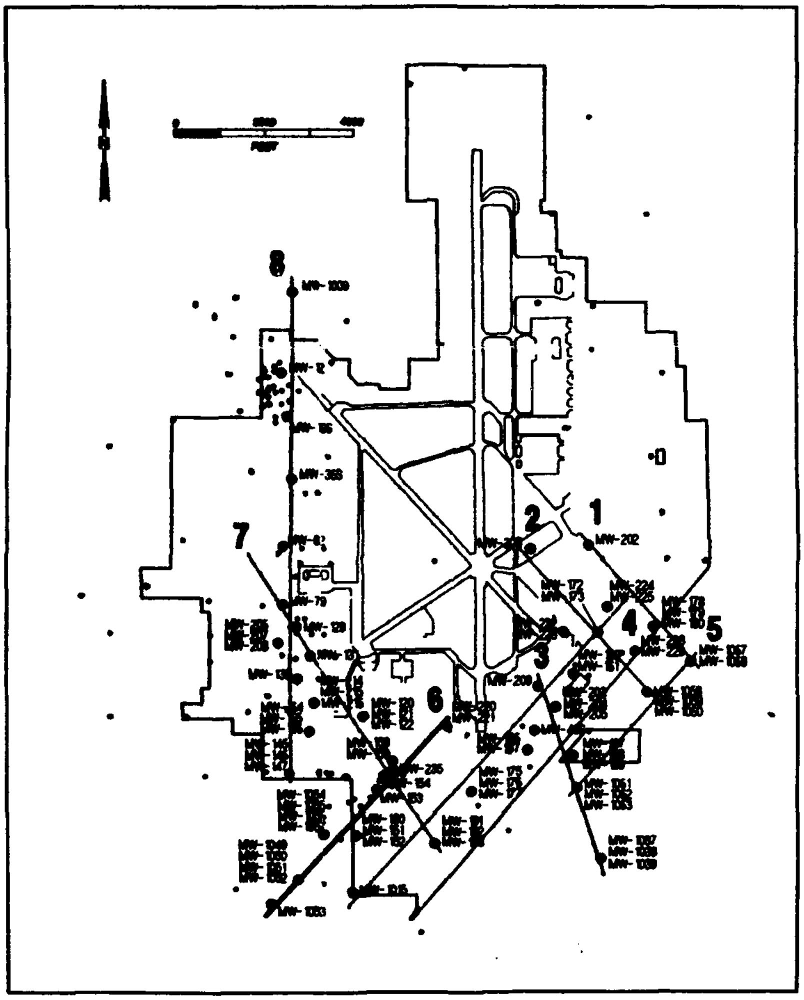
LEAN AND FAT CLAY, SILTY CLAY, AND CLAYEY SILT

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

-100'

-200'

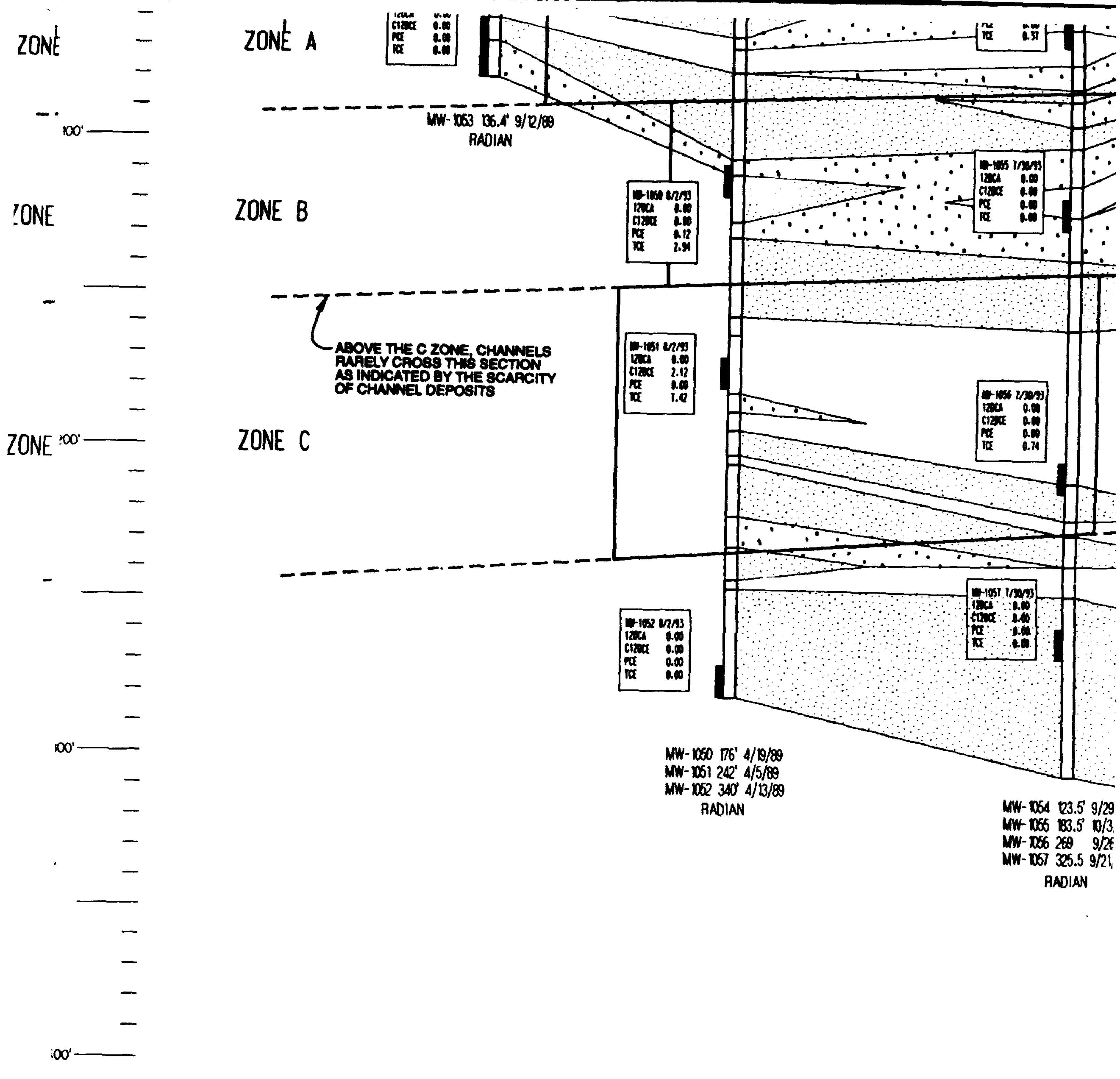


-300'

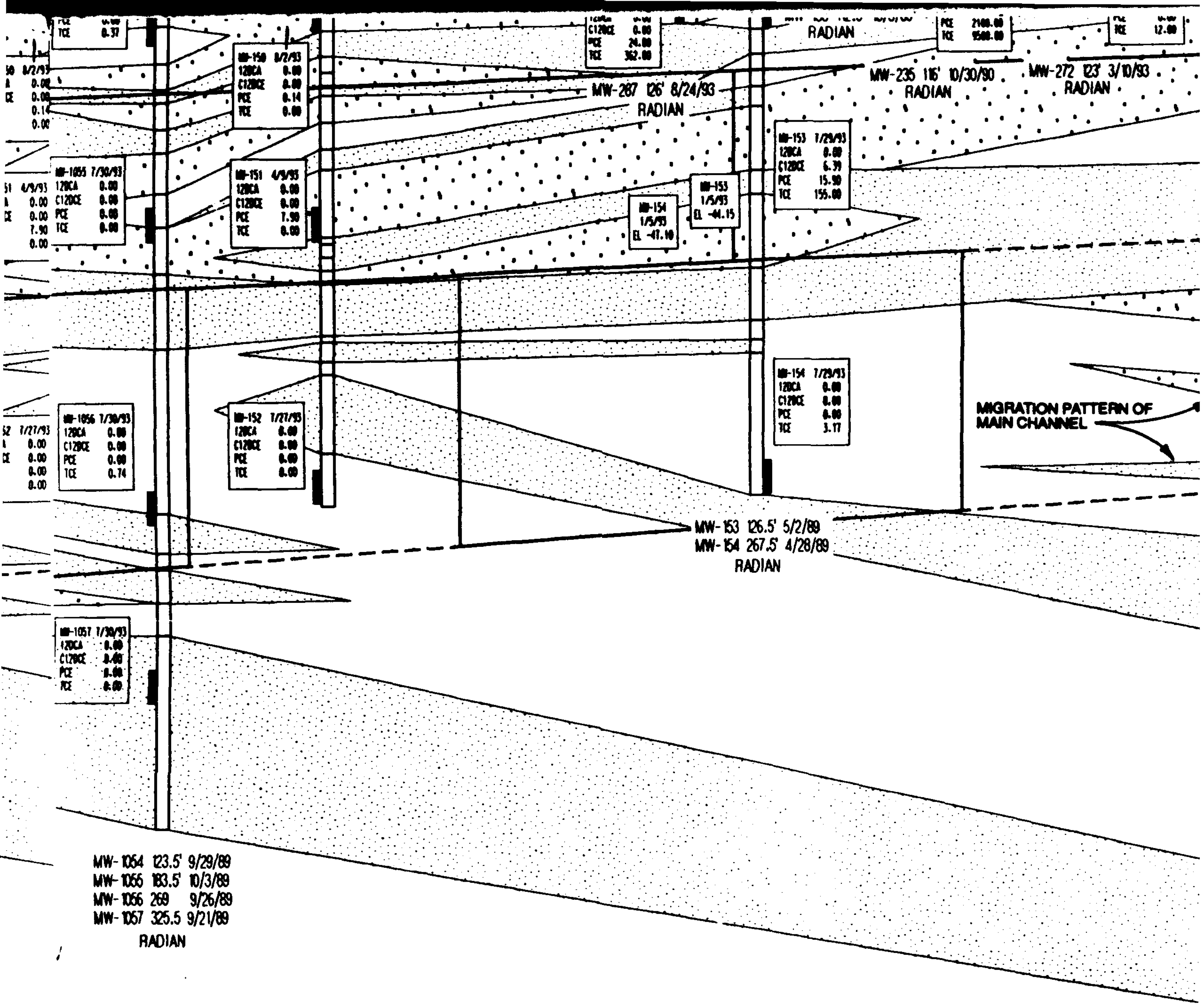
SITE MAP

-400'

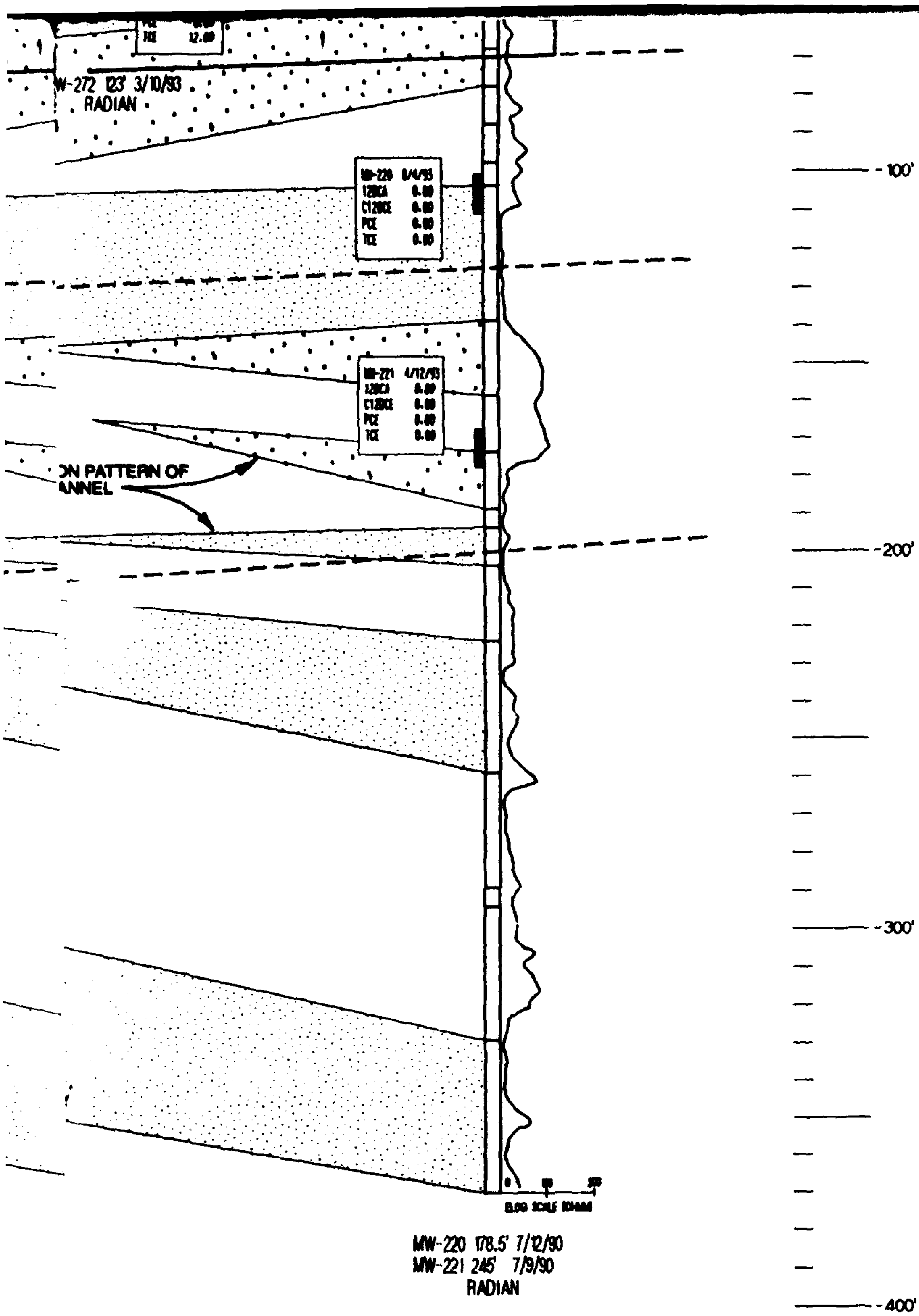
5


ZONE
ZONE A
ZONE
ZONE B
ZONE
ZONE C
100'
200'
300'
400'
C12DCE 0.00
PCE 0.00
TCE 0.00
TCE 0.37
MW-1053 136.4' 9/12/89
RADIAN
MW-1050 8/2/93
12DCA 0.00
C12DCE 0.00
PCE 0.12
TCE 2.94
MW-1055 7/30/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
ABOVE THE C ZONE, CHANNELS RARELY CROSS THIS SECTION AS INDICATED BY THE SCARCITY OF CHANNEL DEPOSITS
MW-1051 8/2/93
12DCA 0.00
C12DCE 2.12
PCE 0.00
TCE 7.42
MW-1056 7/30/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.74
MW-1057 7/30/93
12DCA 0.00
C12DCE 0.40
PCE 0.00
TCE 0.00
MW-1052 8/2/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1050 176' 4/19/89
MW-1051 242' 4/5/89
MW-1052 340' 4/13/89
RADIAN
MW-1054 123.5' 9/29
MW-1055 183.5' 10/3
MW-1056 269 9/26
MW-1057 325.5 9/21
RADIAN

6



RADIAN
MW-150 8/2/93
12DCA 0.00
C12DCE 0.00
PCE 0.14
TCE 0.00
MW-287 126' 8/24/93
RADIAN
MW-235 116' 10/30/90
RADIAN
MW-272 123' 3/10/93
RADIAN
MW-153 7/29/93
12DCA 0.00
C12DCE 6.39
PCE 15.90
TCE 155.00
MW-1055 7/30/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-151 4/9/93
12DCA 0.00
C12DCE 0.00
PCE 7.90
TCE 0.00
MW-154
1/5/93
EL -47.10
MW-153
1/5/93
EL -44.15
MW-154 7/29/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 3.17
MIGRATION PATTERN OF MAIN CHANNEL
MW-1056 7/30/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.74
MW-152 7/27/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-153 126.5' 5/2/89
MW-154 267.5' 4/28/89
RADIAN
MW-1057 7/30/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1054 123.5' 9/29/89
MW-1055 183.5' 10/3/89
MW-1056 269 9/26/89
MW-1057 325.5 9/21/89
RADIAN


TCE 12.00
W-272 123' 3/10/93
RADIAN
PCE 0.00
TCE 0.00
PCE 0.00
TCE 0.00
ON PATTERN OF
ANNEL
ELOG SCALE (OHMM)
MW-220 178.5' 7/12/90
MW-221 245' 7/9/90
RADIAN
- 100'
- 200'
- 300'
- 400'

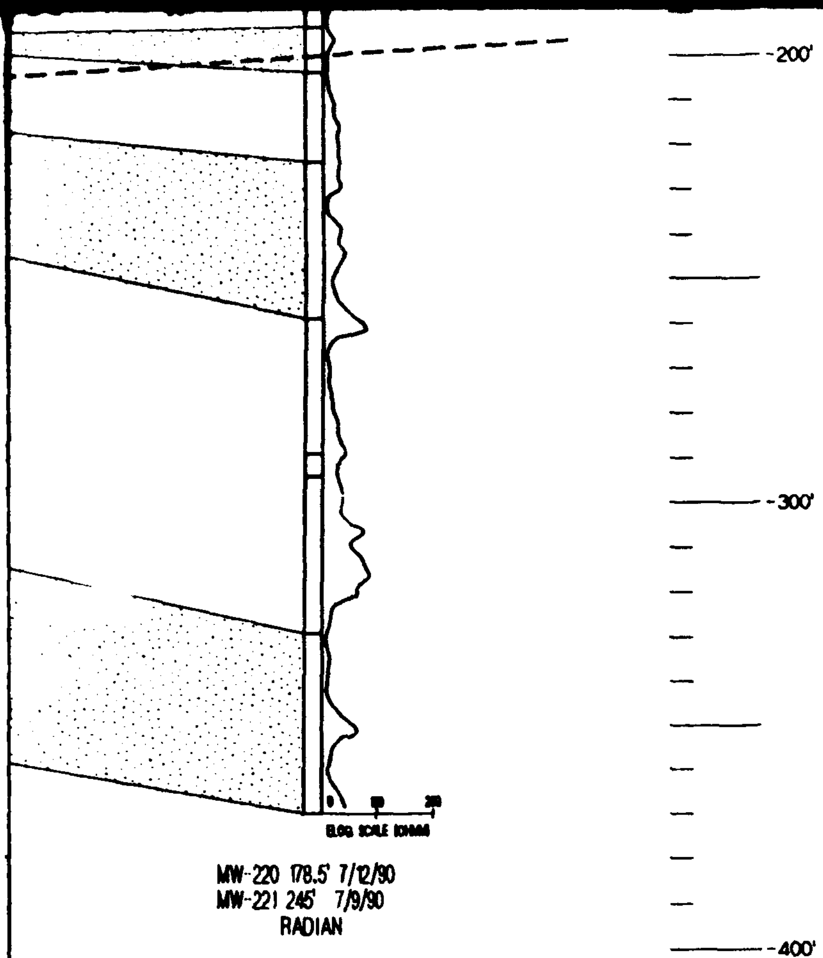


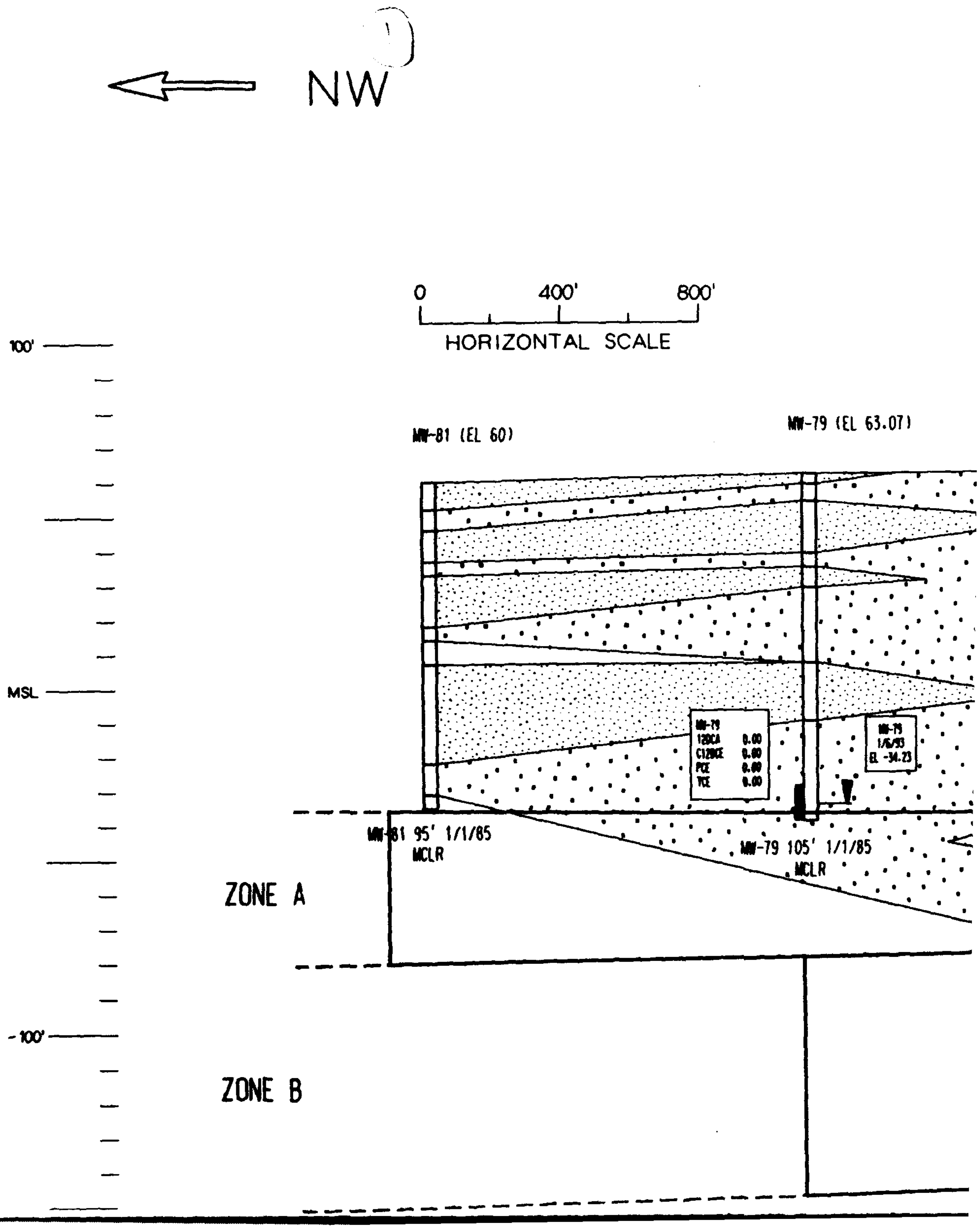
FIGURE 3-6

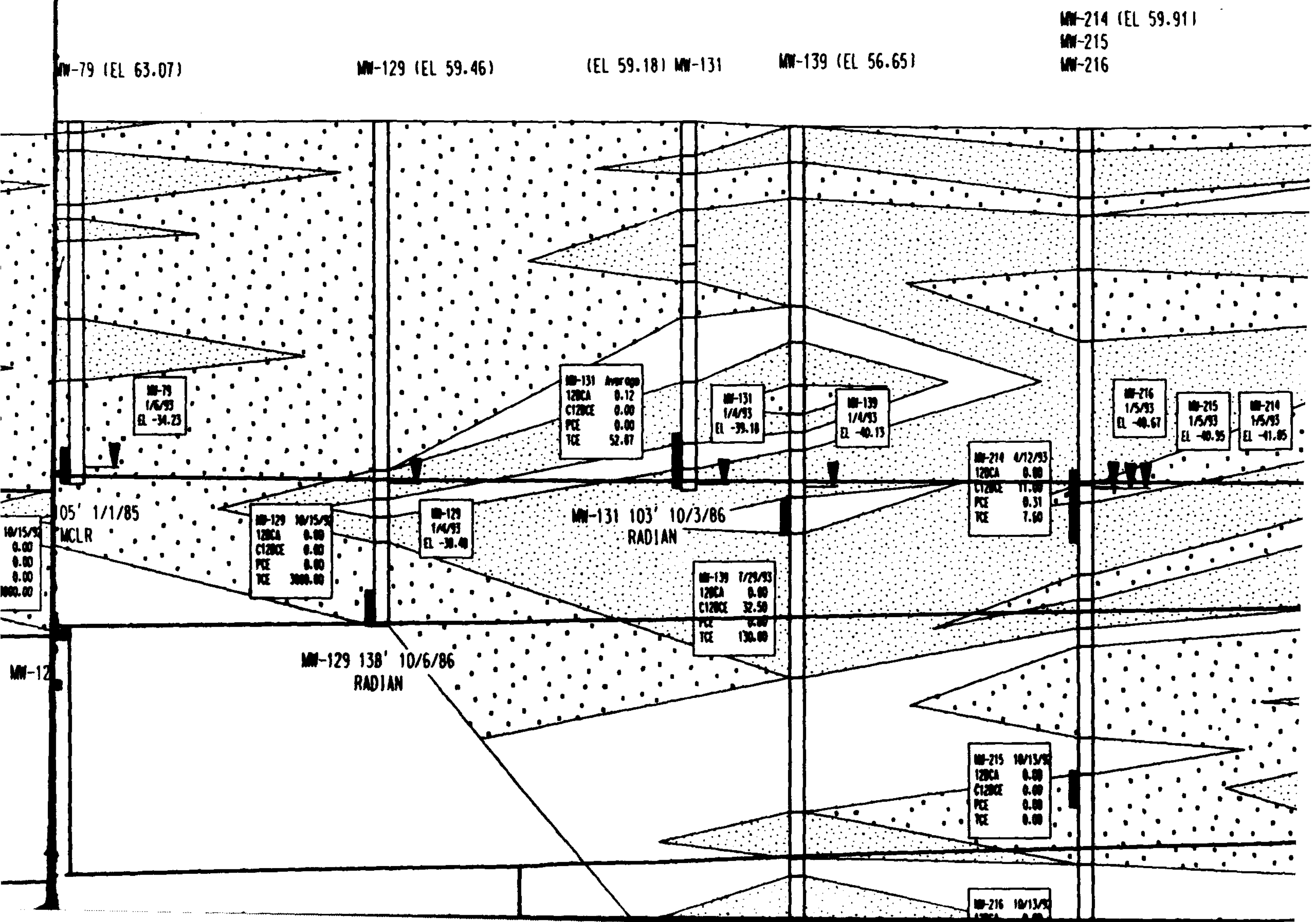
CROSS SECTION 6

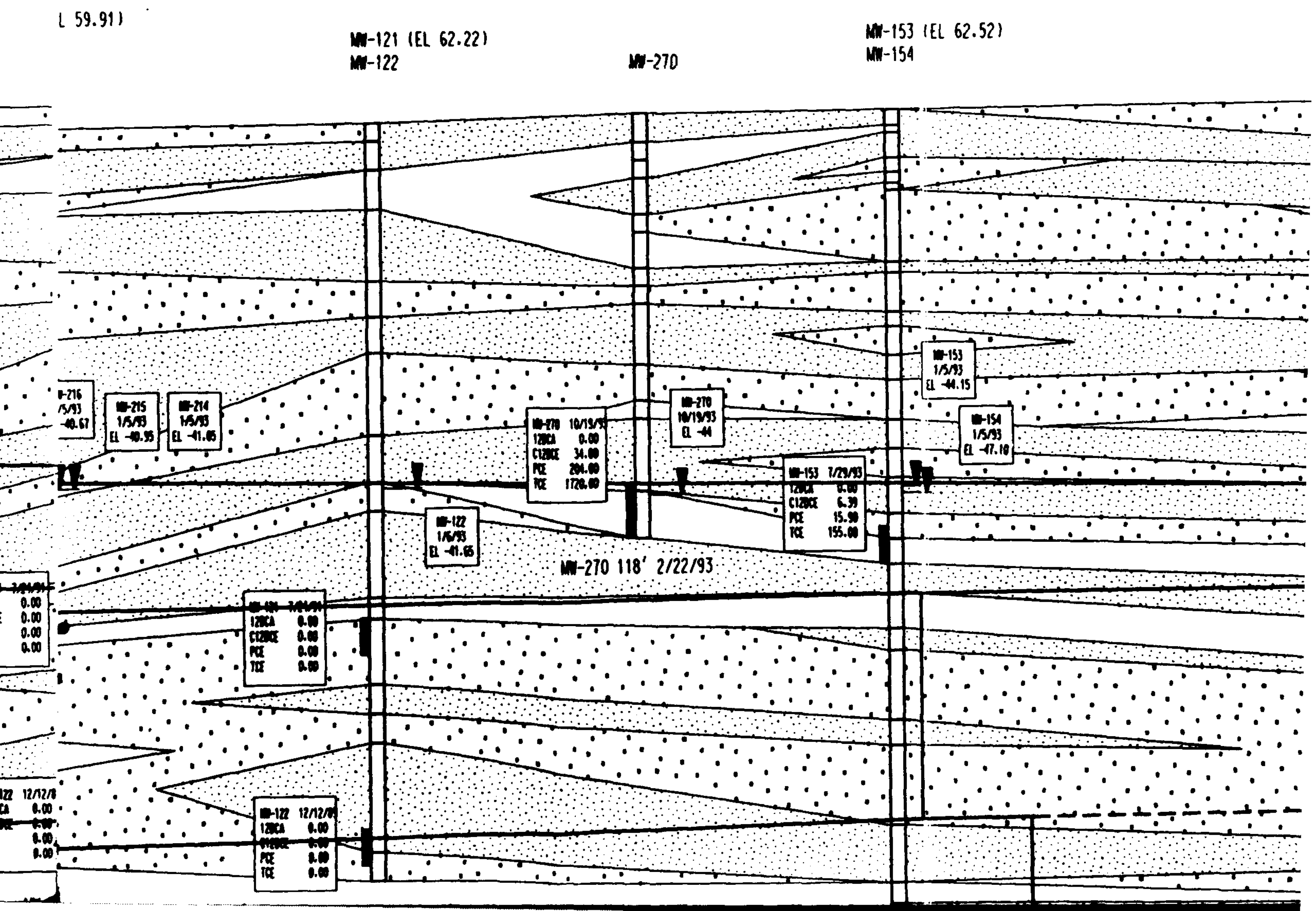
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

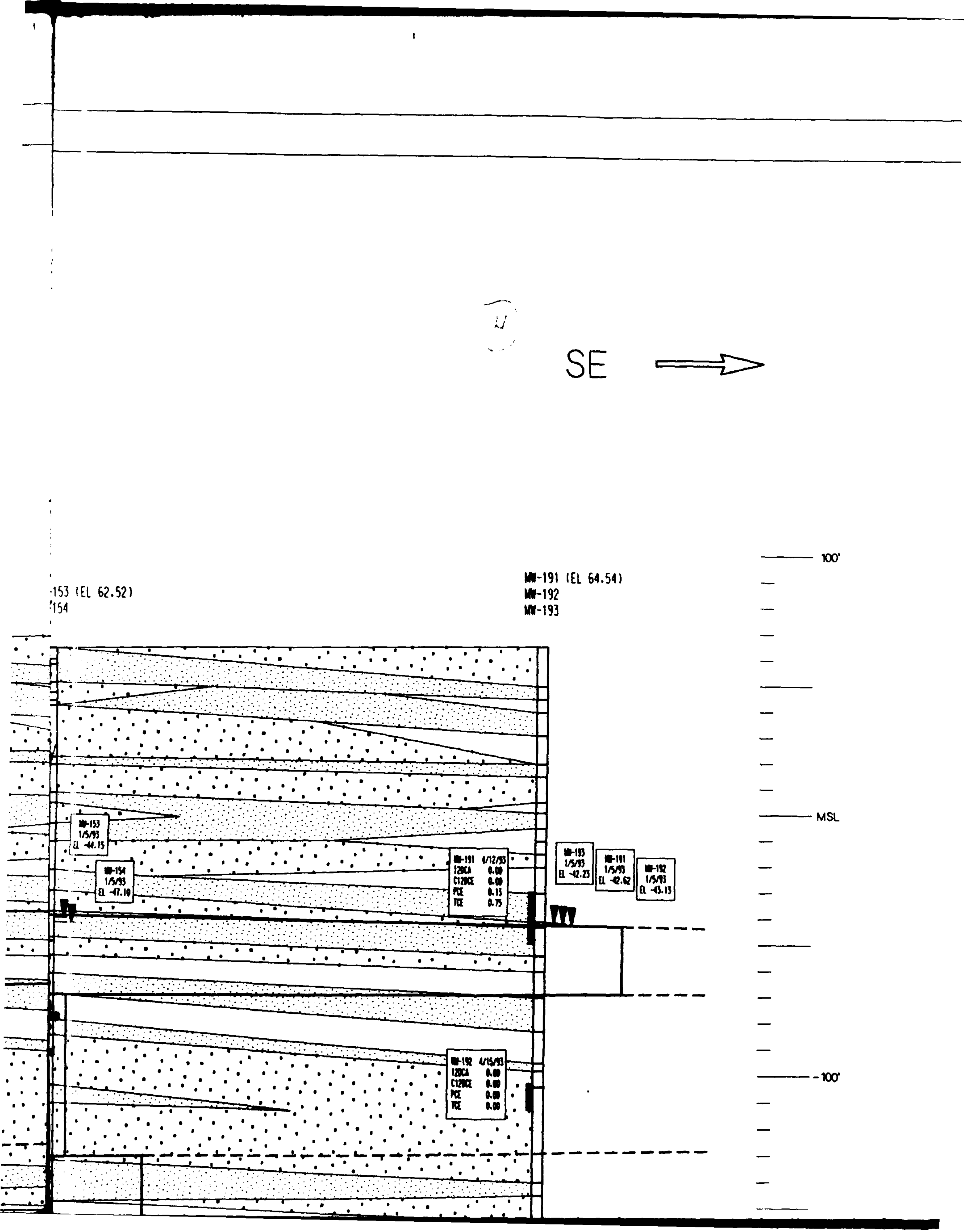
9


NW
0
400'
800'
HORIZONTAL SCALE
100'
MSL
-100'
MW-81 (EL 60)
MW-79 (EL 63.07)
MW-79
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-79
1/6/93
EL -34.23
MW-81 95' 1/1/85
MCLR
MW-79 105' 1/1/85
MCLR
ZONE A
ZONE B

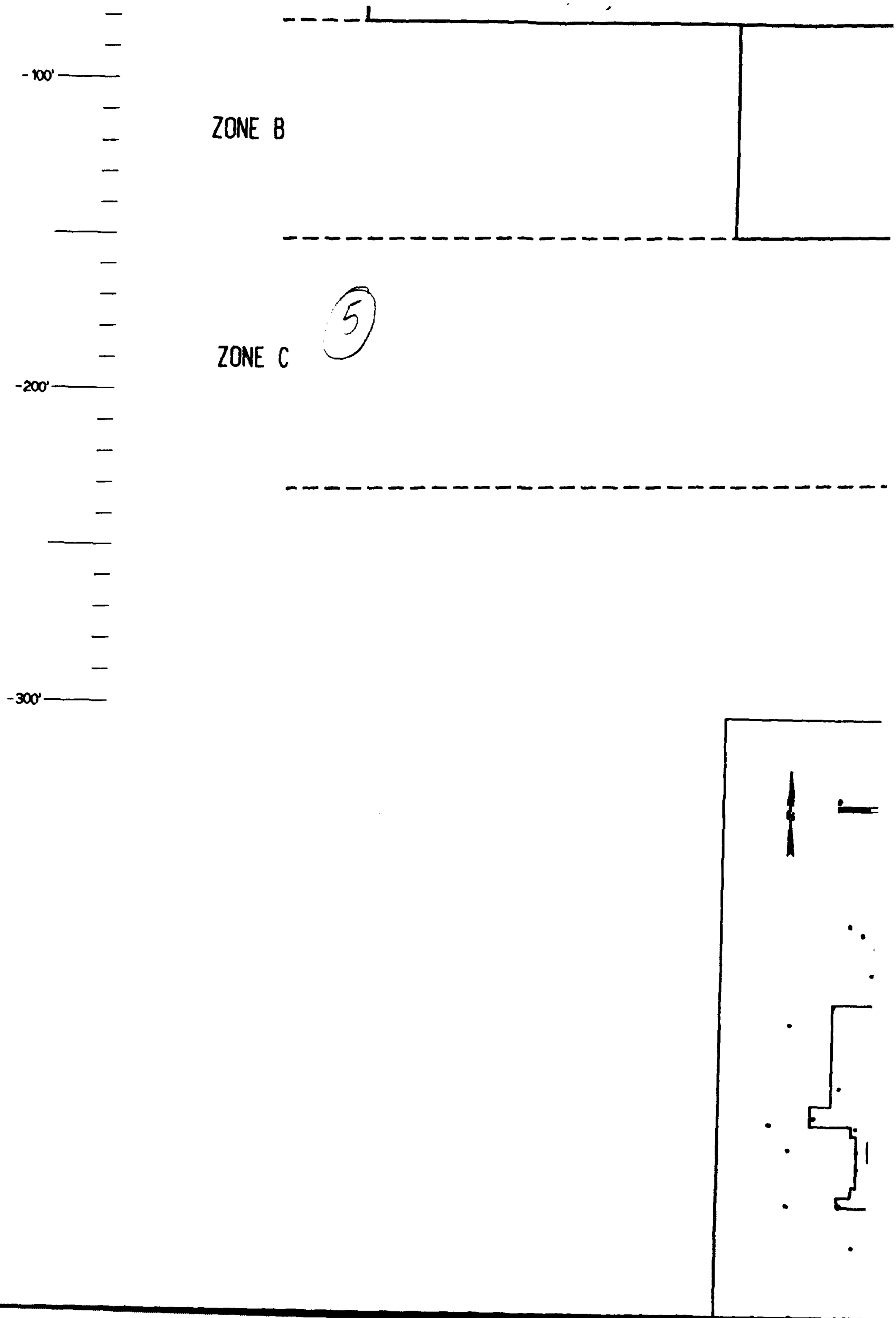

MW-214 (EL 59.91)
MW-215
MW-216
W-79 (EL 63.07)
MW-129 (EL 59.46)
(EL 59.18) MW-131
MW-139 (EL 56.65)
05' 1/1/85
MCLR
MW-131 103' 10/3/86
RADIAN
MW-129 138' 10/6/86
RADIAN



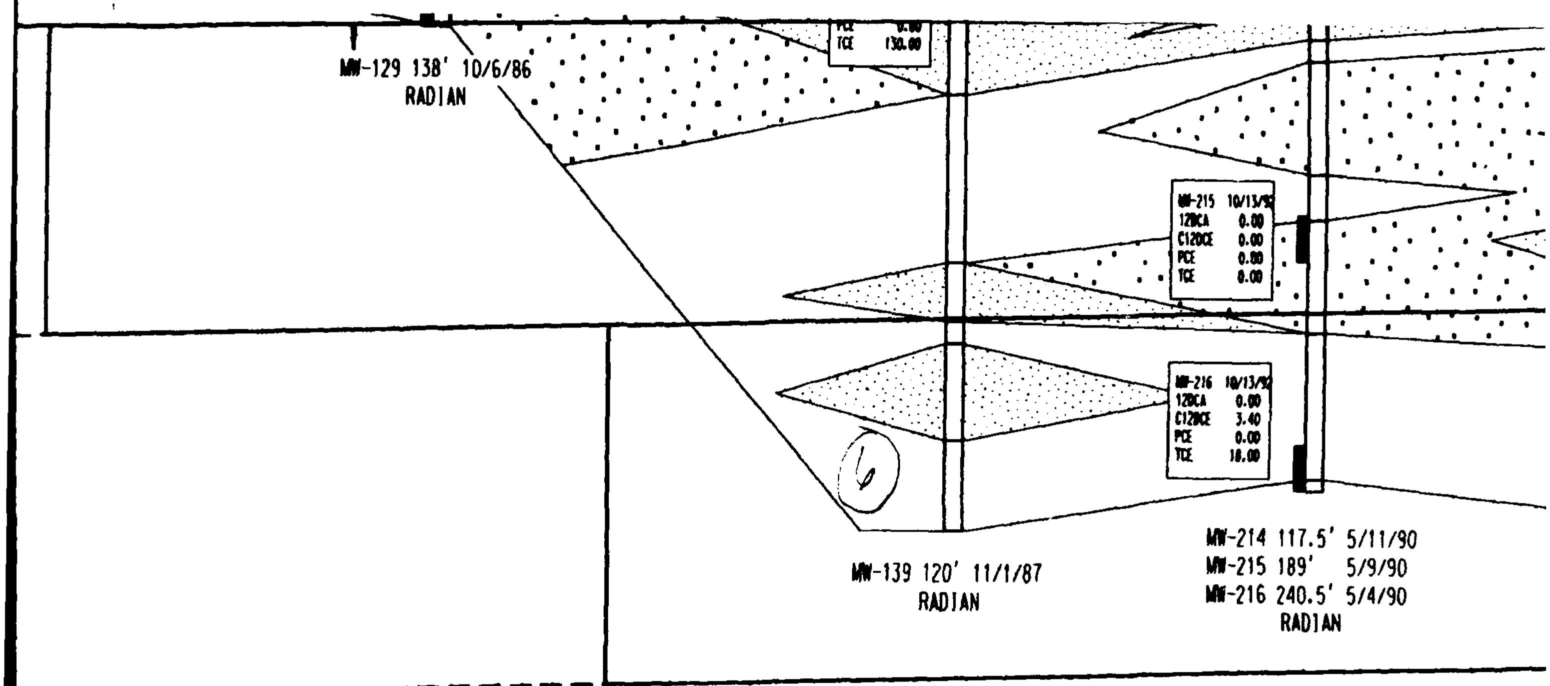
L 59.91)
MW-121 (EL 62.22)
MW-122
MW-270
MW-153 (EL 62.52)
MW-154
MW-215 1/5/93 EL -40.95
MW-214 1/5/93 EL -41.05
MW-270 10/19/93 12DCA 0.00 C12DCE 34.00 PCE 204.00 TCE 1720.00
MW-270 10/19/93 EL -44
MW-153 1/5/93 EL -44.15
MW-154 1/5/93 EL -47.10
MW-122 1/6/93 EL -41.65
MW-153 7/29/93 C12DCE 6.39 PCE 15.90 TCE 155.00
MW-270 118' 2/22/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-122 12/12/
12DCA 0.00
PCE 0.00
TCE 0.00

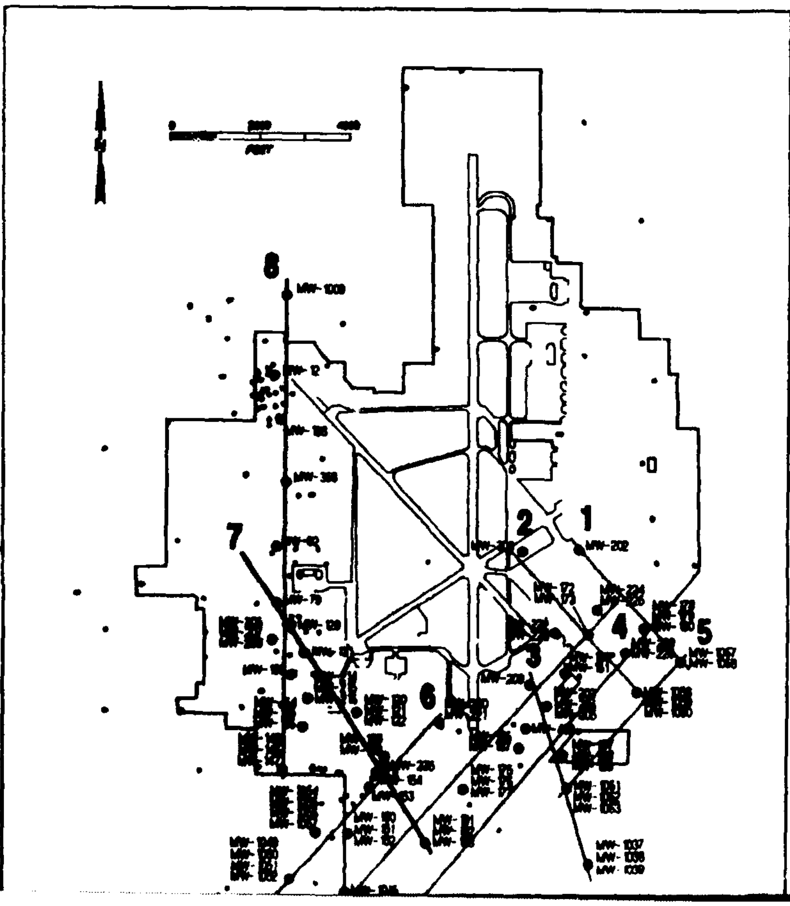


SE
100'
MSL
-100'
-153 (EL 62.52)
154
MW-191 (EL 64.54)
MW-192
MW-193
MW-153
1/5/93
EL -44.15
MW-154
1/5/93
EL -47.10
MW-191 4/12/93
12DCA 0.00
C12DCE 0.00
PCE 0.13
TCE 0.75
MW-193
1/5/93
EL -42.23
MW-191
1/5/93
EL -42.62
MW-192
1/5/93
EL -43.13
MW-192 4/15/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00



-100'
ZONE B
ZONE C
5
-200'
-300'





LEGE

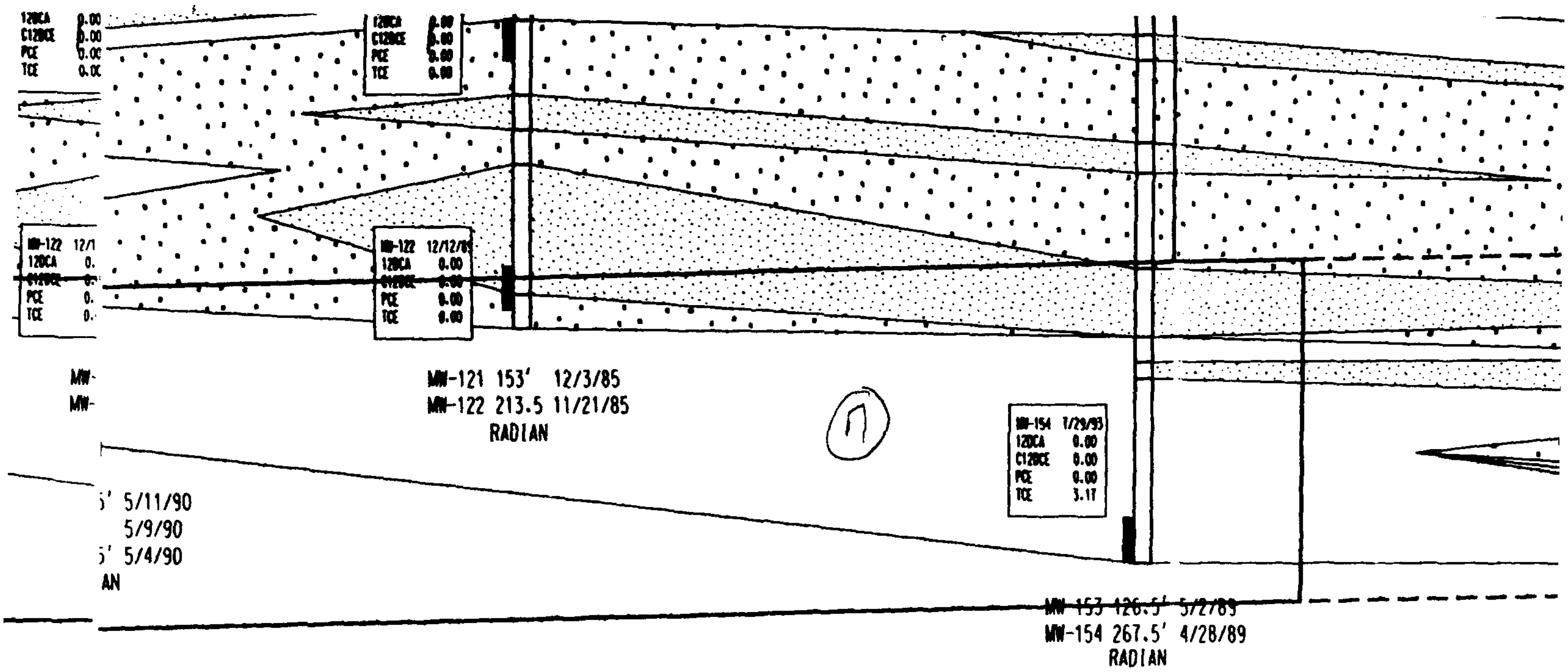
NOTE

1. St
elevat
depos

2. At
forces

3. Ma

4. At



LEGEND

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

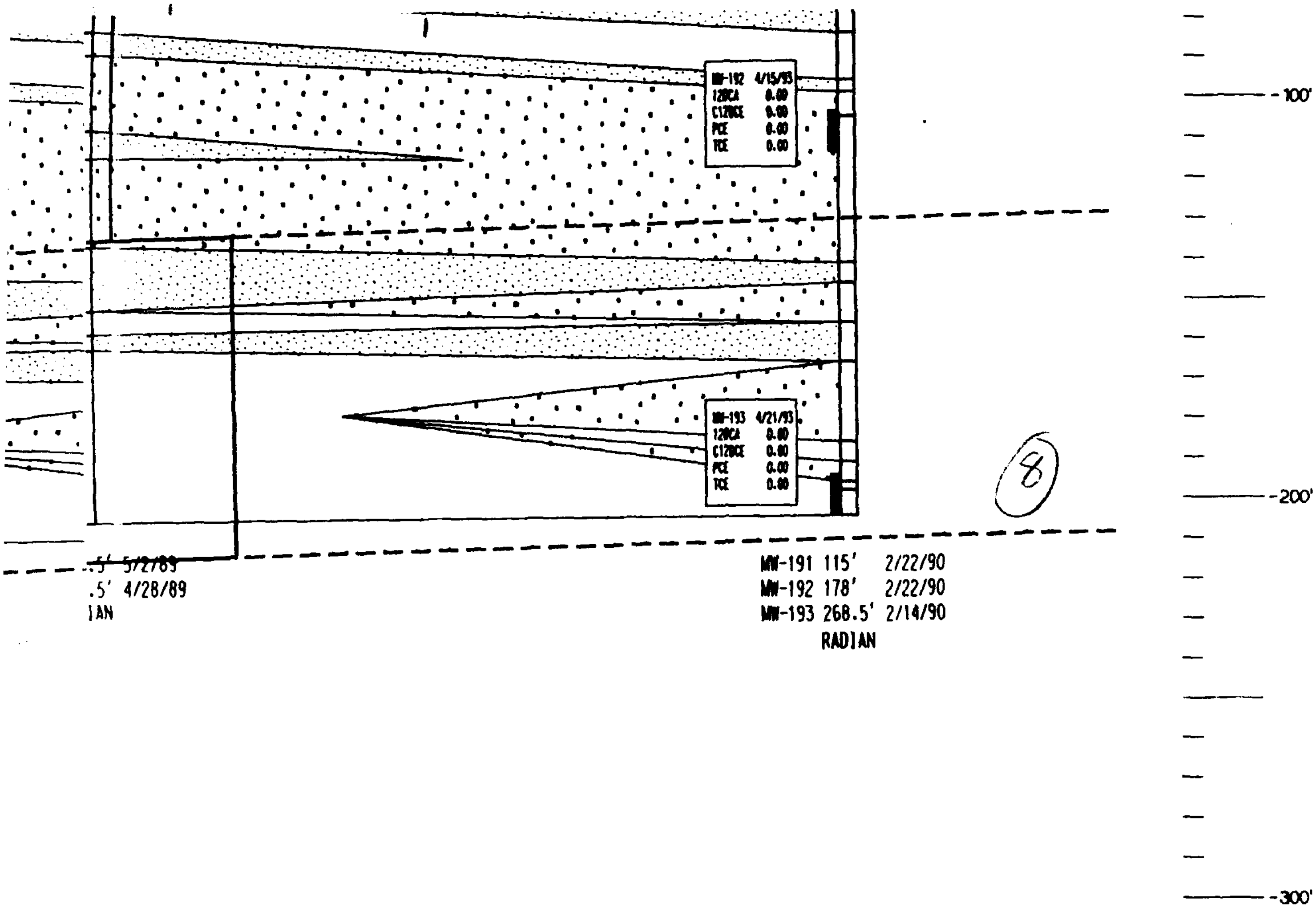
NOTES:

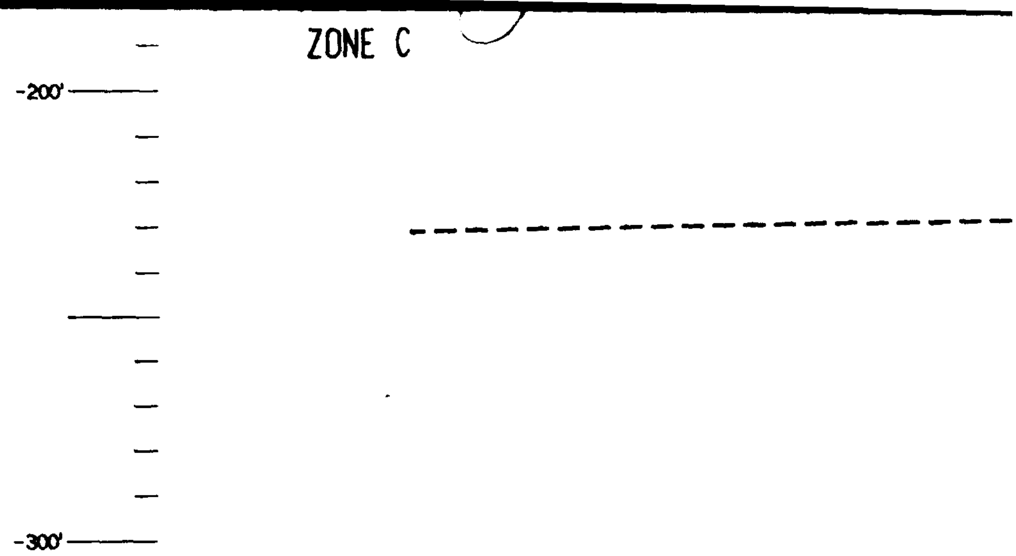
1. Strong fluvial regime with abundant sand and gravel in the D zone from elevations -180 to -160. Flow direction is southwest due to breach of alluvial deposits in southern portion of cross section.

2. At elevation -160 fluvial regime subsides and large influx of alluvial deposits forces channel northward.

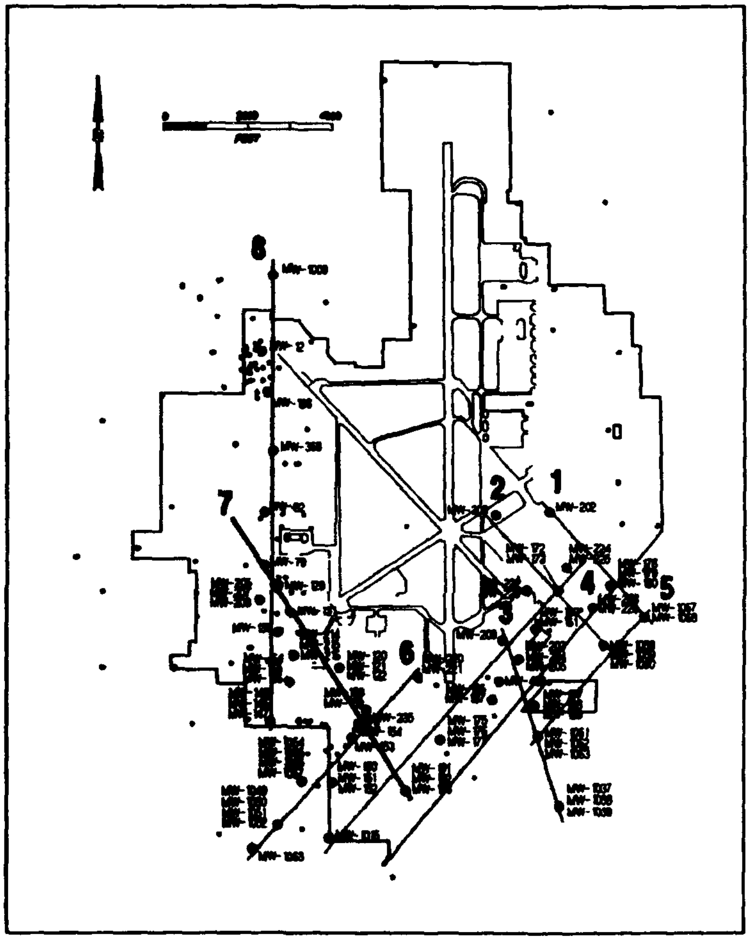
3. Main channel located in the vicinity of MW-139 in the B zone.

4. At elevation -140 dominant streams are within the eastern portion of the base, as indicated by the lack of channel deposits.


MW-192 4/15/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-193 4/21/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
-100'
-200'
-300'
.5' 4/28/89
MW-191 115' 2/22/90
MW-192 178' 2/22/90
MW-193 268.5' 2/14/90
RADIAN


ZONE C
-200'
-300'

MW-139 120' 11/1/87
RADIAN



SITE MAP

(10)

- - -300'

215 189'
216 240.
RAD

RADIAN

MW-153 126.5'
MW-154 267.5'
RADIAN

LEGEND

Fine stipple	FINE-GRAINED MATERIALS INCLUDE SILT, CLAY SANDY SILT OR CLAY, GRAVELLY SILT OR CLAY, LEAN AND FAT CLAY, SILTY CLAY, AND CLAYEY SILT
Coarse dots	MEDIUM-GRAINED MATERIALS INCLUDE SILTY OR CLAYEY SAND OR GRAVEL
Blank	COARSE-GRAINED MATERIALS INCLUDE POORLY GRADED OR WELL GRADED SAND OR GRAVEL WITH LESS THAN 5% FINES

NOTES:

1. Strong fluvial regime with abundant sand and gravel in the D zone from elevations -160 to -160. Flow direction is southwest due to breach of alluvial deposits in southern portion of cross section.

2. At elevation -160 fluvial regime subsides and large influx of alluvial deposits forces channel northward.

3. Main channel located in the vicinity of MW-139 in the B zone.

4. At elevation -140 dominant streams are within the eastern portion of the base, as indicated by the lack of channel deposits.

Flow direction of depositional channels is approximately parallel to the cross section. Groundwater generally follows the course of the channel deposits, but is strongly influenced by regional pumping south of the Base.

19

MW-153 126.5' 5/2/89
MW-154 267.5' 4/28/89
RADIAN

MW-191 115' 2/22/90
MW-192 178' 2/22/90
MW-193 268.5' 2/14/90
RADIAN

be.

rt is

FIGURE 3-7

CROSS SE

GROUNDWATER
McCLELLAN AIF
SACRAMENTO, (

12

MW-192 178' 2/22/90
MW-193 268.5' 2/14/90
RADIAN

-300'

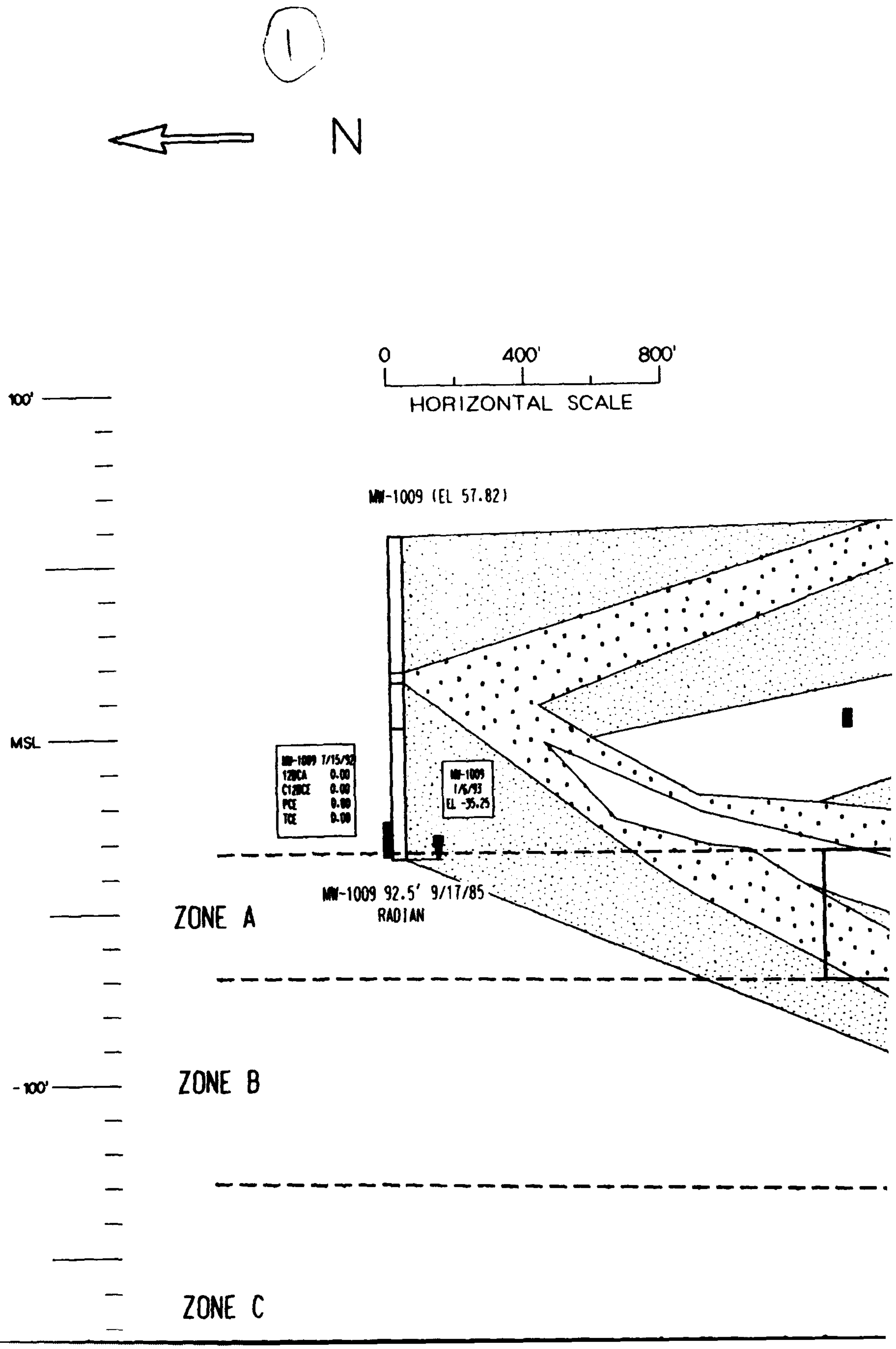
0'

FIGURE 3-7

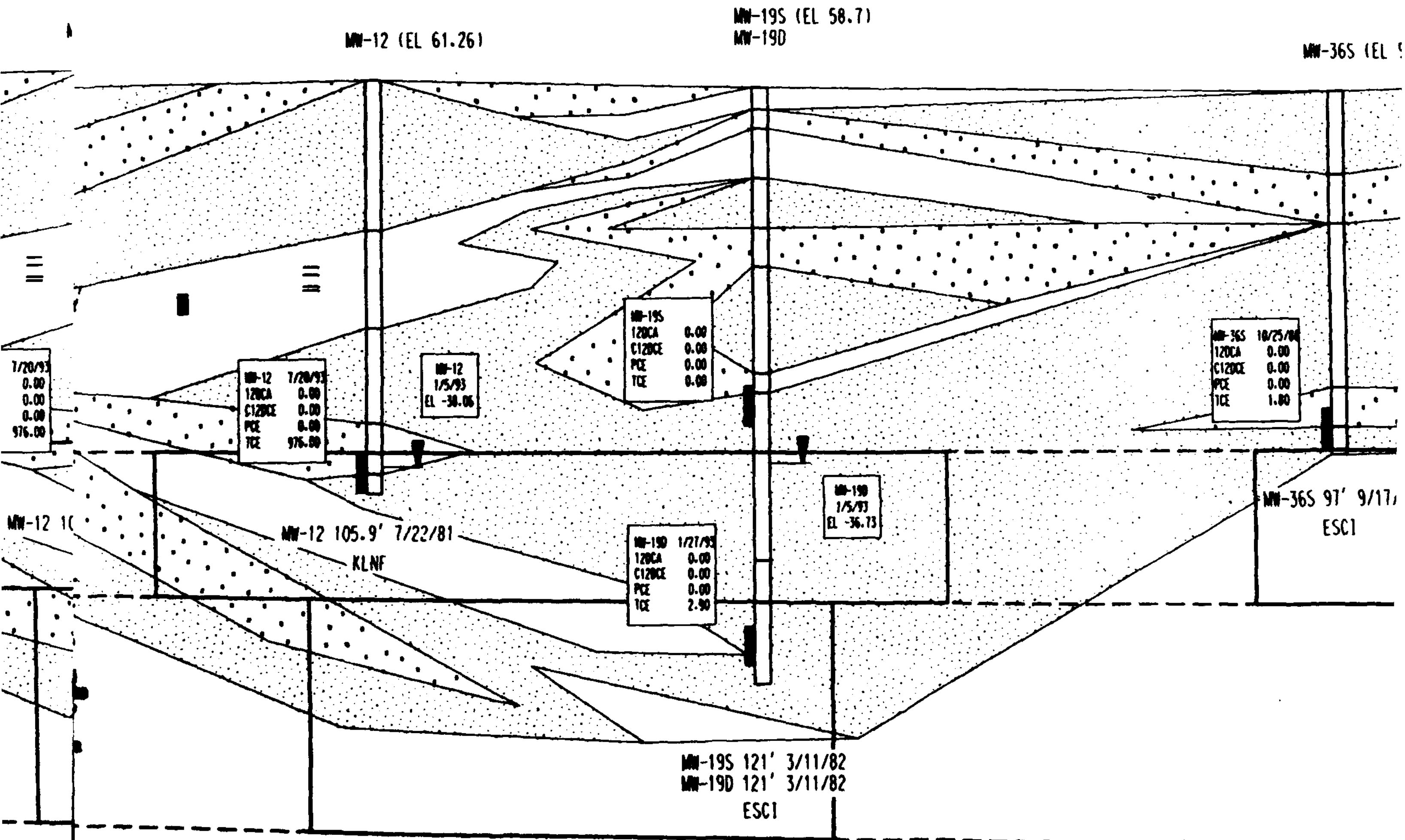
CROSS SECTION 7

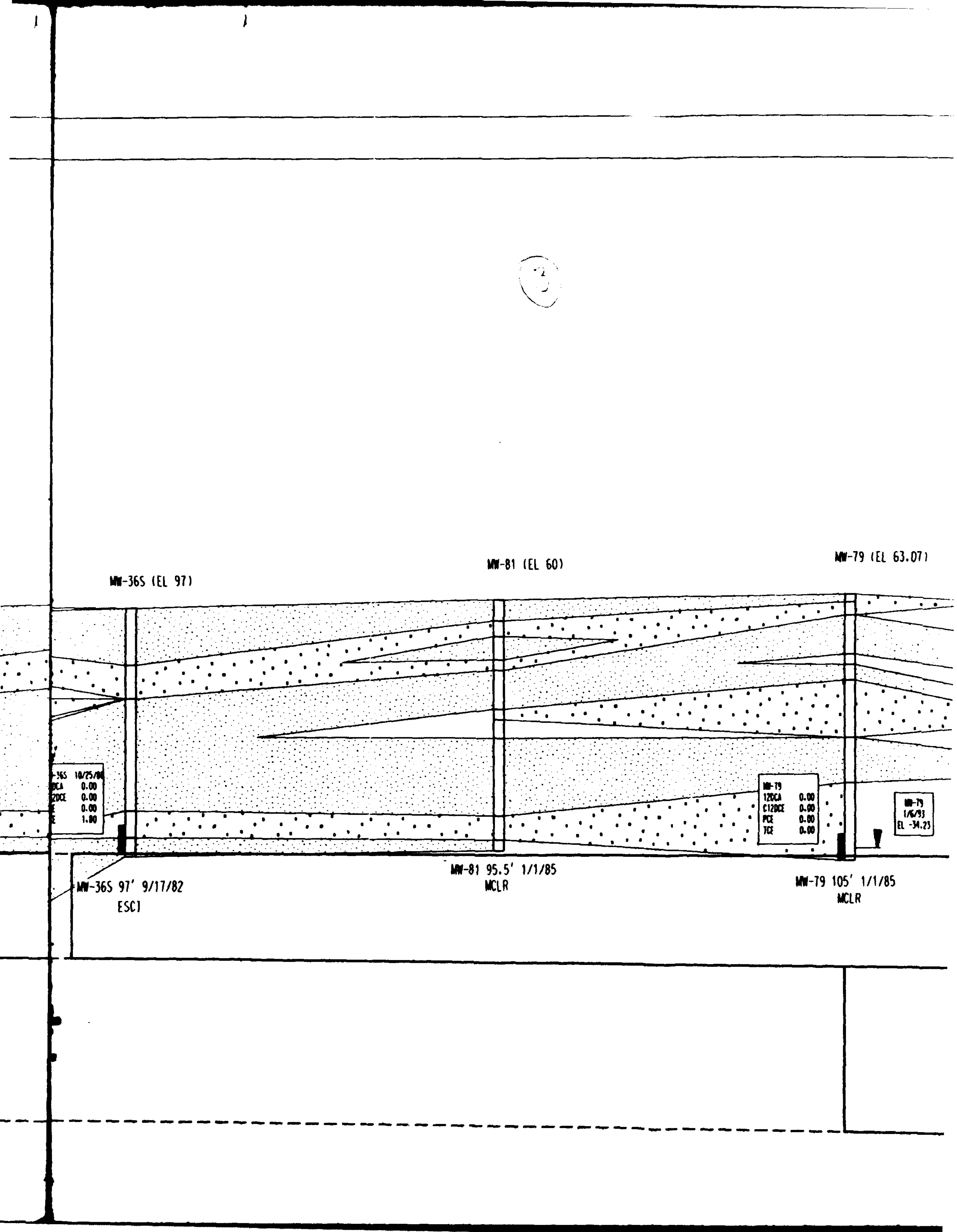
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

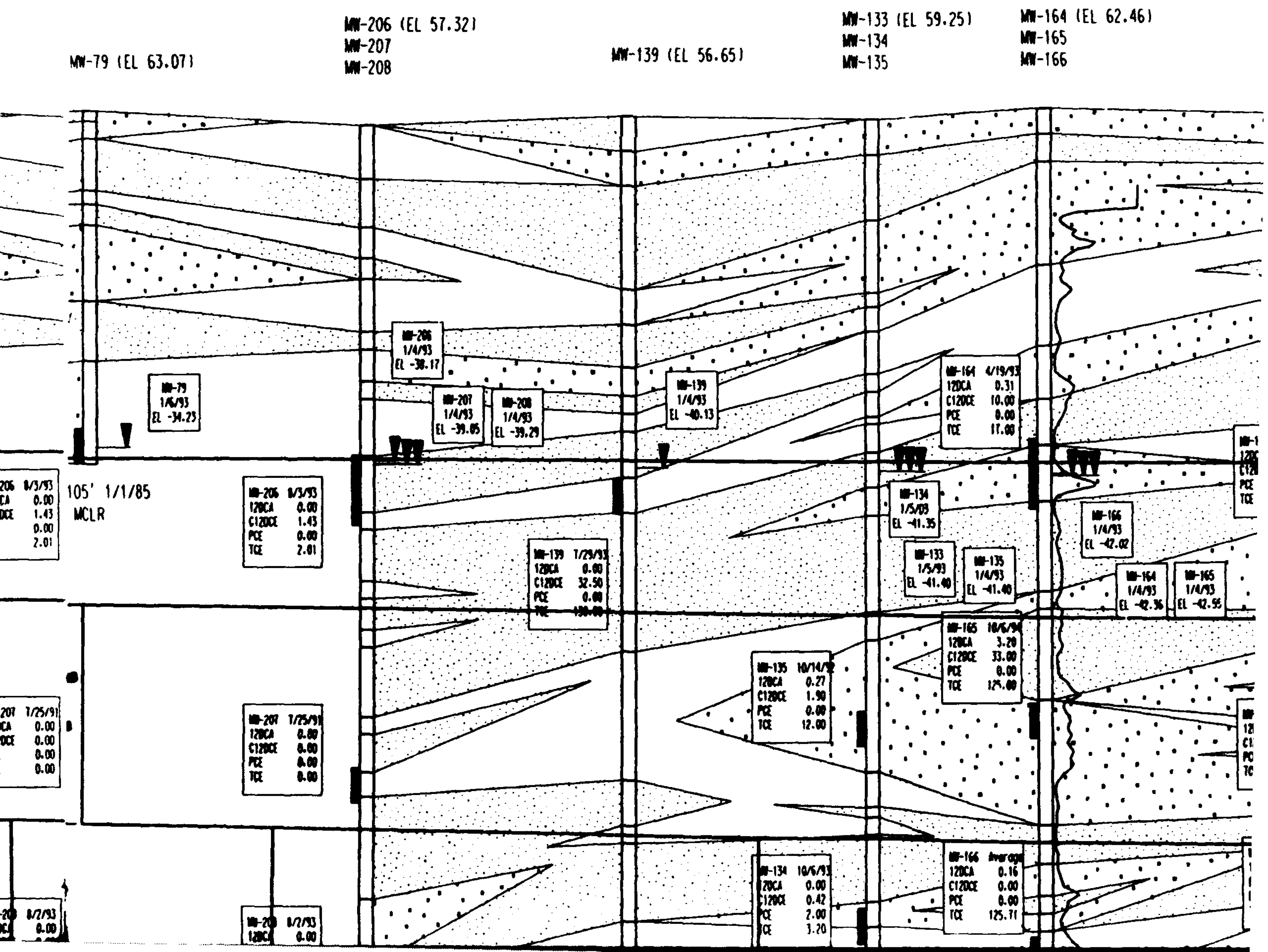
13



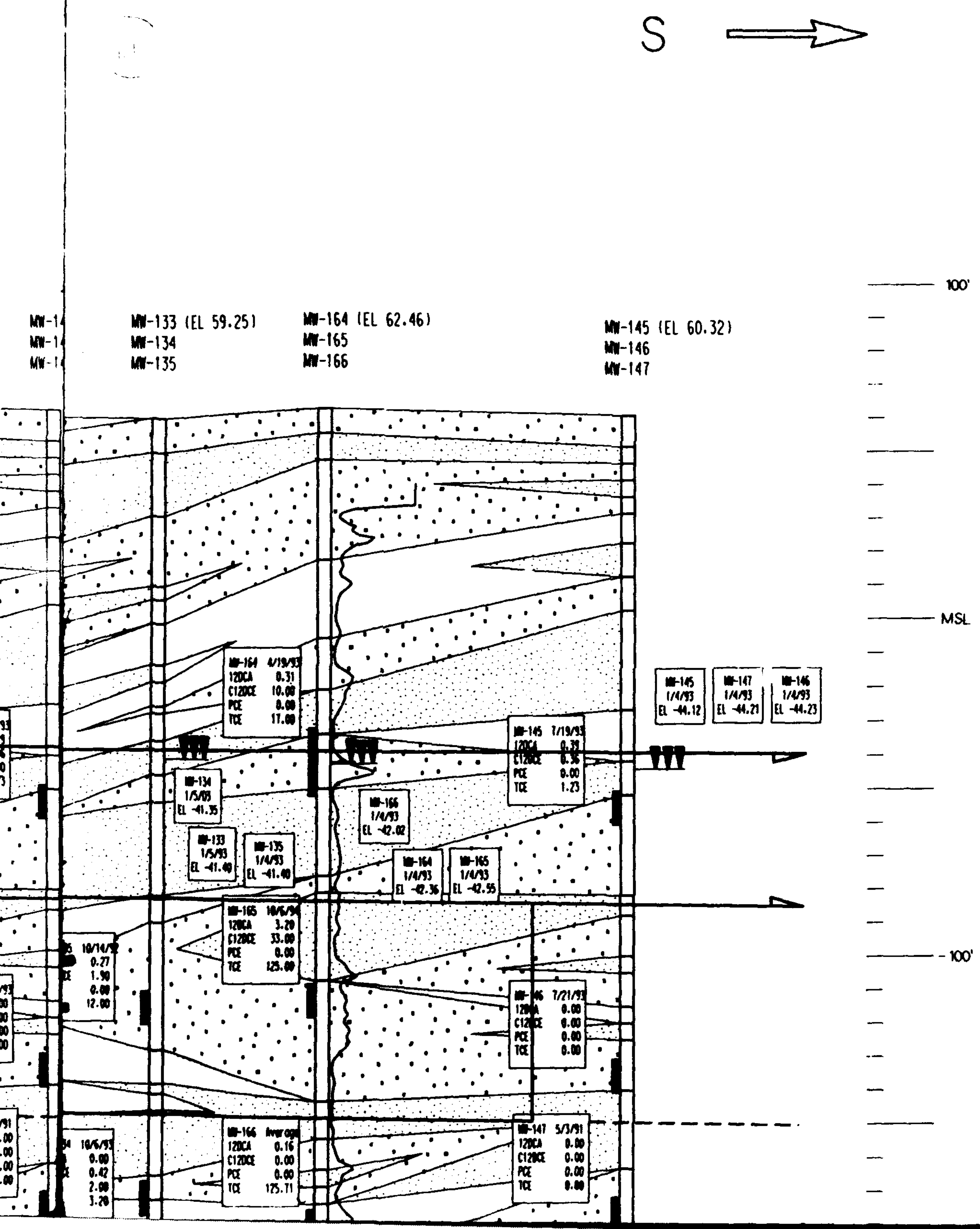
1
N
0
400'
800'
HORIZONTAL SCALE
100'
MSL
-100'
MW-1009 (EL 57.82)
MW-1009 7/15/92
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-1009
1/6/93
EL -35.25
MW-1009 92.5' 9/17/85
RADIAN
ZONE A
ZONE B
ZONE C


MW-19S (EL 58.7)
MW-19D
MW-12 (EL 61.26)
MW-36S (EL
MW-12 7/20/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 976.00
7/20/93
0.00
0.00
0.00
976.00
MW-12
1/5/93
EL -30.06
MW-19S
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-36S 10/25/
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 1.80
MW-19D
1/5/93
EL -36.73
MW-19D 1/27/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 2.90
MW-12 105.9' 7/22/81
KLNF
MW-12 1(
MW-36S 97' 9/17/
ESC1
MW-19S 121' 3/11/82
MW-19D 121' 3/11/82
ESC1


MW-36S (EL 97)
MW-81 (EL 60)
MW-79 (EL 63.07)
-36S 10/25/
DCA 0.00
2DCE 0.00
0.00
1.80
MW-79
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-79
1/6/93
EL -34.23
MW-36S 97' 9/17/82
ESCI
MW-81 95.5' 1/1/85
MCLR
MW-79 105' 1/1/85
MCLR



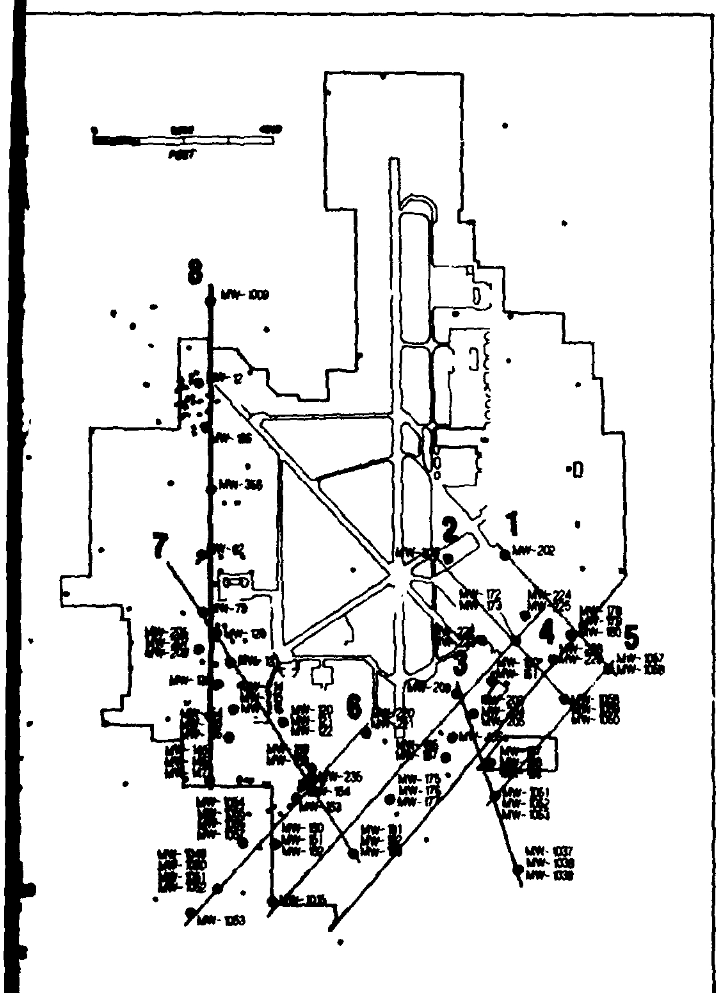
MW-79 (EL 63.07)
MW-206 (EL 57.32)
MW-207
MW-208
MW-139 (EL 56.65)
MW-133 (EL 59.25)
MW-134
MW-135
MW-164 (EL 62.46)
MW-165
MW-166
105' 1/1/85
MCLR
MW-206 1/4/93 EL -38.17
MW-79 1/6/93 EL -34.23
MW-207 1/4/93 EL -39.05
MW-208 1/4/93 EL -39.29
MW-139 1/4/93 EL -40.13
MW-164 4/19/93 12DCA 0.31 C12DCE 10.00 PCE 0.00 TCE 17.00
MW-206 8/3/93 12DCA 0.00 C12DCE 1.43 PCE 0.00 TCE 2.01
MW-134 1/5/93 EL -41.35
MW-166 1/4/93 EL -42.02
MW-133 1/5/93 EL -41.40
MW-135 1/4/93 EL -41.40
MW-164 1/4/93 EL -42.36
MW-165 1/4/93 EL -42.55
MW-139 7/29/93 12DCA 0.00 C12DCE 32.50 PCE 0.00
MW-165 10/6/93 12DCA 3.20 C12DCE 33.00 PCE 0.00
MW-135 10/14/93 12DCA 0.27 C12DCE 1.90 PCE 0.00 TCE 12.00
MW-207 7/25/93 12DCA 0.00 C12DCE 0.00 PCE 0.00 TCE 0.00
MW-134 10/6/93 12DCA 0.00 C12DCE 0.42 PCE 2.00 TCE 3.20
MW-166 Average 12DCA 0.16 C12DCE 0.00 PCE 0.00 TCE 125.71
MW-208 8/2/93 12DCA 0.00



S
MW-133 (EL 59.25)
MW-134
MW-135
MW-164 (EL 62.46)
MW-165
MW-166
MW-145 (EL 60.32)
MW-146
MW-147
100'
MSL
-100'
MW-164 4/19/93
12DCA 0.31
C12DCE 10.00
PCE 0.00
TCE 17.00
MW-145 1/4/93 EL -44.12
MW-147 1/4/93 EL -44.21
MW-146 1/4/93 EL -44.23
MW-145 7/19/93
PCE 0.00
TCE 1.23
MW-134 1/5/93 EL -41.35
MW-166 1/4/93 EL -42.02
MW-133 1/5/93 EL -41.40
MW-135 1/4/93 EL -41.40
MW-164 1/4/93 EL -42.36
MW-165 1/4/93 EL -42.55
MW-165 10/6/93
12DCA 3.20
C12DCE 33.00
PCE 0.00
TCE 125.00
MW-146 7/21/93
TCE 0.00
MW-166 Average
12DCA 0.16
C12DCE 0.00
PCE 0.00
TCE 175.71
MW-147 5/3/91
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00


ZONE C
-200'
-300'
-400'

MW-19S 121' 3/11/82
MW-19D 121' 3/11/82
ESCI



SITE MAP

LEGEND

FINE-GRAI
SANDY SIL
LEAN AND
SILT

MEDIUM-G
OR CLAYE

COARSE-G
GRADED O
LESS THA

17

END

MATERIALS I
CLAY.GRAVE
:LAY.SILTY

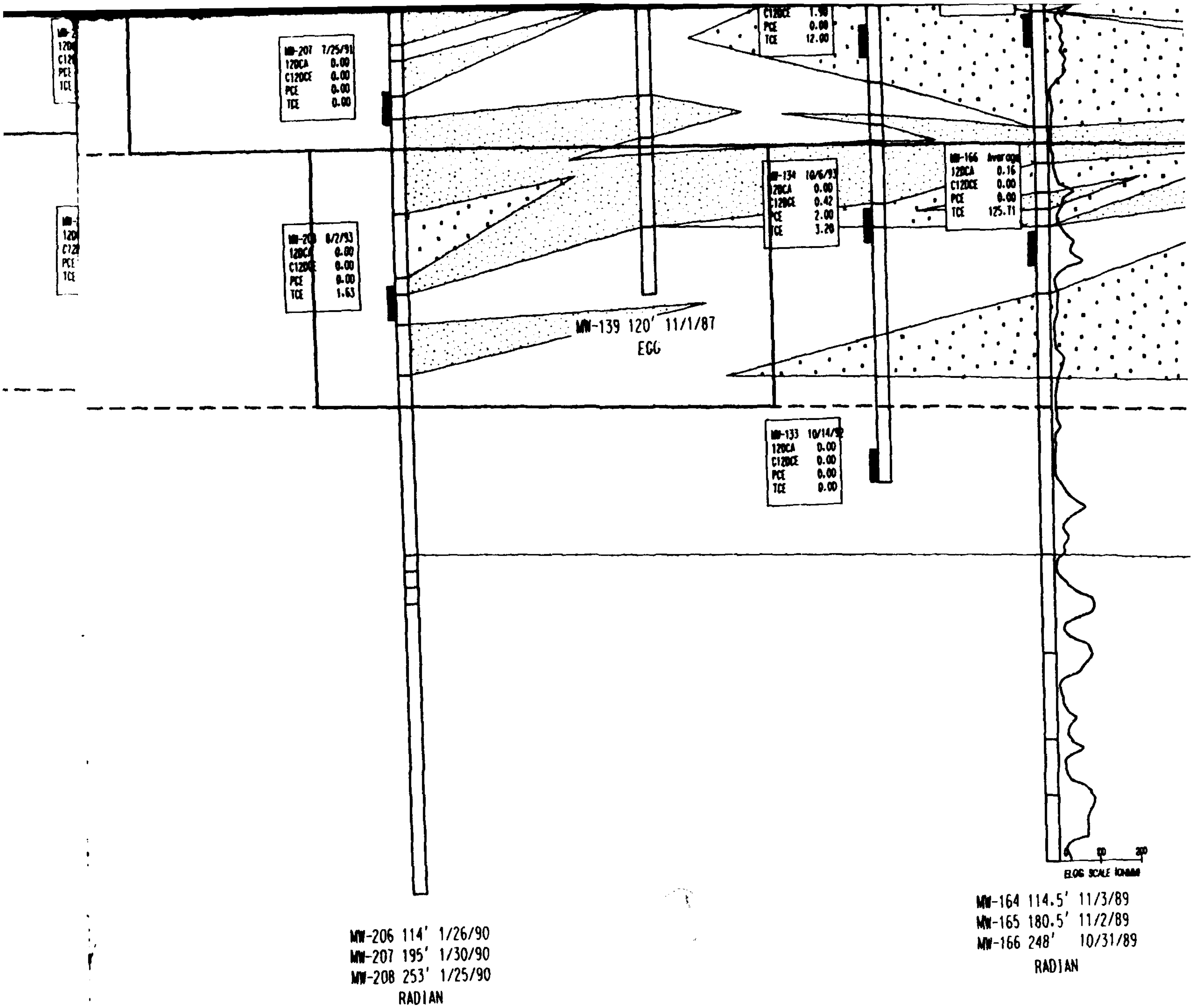
FINE-GRAINED MATERIALS INCLUDE SILT.CLAY SANDY SILT OR CLAY.GRAVELLY SILT OR CLAY. LEAN AND FAT CLAY.SILTY CLAY.AND CLAYEY SILT

D MATERIAL
D OR GRAVE

MEDIUM-GRAINED MATERIALS INCLUDE SILTY OR CLAYEY SAND OR GRAVEL

D MATERIAL
L GRADED S
FINES

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



MW-207 7/25/91
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
PCE 0.00
TCE 12.00
MW-134 10/6/93
12DCA 0.00
C12DCE 0.42
PCE 2.00
TCE 3.20
MW-166 Average
12DCA 0.16
C12DCE 0.00
PCE 0.00
TCE 125.71
PCE 0.00
TCE 1.63
MW-139 120' 11/1/87
EGG
MW-133 10/14/92
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
ELOG SCALE (OHMM)
MW-206 114' 1/26/90
MW-207 195' 1/30/90
MW-208 253' 1/25/90
RADIAN
MW-164 114.5' 11/3/89
MW-165 180.5' 11/2/89
MW-166 248' 10/31/89
RADIAN

FIGURE 3-8

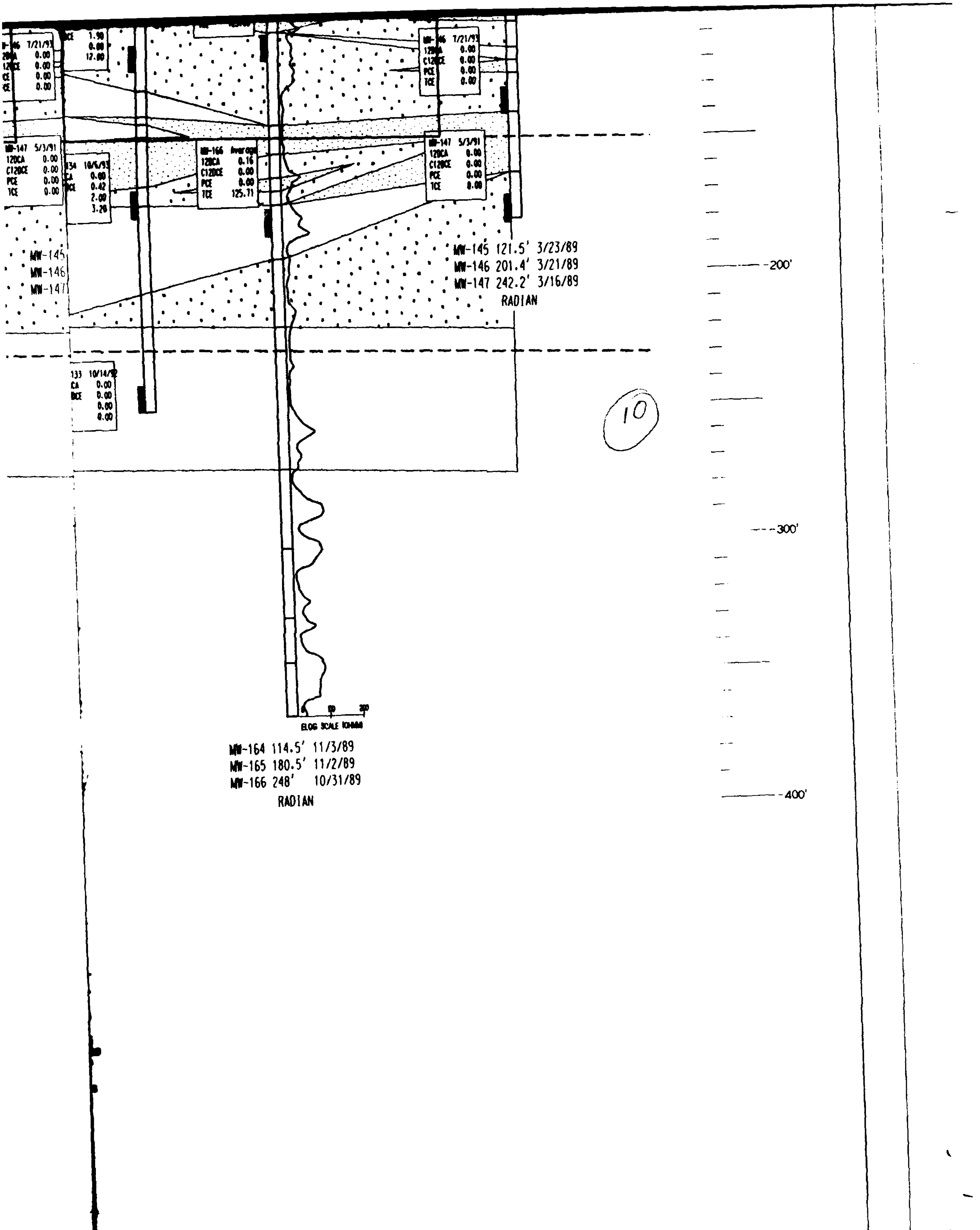

MW-145 121.5' 3/23/89
MW-146 201.4' 3/21/89
MW-147 242.2' 3/16/89
RADIAN
MW-166 Average
12DCA 0.16
C12DCE 0.00
PCE 0.00
TCE 125.71
MW-147 5/3/91
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
MW-146 7/21/93
12DCA 0.00
C12DCE 0.00
PCE 0.00
TCE 0.00
ELOG SCALE (OHMS)
MW-164 114.5' 11/3/89
MW-165 180.5' 11/2/89
MW-166 248' 10/31/89
RADIAN
-200'
-300'
-400'
10

FIGURE 3-8

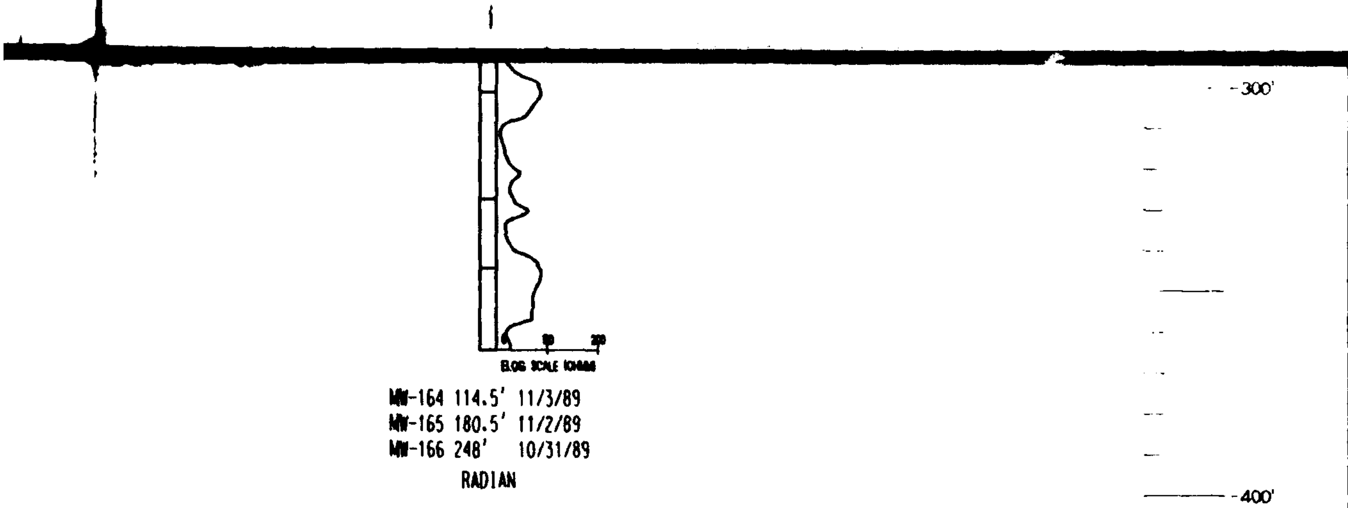


FIGURE 3-8

CROSS SECTION 8

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Chapter 4
Conceptual Model

As a convenience to the reader because of the large volume of data contained in this chapter, all oversize figures (11" x 17" or larger) have been located at the end of the chapter.

4.1 Objectives of the Conceptual Model

McClellan AFB defines a conceptual model as a physical construct of a site(s) system that depicts processes affecting the transport of contaminants from the source(s) through environmental media to receptors.

A conceptual model may be of any length depending on the complexity of the site's systems and processes being described. The groundwater beneath McClellan AFB is a complex system because of the multiple sources, significant regional groundwater influences, several remedial actions in operation, and extremely heterogeneous geology. In addition, these conditions have changed over time.

Specific objectives of the conceptual model for the Groundwater OU include:

- Providing a description of the site's physical and geologic conditions relevant to the transport and remediation of the groundwater contamination
- Providing an understanding of the sources of contamination
- Providing an understanding of the prevalent contaminants
- Providing an understanding of the physical and chemical properties of the prevalent contaminants relevant to the transport and remediation of the contaminated groundwater
- Providing an understanding of the temporal changes in the physical systems and processes (e.g., temporal changes in flow velocities or directions)
- Providing an understanding of the regional influences on groundwater conditions at the Base
- Resolving differences between theoretical factors and observed conditions, given the systems and proces[illegible]-sented in the conceptual model

When new water quality data and site condition information become available, they can be incorporated into the conceptual model. The conceptual model will be refined and updated as input from within the

IRP becomes available. Chapter 7, Data Management and Collection, will discuss how new information will be incorporated into the conceptual model.

Figure 4-1 explains the framework of the conceptual model. Understanding current observed conditions and predicting future conditions can be achieved by incorporating the following information:

- Site characteristics
- Location of source areas, type of contaminants, and the time of discharge
- Physical and chemical properties of contaminants
- Hydrogeologic environment

The conceptual model will incorporate this information to explain the nature and extent of contamination in the groundwater system.

4.2 Site Characteristics

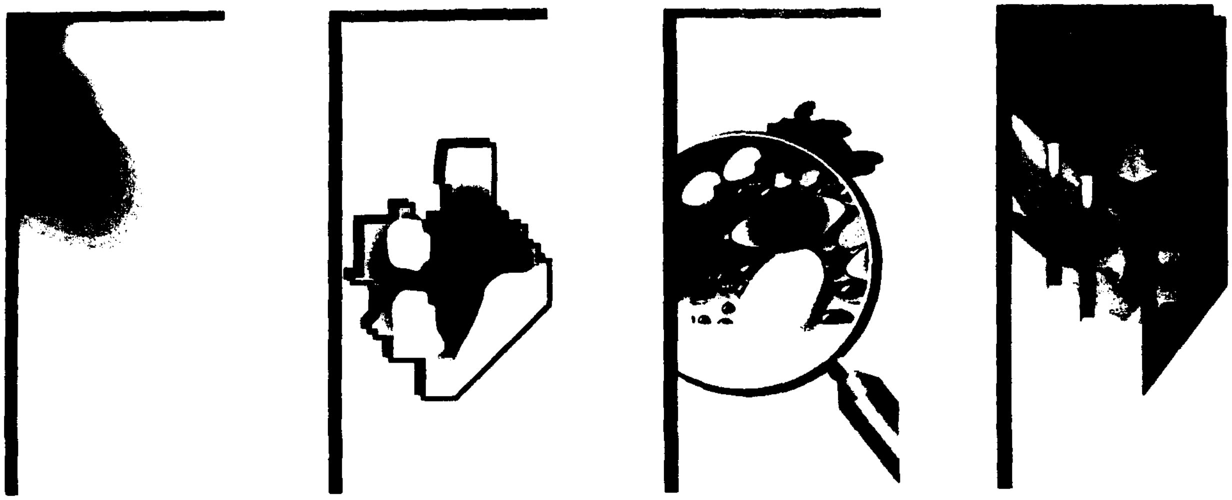
The physical characteristics of the site make up the first component of the conceptual model. To understand the factors that affect groundwater flow and contaminant transport, the physical media that comprise the groundwater system must first be presented. The following section will discuss the depositional environment in which the groundwater system was created, followed by how the monitoring zones within this sedimentary sequence have been delineated and interpreted. This section will conclude by presenting the aquifer properties of each of the monitoring zones.

4.2.1 Monitoring Zone Designations

Radian Corporation divided the groundwater subsurface into five distinct monitoring zones (A, B, C, D, and E) for interpretation based primarily on geophysical logs between pilot borings (Radian, 1992).

Strong evidence suggests that the groundwater system functions more as a single unit than as separate hydrostratigraphic units. The following observations suggest the units are hydraulically linked:

- Water levels and flow directions in zones are similar.
- The lithology is heterogeneous, indicating no laterally continuous aquifers or aquitards. See cross section through OU A (Figure (3-2).
- The influence of regional pumpage is observed in all monitoring zones without significant time lags.



SITE CHARACTERISTICS
(Section 4.2)

- Aquifer parameters
- Depositional environment

SOURCE AREA INFORMATION
(Section 4.3)

- Type of contaminants
- Time of discharge
- Location of sources

FATE AND TRANSPORT
(Section 4.4)

- Relative mobility
- Partioning characteristics
- Transport processes
- Biodegradation potential

PHYSICAL TRANSPORT MECHANISMS
(Section 4.5)

- Vertical & horizontal gradients
- Base & regional extraction systems
- Groundwater flow directions

EXISTING CONDITIONS

FUTURE CONDITONS

FIGURE 4-1
FRAMEWORK OF THE CONCEPTUAL MODEL
GROUNDWATER OPERABLE UNIT RI/F
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_03

CH2MHILL

- Stiff and Piper diagrams show that the inorganic water quality in all zones is similar.

Water Levels and Flow Directions

The water levels measured in the monitoring zones at the Base are similar spatially, and decline with depth in response to recharge at the surface and pumping withdrawals at depth (see Figure 4-2). Groundwater flow directions and horizontal gradients are very similar in each of the monitoring zones (see Figure 4-3). These observations support the hypothesis of a sedimentary sequence that is hydraulically connected but shows some degree of horizontal to vertical anisotrophy.

Heterogeneous Lithology

The lithology present in the subsurface at McClellan AFB is highly variable. The cross sections presented in Figure 4-4 suggest that individual lithologic units rarely extend laterally for more than 50 feet. The texture of the sediments present ranges from gravels and sands to silts and clays. No thick, laterally continuous low permeability units are indicated from any of the cross sections developed for the Base to date. Therefore, no physical evidence exists to support the hypothesis of multiple isolated aquifers beneath the Base.

Response to Regional Pumping

The temporal variations in vertical gradients at the Base are produced primarily by changes in regional pumping stresses. If significant aquitards existed separating the monitoring zones, the water level responses to regional pumping wells screened in the deeper D and E zones in each shallow monitoring zone would be damped. The shallow zones would be almost totally isolated from regional pumping influences while the deeper zones would be strongly affected. No such pattern is observed at McClellan AFB, indicating that the monitoring zones are hydraulically linked.

Stiff and Piper Diagrams

Stiff and piper (also known as trilinear) diagrams graphically portray the distribution of inorganic constituents in groundwater samples. Plotting the constituents in groundwater samples collected from different aquifers on a piper or stiff diagram is an effective method for determining whether the water in each aquifer shares a common source. If all aquifers contain waters of similar composition, it is likely that the units are hydraulically connected, and groundwater moves between aquifers. The piper/trilinear plots (Figure 4-5) and stiff diagram plots (Figure 4-6) strongly suggest that the groundwater contained in the A, B, and C aquifers all originates from a similar source. Therefore, it is likely that the monitoring zones at the Base behave as a single layered aquifer instead of several isolated aquifers. Figure 4-6 shows the stiff diagrams for several A-, B-, and C-zone wells in plan view.

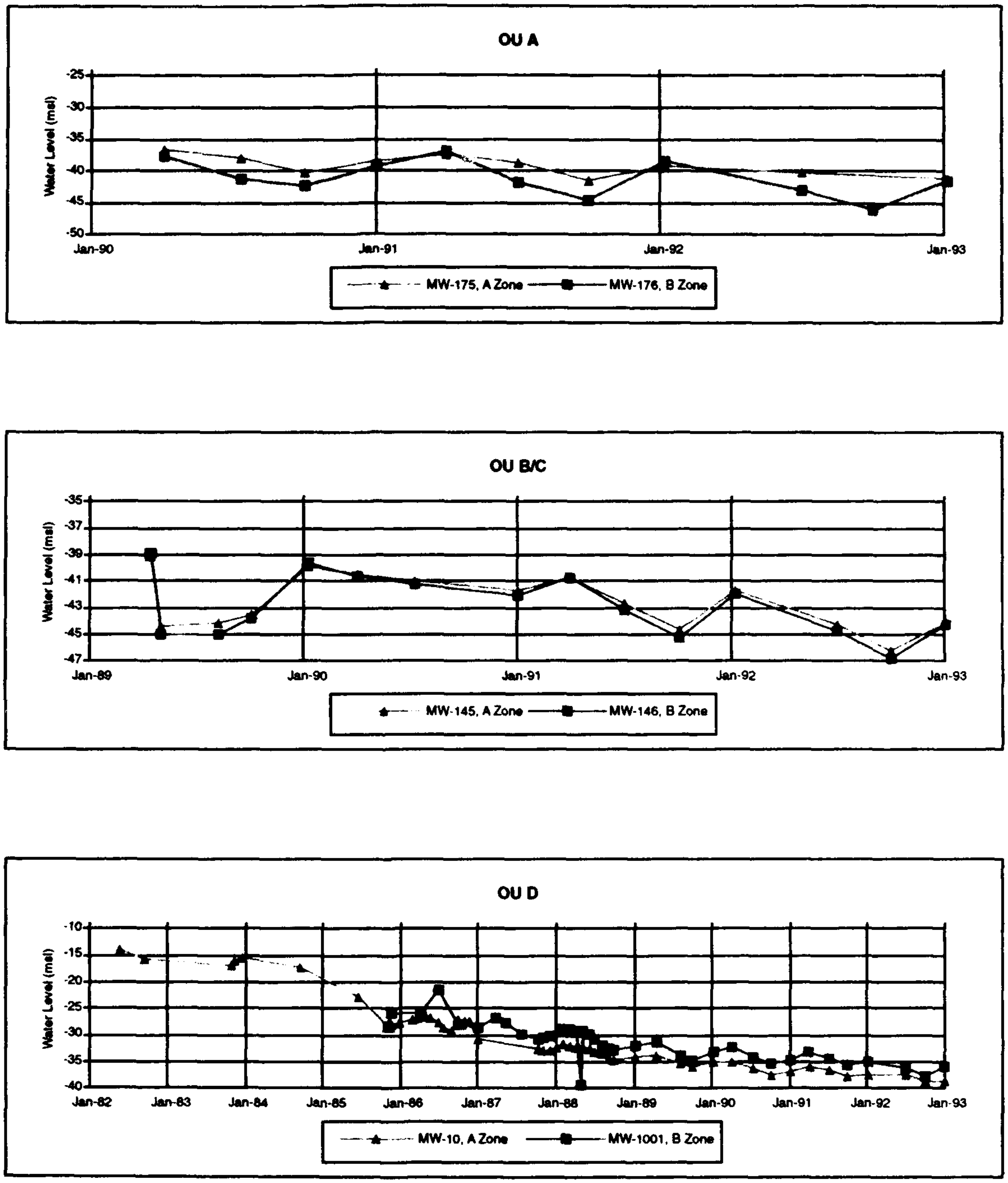


FIGURE 4-2
HYDROGRAPHS OF WELLS IN THE A AND B ZONES OF OU A, OU B/C, AND OU D
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_114

CH2M HILL

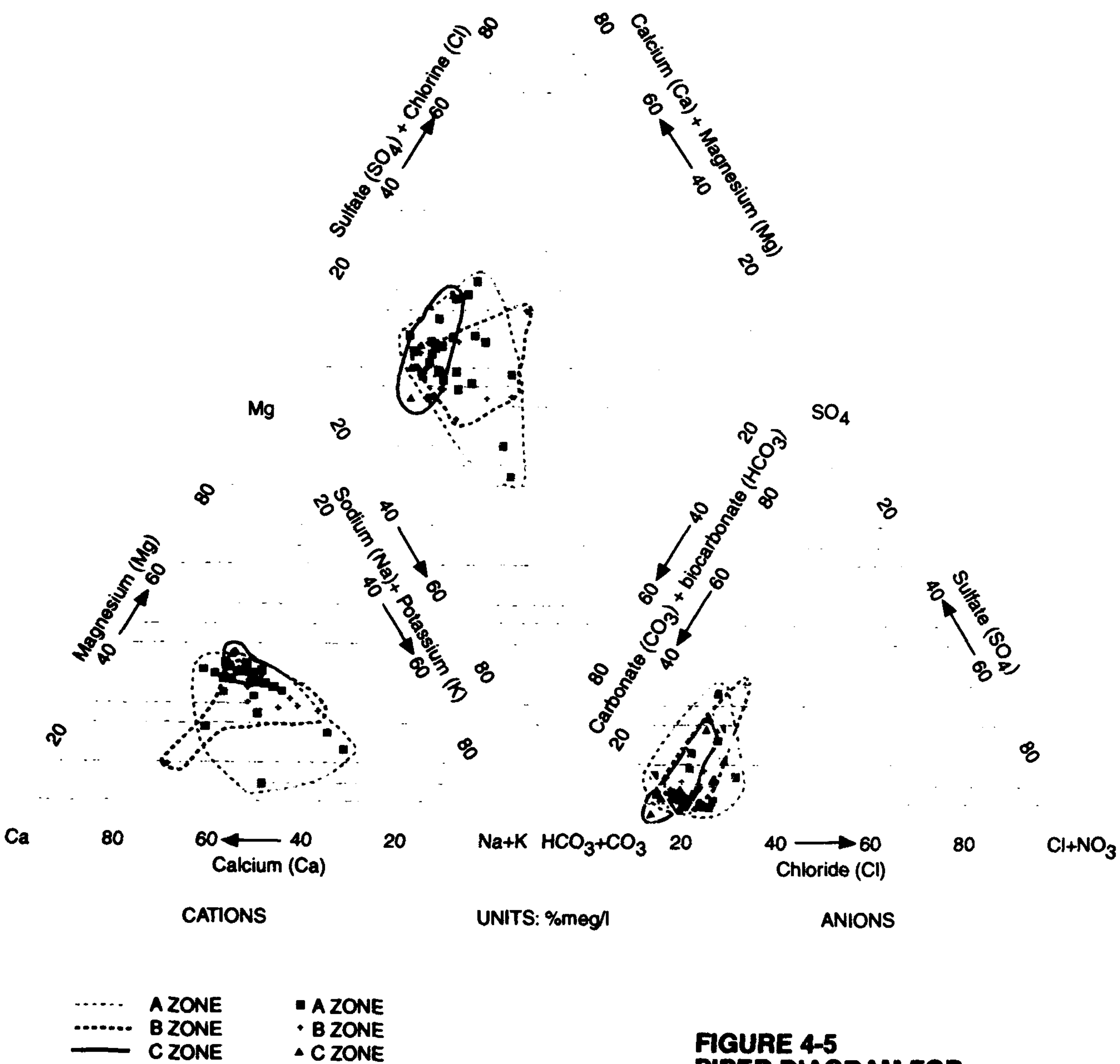


FIGURE 4-5
PIPER DIAGRAM FOR MONITORING ZONES A, B, AND C
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_78

CH2M HILL

4.2.2 Aquifer Properties

Test data from all single-well and multiple-well aquifer tests performed on wells screened in Monitoring Zones A, B, and C (presented in the PGOURI) were evaluated to estimate the distribution of transmissivity across the Base. Several different analytical methods were used to interpret the results of these tests, resulting in widely varying estimates of the aquifer transmissivities. The Jacob semilog method and the Theis Recovery method yielded the highest transmissivity estimates, while the Papadopolus-Cooper method yielded the lowest estimates. A complete description of these three analytical methods, including all assumptions and governing equations, are contained in Kruseman and de Ridder, 1991. The lower Papadopolus-Cooper estimates were more consistent with the specific capacity values measured in the pumping wells during the aquifer tests. This is not surprising because the Jacob method calculates transmissivity based solely on the slope of the semilog drawdown curve, while the Papadopolus-Cooper method takes into account the total drawdown observed in a well at a specific pumping rate.

Single Well Tests

Six single well aquifer tests were conducted in wells screened in Monitoring Zone A, with five of the six tested wells located in OU A. The thickness of the unconfined Monitoring Zone A ranges from 9 to 50 feet, and most of the monitoring wells are screened across the water table (Radian, 1992). The results of these aquifer tests are summarized in Table 4-1 by monitoring zone, and a complete list of the aquifer test results is presented in Appendix J (Table J-1). The results of these tests suggest that the transmissivity of Monitoring Zone A ranges from 300 to 16,000 gpd/ft using the Jacob Method, 100 to 28,000 gpd/ft using the Theis Recovery method, and 300 to 7,200 gpd/ft using the Papadopulos-Cooper method.

Eleven single well tests were conducted in wells screened in Monitoring Zone B, with nine of the eleven wells located in OU A. Monitoring Zone B is semiconfined and ranges in thickness from 40 to 75 feet (Radian,1992). The results of these aquifer tests are summarized in Table 4-1 by monitoring zone, and a complete list of the aquifer test results is presented in Appendix J (Table J-1). The results of these tests using the Jacob method suggest that the transmissivity of Monitoring Zone B ranges from 3,800 to 20,000 gpd/ft, while the Theis Recovery method suggests a range from 4,000 to 17,000 gpd/ft, and the Papadopulos-Cooper method suggests a range from 1,000 to 5,000 gpd/ft. A slug test and a pumping test were performed on a single well (MW-179) to compare the results of the two methods. The transmissivity was based on the slug test results and (1,900 gpd/ft) was much lower than the estimates obtained from the pumping test (5,000 to 9,600 gpd/ft). This is because of the fact that slug tests stress a limited portion of the aquifer directly adjacent to the well, while aquifer tests stress portions of the aquifer at greater distances from the extraction well. These results suggest that the sediments directly adjacent to the Well MW-179 have a lower transmissivity than those at greater distances or that the vertical leakance from adjacent layers is more extensive at greater distances from the well.

Ten single well aquifer tests were conducted on C zone wells, with the results summarized in Table 4-2 and listed completely in Appendix J. Monitoring Zone C is semiconfined and ranges in thickness from 52 to 88 feet (Radian,1992). The transmissivity of the C zone was estimated to range from 1,600 to 87,000 gpd/ft using the Jacob method, 3,500 to 58,000 gpd/ft using the Theis Recovery method, and 1,800 to 16,300 gpd/ft using the Papadopulos-Cooper method. Caution should be exercised in assuming transmissivities for the C zone greater than 50,000 gpd/ft. These values seem quite high based on the specific capacity values measured in the monitoring wells during the aquifer tests (8 to 10 gpm/ft of drawdown), the sediment types observed in borings, and the historic performance of extraction wells constructed at the Base to date.

Multiple-Well Tests

Ten multiple-well aquifer tests have been conducted at McClellan AFB, seven in OU C at the contractor's staging area and the Sector C extraction wellfield, and three in OU D. The information collected during these aquifer tests was used to develop the aquifer property estimates summarized in Appendix J. The data collected during the aquifer tests performed by Radian were evaluated using the Walton method, Neuman-Witherspoon method, Jacob straight-line method, and the Theis Recovery method. The data collected during the aquifer tests conducted by CH2M HILL were evaluated using the Jacob straight-line method, the Theis Recovery method, and the Hantush and Jacob curve-matching method. The 30-day aquifer test performed by McLaren Environmental Engineering was evaluated by matching the observed drawdown with an analytical groundwater flow model. The range of transmissivity estimates from these tests is consistent with those developed from the results of the single well aquifer testing summarized in Appendix J. The storage coefficient estimates from these tests are on the high end of typical values for confined aquifers (0.005 to 0.00005) (Freeze and Cherry, 1979). This suggests that the shallow aquifers at the site behave as unconfined to semiconfined aquifers. Monitoring Zone A is unconfined, producing water from storage mainly by gravity drainage. Monitoring Zones B and C produce water through a combination of pore pressure decline (typical of confined aquifers) and leakage from adjacent units.

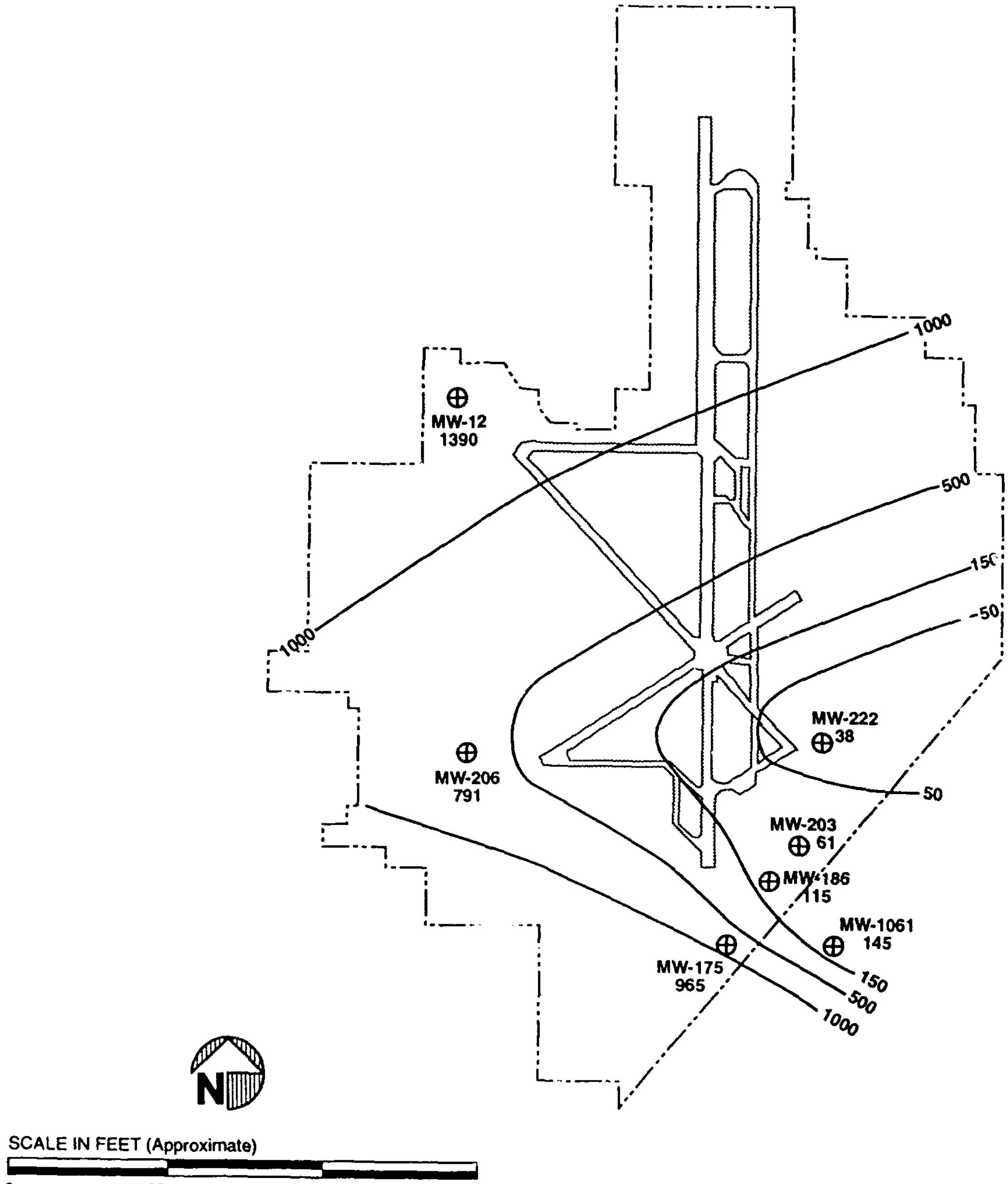
The results of the multiple-well aquifer tests performed by Radian were also used to estimate the vertical hydraulic conductivity of the fine-grained units at the site. Accurate estimates of vertical hydraulic conductivity are important as it partially determines the extent of vertical leakage that occurs when an extraction well pumps from a particular monitoring zone. The magnitude of the vertical leakance has a strong influence on the vertical capture that an extraction well can produce and therefore impacts the number of extraction wells required to remediate a given volume of contaminated aquifer. The results of the vertical permeability analysis, presented in Table 3-6 of the Preliminary GW OU RI, suggest that the general vertical hydraulic conductivity of the fine-grained materials is between 0.14 and 0.41 ft/day. One calculation produced a vertical hydraulic conductivity estimate of 4.1 ft/day, which may reflect a particularly permeable zone in the otherwise fine-grained sediments between Monitoring Zones A and B.

Because of the heterogeneous nature of the sedimentary deposits at McClellan AFB, none of the wells tested are actually "fully penetrating" a discrete aquifer. In reality, significant vertical flow components exist as water moves toward the pumping wells, both within designated monitoring zones and between adjacent monitoring zones. This results in flow conditions surrounding a pumping well that deviate from radial flow conditions, producing longer flow lines for the water particles and forcing the groundwater flow lines to converge through a smaller cross-sectional area while approaching the well screen. The additional head loss that results from these flow conditions will increase the drawdown measured in the pumping well during an aquifer test.

The approach adopted by CH2M HILL in estimating aquifer properties for use in groundwater extraction simulation was to evaluate the test results using a method that incorporates the magnitude of drawdown that is observed in the wells during pumping and is consistent with the specific capacities measured in existing extraction wells at the Base. This method was clearly the Papadopolus-Cooper method. Figures 4-7, 4-8, and 4-9 show the contours of transmissivities in Monitoring Zones A, B, and C based on these tests. Table 4-1 presents a range of transmissivities and hydraulic conductivities for Monitoring Zones A, B, and C in each OU. None of the extraction wells operating onbase have measured specific capacities that indicate transmissivities high enough to even approach the values obtained from the Jacob method. According to the current data, transmissivities are believed to be lower than those estimated by the Jacob method. This approach will result in a conservative estimate of the number of extraction wells that will be required to contain existing contamination, even in low transmissivity conditions. This design will address the uncertainty that exists in actual aquifer characteristics at the site, since it will be effective in all but worst-case conditions. Additional aquifer tests will be performed at the site prior to remedial design. If transmissivities are found to be higher than those originally estimated, fewer extraction wells will be needed for capture.

4.3 Source Areas

The location of source areas and the time of contaminant release into the environment make up the second component of the conceptual model. The historic Base activities and disposal practices have been the primary source of contamination in the groundwater at McClellan AFB. The nature and extent of VOC contamination at each Operable Unit is different because the type of wastes released and the historic disposal practices at each Operable Unit were different. The following section describes the sources of contamination at the Base. The section begins



LEGEND

⊕ Aquifer Tested Monitoring Well

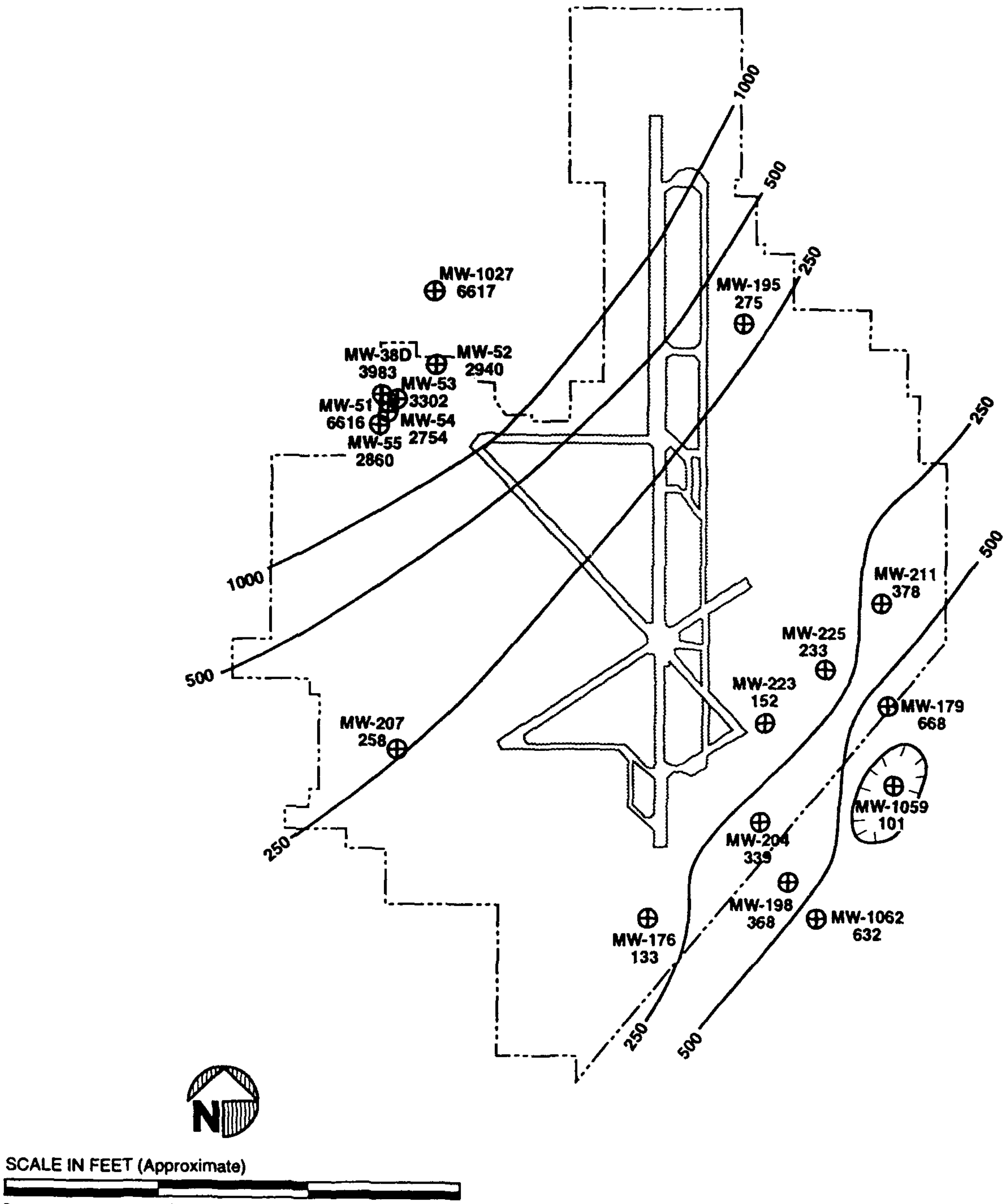
791 Transmissivity Estimate From Aquifer Test (ft²/day)

—— Transmissivity Contour (ft²/day)

FIGURE 4-7
TRANSMISSIVITY (FT²/DAY) IN THE A ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_06

CH2M HILL



LEGEND

⊕ Aquifer Tested Monitoring Well

133 Transmissivity Estimate from Aquifer Test (ft^2/day)

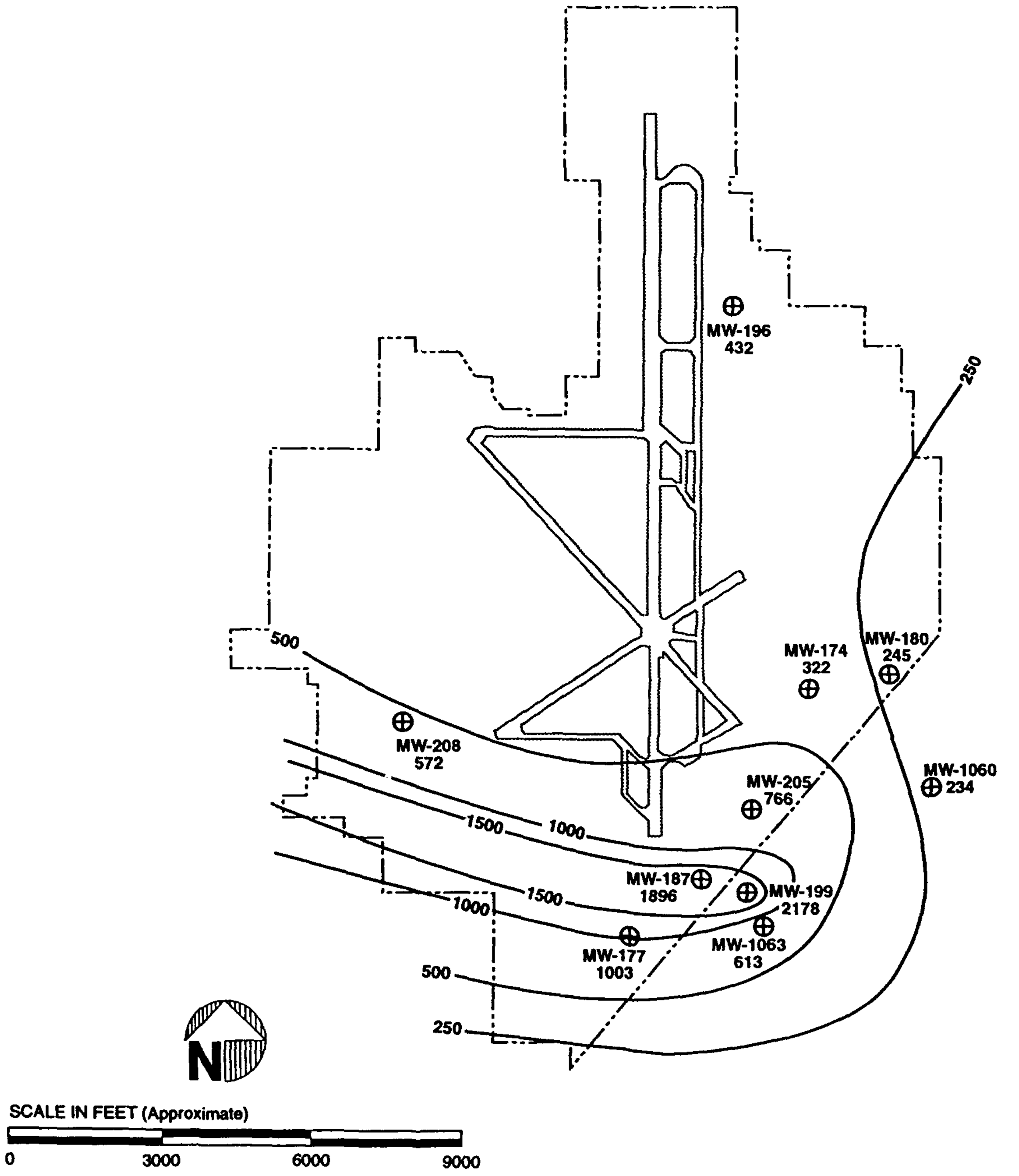
Transmissivity Contours (ft^2/day)

RDD1454_07

FIGURE 4-8
TRANSMISSIVITY (FT^2/DAY
IN THE B ZONE

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



LEGEND

⊕ Aquifer Tested Monitoring Well

572 Transmissivity Estimate From Aquifer Test (ft²/day)

Transmissivity Contour (ft²/day)

RDD1454_08

FIGURE 4-9
TRANSMISSIVITY DISTRIBUTION IN THE C ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

FIGURE 3-8

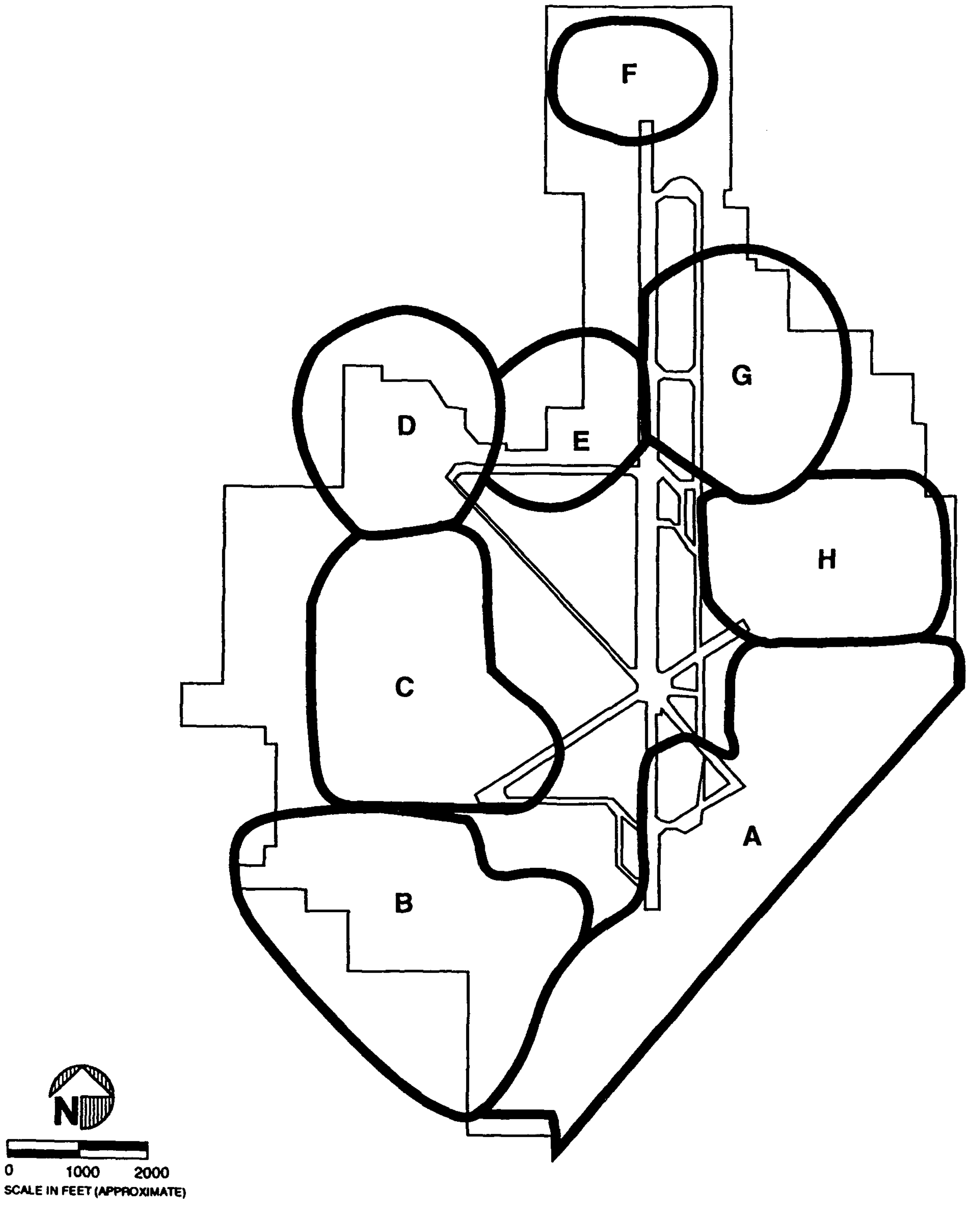
Table 4-1
Approximate Aquifer Parameters

Zone	Aquifer Parameters	OU A	OU B/C	OU D	OU G
Ground Surface (ft msl)		70	62	62	72
A	Transmissivities (ft^2/day)	13 to 3,757	788 to 2,179	1,390	--
	Hydraulic Conductivities (ft/day)	0.65 to 188	22.5 to 62.25	39.7	--
	Zone Thickness (ft)	20	35	35	20
	Depth (ft msl)	-35 to -55	-45 to -80	-37 to -72	-30 to -50
	Depth (ft bgs)	105 to 125	107 to 142	99 to 134	102 to 122
B	Transmissivities (ft^2/day)	107 to 2,727	254 to 1,270	2,754 to 6,617	281 to 2,259
	Hydraulic Conductivities (ft/day)	214 to 54.54	3.9 to 19.5	45.9 to 110.3	7.0 to 56.5
	Zone Thickness (ft)	50	65	60	40
	Depth (ft msl)	-55 to -105	-80 to -145	-72 to -132	-50 to -90
	Depth (ft bgs)	125 to 175	142 to 205	134 to 194	122 to 162
C	Transmissivities (ft^2/Day)	213 to 11,631	521 to 1,070	1,900 to 2,100	428 to 1,992
	Hydraulic Conductivities (ft/day)	3.0 to 166	7.0 to 14.3	23.8 to 26.25	7.8 to 36.2
	Zone Thickness (ft)	70	75	80	55
	Depth (ft msl)	-105 to -175	-145 to -220	-132 to -212	-90 to -145
	Depth (ft bgs)	175 to 245	205 to 282	194 to 274	162 to 217

Notes: Hydraulic Conductivity = transmissivity/zone thickness.
-- = Aquifer test was not performed.
Zone thicknesses were estimated from the PGOURI (Radian, 1992).
Source of transmissivities: OU A, OU B/C, OU G–PGOURI (1992);
OU D–*IRP Phase III/IV Area D Site Characterization Study* (CH2M HILL, 1984).

with a brief history of the Base activities, followed by a summary of the types of contaminants disposed of at each of the Operable Units, including the Industrial Waste Line. The approximate Operable Unit boundaries are presented in Figure 4-10.

McClellan AFB was established in 1936 to function as an air repair depot and supply base for the War Department. During World War II, McClellan AFB became a major industrial facility with capabilities ranging from bomber and cargo aircraft maintenance to wastewater treatment capabilities. By the early 1950s, the Base had gone through a transition to assume the role of a jet fighter maintenance depot. From its beginning, McClellan AFB has used a variety of toxic substances as part of routine operation and maintenance activities. Some of the toxic materials used included industrial solvents, caustic cleaners, electroplating wastes laden with heavy metals, jet fuels, and various oils and lubricants (Radian, 1990). Hazardous waste produced as a result of day-to-day operations was disposed of in burial pits, sludge pits, burn pits, and other miscellaneous disposal pits around the Base.



LEGEND

BOUNDARIES OF OPERABLE UNITS

McCLELLAN AIR FORCE BASE BOUNDARY

Source: Radian, 1991
RDD1454_00

FIGURE 4-10
APPROXIMATE BOUNDARIES OF OPERABLE UNITS AT McCLELLAN AIR FORCE BASE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

In 1979, concern arose over waste disposal practices, surface spills at chemical storage yards and wastewater treatment plants, and leaks in the industrial waste conveyance line that had allowed toxic chemicals to contaminate soil and groundwater at McClellan AFB. A groundwater sampling effort commenced that same year, and by 1980 it was confirmed that trichloroethene (TCE) was present in certain Base wells.

In response to this finding, McClellan AFB developed an investigatory program aimed at evaluating past operation and waste disposal practices, identifying contamination sources, and determining the extent of contamination in soil and groundwater (Radian, 1990). At present, 53 confirmed sites (CSs) and 117 potential release locations (PRLs) have been identified as sources of soil and groundwater contamination around the Base (Radian, 1991). These CSs and PRLs are presented in Figure 4-11 and described in Table 4-2. Nearly 90 percent of the CSs and PRLs are located within the boundaries of OUs A, B, C, and D. Figure 4-11 shows the distribution of CSs and PRLs throughout the Base and where they are located in relation to the OUs. Because the CSs and PRLs were used for specific functions and operations, each OU contains its own history of maintenance activities, contamination discharges, waste production, and contaminant detection.

OU A Source Area History

The following information on OU A was taken from the OU A Preliminary Assessment Summary Report (Radian, 1990) unless otherwise noted.

Development of the area known today as OU A began shortly after the groundbreaking ceremony at McClellan AFB in 1936. Over the course of its 50-year life, OU A was used mainly for industrial activities. Some of those activities included engine and aircraft maintenance, waste disposal and treatment, underground waste conveyance, and aboveground and belowground chemical storage.

Beginning in the late 1930s, aircraft maintenance was a main operation in OU A. Instrument repair shops, plating shops, and paint spray booths occupied several buildings in this area to assist in routine aircraft maintenance. Between 1940 and 1976, engine maintenance and testing procedures used washracks, solvent spray booths, steam cleaning bays, and grinding shops in this area. A variety of waste disposal and treatment facilities were operated in OU A from 1941 to 1981. Landfills used for disposal of sanitary and industrial waste were operated in OU A from the 1940s to 1960s. Sludge produced from both industrial and sanitary wastewater treatment applications was dewatered in the same wastewater sludge beds from 1950 to 1972. Storage facilities and an industrial wastewater conveyance line were installed and operated from the 1940s to 1960s. Underground storage tanks and tank farms were used to store hazardous materials for various purposes. Because of leakage problems, many tanks have been removed around the Base to control the spread of soil and groundwater contamination. In the 1950s, the Industrial Wastewater Line (IWL) was installed in OU A. Its function was to convey industrial wastes to the Industrial Wastewater

Table 4-2
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	1	LF024	CS 024	CS 24	Landfill	Prip	41,000	1964-1969	CERCLA
	2	LF025	PRL 025	PSPRL 25	Landfill	Unknown	110,000	Late 40s, early 50s	CERCLA
	3	ST034	CS 034	PSPRL 34	Waste sol. storage tanks	Prip	100	--	CERCLA
	4	LF037	CS 037	PSPRL 37	Landfill	Sol, POL	125,000	1940-1957	CERCLA
	5	LF038	CS 038	CS 38	Engine Repair Shop	Sol, Prip, Met	240,000	--	CERCLA
	6	LF039	PRL 039	PSPRL 39	Landfill	Unknown	100,000	Before 1941-1946	NFI, REG-CON
	7	WP040	CS 040	PSPRL 40	Indus. wastewater sludge	Sol, POL	21,000	1943-1972	CERCLA
	8	DP070	PRL B-002	UPRL B-2	Spoil pit/borrow pit	Unknown	189,000	--	NFI, REG-CON
	9	LF071	PRL B-003	UPRL B-3	Landfill	Sol, POL	--	--	NFI, REG-CON
	10	WP072	PRL B-004	UPRL B-4	Sludge drying bed	Sol, Met	2,500	1941	NFI, REG-CON
	11	LF073	CSB-005	UPRL B-5	Empty lot	POLs, Sol	12,500	1962	NFI, REG-CON
	12	WP079	PRL P-003	UPRL P-3	Oil pit	Sol, POL	6,270	1946-1987	CERCLA
	13	WP080	PRL P-004	UPRL P-4	Sump	Sol, POL	3,360	Early 1940s-1989	CERCLA
	14	SD081	CS P-005	UPRL P-5	Open Ditch	Sol, Other	2,200	1940-1965	CERCLA
	15	SD082	CS P-006	UPRL P-6	Open Ditch	Sol, Other	2,200	1943-1989	CERCLA
	16	WP084	PRL P-008	UPRL P-8	Acid and cyanide pit	Acetone, Met	38,000	1955	CERCLA
	17	OT086	PRL S-001	UPRL S-1	Plating shop	Sol, CN, Met	12,000	1944-1957	CERCLA
	18	SS087	PRL S-002	UPRL S-2	Chemical warehouse	Sol	9,400	1943	CERCLA
	19	SS088	PRL S-003	UPRL S-3	Acid storage warehouse	Acetone	5,600	1942-1975	NFI, REG-CON
	20	SS089	PRL S-004	UPRL S-4	Treatment plan/sludge beds	Sol, Met, POL	13,000	1943-1989	CERCLA
	21	WP091	PRL S-006	UPRL S-6	IWTP #1	Sol, Met	4,200	Late 1930s-1989	CERCLA
	22	WP092	CS S-007	UPRL S-7	IWTP #3	Sol, Other	8,100	1940-1989	CERCLA
	23	SS094	PRL S-009	UPRL S-9	Asbestos storage	Asbestos	10,000	Oct-Dec 1987	CERCLA
	24	SD099	PRL S-014	UPRL S-14	Paint shop/spray booths	Sol, POL	8,400	1938-1989	CERCLA
	25	SD101	PRL S-016	UPRL S-16	Sol./paint spray booths	POL, Sol	250,000	1937-1989	CERCLA

Table 4-2
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	26	SD102	PRL S-017	UPRL S-17	Repair shop/spray booths	Sol, POL	27,000	1937-???	CERCLA
	27	SD103	PRL S-018	UPRL S-18	Repair shop/clean shop	Sol, POL	27,000	1937-1989	CERCLA
	28	SS104	PRL S-019	UPRL S-19	Entomology storage area	Pesticides	3,600	1940-1970s	CERCLA
	29	SD105	PRL S-020	UPRL S-20	Photo lab	Met, SOL	14,000	1941	CERCLA
	30	SD106	CS S-021	UPRL S-21	Degreaser/spray booths	Sol, POL	28,000	1943-1989	CERCLA
	31	SD107	PRL S-022	UPRL S-22	Repair shop/spray booths	Sol, POL	10,000	Late 1930s	CERCLA
	32	SD108	PRL S-023	UPRL S-23	Plating shop	Sol, Met, CN	14,000	1942	NFI, REG-CON
	33	SD109	CS S-024	UPRL S-24	Depaint washrack	POL, Sol	25,000	1940-1989	CERCLA
	34	SD110	PRL S-025	UPRL S-25	Transformer shop	POL, PCB, Sol	27,000	1943-1989	CERCLA
	35	SD111	CS S-026	UPRL S-26	Mainshop/spray booth	POL, Sol	38,000	1942	CERCLA
	36	SD112	CS S-027	UPRL S-27	Solvent recovery stills	Sol	7,200	1941	CERCLA
	37	SS121	PRL S-036	UPRL S-36	Oil drum storage	Sol, POL	27,000	1943-1989	CERCLA
	38	SS122	PRL S-037	UPRL S-37	Oil drum storage	Sol, PCL	27,000	1946-1988	CERCLA
	39	SS123	PRL S-038	UPRL S-38	Drum storage	Sol	15,000	1943-1989	CERCLA
	40	ST131	PRL T-006	UPRL T-6	UST	Sol	3,100	1952-1980	CERCLA
	41	ST132	PRL T-007	UPRL T-7	Sol pit/waste thinner tank	Sol	14,000	1952-1989	CERCLA
	42	ST134	PRL T-010	UPRL T-10	Solvent tank	Sol	56,000	1938-1989	CERCLA
	43	ST136	CS T-012	UPRL T-12	Waste oil/solvent tank	Sol	2,400	1943-1989	CERCLA
	44	ST137	PRL T-015	UPRL T-15	Tank Farm 1	Sol, POL	25,000	1943-1989	UST
	45	ST138	CS T-016	UPRL T-16	Tank Farm 2	Sol, POL	--	Late 40s/Early 50s	UST
	46	ST139	CS T-017	UPRL T-17	Tank Farm 3W	POL	2,800	1943-1987	UST
	47	ST140	PRL T-018	UPRL T-18	Tank Farm 4	POL	5,400	1940-1989	UST
	48	ST141	PRL T-019	UPRL T-19	Tank Farm 5	POL	5,400	Early 40s-Late 60s	UST
	49	ST142	CS T-020	UPRL T-20	Tank Farm 6	Sol, POL	20,000	1941-1989	CERCLA
	50	ST143	CS T-021	UPRL T-21	UST	Sol, POL	10,000	1943-1989	CERCLA

Table 4-2
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	51	ST144	CS T-030	UPRL T-30	UST	Sol	3,600	1940-1954	CERCLA
	52	ST148	CS T-036	UPRL T-36	UST	Sol	6,700	1943-1989	CERCLA
	53	ST149	CS T-037	UPRL T-37	UST	Sol	6,700	1943-1989	CERCLA
	54	SD156	CS T-047	UPRL T-47	Oil/water separator	POL	6,700	1940-1989	CERCLA
	55	OT159	PRL L-002	--	IWL	Unknown	--	--	CERCLA
	56	OT160	PRL L-003	--	IWL	Unknown	--	--	CERCLA
	57	OT161	PRL L-004	--	IWL	Unknown	--	--	CERCLA
	58	OT169	CS T-057	--	IWL drain at Bldg. 431	Sol, VOC	--	--	CERCLA
	59	ST170	CS T-059	--	UST	Fuel Oil	--	--	UST
	60	ST172	CS T-061	--	UST	Fuel Oil	--	--	UST
	61	ST198	SA 035	--	UST	Diesel	--	1942-1992	UST
	62	SS199	SA 037	--	Motor pool	Unknown	--	--	CERCLA
	63	ST200	SA 038	--	UST	Fuels	--	1938-1991	UST
	64	SS201	SA 040	--	Chemical storage area	Unknown	--	--	CERCLA
	65	SS202	SA 041	--	Metal fabrication	Unknown	--	--	CERCLA
	66	SS203	SA 043	--	Average fluids	Unknown	--	--	CERCLA
	67	WP204	SA 044	--	Sump	Unknown	--	--	CERCLA
	68	SS205	SA 045	--	Soil contamination	Unknown	--	--	CERCLA
	69	ST206	SA 046	--	UST	Diesel	--	1954-1989	UST
	70	SD207	SA 047	--	Washrack 254	Unknown	--	--	CERCLA
	71	ST208	SA 048	--	Warehouse	Paints, Sol	--	--	NFI, REG-CON
	72	ST209	SA 049	--	UST	Diesel	--	1941-1992	UST
	73	ST210	SA 052	--	Blowdown Tanks	Met., Anions	--	1946-1990	CERCLA
	74	WP211	SA 053	--	Washrack	Unknown	--	--	CERCLA
	75	ST212	SA 054	--	Aboveground storage tank	Unknown	--	--	CERCLA

Table 4-2
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	76	SS213	SA 055	--	Laboratory	Unknown	--	--	CERCLA
	77	SD214	SA 056	--	Wastewater	Unknown	--	--	CERCLA
	78	SS215	SA 058	--	Chemical storage tank	Unknown	--	--	CERCLA
	79	ST216	SA 059	--	UST	Diesel	--	1952-1988	UST
	80	WP217	SA 060	--	Indus. wastewater drain	Unknown	--	--	CERCLA
	81	SD218	SA 061	--	Solvent spray booth	Unknown	--	--	CERCLA
	82	SS219	SA 064	--	*Chemical storage*	Unknown	--	--	CERCLA
	83	OT220	SA 065	--	IWL	Unknown	--	--	CERCLA
	84	SS221	SA 066	--	Motor pool	Unknown	--	--	CERCLA
	85	SS222	SA 067	--	Soil contamination	Unknown	--	--	CERCLA
	86	SS223	SA 068	--	Spills	Unknown	--	--	CERCLA
	87	WP224	SA 069	--	Steam Fac./UST	Met/Fuels	--	1942-1993	UST
	88	OT225	SA 070	--	IWL	Unknown	--	--	CERCLA
	89	SS226	SA 071	--	Hazardous mat. storage	Unknown	--	--	CERCLA
	90	WP227	SA 073	--	Sump	Unknown	--	--	CERCLA
	91	ST228	SA 074	--	AGT, UST	Diesel	--	1943-1989	UST
	92	OT229	SA 075	--	IWL	Unknown	--	--	CERCLA
	93	SS230	SA 076	--	Hazardous mat. storage	Unknown	--	--	CERCLA
	94	ST231	SA 077	--	Aboveground storage tank	Unknown	--	--	CERCLA
	95	SD232	SA 078	--	Locomotive washrack	Unknown	--	--	CERCLA
	96	ST233	SA 079	--	Fuel Test Fac.	Sol	--	--	CERCLA
	97	SS234	SA 080	--	Contractor staging	Unknown	--	--	CERCLA
	98	ST235	SA 081	--	Fuel lines	Unknown	--	--	CERCLA
	99	OT236	SA 084	--	Spray booth	Unknown	--	--	CERCLA
	100	WP237	SA 085	--	Oil/water separator	Sol	--	--	CERCLA

Table 4-2
Summary of Sites Identified at
McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
A	101	WP238	SA 086	--	Engine Test/UST	Sol, VOC	--	--	CERCLA
	102	ST239	SA 087	--	UST	POL	--	1944-1986	UST
	103	SS240	SA 088	--	Soil contamination	Unknown	--	--	CERCLA
	104	SS241	SA 089	--	Open storage area	Unknown	--	--	CERCLA
	105	SD242	SA 090	--	Washrack	Unknown	--	--	CERCLA
	106	SS243	SA 091	--	Soil contamination	Unknown	--	--	CERCLA
	107	RW244	SA 093	--	Radionuclide	Unknown	--	--	CERCLA
	108	ST245	SA 094	--	Open storage area	Unknown	--	1964-???	CERCLA
	109	ST246	SA 095	--	UST	Fuel Oil	--	1946-1957	UST
	110	WP247	SA 096	--	UST	Unknown	--	1943-???	CERCLA
	111	SD248	SA 097	--	Tank farm	Unknown	--	--	CERCLA
	112	SS249	SA 098	--	Spray booths	Unknown	--	--	CERCLA
	113	ST250	SA 099	--	Sewage treat./UST	Sewage, Diesel	--	1950-	UST
	114	ST251	SA 100	--	Doc. destruct./UST	Sol, Diesel	--	1973-	UST
	115	WP252	SA 101	--	Sump	Unknown	--		CERCLA
	116	SS253	SA 103	--	Soil contamination	Unknown	--	--	CERCLA
	117	SS254	SA 105	--	Laboratory	Unknown	--	--	CERCLA
	118	ST255	SA 106	--	Salvage yard/UST	Sol, Diesel	--	--	UST
	119	SS256	SA 107	--	Soil contamination	Unknown	--	--	CERCLA
	120	SD257	SA 108	--	Aircraft fluids	Unknown	--	--	CERCLA
	121	SD258	SA 109	--	Magpie Creek contam.	Unknown	--	--	CERCLA
B	122	LF023	CS 023	CS 23	Landfill	Prip	24,000	1966-1989	CERCLA
	123	DP030	CS 030	PSPRL 30	Radio/chem lab/landfill	Sol, Met	39,000	1957-1988	CERCLA
	124	OT031	CS 031	PSPRL 31	Incinerate ash burial pit	Met, POL	53,000	1963-1968	CERCLA
	125	SS036	CS 036	PSPRL 36	Open storage area	Sol, CN	30,000	1958-1980	CERCLA

Table 4-2
Summary of Sites Identified at
McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
B	126	OT045	CS 047	CS 47	Abandoned plating shop	Sol, Met	44,000	1957-1982	CERCLA
	127	WP046	CS 048	CS 48	Abandoned IWTP	Unknown	--	--	CERCLA
	128	OT066	--	--	Base Well 18	Unknown	--	--	CERCLA
	129	DP035	PRL 035	PSPRL 35	Scrap metal burial pit	Unknown	35,000	World War II	NFI, REG-CON
	130	LF069	PRL B-001	UPRL B-1	Landfill	Unknown	109,200	--	NFI, REG-CON
	131	LF076	PRL B-009	UPRL B-9	Landfill	Unknown	50,400	--	NFI, REG-CON
	132	SD078	PRL P-002	UPRL P-2	Waste pond	POL, Sol	18,820	1962-???	CERCLA
	133	SD085	PRL P-009	UPRL P-9	Open drainage ditch	Sol, Met	1,700	1956 to mid-1960s	CERCLA
	134	WP090	PRL S-005	UPRL S-5	Abandoned IWTP	Unknown	5,900	--	CERCLA
	135	SS097	PRL S-012	UPRL S-12	PCB storage	Unknown	20,000	Mid 1940s	NFI, REG-CON
	136	SS098	PRL S-013	UPRL S-13	Open storage	Sol	120,000	1955-1989	CERCLA
	137	SS113	PRL S-028	UPRL S-28	Oil/paint storage	POL	5,000	1968-1987	CERCLA
	138	SS114	PRL S-029	UPRL S-29	PCB storage	PCB	190,000	--	CERCLA
	139	SD115	PRL S-030	UPRL S-30	Depaint washrack	Sol, POL	15,000	1951-???	CERCLA
	140	SS118	PRL S-033	UPRL S-33	Hazardous mat. storage	Sol, Other	84,000	1953	CERCLA
	141	SD119	PRL S-034	UPRL S-34	Degreaser/paint booth	Other, Sol	35,000	--	CERCLA
	142	SD120	PRL S-035	UPRL S-35	Solvent spray booth	Sol, Other	25,000	1946-49; 1965	CERCLA
	143	SD126	PRL S-041	UPRL S-41	MAT K storage	Jet Fuel	125,000	1955-1989	NFI, REG-CON
	144	OT162	PRL L-005	--	Indus. wastewater line	Unknown	--	--	CERCLA
	145	OT163	PRL L-006	--	Indus. wastewater line	Unknown	--	--	CERCLA
	146	ST133	PRL T-008	UPRL T-8	Fuel tank	Unknown	16,000	--	CERCLA
	147	SD154	PRL T-045	UPRL T-45	Oil/water separator	POL, TCE, PCE	3,600	--	UST
	148	SD155	PRL T-046	UPRL T-46	Defuel fac. tanks	POL, TCE, PCE	6,700	Before 1968-???	CERCLA/UST
	149	SD157	PRL T-048	UPRL T-48	Oil/water separator, UST	POL, TCE, PCE	6,700	1968-Present	CERCLA/UST
	150	ST171	PRL T-060	--	UST	POL	--	--	UST

Table 4-2
Summary of Sites Identified at
McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
B	151	WP179	SA 001	--	Surface disposal	Unknown	--	--	NFI, REG-CON
	152	SS180	SA 002	--	Laboratory	Unknown	--	--	CERCLA
	153	SD181	SA 003	--	Washrack	Unknown	--	--	CERCLA
	154	SS182	SA 004	--	Paint shop	Unknown	--	--	CERCLA
	155	SS183	SA 005	--	Paint storage	Unknown	--	--	CERCLA
	156	ST184	SA 006	--	Gas station	MOGAS	--	1954-1991	UST
	157	SD185	SA 007	--	Washrack	Unknown	--	--	CERCLA
	158	ST186	SA 008	--	UST	POL	--	--	UST
	159	SS187	SA 009	--	Hazardous mat. storage	VOC	--	--	NFI, REG-CON
	160	SS188	SA 010	--	Sump	Herbicides	--	--	CERCLA
	161	ST189	SA 011	--	UST	Diesel	--	--	UST
	162	SS191	SA 013	--	Chemical storage area	Unknown	--	--	CERCLA
	163	SD192	SA 014	--	Storm water drainage	Unknown	--	--	CERCLA
	164	SS193	SA 015	--	NW corner lot 10 spill	Unknown	--	--	CERCLA
	165	SD194	SA 016	--	Chemical storage area	Unknown	--	--	CERCLA
	166	SS195	SA 017	--	Oil storage yard	Unknown	--	--	CERCLA
	167	SS196	SA 018	--	Oil storage yard	Unknown	--	--	CERCLA
	168	SD197	SA 019	--	Spray booth	Unknown	--	--	CERCLA
B1	169	OT029	PRL 029	PSPRL 29	Landfill	Unknown	120,000	1950s-1960s	CERCLA
	170	SS190	SA 012	--	DRMO storage area	Unknown	--	--	CERCLA
C	171	SD007	CS 007	CS 7	Sludge/oil pit	Prip, Sol, PCB, POL	35,000	--	CERCLA
	172	LF008	PRL 008	PSPRL 8	Sludge refuse/landfill	Prip, Sol, POL	59,000	--	CERCLA
	173	LF009	PRL 009	PSPRL 9	Landfill	Unknown	30	--	CERCLA
	174	LF010	CS 010	CS 10	Landfill	PCB, Prip	32,000	--	CERCLA
	175	LF011	CS 011	CS 11	Landfill	Prip	32,000	--	CERCLA

Table 4-2
Summary of Sites Identified at
McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
C	176	LF012	CS 012	CS 12	Landfill	Prip	55,000	--	CERCLA
	177	LF013	CS 013	CS 13	Landfill	Prip	54,000	--	CERCLA
	178	LF014	CS 014	CS 14	Landfill	Prip	54,000	--	CERCLA
	179	DP015	PRL 015	PSPRL 15	Sodium valve trench	Unknown	30	--	CERCLA
	180	DP016	PRL 016	PSPRL 16	Sodium valve trench	Unknown	30	--	CERCLA
	181	LF017	PRL 017	PSPRL 17	Landfill	Sol	40,000	--	CERCLA
	182	LF018	PRL 018	PSPRL 18	Landfill	Unknown	40,000	1957-1959	CERCLA
	183	LF019	PRL 019	PSPRL 19	Landfill	Unknown	40,000	1957-1959	CERCLA
	184	DP020	PRL 020	PSPRL 20	Sludge/oil pit	Sol, POL	50,000	1956-1957	CERCLA
	185	DP021	PRL 021	PSPRL 21	Sludge/oil pit	VOC, Sol	50,000	1956-1957	CERCLA
	186	DP028	PRL 028	PSPRL 28	Sludge pit	Prip	3,000	--	CERCLA
	187	SS032	PRL 032	PSPRL 32	Rad/hazardous wastes	Prip	160	1955-1974	CERCLA
	188	LF043	CS 043	CS 43	Burn pit	Prip	20,000	--	CERCLA
	189	LF047	PRL 049	PSPRL 49	Landfill	Unknown	45,000	Before 1971	CERCLA
	190	WP048	PRL 050	PSPRL 50	Settling pond	Unknown	11,000	1946-1971	CERCLA
	191	WP049	PRL 051	PSPRL 51	Holding pond	Unknown	180,000	1982-1989	CERCLA
	192	DP050	CS 052	CS 52	Burn pit	Prip	20,000	--	CERCLA
	193	WP051	PRL 053	PSPRL 53	Settling pond	Sol	96,000	1958???	CERCLA
	194	SS052	PRL 054	PSPRL 54	Storage area	Unknown	6,300	Circa 1970	CERCLA
	195	SS053	PRL 055	PSPRL 55	Acid storage area/landfill	Sol	900	1951-1989	CERCLA
	196	SS054	PRL 056	PSPRL 56	Storage area	Unknown	100,000	1957-1974	CERCLA
	197	LF055	PRL 057	PSPRL 57	Landfill	Unknown	29,000	1956	CERCLA
	198	WP056	PRL 060	PSPRL 60	Holding pond	Unknown	80,000	--	CERCLA
	199	WP057	PRL 061	PSPRL 61	Chemical waste pit	Unknown	900	Early 1950s	CERCLA
	200	WP058	PRL 062	PSPRL 62	Chemical waste pit	Unknown	500	Early 1950s	CERCLA

Table 4-2
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
C	201	SD059	PRL 063	PSPRL 63	Unlined ditch	Unknown	20,000	--	CERCLA
	202	SD060	PRL 064	PSPRL 64	Unlined ditch	Unknown	--	--	CERCLA
	203	LF061	PRL 065	PSPRL 65	Landfill	Unknown	--	--	CERCLA
	204	WP062	PRL 066	PSPRL 66	Ditches and pond	Unknown	--	1946-1989	CERCLA
	205	WP063	CS 067	CS 67	Landfill	Prip, POL	40,000	--	CERCLA
	206	WP068			Groundwater treat. plant	Unknown	--	--	CERCLA
	207	SS096	PRL S-011	UPRL S-11	BCE/PCE storage	PCB, POL, Sol	47,000	1941-1989	CERCLA
	208	SD116	PRL S-031	UPRL S-31	Aircraft paint hangar	Paints, POL, Sol	47,000	1968-1989	CERCLA
	209	SS117	PRL S-032	UPRL S-32	Paint storage area	Paints, POL, Sol	10,080	1968-1989	CERCLA
	210	SD165	PRL P-010	--	Magpie Creek	VOC	--	--	CERCLA
	211	OT166	PRL S-046	--	Unknown	Unknown	--	--	CERCLA
	212	OT168	PRL S-048	--	W of Bldg. 720	Unknown	--	--	CERCLA
C1	213	LF022	CS 022	CS 22	Burn pit/landfill	Prip, Sol, PCB,	40,000	1946-1968	CERCLA
	214	LF041	PRL 041	PSPRL 41	Landfill	POL	106,000	--	CERCLA
	215	LF042	CS 042	CS 42	Oil storage/landfill	Prip	11,000	1946-1960S	CERCLA
	216	WP064	PRL 068	PSPRL 68	Sludge ponds	Prip, PCB, POL	13,000	--	CERCLA
	217	DP065	CS 069	CS 69	Burn pit	Prip	--	--	CERCLA
	218	OT164	PRL L-007	--	Indus. wastewater line	Prip Unknown	--	--	CERCLA
D	219	LF001	CS 001	CS 1	Landfill	Prip	10,500	--	OSD/NVZ
	220	LF002	CS 002	CS 2	Sludge/oil pit	POL, Prip, Sol	20,000	--	OSD/NVZ
	221	LF003	CS 003	CS 3	Sludge/oil pit	Prip	50,700	--	OSD/NVZ
	222	DP004	CS 004	CS 4	Sludge/oil pit	Prip, Sol, POL	15,000	--	OSD/NVZ
	223	DP005	CS 005	CS 5	Sludge/oil pit	Prip	15,600	--	OSD/NVZ

Table 4-2
Summary of Sites Identified at
McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
D	224	DP006	CS 006	CS 6	Oil burn pit	Sol, Met, POL	7,500	--	OSD/NVZ
	225	LF026	CS 026	CS 26	Sludge/oil burn pit	Sol, Met	40,000	--	OSD/NVZ
	226	DP027	PRL 027	PSPRL 27	Sodium valve trench	Unknown	100	Late 40s-Early 50s	OSD/NVZ
	227	WP003	PRL 033	PSPRL 33	IWTP sludge landfarm	Sol	2,000,000	1972	NFI, REG-CON
	228	SD083	PRL P-007	UPRL P-7	Open ditch	POL, Sol	5,000	--	CERCLA
D	229	ST135	PRL T-011	UPRL T-11	Bldg. 1093	Sol	1,000	--	CERCLA
	230	DP151	CS A	CS A	Sludge disposal pit	Sol, Met, Prip	--	--	OSD/NVZ
	231	DP152	CS S	CS S	Fuel/solvent/oil burn pit	Sol, POL, Prip	9,200	--	OSD/NVZ
	232	DP153	CS T	CS T	Fuel/solvent sludge pit	Sol, POL, Prip, Met	8,400	--	OSD/NVZ
	233	DP178	--	--	Vadose zone contam.	VOC	600 acres	Late 40s-Early 50s	CERCLA
E	234	LF044	PRL 045	PSPRL 45	Paint waste landfill	Unknown	150,000	--	CERCLA
	235	SS095	PRL S-010	UPRL S-10	Storage area	Sol, Rad	63,000	--	CERCLA
F	236	LF074	PRL B-006	UPRL B-6	Waste area	Unknown	627,200	--	CERCLA
G	237	SD127	PRL S-042	UPRL S-42	Hobby shop/washrack	Sol, POL	8,100	--	CERCLA
	238	SD128	PRL S-043	UPRL S-43	Aircraft washrack	POL, Sol	49,000	--	CERCLA
	239	SD129	PRL S-044	UPRL S-44	Aircraft maintenance area	Sol, POL	275,000	--	CERCLA
	240	ST145	PRL T-031	UPRL T-31	UST	Sol	12,500	--	CERCLA
	241	ST146	PRL T-032	UPRL T-32	UST	Sol	12,500	--	CERCLA
	242	ST147	PRL T-033	UPRL T-33	UST	Sol	12,500	--	CERCLA
	243	ST150	PRL T-044	UPRL T-44	Stoddard solvent tank	Sol	10,000	--	CERCLA
	244	OT158	PRL L-001	--	Indus. wastewater line	Unknown	--	--	CERCLA
	245	ST173	PRL T-062	--	UST	Unknown	--	--	CERCLA

Table 4-2
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]		Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]
H	246	LF075	PRL B-007	UPRL B-7	Spoil area	Unknown	627,200	1943-1989	CERCLA
	247	SD077	PRL P-001	UPRL P-1	Drainage ditch/ponds	Sol, POL	56,400	1943-1964	CERCLA
	248	OT093	PRL S008	UPRL S-8	Electorplating shop	Sol, CN, Met	35,000	--	CERCLA
	249	SD100	PRL S-015	UPRL S-15	Degreaser/spray booths	Sol, POL	290,000	--	CERCLA
	250	OT124	PRL S-039	UPRL S-39	New museum site	Sol	94,000	--	CERCLA
	251	OT125	PRL S-040	--	S-40 Troop Issue area	Unknown	19,000	1946-1968	CERCLA
	252	SD130	PRL S-045	UPRL S-45	Aircraft maintenance area	POL, Sol	615,000	1941-???	CERCLA
	253	OT167	PRL S-047	--	Unknown	Unknown	--	--	CERCLA
--	254	OT067	--	--	Offbase wells, Raley Blvd.	Unknown	--	--	CERCLA
--	255	OT174	--	--	Davis	Unknown	--	--	AF IRP
	256	ST175	--	--	Lincoln	Unknown	--	--	AF IRP
	257	LF176	--	--	Wilson Park	Unknown	--	--	NFI
	258	ST177	--	--	Camp Kohler	Unknown	--	--	AF IRP

[a]This site number is just a means of sequencing this listing. If new sites are found, the sequencing would change.

[b]Work Information Management System-Environmental Subsystem (WIMS-ES) identification number. The first two letters denote the type of site (e.g., LF=landfill), while the three digits represent a sequencing from 001 to several hundred (in the case of McAFB). The numerical portion is unique at each AFB; for example, there is only on 034 representation; in this case it is preceded by an ST as a descriptor. Thus there is no LF034 or WP034. Other alpha codes are as follows:

DP = Disposal pits
OT = Other, ordnance, burn areas, buildings
SD = Surface runoff, ditches, wash racks, oil/water separators
ST = Underground tanks, above ground tanks, POL lines
FT = Fire training areas
RW = Radioactive wastes
SS = Spills, storage areas
WP = Waste pits, sumps, lagoons, waste treatment, evaporation pits

Table 4-2
Summary of Sites Identified at
McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]	Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]

[a]Some sites have several identifying numbers from different studies or documents. The first column represents those numbers used in the 1992 Comprehensive CERCLA Work Plan (CCWP) while the numbers in the second column are from Attachment A in the 1990 IAG.

CCWP Terminology			IAG Terminology		
CS	=	Confirmed Site	CS	=	Confirmed Site
PRL	=	Potential Release Location	PSPRL	=	Partially Studied PRL
SA	=	Study Area	UPRL	=	Unstudied PRL

[d]
PCB = Polychlorinated Biphenyl
IWL = Industrial Waste Line
IWTP = Industrial Wastewater Treatment Plant
MAT K = Maintenance Apron Terminal No. K
UST = Underground Storage Tank

[e]
CN = Cyanide; Prip = Primary Pollutant
Met = Metals; Sol = Solvents
PCE = Perchloroethylene (or Tetra); TCE = Trichloroethylene
POL = Petroleum, Oil, and Lubricants

[f]Area in square feet (unless otherwise noted)

Table 4-2
Summary of Sites Identified at McClellan AFB

Operable Unit	Site No.[a]	WIMS Site ID[b]	Aliases[c]	Description[d]	Contaminants[e]	Size of Site[f]	Dates of Operation	Status/Regulatory Mechanism[g]

[f]Status--Generally speaking, the status (stage) of sites on base is taken as RI/FS, with most off-base sites in the PA/SI stage (however, Davis is in RI/FS). Exceptions to this rule ar those 16 sites which are NFI (no further investigation) with regulatory concurrence (REG-CON). OSD/NVZ, which applies to 11 sites, indicates and old site designation, now included in the Vadose Zone site (DP-178).

Regulatory Mechanism--All of the 253 on-base sites are being addressed under CERCLA. Twenty-four UST sites containing POL or fuels have been identified for transfer to the UST program under RCRA, Title I, pending regulatory concurrence. Two other sites that need further investigation of contaminants to determine whether CERCLA or UST prevails are listed under the heading CERCLA/UST. Five sites are off-base. One of the off-base sites is being handled under CERCLA, while the other four sites are non-CERCLA, but subject to standard AF IRP procedures.

Source: McClellan AFB Management Action Plan, July, 1993.

Treatment Plants (IWTPs). Discontinuities in the IWL and collection sumps at industrial facilities allowed hazardous chemicals to contaminate the soil and groundwater. Although IWTPs in OU A have been decommissioned, to this day the IWL conveys industrial waste streams from locations around the Base to a treatment plant in OU C.

OU B Source Area History

The following information on OU B was taken from the OU B RI/SAP (Radian Corporation, 1991) unless otherwise noted. The area of the Base located in OU B was reserved for maintenance, storage, electronic equipment repair and testing, and preparation of ground support equipment. Since 1940, hazardous materials are known to have been used, stored, and locally disposed of in OU B. Discharge of contamination has been documented at landfills, underground storage tanks, select locations along the IWL, and in storage lots and maintenance yards.

From 1957 to 1971, various waste disposal pits were operated around OU B where a host of contaminants were confirmed to have been disposed of. Such burial and burn pits are now considered to be major sources of soil and groundwater contamination. The largest documented contamination releases in OU B occurred along sections of the IWL and in hazardous materials storage lots. The IWL runs underground through the middle of OU B and has transported industrial wastewater for approximately 30 years. Laboratories and electroplating shops routinely discharged flows laden with metals, arsenic, and cyanide compounds to the IWL to be transported to IWTPs. Certain storage lots in OU B have been used since 1955 to store hazardous substances. Spills that occurred in such facilities were commonly washed from floors and concrete pads onto the surrounding soil with high pressure hoses.

The IWL has been divided into nine individual sections. Seven of the IWL sections and 32 other sites have been combined into eight investigation clusters (ICs).

OU C Source Area History

The predominant use for the area of McClellan AFB contained within OU C was waste disposal. Burial and burn pits were used to dispose of all forms of solid wastes, industrial waste sludge, waste solvents, oil, various chemicals, parts from aircraft engines, and possibly even medical supplies. Some aboveground facilities were used to store low-level radioactive wastes prior to disposal offbase. Personnel communication with Base employees suggests that all waste streams, wet or dry, were probably disposed of in the landfills in this area. Records and aerial photos indicate that disposal facilities in OU C were operated from the late 1940s until the mid to late 1980s (CH2M HILL, 1993).

OU D Source Area History

Waste disposal was the primary activity in the section of McClellan AFB known today as OU D. In 1956, the first burial pit was created where sodium valves from aircraft engines were disposed of. More burial and burn pits were constructed throughout the 1960s and 1970s, which received refuse solid waste, oil, various chemicals, and liquid industrial sludge. From the late 1970s into the early 1980s, many of the burial and burn pits were closed and covered with soil. In 1985, the Area D cap was constructed over the closed waste pits. By capping this area, the infiltration of surface water and precipitation through the waste pits was reduced, resulting in an apparent reduction of contaminant migration to groundwater. Buildings within OU D are currently used for offices and laboratories, and the waste disposal pits are no longer used to dispose of any form of waste products (CH2M HILL, 1992).

Industrial Waste Line

Information regarding the industrial waste line was attained from various OU PAs, SAPs, and RIs that the IWL passes through.

For approximately 40 years, the IWL has conveyed industrial wastewater from electroplating shops, laboratories, and other industrial facilities throughout the Base to IWTPs in OUs A, B, and C. Although the IWTPs in OUs A and B have since been taken out of service, to this day the IWL conveys industrial waste streams from locations around the Base to the treatment plant in OU C.

Installed throughout the 1940s and 1950s, the IWL has long since been considered a major contributor to soil and groundwater contamination. Discontinuities in the line have allowed solvents, acids, bases, and metals to penetrate into surrounding soil and eventually reach groundwater. During the late 1980s, main sections of the IWL were leak-tested, and some of the leaking sections were repaired. Repairs were not made on all detected leaks because access to some sections was limited by small-diameter pipes, small-diameter elbows, or depth of the pipe below the ground surface. The IWL is located 3 to 20 feet bgs. Table 4-2 lists sections of the IWL in OUs A, B, C, and G that are still considered sources for soil and groundwater contamination. Figure 4-11 shows the route of the IWL. As indicated in the figure, the pipeline forms a U-shape around the southern point of the runway, with its ends extending as far north as OU G on the east and OU C on the west.

OUs E, F, G, and H

Although the source area discussion above only discusses OUs A, B, C, D, and the IWL, it should be mentioned that other OUs do exist at McClellan AFB. Figure 4-10 shows all of the OUs around the Base, including OUs E, F, G, and H, not previously mentioned.

Table 4-2 indicates that several types of contamination source areas have been identified within the boundaries of OUs E, F, G, and H; in OU E a paint waste landfill and open storage areas have been located; OU F contains a waste area of unknown contaminants; OU G has sections of the IWL, aircraft washracks, aircraft maintenance facilities, and underground storage tanks; and OU H contains a spoil area, drainage ditches and ponds, an electroplating shop, degreaser spray booths, and aircraft maintenance facilities.

Although some source areas have been identified, no detailed assessments or investigations have been performed for OUs E, F, G, or H. Therefore, data from these OUs that would be considered pertinent to the Groundwater OU RI/FS Report are not available. Considering the threat that contamination in OUs A through D poses to human health both on and off McClellan AFB, OUs A, B, C, and D were considered a priority for investigation and remedial action over OUs E, F, G, and H. Investigation of site conditions at OUs E through H will likely be conducted in the future.

Waste and Contaminant Types

As outlined above, McClellan AFB activities were categorized and performed in specific areas of the Base. OU A was used mainly for storage and aircraft maintenance, with some waste treatment and disposal locations. OU B was filled with storage lots, maintenance facilities for ground vehicles, and waste disposal and treatment facilities. The predominant focus of OU C activities was waste disposal. Many burial and burn pits are located there where a variety of sanitary and industrial wastes were disposed of. An IWTP is still located in OU C which, to this day, handles flow from the IWL. Contamination sources in OU D are landfills and burn pits, indicative of the main activities performed in that section of McClellan AFB. Table 4-3 summarizes the materials used, wastes produced, and contaminants detected at each of the OUs.

Table 4-3
Summary of Wastes and Contaminants
By Operable Unit

Page 1 of 2

Operable Unit	Type of Waste	Type of Contaminant
A	Confirmed contaminants: Solvents, paints, jet fuel, oil, grease, acids, bases, arsenic, cyanide, industrial and sanitary waste sludge, photoprocessing chemicals, and metals.	TCE; 1,1-DCE; 1,2-DCA; acetone; toluene; carbon tetrachloride; 1,1,1-TCA; chloroform; dichloromethane; benzene; ethylbenzene; chlorofluorocarbon; total xylenes; bis(2-ethylhexyl)-phthalate; and di-n-butylphthalate
B	Confirmed contaminants: Solvents, jet and automobile fuels, laboratory chemicals, metals, cyanide, arsenic, oil, grease, aircraft generators, acids, and bases.	TCE; 1,1-DCE; 1,2-DCA; MEK; oil; grease; chlorofluorocarbon; diethyl ether; low-level radioactive wastewater; carbon disulfide; dichlorobenzene; chloroform; arsenic; cyanide; methylene chloride; barium; chromium; lead; PCBs; and dioxin/furan compounds
C	Confirmed contaminants: Plastic, paper, wood, industrial waste sludge, solvents, oil, chemicals, sodium valves, aircraft engine parts, medical supplies, and low-level radioactive wastes.	TCE; 1,2-DCA; 1,1-DCE; PCE; oil; grease; acetone; 2-butanone; 1,2-dichlorobenzene; fluoranthene; toluene; arsenic; antimony; barium; cadmium; chromium; copper; lead; nickel; silver; thallium; zinc; di-n-butyl phthalate; and bis(2-ethylhexyl) phthalate

Table 4-3
Summary of Wastes and Contaminants
By Operable Unit

Page 2 of 2

Operable Unit	Type of Waste	Type of Contaminant
D	Confirmed contaminants: Sodium valves, plastic, paper, oil, liquid industrial sludge, solvents, and fuels.	TCE; 1,1-DCA; 1,1,1-TCA; PCE; acetone; ethylbenzene; toluene; total xylenes; vinyl chloride; 1,2-dichlorobenzene; 1,3-dichlorobenzene; 1,4-dichlorobenzene; naphthalene; bis(2-ethylhexyl)phthalate; chromium; lead; cadmium; nickel; PCBs; and dioxin/furan compounds
E	Potential contaminants: Paint waste, solvents, radiation, and petroleum products.	Unknown
F	Potential contaminant: Waste.	Unknown
G	Potential contaminants: Petroleum products, solvents, priority pollutants, and VOCs.	Unknown
H	Potential contaminants: Solvents, metals, petroleum products, and VOCs.	Unknown

4.4 Fate and Contaminant Transport

The movement of contaminants and the various transport mechanisms make up the third component of the conceptual model. TCE, cis-1,2-DCE, PCE, 1,2-DCA, and vinyl chloride are the five primary prevalent contaminants at McClellan AFB. This section will discuss how these prevalent contaminants migrate by addressing the following:

- The chemical and physical properties of the VOCs of concern that affect contaminant migration
- Contaminant partitioning into the following phases: dissolved into the groundwater or porewater, sorbed to the aquifer matrix, or existing as a free product
- Transport mechanisms that affect contaminant movement: advection, retardation, molecular diffusion, and hydrodynamic dispersion
- Biodegradation

Contaminant properties will be presented first followed by a discussion of the physical transport mechanisms that are responsible for the distribution of contamination observed.

4.4.1 Factors Affecting VOC Migration

The chemical properties of contaminants govern the fate and transport of each compound. The potential for contaminants to migrate through the vadose zone to the groundwater, and then subsequently in the groundwater depends primarily on the following chemical properties:

- Henry's constant
- Solubility in water
- Organic carbon partition coefficient
- Vapor pressure

The physical properties of the aquifer also affect the multiphase partitioning of contaminants and ultimately their migration mechanisms. The following physical properties were measured during OU B and OU D remedial investigations or calculated from field results:

- Organic carbon content, f_{oc}: 0.001 to 0.003
- Vadose zone moisture content (%): 0.15 to 0.25
- Saturated moisture content (%): 0.30 to 0.35
- Total porosity (n): 0.4 to 0.5
- Dry bulk density (g/cm^3): 1.35 to 1.45
- Saturated bulk density (g/cm^3): 1.9

Table 4-4 summarizes the values of each of the chemical properties of the prevalent contaminants. The following paragraphs summarize how each of these properties contribute to the potential for contaminant migration.

Table 4-4
Physical and Chemical Properties[a] of Prevalent Groundwater Contaminants

VOCs	MCL (µg/l)	Mean[b] Detects (µg/l)	Frequency of Detects	Maximum Detect (µg/l)	Vapor[b] Pressure (mm Hg)	Water[b] Solubility (mg/l)	Henry's[b] Constant ($atm\text{-}m^3/mol$)	Partition[b] Coefficient
TCE	5	45.3	51	26,000	59	1,000	0.00892 [a]	126
cis-1,2-DCE	6	3.54	26	210	200 [a]	3,500	0.0075 [a]	32
PCE	5	13.61	11	2,100	14	150	0.0227 [a]	661
1,2-DCA	0.5	1.7	9	120	64	8,690	0.0011 [a]	14

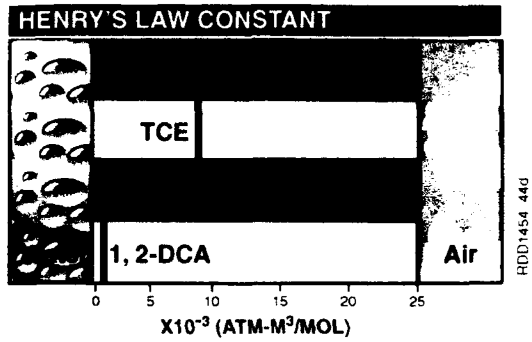
[a] Values are presented at 20°C unless otherwise specified.
[b] Value is at 25° C.
[c] Mean calculated with nondetects as zero.

NOTE: Statistics from data set presented in Section 4.6.1.

Source: U.S. EPA, 1990.

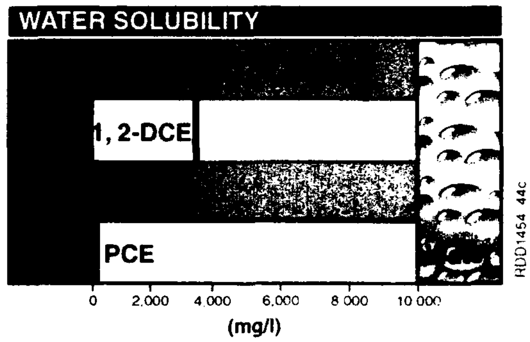
Henry's Constant (K_H)

The ability of a compound to volatilize from water depends on its Henry's constant. The lower the Henry's constant, the less a compound is likely to volatilize from contaminated groundwater or porewater and move to the gas/air phase in the vadose zone. For example, 1,1-DCE has a Henry's constant of 154×10^{-3} (atm-m^3/mol) and has been detected at high concentrations in the soil gas, but is not a primary COC in groundwater and porewater. Conversely, TCE has a significantly lower Henry's constant (9×10^{-3} atm-m^3/mol); it is not as widely detected in soil gas, but is a COC in groundwater and porewater.



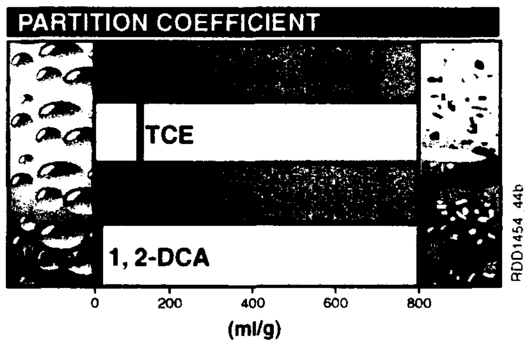
Solubility in Water

The water solubility indicates the maximum concentration that can be attained at 25°C when each compound is dissolved in water. The solubility limit dictates the amount of contaminant found in solution; if the aqueous concentration of a compound equals the water solubility limit, the compound could exist as free product. In fact, if contaminant concentrations detected in groundwater approach even 1 percent of the water solubility, the presence of free product is suspected. More soluble contaminants would be expected to migrate further with aqueous advective flow than less soluble compounds (EPA/540/2-90/011, October 1990).



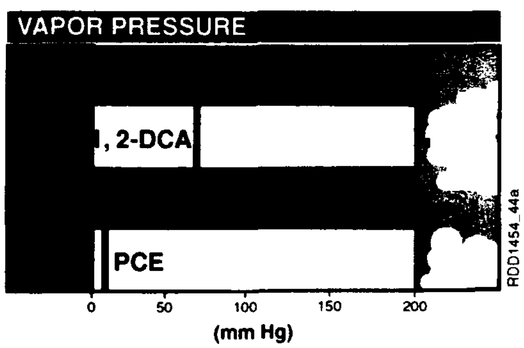
Partition Coefficient (K_{oc})

The organic carbon partition coefficient indicates the tendency of a compound to adsorb to the soil matrix, and therefore its potential for movement during contaminant transport. The higher the K_{oc}, the more the compound is adsorbed to a given amount of organic carbon exchange sites in the soil matrix and the less it is available for transport in the aqueous phase.



Vapor Pressure

The vapor pressure of a given compound is the pressure of vapor in equilibrium with a pure liquid at a given temperature. It indicates the volatilization potential of a compound. The higher the vapor pressure the more likely the compound will enter the vapor phase. The vapor pressure is an important consideration when contamination has been identified to exist as free product, also known as nonaqueous phase liquids (NAPLs). The presence of NAPLs has not been confirmed in the subsurface of McClellan AFB, but is strongly suspected based on the disposal history and the groundwater concentrations observed at the Base.



4.4.2 Multiphase Contaminant Partitioning

The chemical properties of the prevalent contaminants, coupled with the aquifer matrix properties, govern the extent contaminants will partition into phases. Contaminants in the vadose zone can exist in up to four phases: sorbed to the soil matrix, dissolved in soil gas, dissolved in porewater, or as free product. Contaminants in groundwater can exist in up to three phases: sorbed to the soil matrix, dissolved in the groundwater or porewater, or as free product. Figure 4-12 illustrates possible phases above and below the water table.

VOCs in Groundwater – Sorbed or In Solution

Compounds partition differently based on the vapor pressures, Henry's constants, water solubility, and organic carbon partition coefficients, as discussed previously. At equilibrium conditions, the linear relationships that describe partitioning are as follows:

- C(air) = (K_H)(C(water))
- C(soil) = $(f_{oc})(K_{oc})$(C(water))

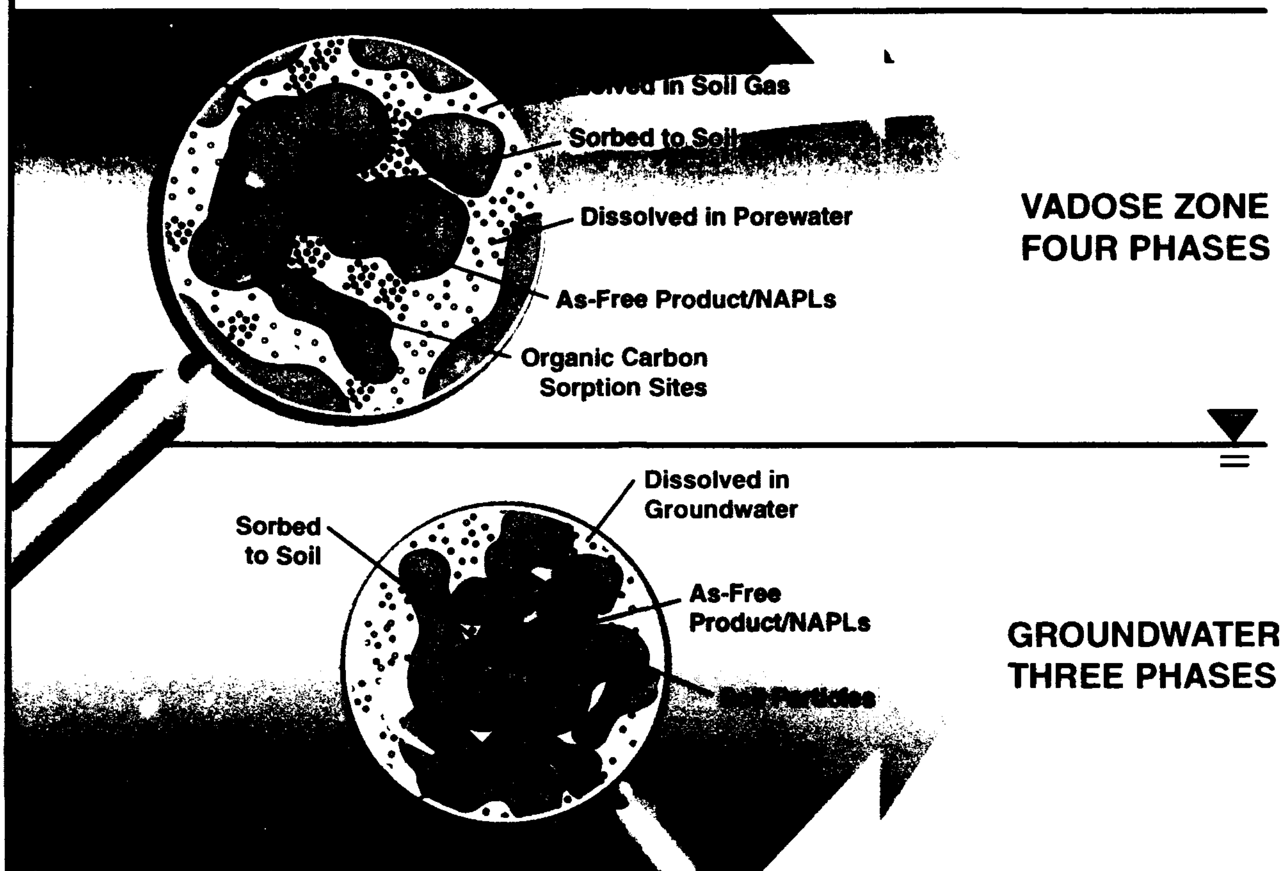
In addition, for a unit volume of aquifer material:

- V(water) = (porosity)(saturation)(unit volume)
- V(air) = (porosity)(1-saturation)(unit volume)

Figure 4-13 demonstrates ideally, based on these relationships, how different contaminants would partition with varying water contents, given an organic carbon content of 0.2 percent. The percent saturation of the McClellan AFB vadose zone soils is about 25 percent. The figures show that at w = 25 percent, PCE is mostly sorbed to the soil matrix and only marginally dissolved in the groundwater or the soil gas. Even at w = 100 percent, 80 percent of PCE mass is sorbed to the soil and only 20 percent exists in the groundwater. This would be expected since PCE has a high organic carbon partition coefficient and low water solubility. The converse is true for 1,1-DCE; at w=25 percent, it exists 45 percent in the soil, 15 percent in the porewater, and 40 percent in the soil gas; in the groundwater (W=100 percent), 1,1-DCE exists 45 percent in the soil and 55 percent in the groundwater. This too is logical since 1,1-DCE has a high Henry's constant, so it will tend to partition from water to air; a moderate water solubility, so it will dissolve in groundwater at saturated conditions; and a low organic partition coefficient, so it tends not to sorb to soil. DDT is particularly interesting, because even at high percent saturation, DDT will partition only onto the soil matrix. Similar analyses can be made for all of the contaminants present at the Base.

VOCs as Free Product – Nonaqueous Phase Liquids (NAPLs)

NAPLs are immiscible fluids that may be present in unsaturated and/or saturated aquifer zones. There are two classifications of NAPLs: light and dense. The classification of a NAPL is based on the unit weight of a NAPL compared to the unit weight of water. Light NAPLs (LNAPLs) are lighter than water and will float if they reach the water table. Dense NAPLs (DNAPLs) are heavier than water and will sink should they encounter the water table.

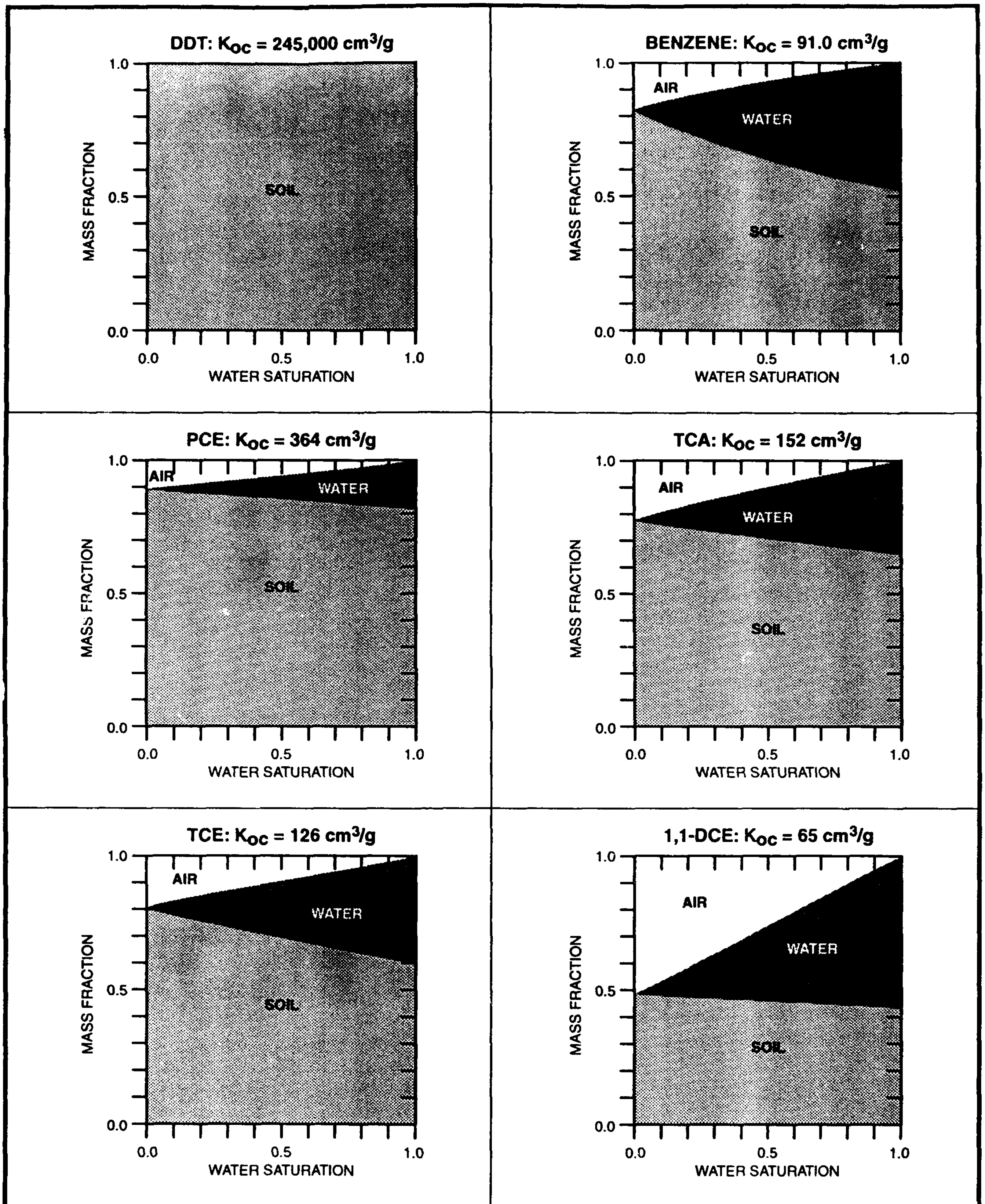


	Vadose Zone	Groundwater	
Sorbed to Soil	●	●	Contaminants tend to sorb to soil when they have high partition coefficients.
Dissolved in Soil Gas	●		Contaminants tend to partition into soil gas when they have high vapor pressures or Henry's constants.
As-Free Product/NAPLs	●	●	Contaminants may exist as NAPLs when they have low vapor pressure.
Dissolved in Groundwater and/or Porewater	●	●	Contaminants tend to dissolve into porewater or groundwater when they have high water solubilities

FIGURE 4-12
MULTIPHASE PARTITIONING OF CONTAMINANTS IN THE SUBSURFACE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454 04

CH2M HILL



NOTE:

foc = 0.002
Source: Charles Graf, 1991

RDD1454_74

FIGURE 4-13
EFFECTS OF K_{OC} ON CONTAMINANT PARTITIONING UNDER EQUILIBRIUM CONDITIONS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Substances that form LNAPLs include: petroleum fuels (gasoline, diesel, and oil) and unchlorinated aliphatic and aromatic hydrocarbons, such as benzene, xylene, naphthalene, hexane, ketones, and ethers (Graf, 1991). Many of these compounds have been detected in soil and groundwater samples at McClellan AFB; therefore, it is likely that LNAPLs exist at some locations around the Base. However, LNAPLs cannot sink through the saturated zone and therefore do not pose as serious a long-term threat to groundwater quality as do DNAPLs. For this reason, this section discusses the presence and implications of DNAPLs in the subsurface environment at McClellan AFB and outlines factors that govern mass movement of DNAPL contaminants in unsaturated and saturated aquifer zones.

Presence, Implications, and Mass Movement of DNAPLs

Information for this section is obtained mainly from *DNAPL Site Investigation* by Robert M. Cohen and James W. Mercer, unless otherwise noted.

Most halogenated fluids are DNAPLs. Some examples include: TCE, tetrachloroethene (PCE), trichloroethane (TCA), methylene chloride, carbon tetrachloride, trichlorotrifluoroethane (Freon-113), pentachlorophenol, coal tar wastes, and pesticides (Graf, 1991). The potential for long-term contamination of groundwater by DNAPL chemicals is high because of their toxicity, limited solubility, and migration potential in soil gas, groundwater, and/or in a separate phase. Remediation plans that do not account for the possible presence of DNAPL contaminants in the vadose zone and/or saturated zone will greatly underestimate the time and effort required to achieve remediation goals.

DNAPL in the Vadose Zone

If present in the vadose zone, DNAPL can continue contaminating groundwater following two transport mechanisms: dissolution and vapor transport.

Once a volume of DNAPL is released at, or below, ground surface, gravity causes it to migrate downward through the soil. This vertical descent is accompanied by lateral spreading caused by capillary forces and layering variations within the soil mass. As the DNAPL sinks through the vadose zone, a certain amount is entrapped in the soil at residual saturation. Depending on the amount of DNAPL released, and the thickness of the vadose zone, the entire mass of DNAPL could be immobilized before reaching groundwater. With each groundwater recharge event, DNAPL captured within the vadose zone will slowly dissolve into infiltrating precipitation and be carried to the water table. Because of its low solubility, DNAPL will remain in the soil for years and act as a long-term source for groundwater contamination.

In addition to dissolving into infiltrating precipitation, DNAPL caught in the vadose zone can volatilize and form a gaseous plume in the soil air around the DNAPL source. If DNAPL vapor density is significantly greater than air, the dense vapors will sink through the vadose zone to the water table and dissolve in groundwater. Through vapor transport, DNAPL trapped in the vadose zone will function as a continuous source for groundwater contamination. Dissolution and vapor transport of DNAPLs in the vadose zone can cause groundwater plumes with high chemical concentrations for a sustained period of time. If DNAPLs are not accounted for, cleanup will take more effort and time than originally anticipated.

DNAPL in the Saturated Zone

If a sufficient volume of DNAPL is released to allow flow above residual saturation through the vadose zone, a mass will accumulate at the capillary fringe. It will spread laterally and deepen until the pressure developed at the base of the accrued DNAPL exceeds the threshold entry pressure of the underlying water-saturated medium. Once within the saturated zone, DNAPL will continue its descent downward until it encounters a finer grain barrier layer. Although vertical migration is halted or slowed at this point, lateral spreading will occur if the barrier layer slopes in any direction. Forces caused by gravity and fluid pressure will drive DNAPL in the sloping direction along a confining layer, even if the barrier layer slopes in a direction opposite to the hydraulic gradient. It is unusual for hydraulic forces to control the flow direction of DNAPL.

Should the DNAPL mass encounter any bowl-shaped depressions, or traps, in the confining layer, it will fill the depressions and form standing reservoirs and pools. Any DNAPL that overflows the pools will continue downslope. Discontinuities such as cracks, root holes, and poorly sealed wells and boreholes provide preferential pathways for the DNAPL to follow and continue to spread. Eventually, the entire DNAPL mass will be present as pools, fingers, and disconnected globules and ganglia throughout the saturated zone. A fixed mass of DNAPL will eventually become immobilized by residual saturation and/or stratigraphic traps.

Throughout the process of mass movement, whether the DNAPL mass remains mobile or becomes stationary, it slowly dissolves into flowing groundwater. Dissolution of DNAPL in the saturated zone can take decades or centuries to complete. Factors affecting the rate at which DNAPL dissolves are chemical solubility, groundwater velocity, and water-DNAPL contact area.

DNAPLs are generally composed of a mixture of multiple chemicals, so the chemical solubility of DNAPLs covers a wide range of limits. Field measurements commonly indicate that organic compounds in groundwater are at concentrations less than 10 percent of DNAPL solubility limits. This remains true even where DNAPLs are known or expected to be present.

Groundwater velocity also determines the rate at which a mass of DNAPL dissolves. As groundwater velocity in the saturated zone increases, the DNAPL mass will dissolve more readily.

Water-DNAPL contact area is the third major contributing factor in the dissolution rate of a DNAPL mass in the saturated zone. DNAPL pools dissolve slower than DNAPL fingers and ganglia, because of the smaller area in which water comes in contact with the DNAPL. Therefore, if DNAPL exists as a pool or reservoir, it can be expected to be particularly long-lasting.

Before remedial alternatives are chosen for a particular site, it is imperative that the issue of DNAPL presence be addressed. Regardless if DNAPLs exist in the vadose zone or saturated zone of an aquifer, they will function as a long-term source for groundwater contamination. The presence of DNAPL will be felt for many years depending on the mass, solubility, and vertical and horizontal dispersion of the DNAPL source. If remediation is implemented at a site before considering the presence of DNAPL, cleanup time, effort, and cost may be drastically underestimated.

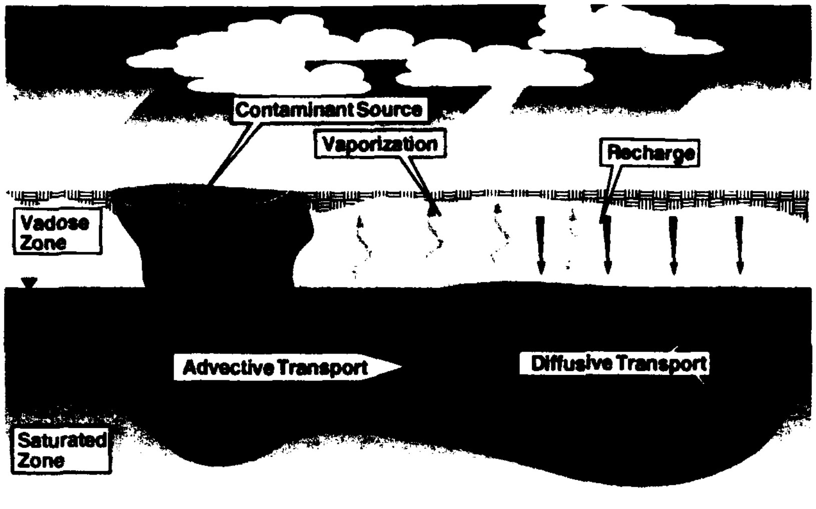
4.4.3 Transport Mechanisms in the Groundwater

Advection, molecular diffusion, and hydrodynamic dispersion are the main groundwater transport mechanisms for any contaminant. The following paragraphs discuss these transport phenomena as they relate to the McClellan AFB groundwater system.

Advection

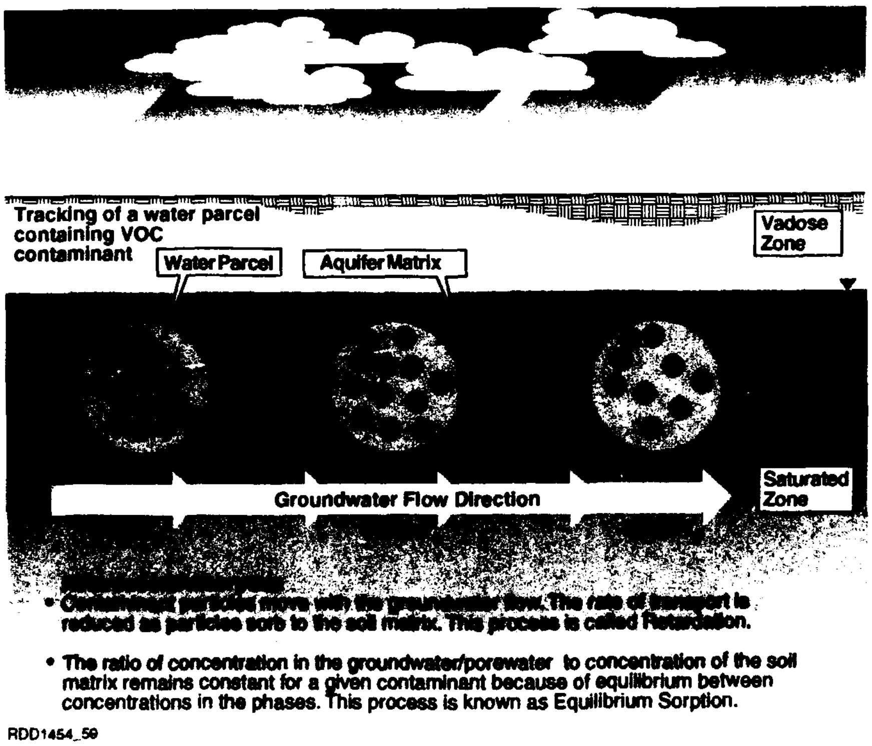
In most situations, advection is the most significant transport phenomenon for chemicals in groundwater. Groundwater moves under the influence of gravity (unconfined and confined aquifers) and/or pressure (confined aquifers) and carries the dissolved chemicals. Thus, advection of the contaminants results from the mean flow of groundwater. Figure 4-14 shows the transport of chemicals by advection (dense red dots area). As can be seen, advective transport contributes most to the movement of chemicals in a subsurface environment. The concentration of a compound in groundwater, and therefore the rate of transport by that water, can be limited by its equilibrium solubility. Usually, the solubility limit of a compound is not a limiting factor except at the source, as the solubility is generally high compared to the concentrations found in groundwater. Generally, the concentration of a contaminant in the groundwater does not reach its water solubility limit. For example, although the maximum recorded TCE concentration sample at a monitoring well is 68,000 μg/l, the water solubility of TCE is approximately 1,200,000 μg/l.

Many chemicals adsorb to the organic layer of the soil matrix and become fixed to the soil surfaces. The portion of the contamination that is sorbed to soil/aquifer material is not subject to advection (cannot flow with groundwater). Therefore, sorption of chemicals on soil or aquifer material "retards" the solute transport by advection. Figure 4-15 illustrates the sorption of contaminant molecules onto soil/aquifer material and the differences between the rate of movement of contaminants versus



RDD1454_58

FIGURE 4-14
TRANSPORT MECHANISMS IN SUBSURFACE FLOW
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



RDD1454_59

FIGURE 4-15
RETARDATION DUE TO SORPTION OF CHEMICALS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

groundwater due to adsorption. The retardation factor R for any chemical is given by:

$$R = 1 + (bulk\ density)(Kp)/porosity$$

where *Kp* is the partition coefficient. The solute velocity in the groundwater (v') is given by:

$$v' = v/R$$

where v is the pore velocity (= Darcy velocity / porosity). The value of R can range from 1 for nonsorbing solutes to as high as 2 to 10 for strongly sorbing VOCs. Thus, the strongly sorbing VOCs might move in groundwater 2 to 10 times slower compared to groundwater.

In the above section, it is assumed that the partitioning of chemical between soil and water is an instantaneous (equilibrium) process. In most cases, sorption-desorption of VOCs is a kinetic process or a combination of equilibrium and kinetic processes. The significance of kinetic sorption-desorption is that remediation of a contaminated aquifer may require flushing of more pore volumes than would be estimated assuming equilibrium conditions.

Molecular Diffusion

Molecular diffusion is a chemical phenomenon that equalizes the solute concentration by moving solute from high concentration zones to low concentration zones and acts in all directions where any concentration gradient occurs (Figure 4-16). The driving force for molecular diffusion is differential concentrations. The diffusion coefficient of a chemical in groundwater is a fraction of its diffusion coefficient in water. Therefore, molecular diffusion in groundwater is a slow process compared to advection and is generally ignored in large-scale systems.

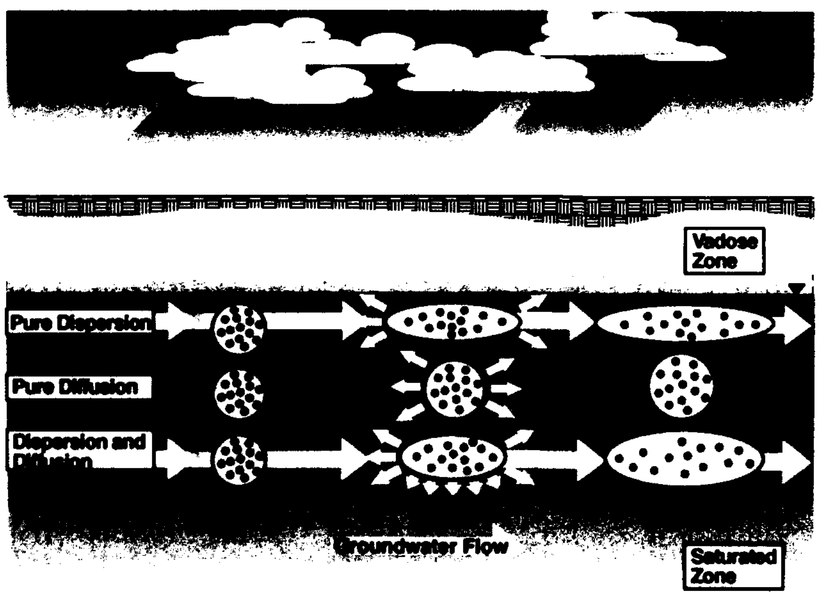


FIGURE 4-16
DIFFUSION AND DISPERSION OF CONTAMINANT IN SUBSURFACE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD 1464_67

Hydrodynamic Dispersion

In groundwater flow, a chemical gradually spreads and occupies an ever increasing volume of the flow domain, beyond the region it is expected to occupy based on average flow alone. This spreading of the chemical mass (dispersion) is a result of variations in local velocity, both in magnitude and direction, along tortuous flow paths. The driving force for dispersion is the local variations in the mean flow velocity. The flow velocity variations can be a result of inhomogeneity at the microscopic scale (presence of pores, grains) as well as at a macroscopic scale (variations in permeability, presence of layers).

Dispersion takes place in the direction of flow (longitudinal dispersion) and in the direction perpendicular to the flow (transverse dispersion). The dispersion coefficient is usually expressed as a fraction of groundwater velocity. The longitudinal dispersion is usually one order of magnitude smaller than advection. The ratio of longitudinal to transverse dispersion is about 5-20:1, making transverse dispersion even smaller. Thus, a chemical mass disperses more along the direction of flow than directions perpendicular to the flow (Figure 4-16).

The sorbed portion of a chemical is not available for dispersion. The effective dispersion coefficient is given by:

$$D' = D/R$$

where D' is the effective dispersion coefficient, D is the theoretical dispersion coefficient, and R is the retardation factor of the solute of interest.

From the above discussion, it can be inferred that, in groundwater transport, the most important phenomenon is the advection of solutes with the groundwater. In addition, an accurate characterization of the sorption coefficient of the solute in question is necessary to estimate the transit times and total pumping required for pump-and-treat systems.

4.4.4 Biodegradation Potential

The VOCs of concern, TCE, PCE, cis-1,2-DCE, and 1,2-DCA, may have been used as solvents in and discharged at source areas or may occur in the groundwater as a result of the natural degradation of parent solvent contaminants. The history of solvent use and disposal/release is not sufficiently understood to positively identify the origin of these prevalent VOCs. This section will discuss the biodegradation mechanisms of the prevalent VOCs at the site followed by a brief description of the natural attenuation potential of the McClellan groundwater system.

Degradation Mechanisms

Natural degradation mechanisms include both biological and abiotic transformation processes.

All of the four common solvents can be biodegraded anaerobically. Anaerobic biotransformation occurs by reductive dehalogenation, in which chlorine atoms are removed from the contaminant molecule one at a time and replaced with hydrogen. Most of the possible degradation products listed above can be formed by this process. For example, anaerobic biodegradation of PCE and TCE follows the sequence: PCE → TCE → 1,2-DCE → VC → ethene and CO_2. The sequences are presented in Figure 4-17.

Of the four common solvents, only TCE is amenable to aerobic biodegradation, and this occurs via cometabolism. Cometabolism occurs when an appropriate primary organic substrate induces a certain group of microorganisms to produce nonspecific enzymes which initiate transformation of a different compound (in this case TCE or certain other prevalent contaminants) without providing benefit to those organisms. Aerobic cometabolism cannot occur in the absence of an appropriate primary substrate (e.g., methane, toluene, phenol, propane, ammonium), oxygen, or the appropriate microorganisms.

The nonchlorinated organic contaminants such as ketones and BTEX are readily biodegradable under aerobic conditions without cometabolism. Aerobic biodegradation of these compounds is most commonly constrained by the availability of oxygen.

The abiotic transformation process can potentially play an important role in natural attenuation of contaminants. Two examples of chemical (abiotic) transformations of prevalent contaminants are the degradation of TCE epoxide (the initial product in aerobic cometabolism of TCE) to organic acids and other products, and the transformation of 1,1,1-TCA to 1,1-DCE.

Natural Attenuation at McClellan AFB

A rigorous assessment of natural attenuation of groundwater contaminants at McClellan AFB would require a considerable effort and is beyond the scope of this feasibility study. Nevertheless, some general comments can be made about possible indications of natural attenuation drawn from groundwater monitoring data.

During the OU D RI sampling performed in summer 1993, elevated concentrations of VC were measured in groundwater from several monitoring wells and three extraction wells. This indicates that significant anaerobic biodegradation of chlorinated ethenes has occurred in their vicinity. Vinyl chloride was also detected in the influent to the groundwater treatment plant in 1992 and 1993. Monitoring wells where vinyl chloride has been detected suggest areas of anaerobic conditions; these areas are presented in Figure 4-18.

Taking a closer look at EW-73 as an example, the prevalent contaminants detected at relatively high concentrations (>1 mg/l) are TCE, 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCE, and VC. PCE was either not detected or present at relatively low levels. It appears likely that TCE is undergoing anaerobic biodegradation to 1,2-DCE and VC (and,

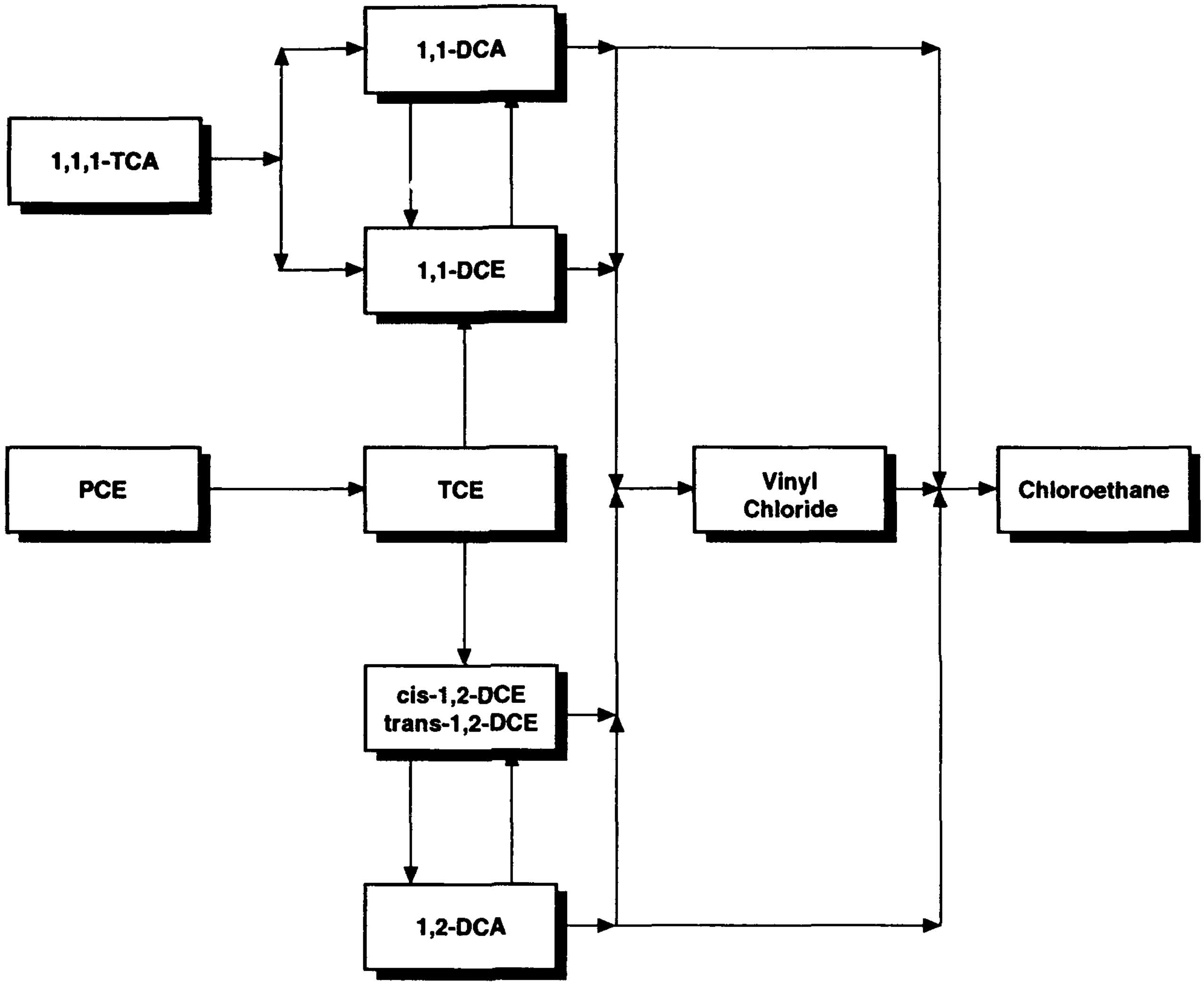


FIGURE 4-17
POTENTIAL BIODEGRADATION PRODUCTS OF VOCs
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_207

CH2M HILL

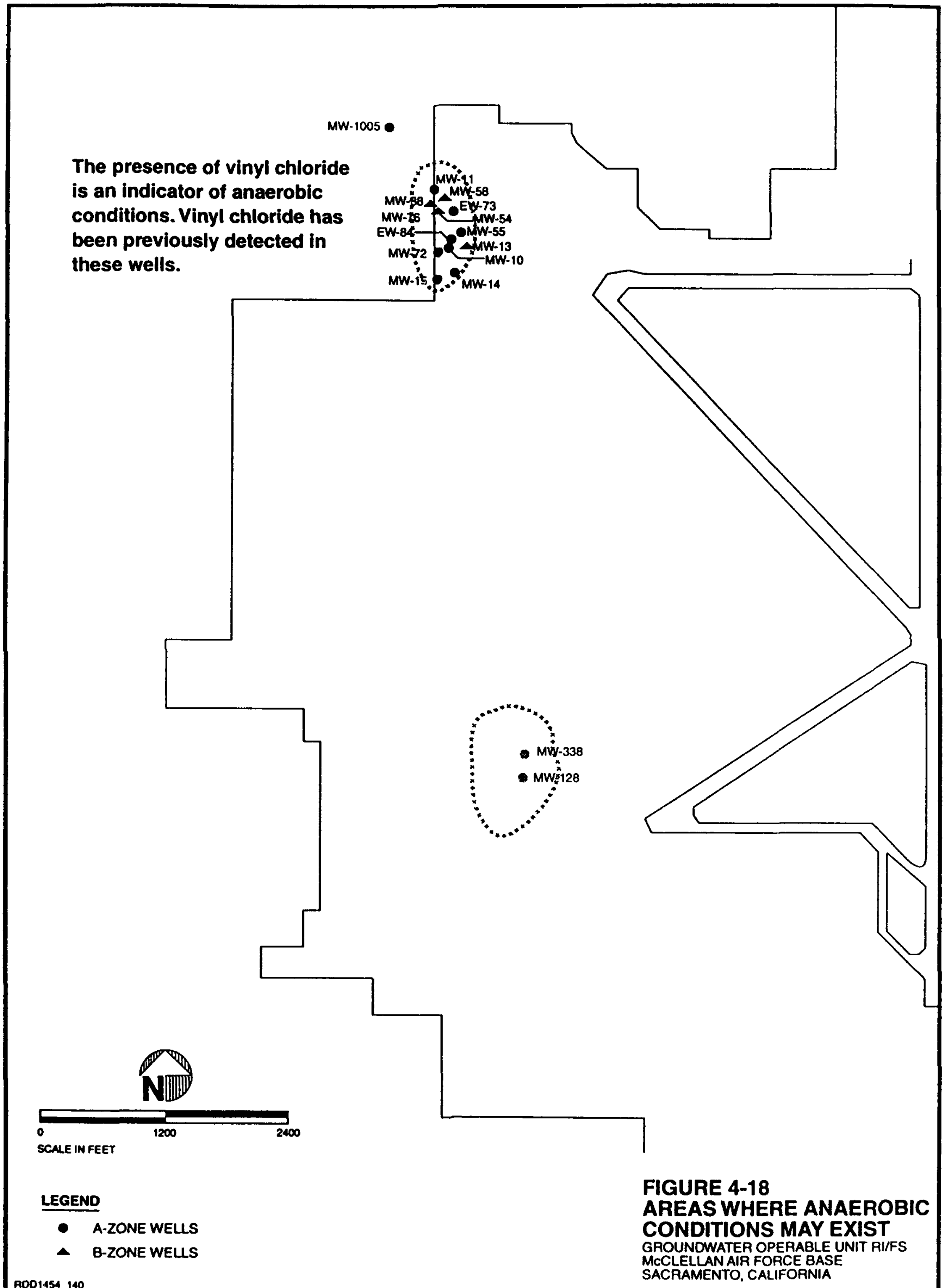


FIGURE 4-18
AREAS WHERE ANAEROBIC CONDITIONS MAY EXIST
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

presumably, innocuous nonchlorinated end products). 1,1,1-TCA may be undergoing transformation by both anaerobic biodegradation to 1,1-DCA and abiotic transformation to 1,1-DCE. However, concentrations of 1,1-DCE are substantially higher than 1,1,1-TCA, so another possible explanation for the presence of 1,1-DCE is that it was used as a solvent at McClellan AFB and is an original contaminant. Since toluene is present at EW-73, it is possible that some aerobic cometabolism of TCE and 1,2-DCE could occur, but there is no way to determine this from the contaminant data. Also, no data have been reviewed (if available) to ascertain the aeration/electron acceptor status of groundwater at EW-73.

In summary, it seems evident that natural attenuation of groundwater contaminants is occurring in at least some locations at McClellan AFB. These natural attenuation processes include anaerobic biodegradation and may also include abiotic and aerobic biodegradation mechanisms. The extent and rate of natural attenuation are impossible to assess without a substantial effort, and probably collection of additional analytical data, which is beyond the scope of this project.

4.5 Physical Transport Mechanisms

The physical groundwater transport mechanisms make up the fourth component of the conceptual model. The direction and extent of contaminant migration often mirrors historical and present groundwater flow; contaminants migrate vertically and horizontally under the influences of regional and Base pumping. This section will discuss how the following physical transport mechanisms and characteristics of the groundwater flow system influence contaminant migration:

- Historical movement of groundwater
- Decline in water levels
- Current horizontal and vertical groundwater flow conditions
- Water balance
- Base and domestic well pumpage
- Base wells to be decommissioned

A presentation of the current groundwater conditions concludes this section.

4.5.1 Historical Movement of Groundwater

During this century, groundwater has been pumped from the area surrounding McClellan AFB for irrigation and municipal or domestic water supply. As a result of the pumping, more groundwater has been extracted for use than has been supplied by natural recharge. Average annual rainfall in the Sacramento area is approximately 17 inches. The water level within the aquifer system has been dropping continuously for approximately 50 years. At the present time, the only discharge of groundwater is by pumping of irrigation and supply wells and by the pumping of onbase extraction wells as part of remedial actions.

Figure 4-19 shows the changes in regional groundwater flow from 1912 to 1989. General groundwater flow directions have varied greatly over the past 80 years, but have persisted in a south to southwesterly direction over the past decade. Increasing agricultural, Base, and community water supply use are the primary causes of the regional groundwater decline. Figure 4-20 illustrates the approximate historic rates of water level decline.

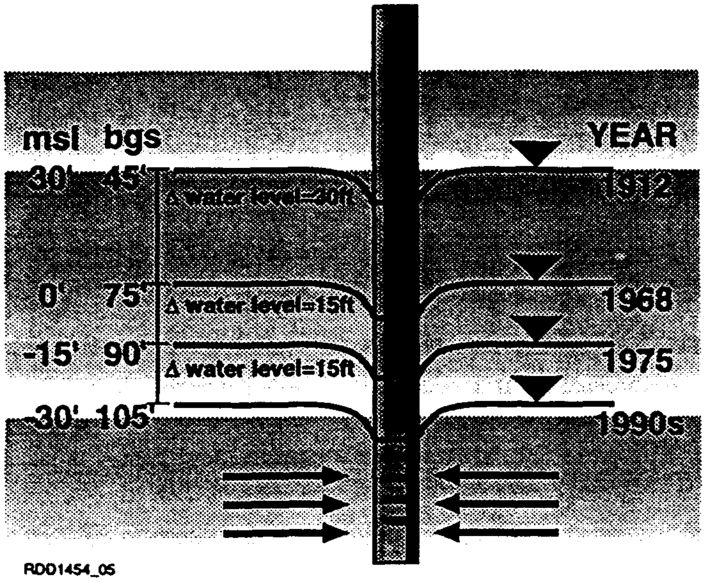


FIGURE 4-20
HISTORIC WATER LEVEL DECLINE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

A significant regional groundwater depression has persisted south of the Base since the early 1980s. This depression is caused by pumping near and on the Base as well as the pattern of recharge entering the aquifer system. The aquifer beneath McClellan AFB receives recharge from the American River to the South, from the Sacramento River to the west, from various small creeks to the North, and from mountain front recharge of precipitation to the east. This spatial distribution of recharge will tend to create a cone of depression near the center of the aquifer surrounded by recharge sources, even if pumping is fairly evenly distributed across the area.

4.5.2 Decline in Water Levels

Within the last 10 years, water levels in Monitoring Zone A have been declining at a rate of 1.1 to 2 feet per year. Agricultural and domestic pumping have caused the regional water level decline. Recent declines (in the Base area) are due primarily to a combination of Base and extraction well pumping superimposed on the regional decline.

The water level decline has been examined in three of the Operable Units. Figure 4-19 shows in plan view the location of these cross sections. Water level declines in OU A, OU B/C, and OU D between 1986 and 1992 are presented in Figures 4-21, 4-22, 4-23, and 4-24. Hydrographs of A-zone wells that depict these water level declines are presented in Figure 4-25.

In OU D, a sharp drop in head occurs in 1987 when the six OU D extraction wells were put into operation. These wells are screened in Monitoring Zones A and B (40 to 60 feet bgs). They collectively pump approximately 80 gpm. The four OU C extraction wells were put into operation in 1988. One well is screened across Monitoring Zones A and B, two are screened in Monitoring Zone B, and one in Monitoring Zone C. The effects of their pumpage may not be as apparent because their pumpage is distributed over three monitoring zones, they are more widely spaced, and they are in close proximity to the drawdown cone created by BW-18.

Two extraction wells have been installed at OU B. Collectively these wells pump only 8 gpm, and no influence on water levels from their extraction is obvious on the figures.

Monitoring Zone A is dewatering due to the regional decline in water levels over time. As a result, several A-zone monitoring wells onbase have already been abandoned or converted to soil vapor monitoring wells. The limited saturated thickness remaining in this unit results in extremely low transmissivities. This will severely limit the amount of water that can be pumped from any single A-zone extraction well and will require that any A-zone remedial action based solely on groundwater extraction include a large number of extraction wells to contain a given target volume.

Smear Zone

The decline of the water table in areas of significant groundwater contamination results in contaminants remaining adsorbed to the soil particles and dissolved in the residual water of the vadose zone. This process creates what is commonly referred to as a "smear zone." Figures 4-26 and 4-27 depict the process by which the water table decline contributes to the contamination of the vadose zone and consequently the creation of a smear zone. The following processes contributed to the development of the smear zone:

- Historically, water levels were close to the bottom of waste pits and source areas. Contaminants migrated from these source areas to the groundwater by dissolving either into the groundwater at the water table interface or into rainwater that was infiltrating through the vadose zone to the water table.

- As the water table declined, depending on their relative phase partitioning tendencies, a certain portion of the contaminants remained in solution in the groundwater, partitioned into soil gas, and sorbed onto soil particles. The contaminants that

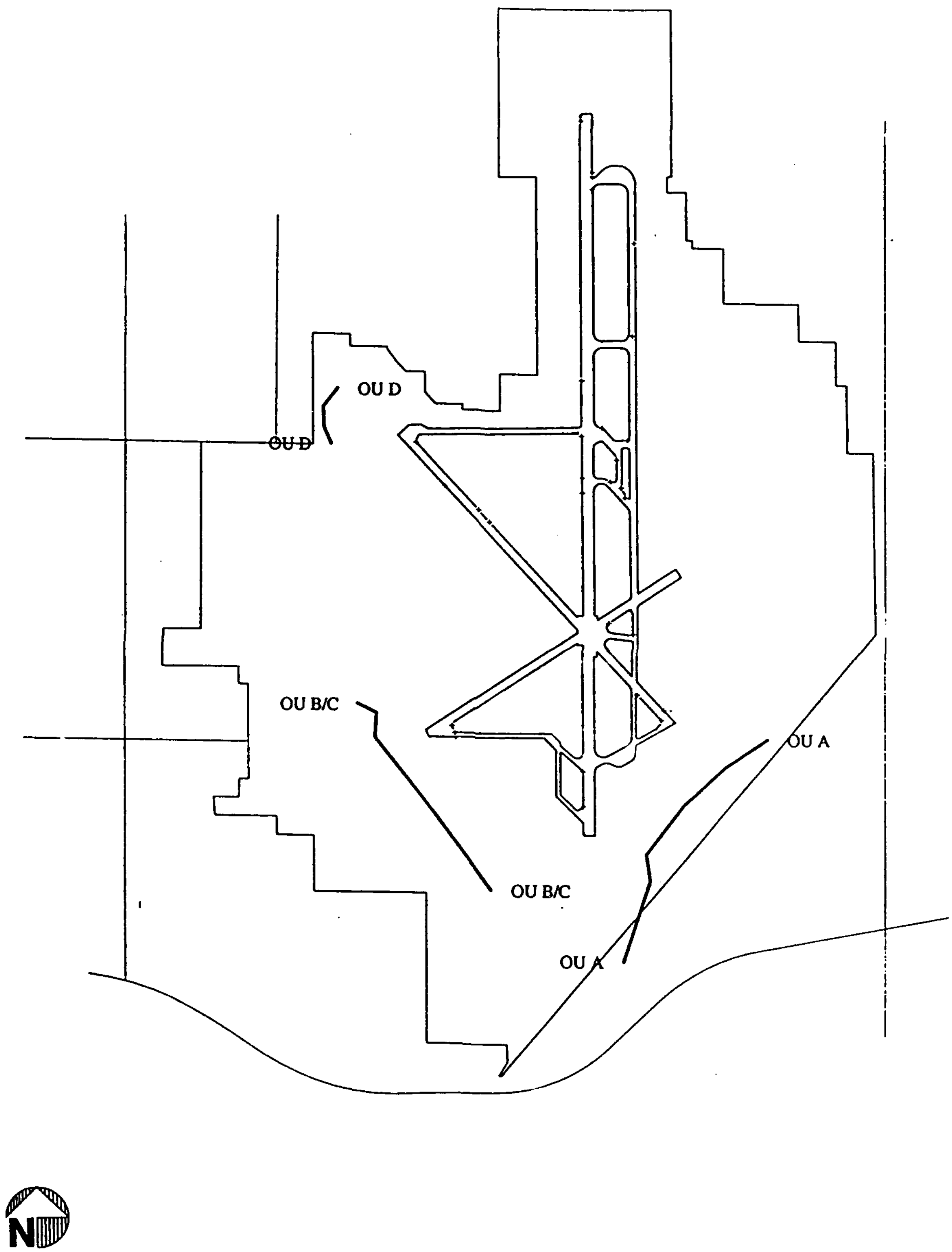


FIGURE 4-21
CROSS-SECTION CUTS LOCATION MAP
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_98

CH2M HILL

OU A

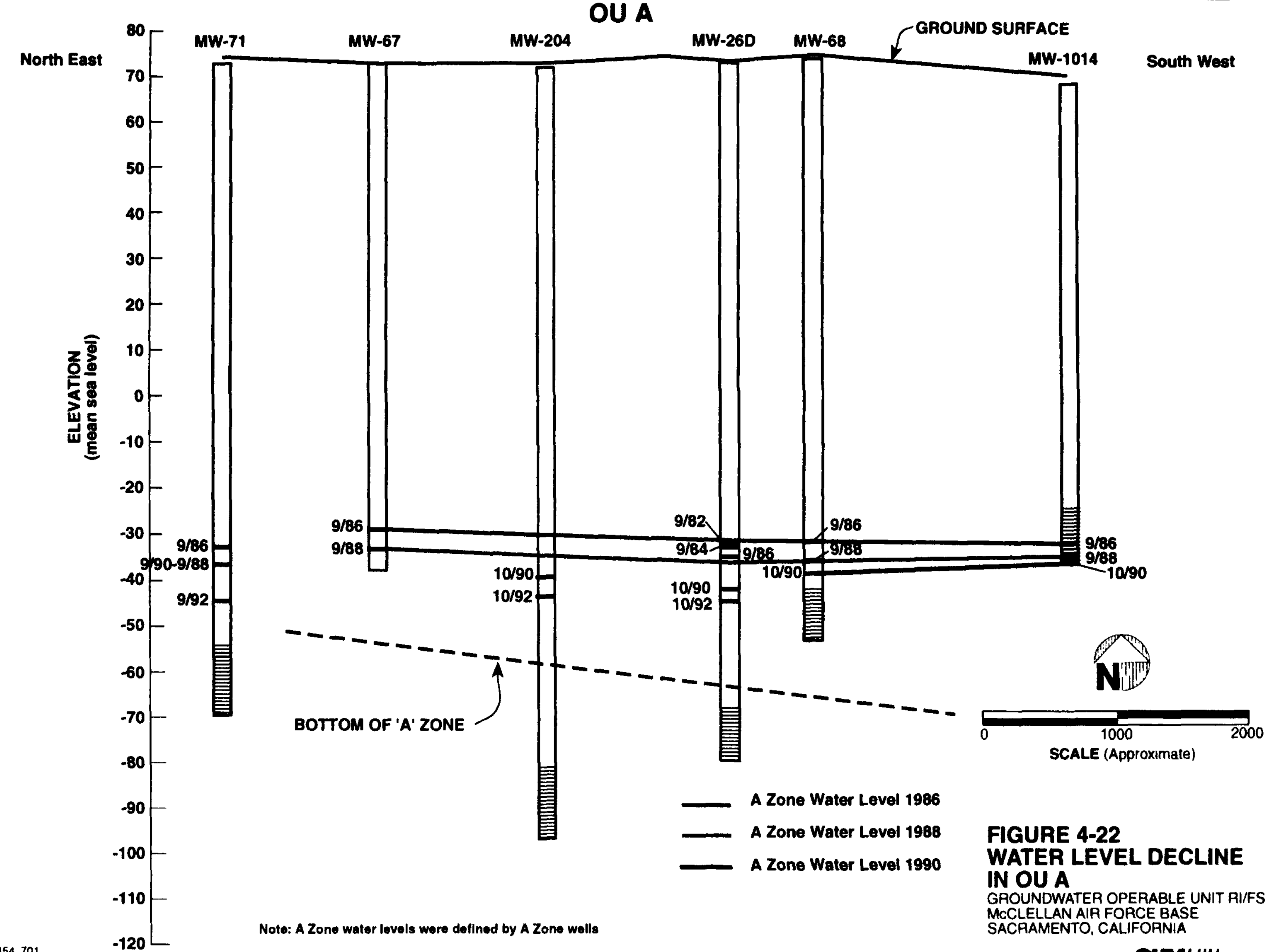
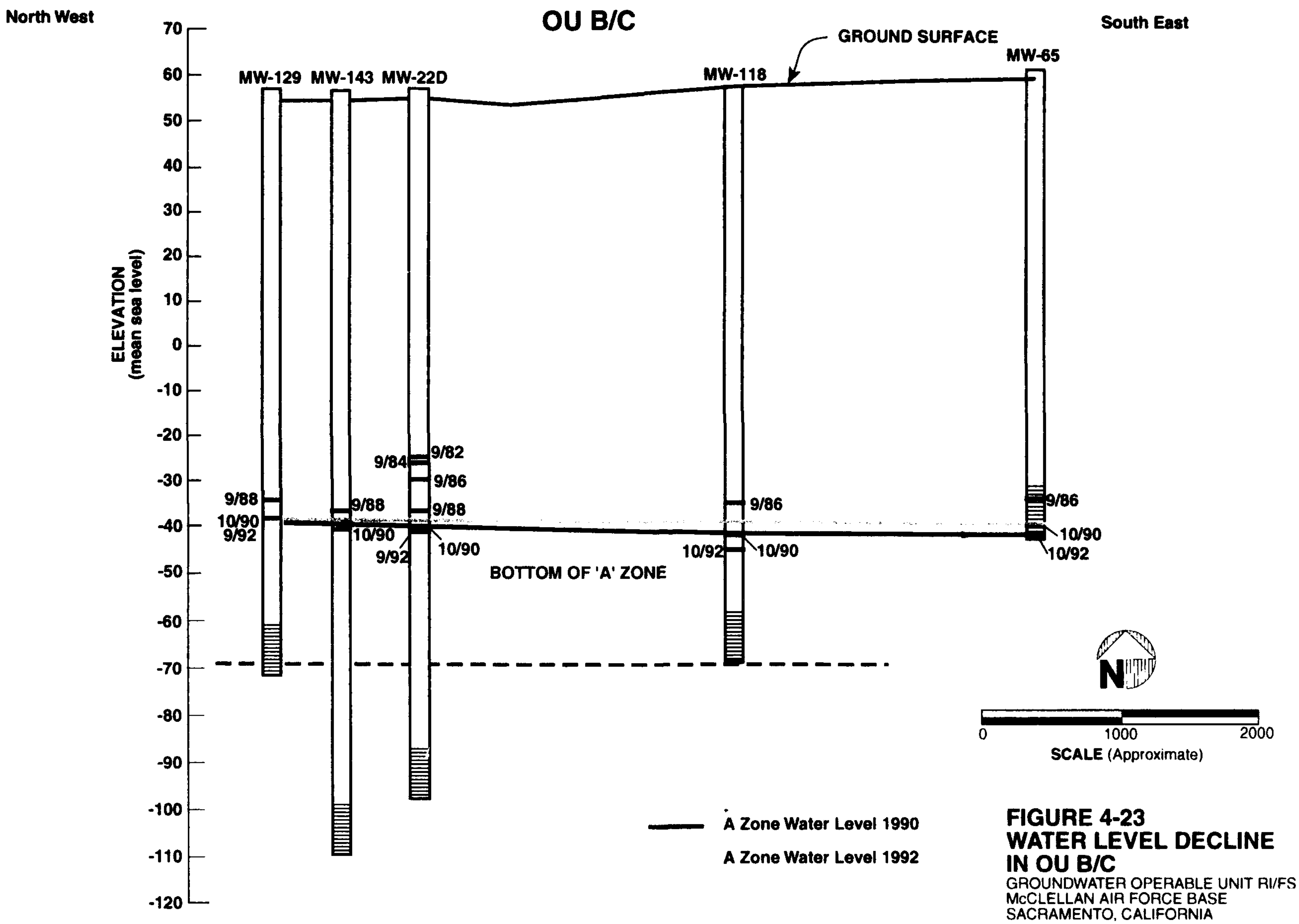


FIGURE 4-22
WATER LEVEL DECLINE IN OU A
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_701

CH2M HILL



Note: A Zone water levels were defined by A Zone wells

FIGURE 4-23
WATER LEVEL DECLINE IN OU B/C
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_702

CH2M HILL

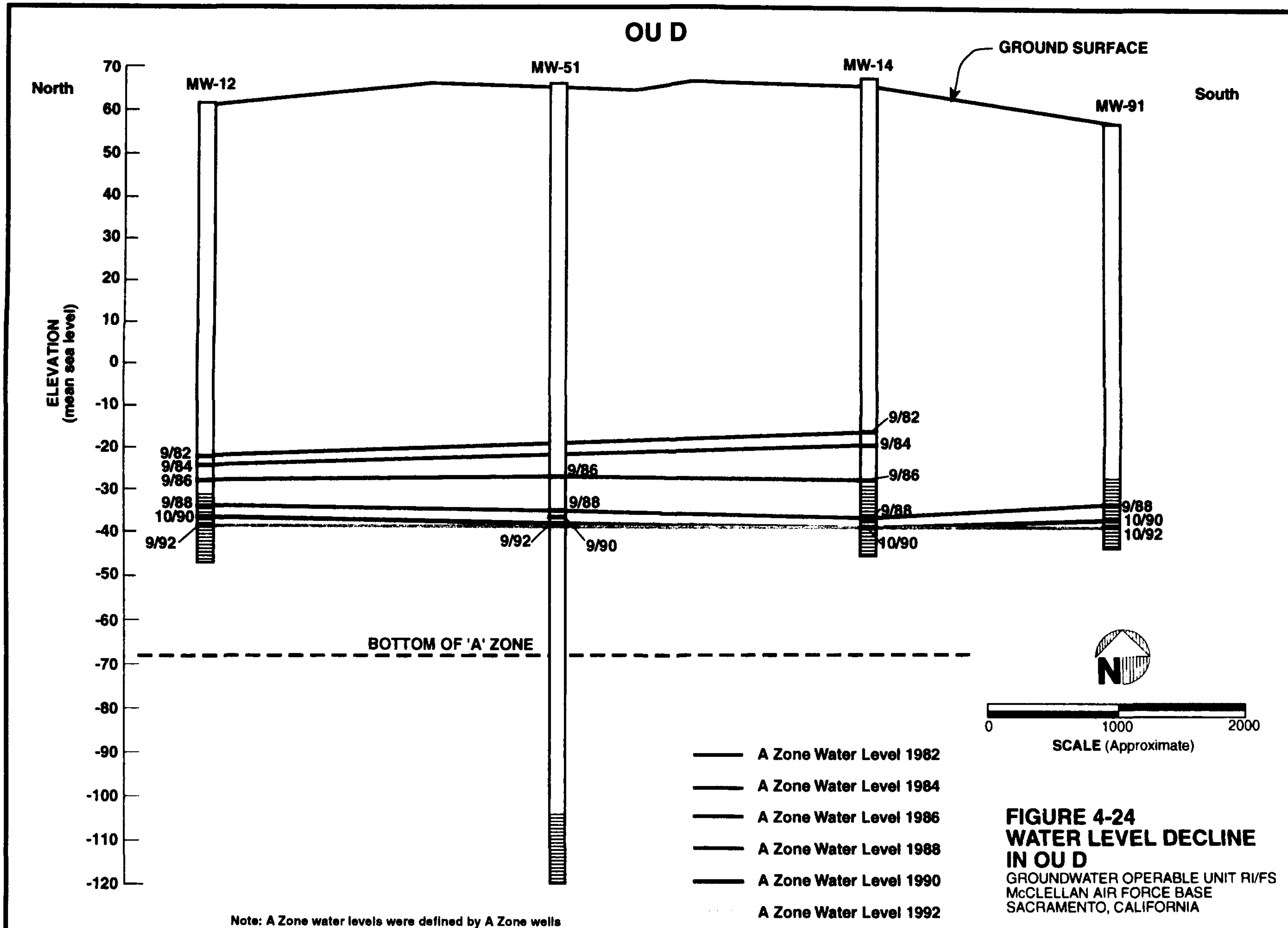


FIGURE 4-24
WATER LEVEL DECLINE IN OU D
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_703

CH2M HILL

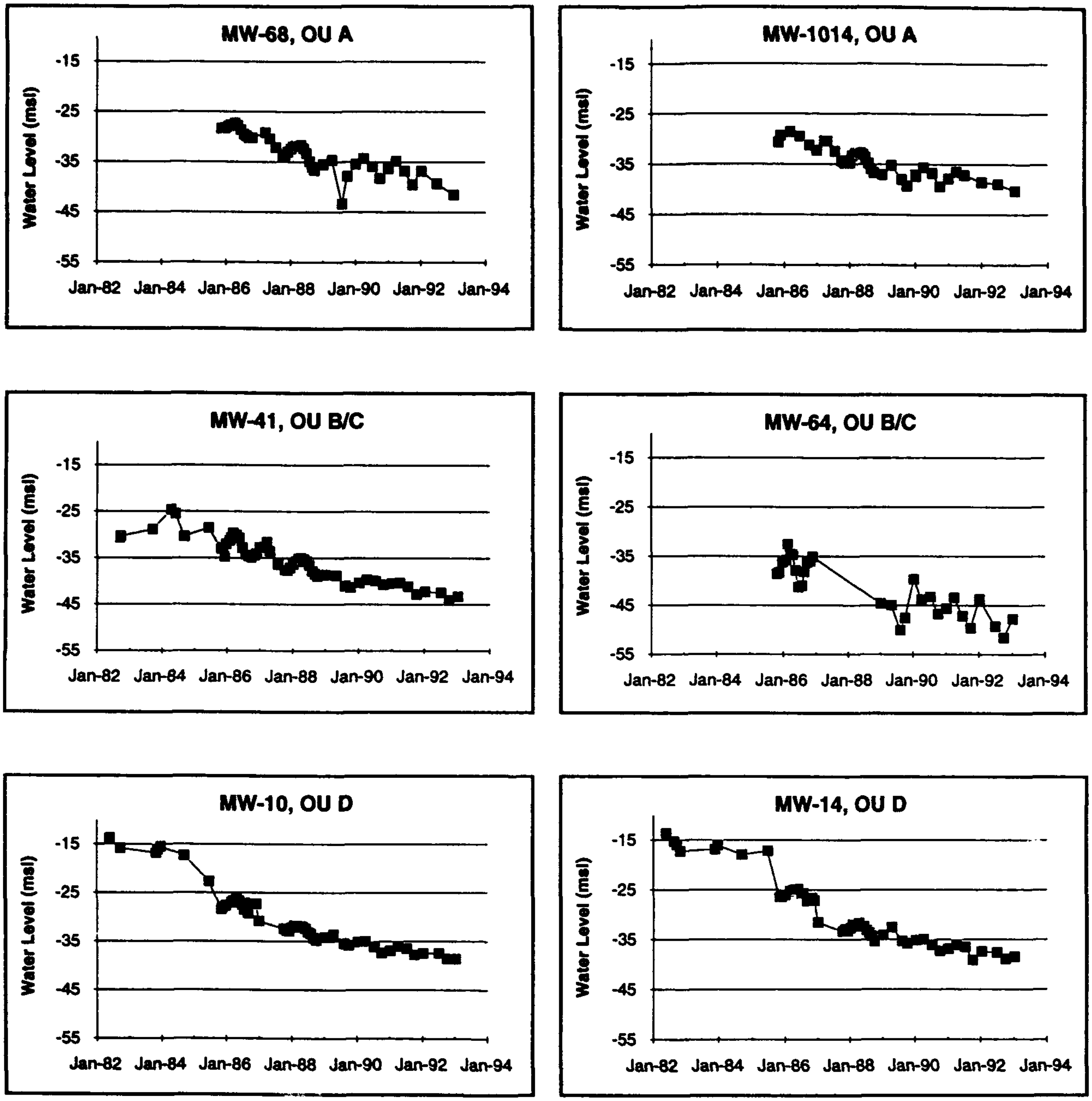


FIGURE 4-25
HYDROGRAPHS OF WELLS IN THE A ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_606

CH2MHILL

volatilized into the soil gas, were dissolved in residual soil water, or were adsorbed onto soil particles while the water table declined constitute the smear zone.

- Prior to the operation of soil vapor extraction systems, contaminants in the soil gas have migrated primarily under diffusive concentration gradients. Compounds sorbed to soil surfaces are considered immobile, except for the component that is flushed from the soil particles by infiltration of precipitation.

- Contaminants that remained in the groundwater have been migrating primarily by liquid advection driven by vertical and horizontal hydraulic gradients.

- As the water table declines, the thickness of the smear zone increases. This increase should be considered when implementing vadose zone remedies and when implementing A-zone extraction options.

- Since the water table has declined from near source area depths, the main migration routes for contaminants from the source areas to the water table are either through infiltration of rainwater, through diffusion of soil gas, or by gravity. To reduce migration by infiltration through the source areas, several source areas have already been excavated and/or capped with low permeability materials.

Contaminant partitioning between the vadose zone and the groundwater is a continuous and dynamic exchange. The physical properties of compounds such as Henry's constant, water solubility, and organic carbon partition coefficient govern the extent that contaminants will partition into soil gas, groundwater, and soil, respectively. When the system is at equilibrium, the contaminant mass in the different phases does not change. But because of groundwater hydraulic gradients and soil gas concentration gradients, the subsurface system is rarely in equilibrium, and there is a constant exchange of contaminants among the three phases.

4.5.3 Particle Tracking Analysis

A major uncertainty that remains at McClellan AFB is the spatial distribution of contamination in the vadose zone between confirmed source areas and the currently identified distribution of contamination in shallow groundwater. Some estimates of where this vadose zone contamination likely exists, and how it is distributed in the subsurface, can be made based on the known historical disposal methods and historical groundwater flow information. The strategy used was to assume that the contaminants originating from the vadose zone source areas moved vertically until they reached the water table in about 1950. Based on historical water level contour maps available periodically from 1953 to 1993 from Sacramento County, the direction and velocity of this contamination in the groundwater could be estimated. The 1993 water levels for the A-zone were obtained from the GSAP. This information was

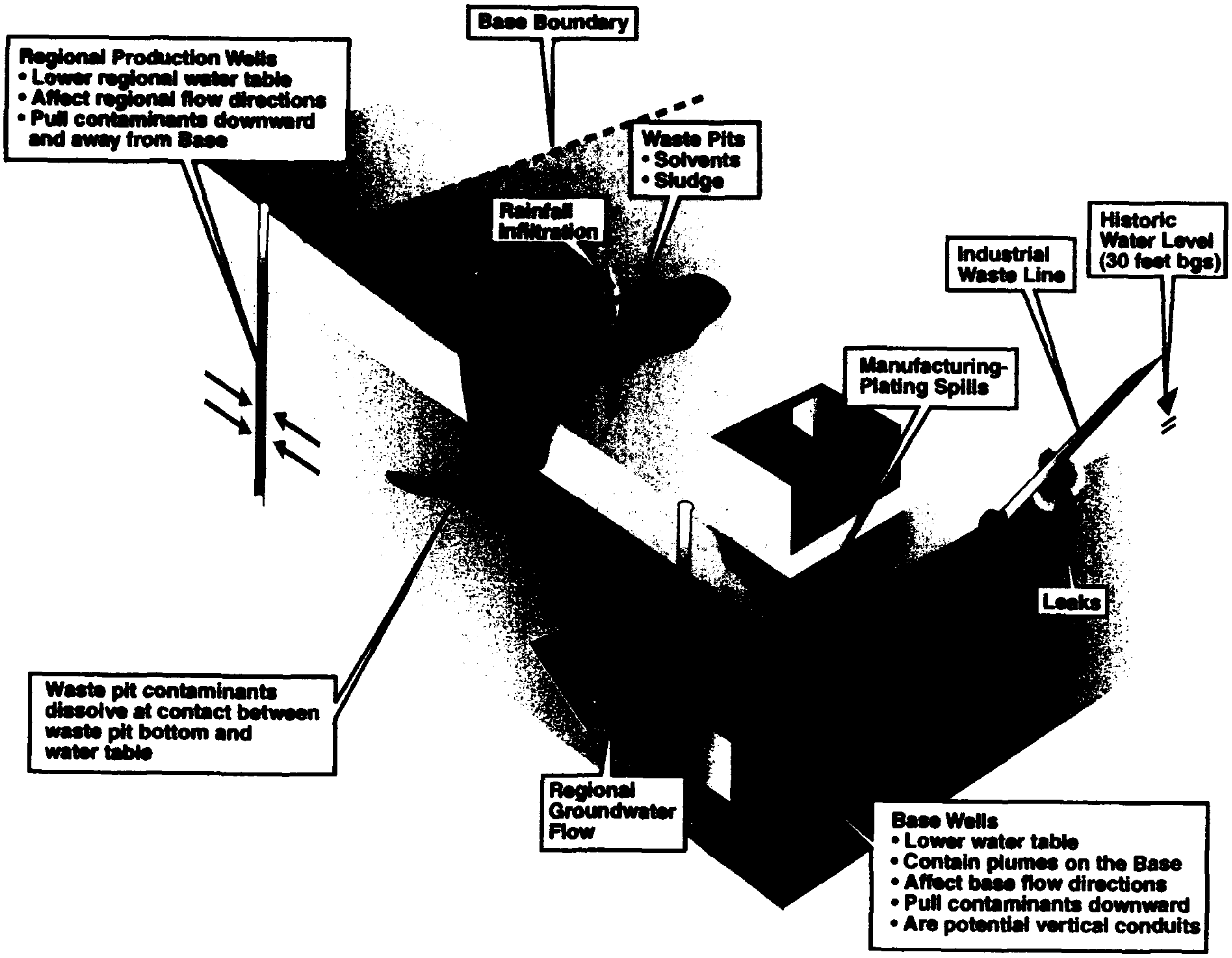


FIGURE 4-26
HISTORIC BASE ACTIVITIES INFLUENCING CONTAMINANT MIGRATION
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_82

CH2M HILL

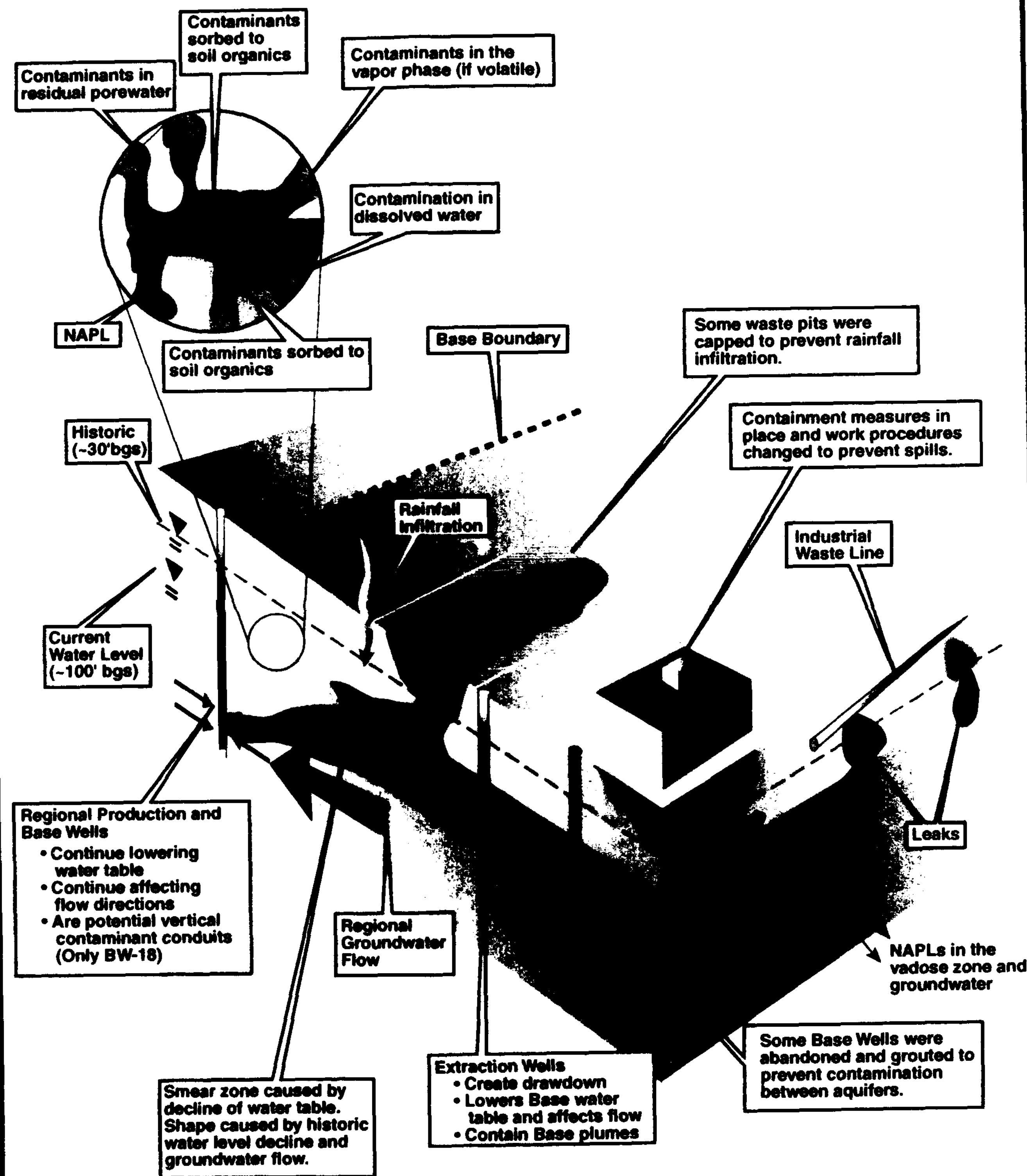


FIGURE 4-27
CURRENT BASE ACTIVITIES INFLUENCING SMEAR ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_83

CH2M HILL

sufficient to calculate the path that a contaminant particle reaching the water table in 1950 would take using the following form of Darcy's law:

$$v = (K \times I)/\theta$$

Where v is the interstitial groundwater velocity (feet/day), K is the aquifer hydraulic conductivity (feet/day), I is the horizontal hydraulic gradient (foot/foot), and θ is the transport porosity of the aquifer (porosity available for advective transport). The hydraulic conductivity was assumed to range between 10 and 30 feet/day. Groundwater contour maps were available at approximately 5-year intervals between 1950 and 1993. These maps were used to calculate the horizontal hydraulic gradient and direction in the vicinity of each OU at McClellen AFB, for the specified time period. Based on these estimates of groundwater velocity, the distance a conservative particle would travel over a 5-year period was calculated, and plotted in the appropriate direction. The term "conservative particle" describes a particle that does not transform and is not retarded by sorption. These pathlines were then traced from the perimeter of the known vadose zone source areas, and an estimate of the areal extent of the smear zone was developed.

The approximate extents of the smear zone originating from the major vadose zone sources identified at the Base are presented on Figures 4-28 and 4-29 for assumed hydraulic conductivities of 10 feet/day and 30 feet/day, respectively. Flow directions were calculated from Sacramento County water level contour maps presented in Figure 4-19. Figures 4-28 and 4-29 show in plan view the extent of the smear zone based on plume migration and the decline of the water table. Because the elevation of the water table beneath the Base is also known for these time periods, the thickness of the smear zone in different locations could also be estimated, and cross sections developed. Figures 4-30 through 4-33 present these cross-sectional representations of the smear zone developed by the declining water table at the Base. Equilibrium calculations based on TCE indicate that as the water table drops, approximately 50 percent of the total mass that existed in the saturated aquifer remains sorbed to the aquifer matrix and dissolved in residual porewater in the vadose zone once it becomes dewatered. This suggests that groundwater containing VOC contamination can contribute a significant mass of contaminants to the newly created vadose zone as water levels decline.

4.5.4 Current Groundwater Conditions

There are strong seasonal variations in regional pumping in the Sacramento area. Hydrographs of wells on the east and west side of the Base (Figure 4-34) show how increased pumping in response to high water demand at the end of the summer produces lower water levels, while lower demand in the spring results in higher water levels. The following sections describe the horizontal and vertical groundwater flow conditions that exist at the Base in response to these regional pumping stresses.

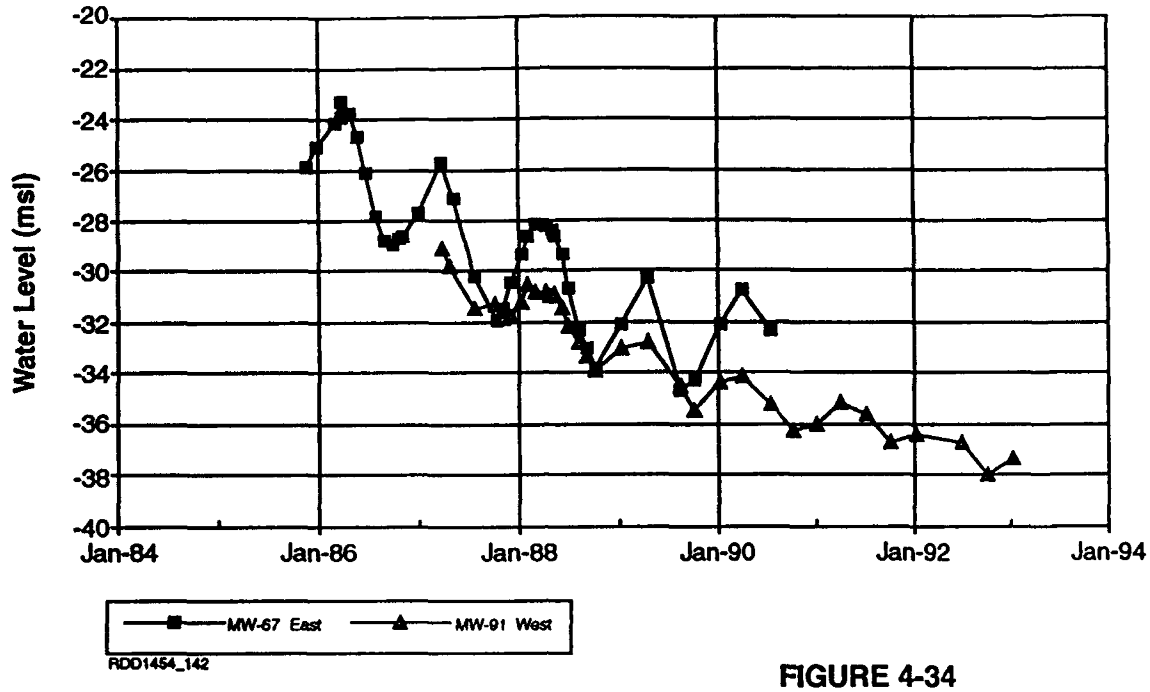


FIGURE 4-34
HYDROGRAPHS FOR A ZONE WELLS ON THE EAST AND WEST SIDE OF BASE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Horizontal Flow

Base wells, domestic production wells, extraction wells, and regional pumping influences all affect the local groundwater flow directions at the Base. Figures 4-35, 4-36, 4-37, and 4-38 are water level contour maps for each monitoring zone based on water level measurements collected in January 1993. Groundwater flow in Monitoring Zones A, B, C, D, and E is generally from the northeast to the southwest.

In the southern part of the Base, BW-18 has a large radius of influence and hence groundwater locally moves toward BW-18 from all directions. BW-18 is perforated in the B through E zones to a depth of 400 feet, and pumps at an average rate of approximately 975 gpm. This pumping rate is an annual average based on the 1992 quarterly monitoring reports produced by Metcalf & Eddy.

The OU D extraction wells also have a significant local influence on groundwater flow paths. The six OU D extraction wells appear to have captured the groundwater in Monitoring Zone A beneath the source areas. Effects of the OU C extraction system in Monitoring Zone B are observable. The effects of the OU B extraction system are less apparent because of the superimposed influence of the adjacent BW-18, and the extremely low flow rate of these extraction wells.

Vertical Flow

The vertical hydraulic gradients that exist at the Base are predominantly downward, except in areas where shallow extraction is occurring. This downward gradient is the result of hydraulic head differences between recharge areas and discharge areas. Surface infiltration is the major source of recharge. Regional pumping is the major component of discharge. Consequently, water moves from the recharge area (ground surface) of higher hydraulic head to the discharge area (regional aquifer) of lower hydraulic head.

This pervasive downward gradient has implications on the movement of contamination at the Base. Contaminated groundwater will move horizontally in response to the horizontal gradients, but will also move vertically in response to the downward gradient. Because the horizontal hydraulic conductivity of the layered sediments is about 5 to 15 times the vertical hydraulic conductivity, contaminants will move further in the horizontal plane. However, unless groundwater extraction is initiated in the shallow aquifers at the site, contamination will continue to move downward into deeper units and eventually threaten regional municipal supply wells.

4.5.5 Water Balance

The purpose of this section is to develop a rough estimate of the quantity of water that moves through the contaminated sediments at McClellan AFB, and to estimate the quantity of water that may move vertically between the shallow contaminated aquifers at the site and the lower regional aquifer. The term "shallow aquifer" used in this analysis represents the collective contaminated aquifers at the site (A-, B-, and C-zones). Because the aquifer properties at the Base are extremely variable, this section uses average parameter values to calculate the approximate magnitude of the major water budget components at the site.

The significant water budget components at McClellan AFB include:

- Infiltration of precipitation
- Groundwater extraction
- Lateral groundwater inflow and outflow
- Deep percolation from the shallow aquifers to the regional aquifer
- Changes in aquifer storage due to declining groundwater levels

Each of these water budget components, along with the method used to calculate their magnitudes, are discussed in more detail below.

Infiltration of Precipitation

The infiltration of precipitation at the Base varies spatially due to land use and topography. Areas with little pavement and topographic low areas, where precipitation runoff may pond, receive the greatest rate of recharge. Heavily urbanized areas, with buildings, storm drains, and extensive asphalt and concrete likely receive little natural recharge. McClellan AFB contains areas representing both of these land use types, with urbanization slightly more dense in the southern portions of the Base. For the purposes of the water balance presented here, an average precipitation recharge rate of 2 inches per year was assumed, which converts to a recharge volume of approximately 470 acre-feet per year over the 2,850-acre site (Figure 4-39). Two inches of recharge per year represents approximately 15 percent of the annual rainfall at the site. This parameter is quite uncertain, and arguments could be made for selecting a higher or lower recharge rate at the site.

Groundwater Extraction

The groundwater extraction rates used in this water balance were derived from the 1992 Metcalf & Eddy Quarterly Monitoring Reports. The average extraction rates assigned to each existing extraction well are presented in Table 4-5.

Table 4-5
Summary of Existing Groundwater Extraction
McClellan AFB

Well Name	OU Location	Monitoring Zone	Avg Pumping Rate (1992)- gpm
EW-73	OU D	A/B	20.5
EW-83	OU D	A/B	6.1
EW-84	OU D	A/B	6.5
EW-85	OU D	A/B	11.7
EW-86	OU D	A/B	12.2
EW-87	OU D	A/B	12.3
EW-137	OU C	B	7.7
EW-140	OU B	B	25.4
EW-141	OU B	C	17.2
EW-144	OU C	B	19.2
EW-233	OU B	A	5.2
EW-234	OU B	A	1.6
EW-246	OU B	A	N/A
EW-63	OU B	B	N/A
EW-247	OU B	C	N/A

Notes: N/A - Information not available

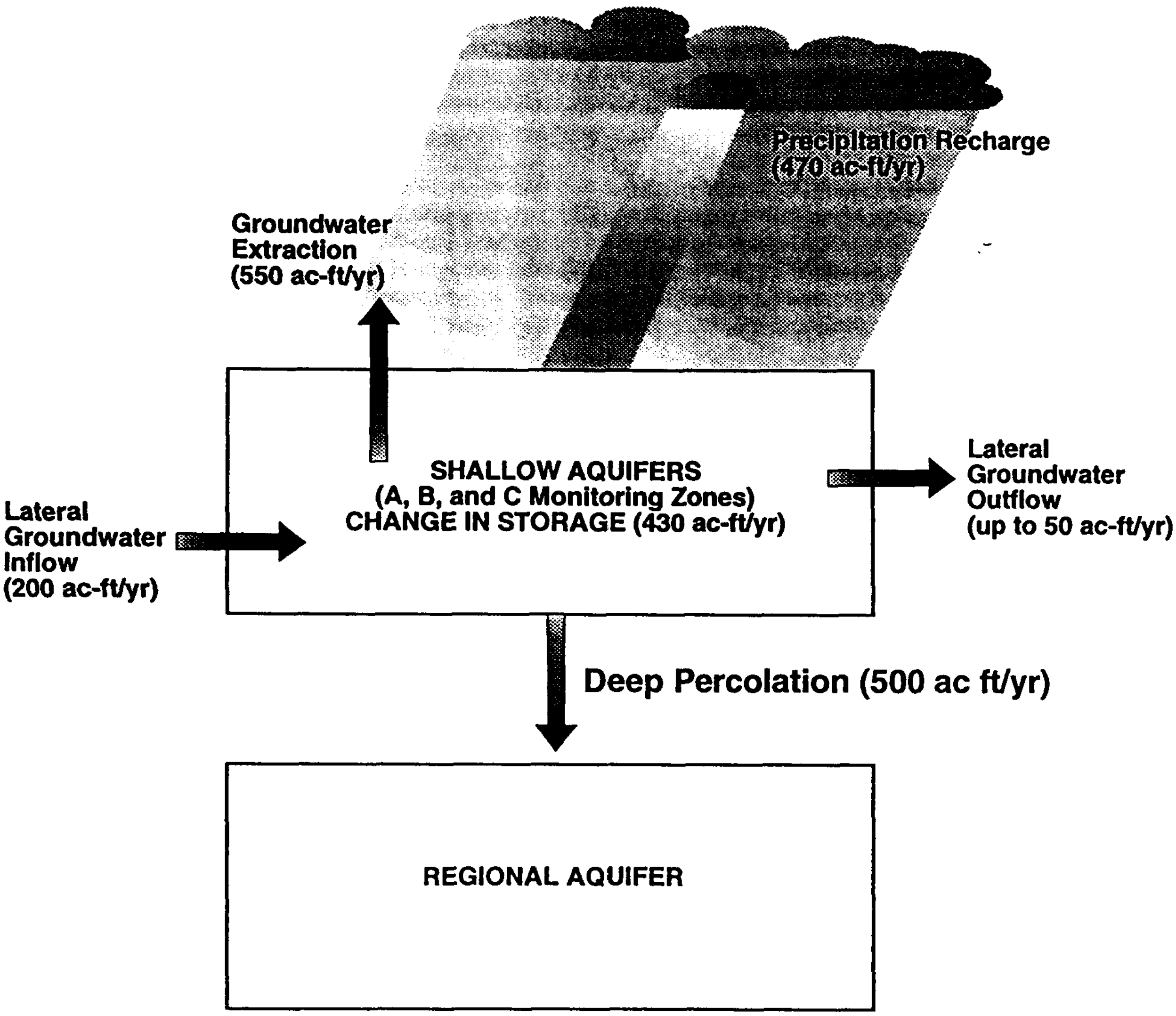


FIGURE 4-39
WATER BALANCE OF SUBSURFACE FLOW DOMAIN
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_212

CH2M HILL

The only other groundwater production from the shallow aquifers at the Base is from Base Well 18. It is assumed that approximately 20 percent of its 975-gpm average pumping rate is drawn from the B-, and C-zone aquifers at the site. This is based on the fact that approximately half of its screen interval is in the B- and C-zones and half is in the D- and E-zones. A value of 20 percent was used to account for the fact that the D- and E-zone aquifers presumably have higher transmissivities than the B- and C-zone aquifers. The total groundwater extraction from the shallow aquifers was then calculated to be approximately 340 gpm, or 550 acre-feet per year.

Change in Aquifer Storage

The change in aquifer storage represents the volume of water that is lost from storage in the A-zone due to the declining water levels observed at the site. Change in storage is calculated by multiplying the product of the annual water level decline and the Base area (2,850 acres), with the specific yield of the sediments at the site. A specific yield of 0.15 and an average water level decline of 1 ft/year was assumed for this analysis. This calculation results in a loss of storage in the A-zone of approximately 430 acre-feet per year.

Lateral Groundwater Flow

The lateral groundwater inflow was calculated based on the application of Darcy's law to the A-, B-, and C-zone aquifers at the site. The form of Darcy's law used in these calculations is as follows:

$$Q = T\ I\ L$$

where:

T = the average aquifer transmissivity in feet squared per day

I = the horizontal hydraulic gradient

L = the width of the flowfield normal to the groundwater flow direction through which the inflow occurs

Table 4-6 presents the parameters used in these calculations. The average transmissivity values were estimated from aquifer tests performed at the site, although few tests were conducted in the northeast section of the Base, where much of the inflow occurs.

- The average A-zone transmissivity of 600 ft^2/day was based on estimated transmissivities of 1,390 ft^2/day at Well MW-12, 791 ft^2/day at Well MW-206, and 38 ft^2/day at Well MW-222.

- The average B-zone transmissivity of 600 ft^2/day was based on estimated transmissivities of 6,617 ft^2/day at Well MW-1027, 275 ft^2/day at Well MW-195, 233 ft^2/day in Well MW-225, and a value of 378 ft^2/day at Well MW-211.

- The average C-zone transmissivity of 700 ft^2/day was based on estimated transmissivities of 432 ft^2/day at Well MW-196, 572 ft^2/day at Well MW-208, and the tendency for wells in the vicinity of OU D to exhibit higher transmissivities than those in the northeast portion of the Base.

The horizontal hydraulic gradients were obtained from the January 1993 water level contour maps presented as Figures 4-35 through 4-38.

Table 4-6
Parameters Used in Lateral Inflow Calculations

Monitoring Zone	Horizontal Gradient (ft/ft)	Flow Field Width (ft)	Average Transmissivity (ft^2/day)	Average Flow (ac-ft/year)
A	0.001	12,000	600	60
B	0.0008	12,000	600	48
C	0.0013	12,000	700	92
Total Lateral Inflow				200

There is also a small component of lateral groundwater outflow from the Base in the shallow zones as evidenced by the movement of contaminants offbase. However, the groundwater contour maps referenced above indicate that this outflow occurs mainly in deeper units, and the areas where outflow occurs from the A- B-, and C-zones is extremely limited. Darcy's law calculations could not be performed to estimate the quantity of this outflow since no obvious offbase groundwater flow paths are evident on Figures 4-35 through 4-38. It is likely that this is an artifact of the contouring and in reality areas exist where hydraulic gradients direct flow offbase. For the purposes of the water budget presented here, it will be assumed that less than 50 ac-ft/yr of groundwater moves offbase laterally in the shallow aquifers.

Deep Percolation

There is almost no information available with which to calculate the flow rate of groundwater moving downward from the C-zone to the deeper aquifers, due to a lack of D-zone water level information. As a result, the rate of downward flow was calculated based on the other water balance components described above. Table 4-7 summarizes this calculation. Results suggest that approximately 500 acre-feet of water per year move downward from the C-zone into the deeper aquifers. This value cannot be independently verified, but appears reasonable based on the magnitude of the other water budget components at the site.

Each of these water budget components has varying degrees of uncertainty. The groundwater extraction rates have the least uncertainty followed by the change in storage in the A-zone aquifer due to water level declines. The lateral groundwater inflow and outflow values and the infiltration recharge rate are the next most uncertain, with the rate of deep percolation from the shallow zones to the regional aquifer being the

Table 4-7 Estimates of Water Balance Components	
Component	**Average Flow**
Infiltration of Precipitation	470 ac-ft/year
Groundwater Extraction	550 ac-ft/year
Lateral Groundwater Inflow	200 ac-ft/year
Lateral Groundwater Outflow	up to 50 ac-ft/year
Change in Aquifer Storage	430 ac-ft/year
Deep Percolation (Required to Balance)	500 ac-ft/year

most uncertain. The result of this uncertainty is that errors associated with estimates of precipitation recharge and lateral groundwater inflow will directly influence the prediction of deep percolation presented here. If recharge or groundwater inflow are less than estimated, the deep percolation will be reduced by a similar amount. Along the same lines, if the change in storage in the A-zone is larger than estimated, the deep percolation will be greater to compensate.

4.5.6 Pumpage of Base and Municipal Wells

The historical and current pumpage of Base, municipal, and domestic wells have affected the groundwater flow directions. Except for the hydraulic control of the OU D extraction wells, groundwater generally flows to the southern portion of the Base in all zones. This is due primarily to the large pumping influences of BW-18 and the city wells and Caltrans wells located to the south of the Base.

Information pertaining to production wells and pumpage capacity was requested of all the water purveyors within a 5-mile radius of McClellan AFB. This information is summarized in Appendix N, Domestic and Base Well Pumping Information.

The locations of all the known production wells adjacent to the Base are presented in Figure 4-40. Almost all basewell locations were obtained form the Revised Final Well Closure Methods and Procedures report (CH2M HILL, 1993). This report is presented in Appendix O. The available 1992 pumping rates for wells within a 5-mile radius of the Base are presented in Figure 4-41. Pumping rates for years 1973, 1980, and 1986 are presented in Appendix N.

Generally, higher pumping occurred in the southwest and northeast regions of the Base. The aquifer beneath McClellan AFB receives recharge from the American River to the south, from the Sacramento River to the west, from various small creeks to the north, and from mountain-front recharge from precipitation to the east. Thus, the mountain-front precipitation supplies water for the Northridge pumpage, and the American River supplies water for the city well and Citizens Utilities pumpage to the southwest of the Base. The pumpage of the Northridge production wells has contributed to the offbase southeastward migration of contaminants.

Basewide groundwater flow is generally southward. Coupled with the high pumping rates of BW-18, the spacial distribution of recharge will tend to create a cone of depression near the center of the aquifer surrounded by recharge, even if pumping is fairly distributed across the region.

Pumping information was not made available for all production wells within a 5-mile radius of the Base. Consequently, production wells that are not marked with a pumpage magnitude may actually have been pumped and may have contributed to the flow directions, but pumpage information on these wells is not available. Conversely, wells marked as having zero pumpage were not pumped. Figure 4-41 presents available pumpage information, not all pumpage information.

4.5.7 Base Wells Scheduled to be Decommissioned

A total of 35 wells have been identified during data collection activities associated with the well decommissioning program at McClellan AFB (Figure 4-40). Thirty-one of these wells are water supply wells located in and around McClellan AFB. These wells are designated in McClellan AFB files as the Boy Scout Well, Old 29, and BW-1 through BW-29. Four additional wells are located at Camp Kohler, which is located 1 mile east of the Base on Roseville Road. Two are former laundry wells, LW-1 and LW-2; and two wells were constructed as part of a seismic survey. All of these wells and their status are listed in Table 4-8.

Four McClellan AFB wells and one City of Sacramento well were decommissioned during the Phase 1 well decommissioning effort. These wells were BW-1, BW-2, BW-12, BW-27, and City Well 150. During Phase II, five McClellan AFB wells were decommissioned (BW-8, BW-13, BW-17, BW-20, and BW-28). The four wells at Camp Kohler, LW-1, LW-2, the seismic well and the Triax hole, were also decommissioned during Phase II. The latter two wells are seismic survey wells and not water wells.

Fifteen wells are scheduled to be abandoned during Phase III of the well abandonment program. They are BW-3, BW-4, BW-5, BW-6, BW-7, BW-9, BW-11, BW-15, BW-16, BW-19, BW-21, BW-22, BW-23, BW-24, and the Boy Scout well. Phase III is scheduled to begin in April 1994. Several of the wells could act as conduits, allowing contaminated groundwater near the water table to migrate to deeper zones through the wells casing and gravel pack and potentially threaten downgradient drinking water supplies. Several of the wells are discussed in the following paragraphs.

BW-16, BW-3, and BW-19 were scheduled for decommissioning during Phase 1 of well decommissioning, but could not be located in the field in 1990. A recent field inspection located BW-16 in the western part of the Base, approximately 150 feet south of Site 22, a former burn pit. No well construction data are available for this well (CH2M HILL, 1993). The well was probably used as an agricultural well.

Table 4-8
Status of Existing McClellan AFB Production Wells

Well No.	Install Date	Depth (ft)	Location	Comments
B-1	1937	400	Building 231	Decommissioned in 1991.
B-2	1937	405	Building 232	Decommissioned in 1991.
B-3		604	Southwest in field near Bell Avenue and Kilzer Avenue	Tentatively located with BW-19. Casing filled with concrete. To be abandoned in Phase III.
B-4		382	Near Watt Avenue and Roseville Road, off the Base	Inactive. Not visible. Located on old maps. To be abandoned in Phase III.
B-5	1941	368	Off the Base on Old Garden Highway	Known as the "Old River Dock Well." To be abandoned in Phase III.
B-6			Near Patrol Road and Buildings 714 and 715	Inactive. Has not been located. Thought to be old agricultural well. To be abandoned in Phase III.
B-7	1941	398	Near Building 429	To be abandoned in Phase III.
B-8	1942	732	Building 91	Abandoned August 1993.
B-9		660	Near Building 200	Reported to have collapsed. Not visible. Located on old maps in parking lot near BW-20. To be abandoned in Phase III.
B-10		400	East near Building 93 on O'Malley Avenue	Active well. Average flowrate: approximately 260,000 to 670,000 gpd.
B-11		378	Southeast of the Base, near Watt Avenue and Winona Street	Inactive. Not visible. Located on old maps. To be abandoned in Phase III.
B-12	1943	395	Building 395	Decommissioned in 1991.
B-13	1945	391	Building 614	Abandoned December 1992.
B-14			Unknown	Uncertain status. No known location. May be located at Whitney and Eastern Avenues.
B-15	1943	305	North of Building 440 on Dudley Boulevard	Inactive, status uncertain. To be abandoned in Phase III.

Table 4-8
Status of Existing McClellan AFB Production Wells

Well No.	Install Date	Depth (ft)	Location	Comments
B-16			Site 22 on Patrol Road	Inactive. Not visible. Located on old maps. To be abandoned in Phase III.
B-17	prior to 1947	390	Building 699	Abandoned January 1993.
B-18		408	Southwest near Building 664 on Winters Street	Active well. Average flowrate: approximately 800,000 to 1,490,000 gpd.
B-19	1952	360	Southwest in field near Bell Avenue and Kilzer Avenue	Tentativel located with BW-3. Casing filled with concrete. Reported to have collapsed. To be abandoned in Phase III.
B-20	1953	600	In parking lot south of Building 200	Abandoned January 1993.
B-21			Near Building 689	Status uncertain. Has not been located. Thought to be an old agricultural well. May have served the old Aero Club. To be abandoned in Phase III.
B-22			Near Building 1445	Status uncertain. Has not been located. Thought to lie near the northeast corner of the building. To be abandoned in Phase III.
B-23			Near Building 1455	May have been found during parking lot construction. Thought to be an old agricultural well. To be abandoned in Phase III.
B-24			Near Building 1455	May have been found during parking lot construction. Thought to be an old agricultural well. To be abandoned in Phase III.
B-25		408	Off the Base at the Lincoln Communications Site	Active well.
B-26		358	Off the Base at the Davis Communications Site	Active well. Water may be contaminated.
B-27	1962	261	Near Building 1099	Decommissioned in 1991.

Table 4-8
Status of Existing McClellan AFB Production Wells

Well No.	Install Date	Depth (ft)	Location	Comments
B-28	1966	248	Near Building 1082	Abandoned December 1992.
B-29		247	North area, in Building 1455 on Perrin Avenue	Active well. Average flowrate: 200,000 to 950,000 gpd.
Old 29			About 25 feet northeast of BW-29	Was abandoned in 1984 due to sand; new BW-29 drilled just south of former site.
Boy Scout Well			About 75 feet south of BW-29, near Building 1457	Casing is visible, but well status is uncertain. To be abandoned in Phase III.
LW-1			Camp Kohler	Uncovered by backhoe. Has been filled with concrete. Agencies agreed no need to abandon this well.
LW-2			Camp Kohler	Located on old maps, but not uncovered. Abandoned January 1994.
Seismic Well			Camp Kohler	Casing exterior sealed with cement. Not a water well. Abandoned January 1993.
Triax Hole			Camp Kohler	Casing exterior sealed with cement. Not a water well. Abandoned August 1993.

BW-3 and BW-19 are believed to be in the southwest part of the Base near Building 662 and 667 about 200 yards west of the Bell/Kilzer intersection. One of these wells (presumed to be BW-3) has a 6-inch-diameter casing that extends to a depth of 604 feet. The other well (presumed to be BW-19) contains a 14-inch-diameter casing. BW-19 was reportedly constructed in 1952 to a depth of 360 feet with a screen interval between 214 and 314 feet. Both wells were probably used as agricultural wells and reportedly abandoned by McClellan AFB Water Department personnel (LSCE, 1984). Typical past abandonment procedures were to fill the well with sand up to 50 feet belowgrade and then pour cement from 50 feet belowgrade to the ground surface. This procedure does not seal the well, which might then be a conduit for contaminant migration.

Another well, BW-15, was initially believed to be located several miles away from McClellan AFB (LSCE, 1985). Further investigation located this well immediately north of Building 440, on Dudley Boulevard across the street from BW-7 in the southeast portion of the Base. A well log was found at the Department of Water Resources (DWR) that identified a well located by the Rubber Conservation Building. Old maps identify Building 440 as the Rubber Conservation Building and the building to the west as the Dry Cleaning Facility (presently Building 443). Therefore, the log probably refers to BW-15. According to the log, BW-15 was constructed in 1943 to a total depth of 305 feet. The casing was 12 inches in diameter and perforated from a depth of 245 to 270 feet. The present surface features of BW-15 are a concrete pad with a circular hole covered with asphalt and concrete footings that were probably used to support a motor pump (CH2M HILL, 1993).

4.6 Existing and Observed Conditions

The four components, site characteristics, source areas, fate and contaminant transport, and physical transport mechanisms, frame the conceptual model and provide the information base necessary to interpret and discuss the existing and observed conditions. This section will discuss the current groundwater conditions by presenting the prevalent VOC contaminants and by summarizing the monitoring history. These discussions will be followed by a summary of the water quality information from Base and production wells along with a presentation of the extent of contamination of the prevalent VOCs. No metals were selected as prevalent contaminants. This section will conclude with a discussion concerning the limitations of the metals database and the rationale as to why a data set of representative concentrations was not assembled and why prevalent contaminants were not selected.

4.6.1 Data Set Used in VOC Mass Estimates and Generation of VOC Target Volumes

Water quality data from 279 wells and borings were used to approximate the extent of contamination, to estimate VOC mass, and to generate target volumes. The data set used is presented in Table 4-9. Data were obtained from the following wells:

Table 4-9
Representative Concentration Data Set Used in Extent of Contamination Delineation, Target Volume Generation, and Mass Estimates
(µg/l)

Location Name	Date	Risk	1,2-DCA	c-1,2-DCE	PCE	TCE	1,2-DCE	1,1,1-TCA
EW-137	16-Jul-93	4.36E-05	2.80E-01	9.11E+00	0.00E+00	6.46E+01	0.00E+00	0.00E+00
EW-140	16-Jul-93	5.22E-05	5.28E-01	2.56E+01	0.00E+00	7.50E+01	0.00E+00	0.00E+00
EW-141	16-Jul-93	4.06E-05	0.00E+00	8.15E+00	0.00E+00	6.34E+01	0.00E+00	0.00E+00
EW-141	16-Jul-93	4.06E-05	0.00E+00	8.38E+00	0.00E+00	6.68E+01	0.00E+00	0.00E+00
EW-233	16-Jul-93	5.35E-03	0.00E+00	0.00E+00	8.34E+02	4.51E+03	0.00E+00	0.00E+00
EW-234	16-Jul-93	7.12E-04	0.00E+00	0.00E+00	7.66E+01	7.61E+02	6.89E+01	0.00E+00
MW-0007	21-Jul-93	1.93E-05	4.56E-01	1.32E+01	0.00E+00	2.10E+01	0.00E+00	0.00E+00
MW-0010	6-Apr-93	8.64E-04	1.20E+02	0.00E+00	0.00E+00	3.90E+02	1.70E+02	0.00E+00
MW-0011	28-Jul-93	1.00E-03	0.00E+00	0.00E+00	0.00E+00	1.40E+03	1.36E+04	1.29E+03
MW-0012	20-Jul-93	7.26E-04	0.00E+00	0.00E+00	0.00E+00	9.76E+02	6.61E+03	0.00E+00
MW-0014	6-Apr-93	1.49E-03	0.00E+00	0.00E+00	0.00E+00	2.30E+03	2.10E+03	1.20E+03
MW-0014	6-Apr-93	1.49E-03	0.00E+00	0.00E+00	0.00E+00	2.30E+03	2.40E+03	1.30E+03
MW-0015	28-Jul-93	5.45E-05	0.00E+00	0.00E+00	0.00E+00	8.21E+01	1.51E+02	6.71E+00
MW-0017D	16-Jul-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0018D	6-Feb-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0019D	27-Jan-93	9.05E-07	0.00E+00	0.00E+00	0.00E+00	2.90E+00	1.60E+00	2.70E+00
MW-0020D	19-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0021D	22-Jul-91	2.28E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0021S	Average	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.20E-01	0.00E+00	0.00E+00
MW-0022D	29-Jul-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0023D	21-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0024D	21-Jul-93	8.50E-07	1.67E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0025D	21-Jul-93	1.40E-06	0.00E+00	5.77E-01	0.00E+00	6.65E-01	0.00E+00	0.00E+00
MW-0026D	8-Jan-93	1.15E-05	0.00E+00	0.00E+00	0.00E+00	4.70E+01	0.00E+00	0.00E+00
MW-0027D	8-Jan-93	1.13E-04	1.60E+00	6.00E+00	0.00E+00	3.50E+01	0.00E+00	0.00E+00
MW-0028D	16-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0029D	19-Oct-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0031S	13-Apr-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0033S	26-Apr-90	8.10E-03	0.00E+00	0.00E+00	0.00E+00	2.60E+04	0.00E+00	0.00E+00
MW-0036S	25-Oct-88	5.62E-07	0.00E+00	0.00E+00	0.00E+00	1.80E+00	0.00E+00	0.00E+00
MW-0038D	24-Jun-93	0.00E+00	1.30E+01	0.00E+00	4.60E+01	2.80E+02	0.00E+00	0.00E+00
MW-0041S	27-Jul-93	2.05E-04	0.00E+00	2.38E+01	0.00E+00	2.99E+02	0.00E+00	0.00E+00
MW-0044S	13-Aug-91	5.57E-06	0.00E+00	0.00E+00	4.50E-01	1.60E+01	5.10E+00	0.00E+00
MW-0049S	1-May-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0051	6-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0052	23-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0053	22-Apr-93	2.03E-07	0.00E+00	0.00E+00	0.00E+00	3.20E-01	1.10E+00	0.00E+00
MW-0054	7-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0055	12-Jan-93	1.68E-06	0.00E+00	0.00E+00	2.40E-01	4.40E+00	0.00E+00	0.00E+00
MW-0057	27-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0058	22-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0059	20-Jul-93	4.46E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0060	17-Jul-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0061	26-Jan-93	1.16E-05	0.00E+00	0.00E+00	3.20E-01	3.60E+01	0.00E+00	0.00E+00
MW-0062	26-Jul-93	1.66E-06	0.00E+00	2.87E+00	0.00E+00	2.62E+00	0.00E+00	0.00E+00
MW-0063	28-Jan-93	1.25E-05	0.00E+00	1.50E+01	0.00E+00	4.00E+01	0.00E+00	0.00E+00
MW-0064	27-Jul-93	6.97E-07	0.00E+00	0.00E+00	0.00E+00	5.83E-01	0.00E+00	1.66E+00
MW-0065	11-Oct-91	1.57E-05	0.00E+00	0.00E+00	8.20E-01	4.70E+01	0.00E+00	0.00E+00
MW-0066	18-Jan-93	3.12E-07	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	0.00E+00

Table 4-9
Representative Concentration Data Set Used in Extent of Contamination Delineation, Target Volume Generation, and Mass Estimates
(µg/l)

Location Name	Date	Risk	1,2-DCA	c-1,2-DCE	PCE	TCE	1,2-DCE	1,1,1-TCA
MW-0067	2-May-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0068	22-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0069	15-Jan-93	3.32E-06	0.00E+00	0.00E+00	0.00E+00	1.20E+00	0.00E+00	0.00E+00
MW-0070	16-Jan-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0071	21-Jan-93	3.58E-05	5.00E-01	1.90E+00	0.00E+00	1.80E+01	3.40E+00	0.00E+00
MW-0072	23-Jul-93	3.58E-04	3.79E+01	2.43E+00	0.00E+00	2.46E+02	8.83E+01	0.00E+00
MW-0074	28-Jan-93	1.36E-06	2.10E-01	0.00E+00	0.00E+00	2.90E+00	3.30E+00	0.00E+00
MW-0075	27-Oct-92	1.22E-04	0.00E+00	1.30E+01	0.00E+00	3.90E+02	0.00E+00	0.00E+00
MW-0076	29-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0088	22-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0089	5-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E+02	0.00E+00
MW-0090	24-Jul-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0091	20-Jul-93	2.15E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.49E+01	1.06E+01
MW-0092	14-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0100	13-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0101	22-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0102	15-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0103	26-Jul-93	9.30E-07	0.00E+00	0.00E+00	0.00E+00	1.22E+00	0.00E+00	0.00E+00
MW-0104	19-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0105	19-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0106	27-Dec-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0107	2-Jan-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0108	16-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+(
MW-0109	16-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0110	30-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0111	2-Aug-93	1.85E-06	0.00E+00	1.24E+00	0.00E+00	2.91E+00	0.00E+00	0.00E+00
MW-0112	18-Jan-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0113	26-Jul-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0114	20-Apr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0115	29-Oct-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0116	11-Oct-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0120	11-Jul-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0121	24-Jul-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0122	12-Dec-89	2.28E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0128	15-Oct-92	3.43E-03	0.00E+00	0.00E+00	0.00E+00	1.10E+04	0.00E+00	0.00E+00
MW-0129	15-Oct-92	1.19E-03	0.00E+00	0.00E+00	0.00E+00	3.80E+03	0.00E+00	0.00E+00
MW-0130	15-Oct-92	8.43E-07	0.00E+00	5.80E-01	0.00E+00	2.70E+00	0.00E+00	0.00E+00
MW-0131	Average	0.00E+00	1.20E-01	0.00E+00	0.00E+00	5.29E+01	2.00E+00	4.17E+00
MW-0132	6-Aug-93	2.55E-05	6.48E-01	1.21E+01	0.00E+00	3.50E+01	0.00E+00	0.00E+00
MW-0132	6-Aug-93	2.55E-05	6.48E-01	1.21E+01	0.00E+00	3.50E+01	0.00E+00	1.31E+00
MW-0133	14-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0134	6-Oct-93		0.00E+00	4.20E-01	2.00E+00	3.20E+00	0.00E+00	0.00E+00
MW-0135	15-Apr-93	1.33E-05	2.70E-01	1.90E+00	0.00E+00	1.20E+01	0.00E+00	0.00E+00
MW-0136	14-Oct-92	1.25E-05	2.80E-01	1.50E+00	0.00E+00	3.80E+01	0.00E+00	0.00E+00
MW-0138	14-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0139	29-Jul-93	1.03E-04	0.00E+00	3.25E+01	0.00E+00	1.30E+02	0.00E+00	0.00E+00
MW-0142	13-Jul-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+0
MW-0143	19-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0145	19-Jul-93	2.75E-06	3.86E-01	3.62E-01	0.00E+00	1.23E+00	0.00E+00	0.00E+00

Table 4-9
Representative Concentration Data Set Used in Extent of Contamination Delineation, Target Volume Generation, and Mass Estimates
(µg/l)

Location Name	Date	Risk	1,2-DCA	c-1,2-DCE	PCE	TCE	1,2-DCE	1,1,1-TCA
MW-0146	21-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0147	3-May-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0148	21-Jul-93	8.06E-06	3.69E-01	2.65E+00	0.00E+00	9.73E+00	0.00E+00	0.00E+00
MW-0149	8-Apr-93	2.48E-07	0.00E+00	0.00E+00	0.00E+00	3.90E-01	0.00E+00	0.00E+00
MW-0150	2-Aug-93	4.67E-06	0.00E+00	0.00E+00	1.35E-01	0.00E+00	0.00E+00	0.00E+00
MW-0151	9-Apr-93	2.31E-05	0.00E+00	0.00E+00	7.90E+00	0.00E+00	0.00E+00	0.00E+00
MW-0152	27-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0153	29-Jul-93	1.46E-04	0.00E+00	6.39E+00	1.59E+01	1.55E+02	0.00E+00	0.00E+00
MW-0154	29-Jul-93	2.01E-06	0.00E+00	0.00E+00	0.00E+00	3.17E+00	0.00E+00	0.00E+00
MW-0155	28-Jul-93	2.64E-05	0.00E+00	1.68E+01	0.00E+00	2.97E+01	0.00E+00	0.00E+00
MW-0156	29-Jul-93	7.38E-05	0.00E+00	3.81E+01	0.00E+00	1.14E+02	0.00E+00	0.00E+00
MW-0157	29-Jul-93	6.82E-04	0.00E+00	0.00E+00	8.62E+01	6.64E+02	0.00E+00	4.84E+00
MW-0158	3-Aug-93	4.50E-04	0.00E+00	1.59E+01	5.07E+01	4.67E+02	0.00E+00	0.00E+00
MW-0159	3-Aug-93	2.72E-04	0.00E+00	3.87E+01	3.25E+01	2.63E+02	0.00E+00	0.00E+00
MW-0160	21-Oct-92	4.34E-05	6.50E+00	4.80E+01	0.00E+00	7.20E+01	6.60E+00	0.00E+00
MW-0161	26-Jul-93	7.71E-07	0.00E+00	0.00E+00	0.00E+00	9.68E-01	0.00E+00	0.00E+00
MW-0162	27-Jul-93	2.13E-05	0.00E+00	0.00E+00	3.18E+00	1.83E+01	0.00E+00	0.00E+00
MW-0163	27-Jan-93	1.72E-06	0.00E+00	6.90E-01	0.00E+00	5.50E+00	0.00E+00	0.00E+00
MW-0164	19-Apr-93	1.61E-05	3.10E-01	1.00E+01	0.00E+00	1.70E+01	8.20E-01	0.00E+00
MW-0164	19-Apr-93	1.61E-05	3.10E-01	1.00E+01	0.00E+00	1.70E+01	1.30E+00	0.00E+00
MW-0165	6-Oct-93		3.20E+00	3.30E+01	0.00E+00	1.25E+02	0.00E+00	0.00E+00
MW-0166	Average	0.00E+00	1.60E-01	0.00E+00	0.00E+00	1.26E+02	7.90E-01	0.00E+00
MW-0167	19-Apr-93	1.96E-05	3.60E-01	1.10E+01	0.00E+00	2.80E+01	0.00E+00	0.00E+00
MW-0168	25-Oct-90	8.74E-08	0.00E+00	0.00E+00	0.00E+00	2.80E-01	0.00E+00	0.00E+00
MW-0169	4-Aug-93	2.65E-06	0.00E+00	0.00E+00	0.00E+00	4.17E+00	0.00E+00	0.00E+00
MW-0170	8-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0171	12-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0172	9-Aug-91	7.33E-03	0.00E+00	0.00E+00	0.00E+00	1.70E+04	0.00E+00	0.00E+00
MW-0173	29-Jul-93	3.70E-04	0.00E+00	0.00E+00	0.00E+00	2.57E+02	0.00E+00	0.00E+00
MW-0174	13-Apr-93	4.89E-07	0.00E+00	0.00E+00	0.00E+00	7.70E-01	0.00E+00	0.00E+00
MW-0175	8-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0176	8-Apr-93	3.81E-07	0.00E+00	0.00E+00	0.00E+00	6.00E-01	0.00E+00	0.00E+00
MW-0177	19-Jan-93	2.24E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0178	13-Apr-93	2.51E-04	0.00E+00	0.00E+00	0.00E+00	8.90E+01	0.00E+00	0.00E+00
MW-0179	13-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0180	7-Aug-91	1.84E-06	0.00E+00	0.00E+00	0.00E+00	5.90E+00	0.00E+00	0.00E+00
MW-0181	28-Jan-93	1.97E-07	0.00E+00	0.00E+00	0.00E+00	6.30E-01	0.00E+00	0.00E+00
MW-0182	11-Jul-91	1.12E-06	0.00E+00	0.00E+00	0.00E+00	3.40E+00	0.00E+00	0.00E+00
MW-0182	11-Jul-91	1.12E-06	0.00E+00	0.00E+00	0.00E+00	3.60E+00	0.00E+00	0.00E+00
MW-0183	26-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0184	24-Jul-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0185	13-Apr-93	2.22E-06	0.00E+00	2.10E+00	0.00E+00	3.50E+00	0.00E+00	0.00E+00
MW-0186	5-Aug-91	2.22E-05	0.00E+00	0.00E+00	0.00E+00	4.30E+01	0.00E+00	0.00E+00
MW-0187	23-Apr-93	1.95E-06	0.00E+00	0.00E+00	3.20E-01	1.60E+00	0.00E+00	0.00E+00
MW-0188	19-Jan-93	3.12E-07	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	0.00E+00
MW-0189	21-Apr-93	4.42E-05	0.00E+00	0.00E+00	8.60E+00	3.00E+01	0.00E+00	0.00E+00
MW-0190	29-Jul-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0191	12-Apr-93	8.57E-07	0.00E+00	0.00E+00	1.30E-01	7.50E-01	0.00E+00	0.00E+00
MW-0192	15-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 4-9
Representative Concentration Data Set Used in Extent of Contamination
Delineation, Target Volume Generation, and Mass Estimates
(µg/l)

Location Name	Date	Risk	1,2-DCA	c-1,2-DCE	PCE	TCE	1,2-DCE	1,1,1-TCA
MW-0193	21-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0194	14-Apr-93	6.29E-06	0.00E+00	0.00E+00	3.90E-01	8.10E+00	0.00E+00	0.00E+00
MW-0195	22-Apr-93	5.24E-06	0.00E+00	0.00E+00	1.40E+00	1.80E+00	0.00E+00	0.00E+00
MW-0196	28-Jul-93	1.23E-06	0.00E+00	0.00E+00	0.00E+00	1.53E+00	4.07E+00	9.78E-01
MW-0197	4-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0198	15-Apr-93	8.26E-07	0.00E+00	0.00E+00	0.00E+00	1.30E+00	0.00E+00	0.00E+00
MW-0199	15-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0200	4-Aug-93	1.95E-05	3.18E-01	1.76E+01	0.00E+00	1.58E+01	0.00E+00	0.00E+00
MW-0201	9-Apr-93	4.51E-07	0.00E+00	0.00E+00	0.00E+00	7.10E-01	0.00E+00	0.00E+00
MW-0202	2-May-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0203	9-Jul-91	5.93E-06	0.00E+00	0.00E+00	0.00E+00	1.90E+01	0.00E+00	0.00E+00
MW-0204	4-Aug-93	3.23E-07	0.00E+00	0.00E+00	0.00E+00	5.08E-01	0.00E+00	0.00E+00
MW-0205	4-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0206	3-Aug-93	2.52E-06	0.00E+00	1.43E+00	0.00E+00	2.01E+00	0.00E+00	0.00E+00
MW-0207	25-Jul-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0208	2-Aug-93	1.94E-06	0.00E+00	0.00E+00	0.00E+00	1.63E+00	0.00E+00	0.00E+00
MW-0209	9-Aug-91	9.36E-04	0.00E+00	0.00E+00	0.00E+00	3.00E+03	0.00E+00	0.00E+00
MW-0210	6-Aug-93	4.50E-05	6.77E-01	0.00E+00	6.42E-01	6.85E+00	0.00E+00	0.00E+00
MW-0211	11-Oct-93		0.00E+00	0.00E+00	0.00E+00	6.30E-01	0.00E+00	0.00E+00
MW-0212	7-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0213	22-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0214	12-Apr-93	9.12E-06	0.00E+00	1.10E+01	3.10E-01	7.60E+00	0.00E+00	0.00E+00
MW-0215	13-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+0
MW-0216	13-Oct-92	4.68E-06	0.00E+00	3.40E+00	0.00E+00	1.80E+01	0.00E+00	0.00E+00
MW-0217	23-Jul-93	6.28E-05	2.07E-01	2.91E+01	1.98E+00	7.54E+01	0.00E+00	0.00E+00
MW-0218	23-Jul-93	7.49E-07	0.00E+00	6.68E-01	0.00E+00	1.50E+00	0.00E+00	0.00E+00
MW-0219	23-Jul-93	1.14E-05	0.00E+00	6.41E+00	0.00E+00	1.80E+01	0.00E+00	1.02E+00
MW-0220	4-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0221	12-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0222	5-Aug-93	4.78E-05	0.00E+00	3.97E+00	0.00E+00	2.06E+01	0.00E+00	0.00E+00
MW-0223	5-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0224	13-Apr-93	8.87E-03	0.00E+00	2.10E+02	0.00E+00	1.40E+04	0.00E+00	0.00E+00
MW-0225	5-Aug-93	4.08E-05	0.00E+00	0.00E+00	0.00E+00	5.15E+01	0.00E+00	0.00E+00
MW-0226	16-Apr-93	5.61E-06	0.00E+00	0.00E+00	2.90E-01	7.50E+00	0.00E+00	0.00E+00
MW-0227	28-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0228	5-Aug-93	1.72E-04	3.05E+01	0.00E+00	0.00E+00	2.17E+00	0.00E+00	0.00E+00
MW-0228	5-Aug-93	1.72E-04	3.05E+01	0.00E+00	0.00E+00	2.17E+00	2.80E+00	0.00E+00
MW-0229	16-Apr-93	2.92E-07	0.00E+00	0.00E+00	0.00E+00	4.60E-01	0.00E+00	0.00E+00
MW-0230	16-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0231	9-Aug-91	5.31E-07	0.00E+00	0.00E+00	0.00E+00	1.70E+00	0.00E+00	0.00E+00
MW-0232	3-May-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-0235	21-Apr-93	1.22E-02	0.00E+00	0.00E+00	2.10E+03	9.50E+03	0.00E+00	0.00E+00
MW-0236	4-Aug-93	1.02E-03	0.00E+00	0.00E+00	1.04E+02	1.12E+03	0.00E+00	0.00E+00
MW-1000	6-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1001	7-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1002	2-Aug-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1003	6-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+0(
MW-1004	6-Oct-92	9.13E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1005	24-Jan-92	4.68E-07	0.00E+00	0.00E+00	0.00E+00	1.90E+00	0.00E+00	0.00E+00

Table 4-9
Representative Concentration Data Set Used in Extent of Contamination Delineation, Target Volume Generation, and Mass Estimates
(µg/l)

Location Name	Date	Risk	1,2-DCA	c-1,2-DCE	PCE	TCE	1,2-DCE	1,1,1-TCA
MW-1005	24-Jan-92	4.68E-07	0.00E+00	0.00E+00	0.00E+00	1.90E+00	6.60E+00	2.50E+00
MW-1009	15-Jul-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1010	19-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1011	2-Jan-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1012	23-Oct-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1013	20-Apr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1014	27-Apr-89	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1015	30-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1016	5-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1017	10-Apr-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1018	15-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1019	20-Jul-93	3.72E-07	0.00E+00	0.00E+00	0.00E+00	5.85E-01	0.00E+00	0.00E+00
MW-1020	8-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1021	28-Jul-93	6.73E-06	0.00E+00	2.84E+00	0.00E+00	9.99E+00	0.00E+00	6.54E-01
MW-1022	28-Jul-93	6.49E-06	0.00E+00	6.02E-01	0.00E+00	9.27E+00	0.00E+00	0.00E+00
MW-1023	9-Oct-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1024	18-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1025	13-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1026	21-Jan-93	1.06E-07	0.00E+00	0.00E+00	0.00E+00	3.40E-01	0.00E+00	0.00E+00
MW-1027	21-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1028	21-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1029	27-Jan-92	2.26E-06	0.00E+00	0.00E+00	0.00E+00	3.80E+00	0.00E+00	6.80E-01
MW-1030	15-Jan-92	1.02E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1031	17-Oct-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1032	17-Jul-92	1.58E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1033	14-Oct-88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1034	26-Apr-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1035	28-Jul-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1036	2-May-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1037	30-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1038	20-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1039	20-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1040	22-Oct-91	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1041	11-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1042	11-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1043	11-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1044	5-Aug-93	5.15E-06	0.00E+00	5.22E-01	0.00E+00	1.78E+00	0.00E+00	0.00E+00
MW-1045	5-Aug-93	5.54E-06	0.00E+00	2.64E+00	0.00E+00	8.72E+00	0.00E+00	0.00E+00
MW-1046	5-Aug-93	2.58E-06	0.00E+00	1.23E+00	0.00E+00	4.06E+00	0.00E+00	0.00E+00
MW-1047	3-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1048	31-Jan-92	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1049	2-Aug-93	6.35E-06	0.00E+00	3.44E+00	0.00E+00	1.00E+01	0.00E+00	0.00E+00
MW-1050	2-Aug-93	2.63E-06	0.00E+00	8.00E-01	1.23E-01	2.94E+00	0.00E+00	0.00E+00
MW-1051	2-Aug-93	5.11E-06	0.00E+00	2.12E+00	0.00E+00	7.42E+00	0.00E+00	2.20E+00
MW-1052	2-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1053	3-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1054	30-Jul-93	2.34E-07	0.00E+00	0.00E+00	0.00E+00	3.68E-01	0.00E+00	0.00E+00
MW-1055	30-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1056	30-Jul-93	4.69E-07	0.00E+00	0.00E+00	0.00E+00	7.38E-01	0.00E+00	0.00E+00

Table 4-9
Representative Concentration Data Set Used in Extent of Contamination Delineation, Target Volume Generation, and Mass Estimates
(µg/l)

Location Name	Date	Risk	1,2-DCA	c-1,2-DCE	PCE	TCE	1,2-DCE	1,1,1-TCA
MW-1057	30-Jul-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1058	3-Aug-93	4.30E-07	0.00E+00	0.00E+00	0.00E+00	6.77E-01	0.00E+00	0.00E+00
MW-1059	3-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1060	3-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1061	5-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1062	5-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1063	26-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1064	20-Jan-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1065	4-Aug-93	6.25E-06	0.00E+00	9.16E-01	1.59E+00	4.63E-01	0.00E+00	0.00E+00
MW-1066	20-Jan-93	1.92E-06	0.00E+00	5.90E-01	1.50E+00	0.00E+00	0.00E+00	0.00E+00
MW-1067	4-Aug-93	1.38E-05	0.00E+00	0.00E+00	0.00E+00	1.43E+00	0.00E+00	0.00E+00
MW-1068	4-Aug-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MW-1069	13-Apr-93	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

- Five southern OU A wells installed and sampled between December 1993 and January 1994 by Jacobs Engineering

- Seven borings and five monitoring wells installed as part of the OU D RI and sampled between June 1993 and December 1993 by CH2M HILL

- 262 monitoring wells sampled through the GSAP program by Radian Corporation.

Data from the GSAP program were available in electronic format for all results up to the third quarter 1993 sampling period. These samples will be referred to as being "in the database." Cancer risk calculations were performed on all data in the database (i.e., in electronic format up to the third quarter of 1993). Fourth quarter 1993 GSAP data were available only in hardcopy from the quarterly data summary report (Radian, 1993). Results from this quarter were incorporated for newly installed wells that were not sampled previously or in areas where temporal data gaps exist in the database. Use of the fourth quarter 1993 data is described below. Fourth quarter data for all sampled wells was not used because the results were not available in electronic format and risk calculations could not be performed on these samples. Risk calculations are cumulative over a suite of contaminants. The calculation of risk is automated. For wells without risk calculations, prevalent contaminant concentrations were examined in generating the target volumes and delineating the extent of contamination. Concentration of all contaminants must be available so that calculations can be complete. The effects of the fourth quarter data were considered in the target volume generation and are discussed in the section discussing target volumes.

The data set representing current groundwater conditions was assembled, and the extent of contamination, VOC mass, and target volumes were estimated. Approximately 196 wells were sampled within the last 2 years. Hence, water quality trends of all other wells were examined to extrapolate to current groundwater conditions. The following steps were taken in assembling the data set:

- Water quality data collected from the newly installed OU A and OU D wells were incorporated into the data set. MW-38D was also sampled for the OU D RI and was included in the data set; it was last sampled in June 1985. Risk values were not calculated for these wells.

- For wells in the database, the most recent result for each well sampled during 1992 or 1993 were incorporated into the data set. Sampling performed within the last 2 years is considered representative of current conditions. Risk values were calculated for these wells.

- For wells in the database that were last sampled between 1988 and 1991, their data trends were examined to approximate what current water quality concentrations might be. These wells were divided into three categories:

- Wells that were consistently nondetect: In most cases, these wells were not sampled after 1991 because concentrations were consistently nondetect. Hence for consistently nondetect wells, the most recent nondetect result was used. Risk values were calculated for these wells.

- Wells with fluctuating concentrations: Fourth quarter 1993 results for three wells with fluctuating concentrations, MW-134, MW-165, and MW-211, were available from the data summary report and were incorporated into the data set. Average concentrations were calculated and incorporated into the data set for three wells, MW-131, MW-166, and MW-21S. These wells experienced fluctuating concentrations but were not sampled during the fourth quarter of 1993. Risk values were not calculated for these six wells.

- Wells with increasing or decreasing concentrations: Concentrations in MW-120 were consistently declining. It was last sampled in July 1989 at nondetectable levels for prevalent contaminants; therefore, that sample record and the associated risk were incorporated in the data set. Concentrations in MW-44S were increasing; therefore, the most recent record and risk value in the data base was used.

• Newly installed wells that were sampled in the fourth quarter of 1993: Results for MW-282, MW-283, MW-284, MW-285, MW-286, MW-287, MW-288, and MW-999 were taken from the fourth quarter data summary report. Risk values were not calculated for these wells.

Thirty-six monitoring wells were last sampled prior to or during 1986 and were not included in the data set because their results are not representative of current water quality conditions, and estimates of current conditions could not be made with the available data. Water quality information from the OU D extraction wells and EW-144 were not used in the mass estimates or the generation of the target volumes because they are screened thorough more than one zone and their concentrations are not representative of concentrations from a single zone. EW-144 has two screened intervals that extend from the bottom of the A Zone to the bottom of the B Zone. The OU D extraction wells have 120-foot screened intervals that extend from the vadose zone through the A Zone to the middle of the B Zone. The data from these wells are shown on the figures showing extent of contamination and target volumes, but they were not used in delineating the target volumes. Because contaminant data for the OU D extraction wells were collected during the OU D RI field work, risk values were not calculated for the OU D extraction wells. In all cases, due to contamination in surrounding monitoring wells, a target volume was still delineated in the areas where these extraction wells are located.

4.6.2 Prevalent Contaminants

VOCs

Four VOCs (TCE, cis-1,2-DCE, PCE, and 1,2-DCA) were selected as prevalent contaminants based on the following criteria:

- Frequency of detections
- Concentration measurements above MCLs
- Health risk posed by the contaminant

These four VOC compounds, their MCLs, concentrations, and their summary statistics are presented in Table 4-10. Concentrations were assumed to reflect background conditions when there were no detectable concentrations of VOCs using reliable analytical methods. In most cases, this was met using EPA Methods 601 and 602 with a 0.5 μg/l detection level.

Table 4-10
Statistics[a] of Prevalent Contaminants

Contaminant	MCLs[b] (μg/l)	Frequency of Detection (%)	Mean[c] (μg/l)	Maximum Detection (μg/l)
TCE	5	51	453	26,000
cis-1,2-DCE	6	26	3.54	210
PCE	5	11	13.61	2,100
1,2-DCA	0.5	9	1.2	120

[a]From most recent VOC concentrations measured during or after 1988 for all wells in the data base.
[b]California Department of Health Services primary MCL.
[c]Mean calculated with non-detect as zero.

Results from the compiled data set were used to select TCE, cis-1,2-DCE, PCE, and 1,2-DCA as the prevalent contaminants. The graphs in Figure 4-42 compare summary statistics by year for TCE, PCE, 1,2-DCA, total 1,2-DCE, 1,1,1-TCA, and 1,1-DCE.

For most contaminants, the frequency of detections has been increasing with time, but their maximum and mean concentrations have been decreasing. This may be the result of the following:

- Because of regional, Base, and extraction well pumpage, contaminant plumes have been migrating.

- Contaminant mass has been removed by extraction wells installed for remedial actions.

- Several wells that have been sampled consistently at non-detect levels have been dropped from the monitoring program.

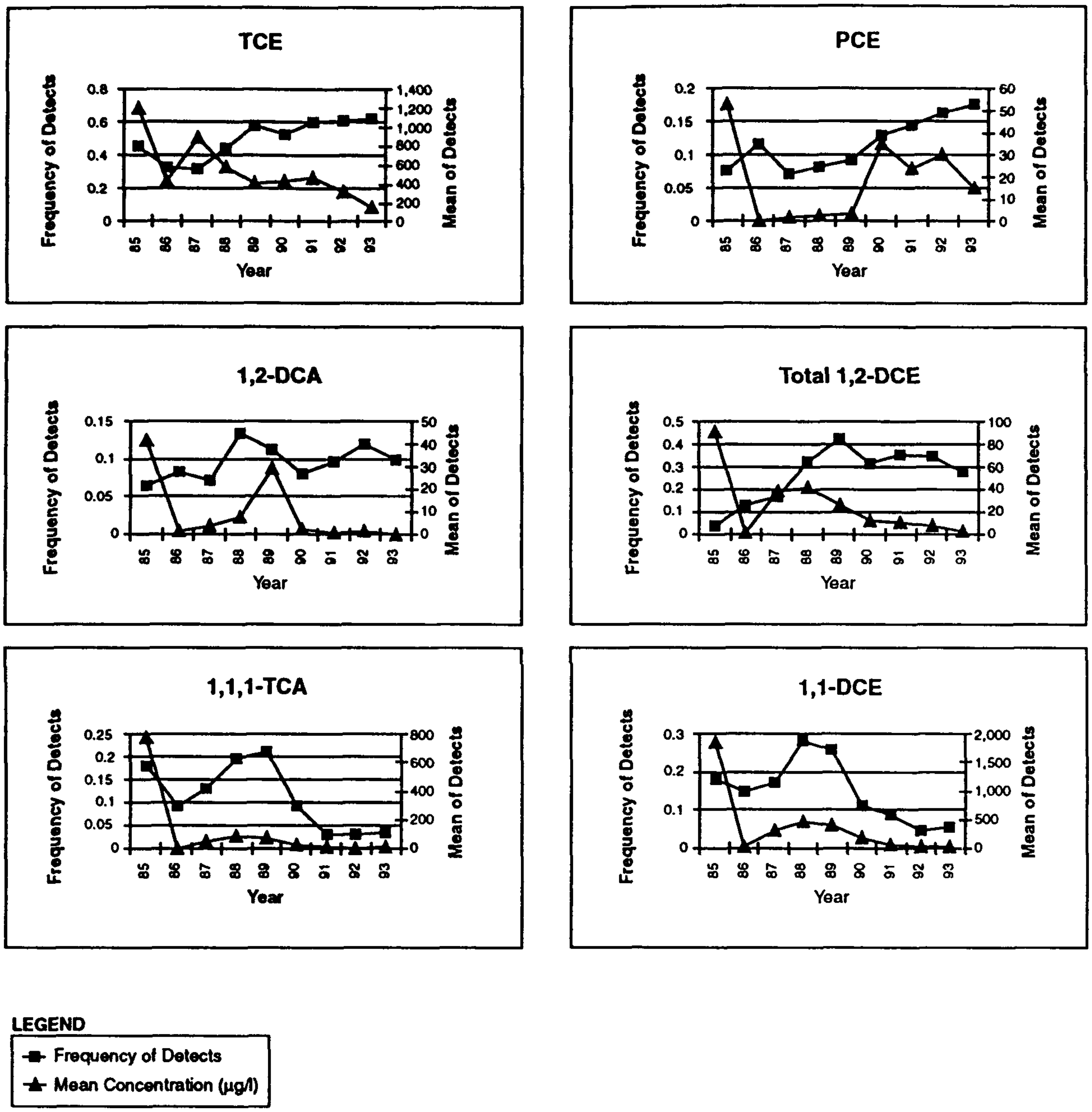


FIGURE 4-42
FREQUENCY OF SAMPLING DETECTS AND MEAN CONCENTRATIONS FOR SELECTED VOCS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

- New wells have been added to the program to further define the lateral extent of the contaminant plumes. This has led to the addition of numerous wells in relatively low groundwater contamination areas.

Hence, compounds have been detected in more sampled wells, but at lower concentrations. These activities are discussed in Chapters 2 and 3.

4.6.3 Groundwater Monitoring History

Since the discovery of VOCs in the groundwater supplies at McClellan AFB in 1979, several steps have been taken to characterize the hydrogeologic characteristics of the groundwater system and to assess the magnitude and extent of groundwater contamination.

Monitoring Network

Over 300 monitoring wells and 14 extraction wells have been installed Basewide. Table 4-11 summarizes the number of wells installed in each zone and includes wells that are currently active, decommissioned, or dry. In 1986, a monitoring program began that sampled for VOCs, semivolatile organic compounds, metals, pesticides, and dioxins.

Table 4-11
Monitoring Wells Installed to Date

Zone	Monitoring Wells	Extraction Wells
A	172	9[a]
B	94	4
C	38	2
D	10	1
E	3	–
ATE[b]	4	–
TOTAL	321	15

[a]The six OU D extraction wells are screened from the vadose zone through all of the A zone to the middle of the B zone. They were counted as A-zone wells.
[b]ATE = Screened through the A to E zones.

Several of these wells have gone dry and have not been sampled in the last 2 years. Some wells have never been sampled, or their results are not currently available. Water quality information for 303 monitoring wells, 12 extraction wells, and 7 borings is currently available and incorporated into this conceptual model. Table 4-12 presents the distribution, by year, of the most recent sampling performed in each of these wells.

Table 4-12 Distribution of the Most Recent Year of Sampling	
Most Recent Year of Sampling	**Number of Wells/ Borings**
1993	196
1992	31
1991	38
1990	9
1989	9
1988	3
1987	0
1986	10
1985	18
1984	2
1983	0
1982	6
Total	322

Water quality information collected during and after 1988 was incorporated into the data set presented in Section 4.6.1.

Interpretation of Monitoring Network

The current monitoring well network provides specific lateral and vertical snapshots of the groundwater system. Using information regarding source areas, contaminant properties, and groundwater flow directions, water quality and water level results from specific wells have been interpreted to estimate the extent of VOC and metals contamination, as well as to determine target areas. The ultimate results of this study are dependent on the monitoring network (i.e., the location and depths of the monitoring wells). Monitoring wells were initially placed to confirm areas of high contaminant concentrations. During subsequent phases, wells were placed to delineate the vertical and lateral extent of contamination. Figures 4-43, 4-44, 4-45, and 4-46 show the current monitoring well locations by zone.

Uncertainty exists regarding interpretation of the results of the groundwater monitoring network. For example, Figure 4-47 presents the results of TCE sampling in B zone monitoring wells in OU A. The light blue line shows the approximate extent of contamination based on current results. The dark blue line shows the extent of contamination that would result if data from Wells MW-26D, MW-223, and MW-1059 were not available. This scenario of missing wells demonstrates that interpretation of groundwater quality data and the extent of contamination is dependent on the location of monitoring wells. The extent could only be bound

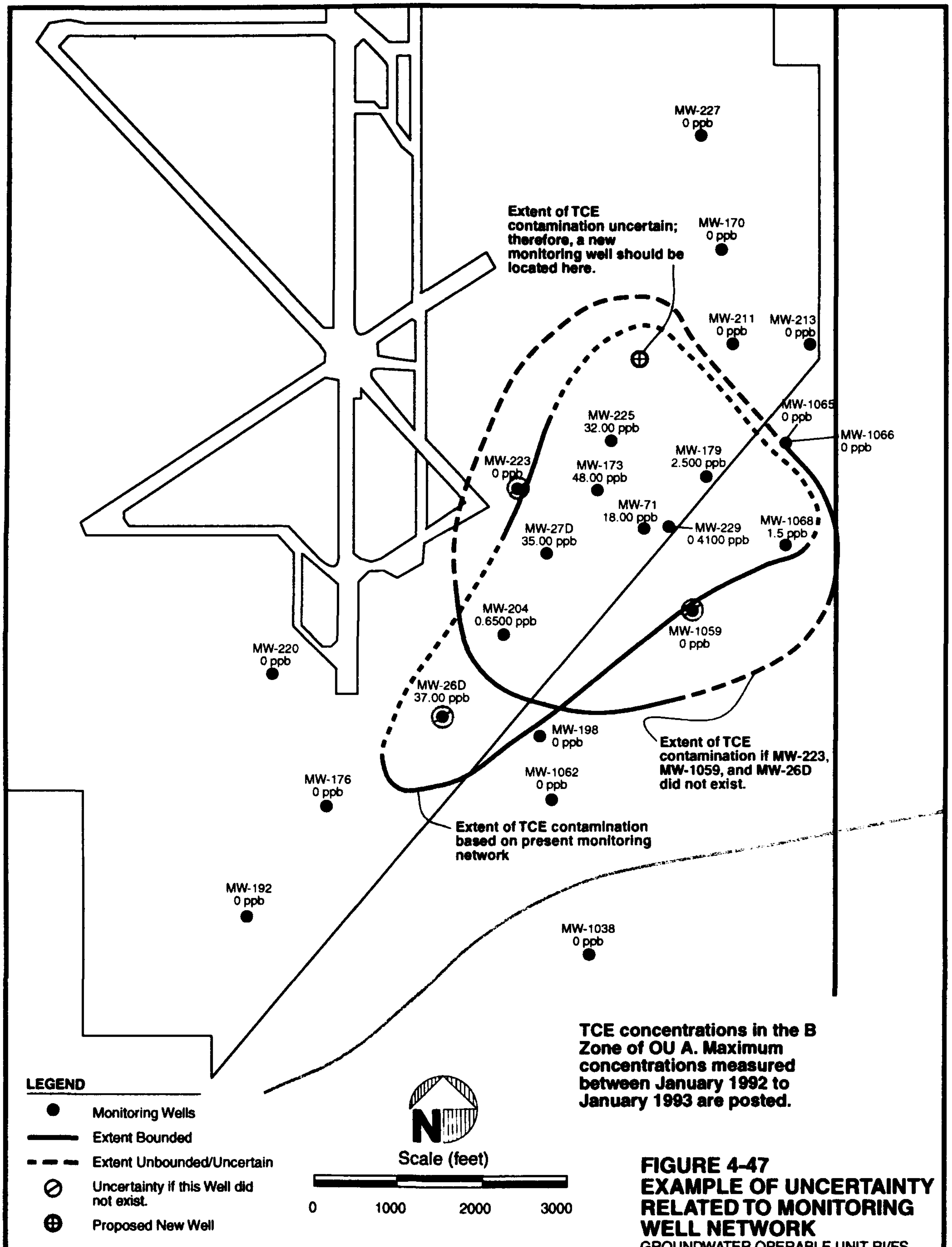


FIGURE 4-47
EXAMPLE OF UNCERTAINTY RELATED TO MONITORING WELL NETWORK
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

with confidence in areas where wells have consistently measured non-detect. Conversely, plumes could only be identified in areas where wells have consistently measured detects.

Summary of Past Monitoring

Figure 4-48 presents a time line of the most significant groundwater monitoring events that have been performed at McClellan AFB. General results of the previous IRP groundwater investigations are listed below:

- Past disposal sites, metal plating operations, and the leaking of the IWL may have contributed to the soil and groundwater contamination.

- Base production wells and monitoring wells could be serving as conduits for contaminant migration into deeper aquifers.

- Aquifers are not separated from one another; they provide a natural path for contaminant migration.

- Domestic, regional, and Base well pumpage affects groundwater movement.

- Known VOC contamination exists onbase in three distinct plumes. TCE is the most prevalent organic compound. VOCs and metals contaminants are moving with the groundwater flow (Radian, 1986 to 1993).

- Groundwater flow is generally toward the south and southwest.

More detailed analysis of the groundwater system will be presented in upcoming sections of this chapter.

4.6.4 Water Quality Information for Base and Production Wells

Contamination of municipal and Base water supplies has led to the closure of several Base wells and the reduction of pumpage in several city wells. The following paragraphs summarize the available water quality information on Base and city wells. This information was gathered from Base closure reports and production well and municipal well quarterly reports.

BW-18

BW-18 has four screened intervals occurring from 169 to 185, 210 to 260, 304 to 349, and 378 to 387 feet bgs. These screen intervals can be assigned to Monitoring Zones B, C, D, and E. In 1992, the well pumped an average of approximately 975 gallons per minute. Most of the pumped water draws from the deeper, less contaminated D and E aquifer zones.

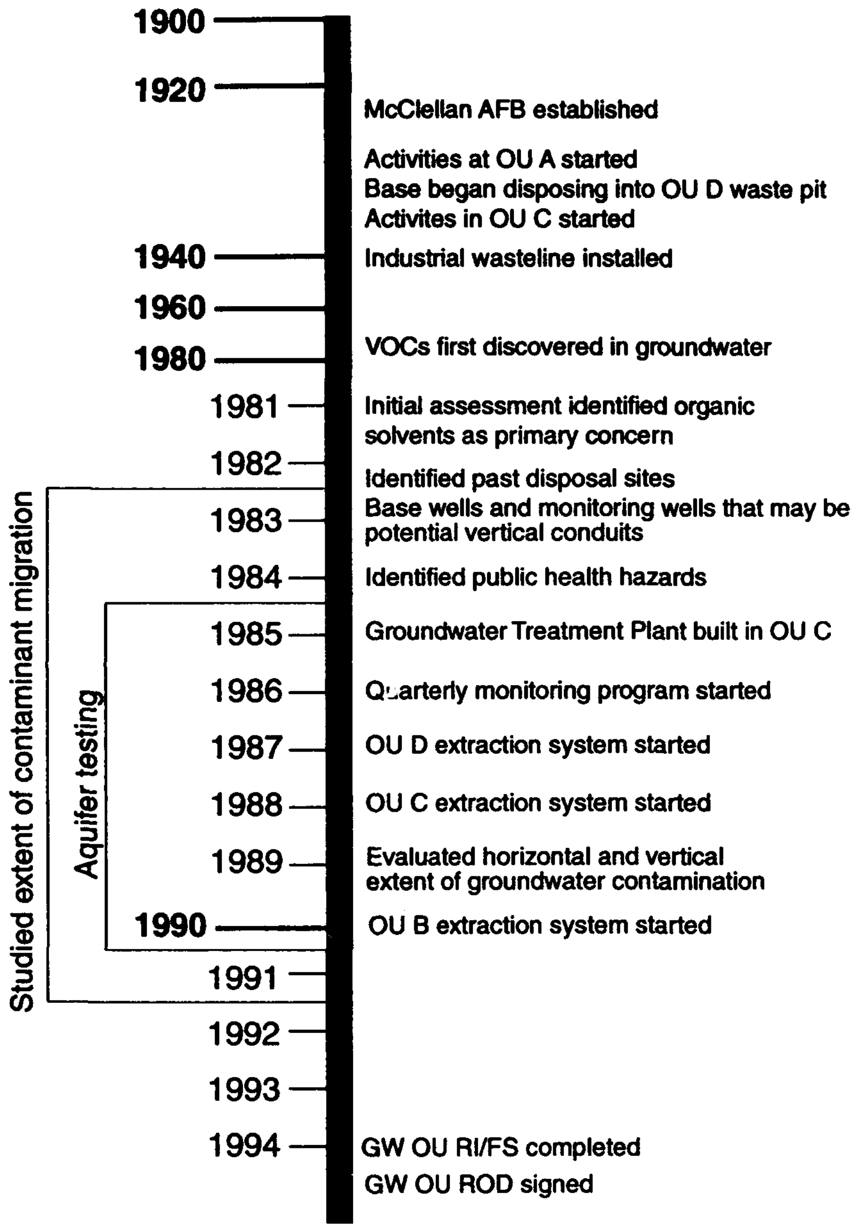


FIGURE 4-48
GROUNDWATER MONITORING HISTORY
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_12

CH2M HILL

During operation, BW-18 has a zone of capture that is apparent in Monitoring Zones A, B, and C. Pumping at BW-18 induces a vertical downward gradient between aquifer zones and therefore creates potential contaminant migration pathways. Contaminant migration might also occur through the well's gravel pack, which extends from the base of the well to Monitoring Zone A.

From 1981 to 1984, BW-18 was out of service because of contamination. Samples collected from BW-18 by Radian Corporation during 1990 and 1992 have contained concentrations of TCE exceeding the MCL. To reduce the contaminant level in the pumped water, a wellhead water treatment unit consisting of carbon filters has been installed.

Once surrounding contaminated areas are contained by remedy extraction wells, BW-18 will be abandoned to reduce the risk of vertical migration of contaminants into the deeper aquifer zones. The remedy extraction well system will have screen intervals only in the A, B, and C aquifer zones, which will more efficiently remove contaminants and will also prevent the offsite migration of contaminated groundwater.

City Well 150

After the initial sampling of several Base wells in 1979 revealed low levels of TCE, additional samples from several onbase and offbase wells were collected. As a result of the investigation, two Base wells (BW-1 and BW-2) and two private household offbase wells (Higgs and Russell) were shut down because of the presence of TCE. High levels of TCE exceeding the MCL of 5 ppb were also obtained from samples collected from CW-150 (screened 144 to 372 feet bgs). CW-150, located near the southwest boundary of the Base in OU B and about 1,500 feet west of BW-18, was left in service and only pumped during periods of high demand.

Water derived from CW-150 was blended within the distribution system to levels that met the accepted state standards. The data in the figure show rising TCE concentrations during the summer months, which is probably caused by increasing pumping rates. However, TCE levels have not exceeded the MCL since July 1981, and have not decreased below 1 ppb since 1986. The well was put out of operation in April 1989 and decommissioned in April 1991. A time-series plot of concentrations measured at CW-150 between 1979 and 1989 is present in Figure 4-49.

Hydraulic Influence of BW-18

Because BW-18 and CW-150 are both screened within the same aquifer zones, the decreasing level of TCE in CW-150 might be related to increasing pumping rates at BW-18. Samples collected from BW-18 during 1990-1992 by Radian Corporation have contained TCE concentrations exceeding the MCL. BW-18's extent of hydraulic influence on local flow patterns is observable in the approximate circular shape of water level contours around the well. Groundwater appears to flow

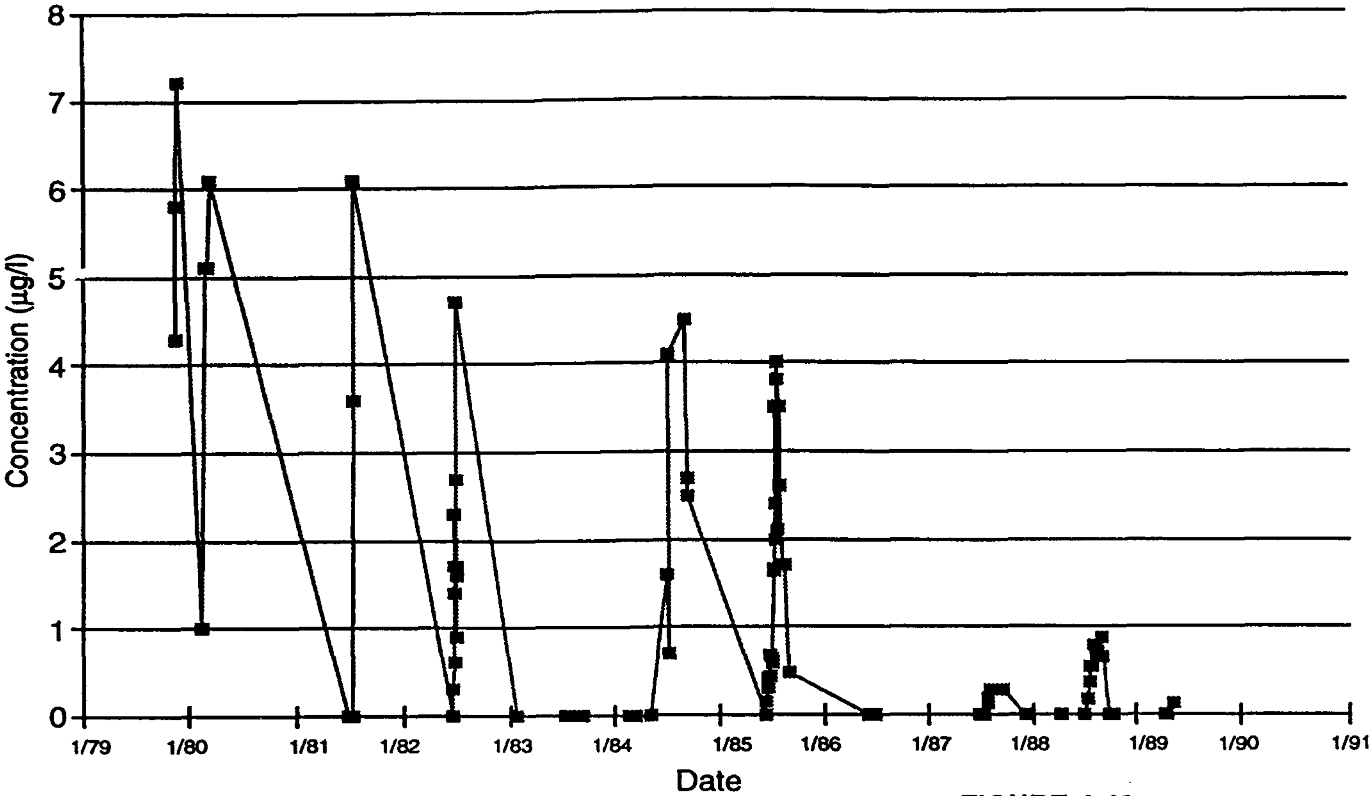


FIGURE 4-49
TCE TIME SERIES FOR CW-150
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_209

toward BW-18. When BW-18 is not pumping, groundwater flows south or southwest beneath OU B. (Radian, September 1992).

According to Luhdorff & Scalmanini (February 1984), community wells near BW-18 were found to have low levels of contamination. Municipal wells in the vicinity of the Base, including several wells downgradient from BW-18, have been sampled for VOCs from June 1991 to February 1993, and no detectable or low levels of VOCs were detected (Radian, March 1993). Most of these wells draw their water primarily from deeper groundwater zones, except CW-131 (screened 36 to 95 feet bgs), CW-132 (screened 36 to 300 feet bgs), and CW-155 (screened 6 to 430 feet bgs). CW-132 has been out of service since January 28, 1993.

4.6.5 Extent of VOC Contamination

The nature and extent of VOC and metals contamination was estimated by studying the VOC data set presented in Section 4.6.1. The four prevalent contaminants, TCE, PCE, cis-1,2-DCE, and 1,2-DCA, were examined in detail.

The horizontal and vertical extent of contamination were determined by studying the contaminant concentration results in plan view and in profile view. Groundwater contamination at the Base can be divided into three distinct plumes that migrate from the original source areas. These plumes are the OU A, OU B/C, and OU D plumes. The groundwater system has been divided into five layers: the A, B, C, D, and E Monitoring Zones. The extent of contamination will be examined by plume and then contamination will be studied by zone for each plume.

Since there are limited wells in the D and E Zone, the D and E Zones will be examined together.

The general groundwater flow at McClellan AFB has been from northeast to southwest. The withdrawals from the Base wells in the past and currently from extraction wells change the local groundwater flow patterns. The groundwater levels have declined more than 60 feet during the past few decades because of withdrawals for agriculture and urban water uses (McLaren, 1986). Today the water table exists at a depth of about 95 to 105 feet beneath the surface, with seasonal fluctuations of up to 5 feet. The gradual decline of the water table and the seasonal fluctuations creates "smear zones" beneath the contamination source sites. These zones are created because of flushing action of the water entering and leaving the contamination source areas. Smearing of the contamination is a relatively rapid vertical transport phenomenon compared to diffusion or dispersion and can be an important mechanism for contaminant migration. These smear zones may extend from the contamination source at the surface to the water table. The intent of this section is to study the groundwater contaminant plumes in comparison to the contaminant source sites which have been identified on the Base. These source sites have been classified as CSs and PRLs. Some areas are designated as study areas (yet to be studied). In addition, an IWL runs through the Base, which is considered a source of contaminants through leakage and pipe failure.

The following sections will present the vertical and horizontal extent of contamination for the prevalent contaminants. TCE is the most frequently detected contaminant because its migration has been so widespread; therefore, the vertical and lateral migration of TCE will be discussed in more detail. Figures 4-50, 4-52, 4-54, and 4-56 show the water levels and extent of TCE, cis-1,2-DCE, PCE, 1,2-DCA, and vinyl chloride contamination in Monitoring Zones A, B, C, and D/E, respectively. Figures 4-51, 4-53, and 4-55 present the analytical data used to develop the contaminant contours for Monitoring Zones A, B, and C. Groundwater contours, source areas, groundwater monitoring wells, and active base wells are also presented on these figures.

Several cross sections of the subsurface have been constructed to evaluate the distribution of contamination. The locations of these sections are presented in Figure 4-57. Eleven profiles show the vertical extent of contamination; these profiles through the OU A, OU B/C, and OU D plumes are presented in Figures 4-58, 6-59, and 4-60, respectively. The extent of TCE contamination is presented in these figures as well as the concentrations of 1,2-DCA, cis-1,2-DCE, and PCE. Eight lithologic cross sections showing subsurface lithology, water levels, monitoring zones, and prevalent contaminant concentrations are presented in Chapter 3 as Figures 3-2 through 3-8. A thorough discussion of the subsurface lithology is also presented in Chapter 3. Nineteen cross sections interpolated from geophysical logs have been prepared by Radian and are presented in the PGOURI (Radian, 1992).

Operable Unit A Plume

The general groundwater flow direction in OU A is southwest. Several Base wells on the northeast side of OU A have been in operation in the past (BW-8, -9, and -20). BW-10 is still operative but does not influence contaminant migration in the A, B, and C Zones. These Base wells strongly influence local groundwater flow directions, especially in the aquifers where they are screened.

TCE is the most prevalent contaminant in the OU A plume; its presence defines the target volumes in all areas except in the B Zone, the northeast end of the plume, where PCE and cis-1,2-DCE are present. On Figures 4-52, 4-52, 4-54, and 4-56, the solid lines indicate a higher level of confidence in the plume boundary, while the dashed lines indicate an estimate of the plume boundary. These regions can be seen in Monitoring Zones A, B, and C in decreasing magnitude. The small areal extent of the plume indicates that horizontal migration of TCE has been slow at OU A. This observation is consistent with the low transmissivities observed in the aquifer tests conducted in A-zone wells located at OU A. The TCE may have been partially immobilized in the soil zones by a strong sorption onto the site soils. TCE has a high log K_{oc} value of 2.10, indicating strong sorption to soil and aquifer material. This hypothesis is supported by the fact that low permeability sediments often contain a greater quantity of organic matter than more permeable sediments.

The areas of highest contamination in the OU A plume are delineated by MW-224 and MW-172 that has detected TCE at 14,000 μg/l and 17,000 μg/l, respectively. Source area activities that may have contributed to high contamination include spills during maintenance operations and IWL and underground storage tanks leaks. The general groundwater flow direction to the southwest explains the southwest migration of the TCE plume. The dense network of Base wells in the northeast direction of the source sites may explain the migration of TCE in the northeast direction. These Base wells (BW-8, -9, and -20) have been in operation in the past.

Horizontal Extent of Contamination

The OU A cis-1,2-DCE, PCE, and 1,2-DCA plumes are also shown in Figures 4-50, 4-52, 4-54, and 4-56, along with groundwater contours, source areas, and the groundwater monitoring wells in OU A. In Monitoring Zones A and B at OU A, cis-1,2-DCE, PCE, and 1,2-DCA are found. The center of these plumes lie to the northeast of all the CSs. This again may be because of historic Base well pumpage in that direction. The concentrations of these chemicals all decrease with depth. The vertical movement of these contaminants seems to be limited as there are no detections observed in Monitoring Zone C (depth 180 to 250 feet).

The A Zone TCE plume is unbound to the northwest along the runway. It is bounded to the east by nondetects in MW-212 but unbounded to the south and southwest. New data were obtained in December 1993 and January 1994 from five wells located in the southeast section of the OU A plume near Site 24. Four were A-Zone wells and one was a B-Zone well. TCE was measured in two of the A-Zone onbase wells MW-289 and MW-291 at 140 μg/l and 70 μg/l, respectively. TCE was not detected at the two offbase A-Zone monitoring wells and one B-Zone onbase well. Based on current information, this section of the OU A plume is considered bound. These wells should continue to be monitored to determine the extent of offbase contamination.

The B Zone TCE plume is bound on the northeast end by MW-213, MW-1065, MW-1066 MW-179 and MW-229. It is unbound to the northwest along U.S. 80 and to the west end.

Two separate smaller plumes exist in the C Zone. The northern plume appears unbound to the north. They both appear bound to the south. Both plumes are below areas of elevated concentrations in the A and B Zone. TCE levels above MCLs were detected in only one C-Zone well.

The presence of contamination in the D Zone and E Zone monitoring wells cannot be addressed because monitoring wells do not exist in those zones within OU A. The low level of C Zone contamination suggests that there is likely little or no deeper zone contamination.

Cis-1,2-DCE, PCE and 1,2-DCA plumes have been identified in OU A and are also presented in Figures 4-50 to Figure 4-56. All three contaminants have been detected in the A and B Zones, but not in the C Zone; vertical movement of these contaminants appears to be limited. Cis-1,2-DCE is the second most prevalent contaminant in OU A.

Vertical Extent of OU A Contamination

Vertically, the TCE concentrations are the highest in Monitoring Zone A and are decreasing in Monitoring Zones B and C. The vertical spacial distribution of the prevalent contaminants is presented in Figure 4-58. This suggests that the bulk of the TCE mass is still in Monitoring Zone A and is migrating slowly downward toward Monitoring Zones B, C, and D.

Five lithologic cross sections cut through OU A have been prepared and are presented in Chapter 3. Cross Sections 1 through 5 are presented in Figures 3-2 through 3-8. Cross Sections 1, 2, and 3 are perpendicular to groundwater flow. The offbase migration of contaminants to MW-1058 and MW-1067 in the A Zone and MW-1065 and MW-1066 in the B Zone is observed in Cross Sections 1 and 2. Cross Section 4 is parallel to groundwater flow. The distribution of contamination from the hot spots (defined by MW-172, MW-209, and MW-224) is observed in

Cross Section 4. Contamination in the A Zone within the vicinity of MW-172 has migrated to the B Zone.

Chemicals less strongly sorbed to soil than TCE are cis-1,2-DCE and 1,2-DCA, while PCE is more strongly sorbed to soil than TCE (see Section 4.3.1). The observed concentrations of 1,2-DCA and cis-1,2-DCE in Monitoring Zones A, B, and C are lower than TCE. PCE concentrations are also much lower compared to TCE. This indicates that TCE is probably the most abundant contaminant in the source area contributing mass to groundwater.

Operable Unit B/C Plume

The general groundwater flow direction in OU B/C is in a south to southwest direction; however, flow appears to be converging toward active production Well BW-18 in that area. Groundwater flow may also be influenced by the pumping of offbase supply wells located south of the Base (Radian Corporation, 1991).

TCE, cis-1,2-DCE, 1,2-DCA, and PCE plumes have been delineated in OUs B and C to form the OU B/C plume. TCE is the most prevalent contaminant, and cis-1,2-DCE is the second most prevalent contaminant. In the A Zone, two areas of elevated TCE concentrations (above 500 μg/l) have been identified in OU B above IC 1 and IC 7. MW-128, MW-33S, and MW-999 in OU C near Site 22, have measured TCE concentrations above 10,000 μg/l. A burn pit/landfill for priority pollutants was located at Site 22. In the B and C Zone, migration of contaminants in the north area of the plume appears limited in the east-west direction by the pumping of Extraction Wells EW-137, EW-140, EW-141, and EW-144. Basewide, contaminants appear to move southward toward BW-18.

The TCE concentrations are the highest in Monitoring Zone A and are lower in Monitoring Zones B, C, D, and E. This suggests that the bulk of the TCE plume remains in Monitoring Zone A and is slowly moving downward.

In the A Zone and the B Zone, the main body of the OU B/C TCE plume is generally bounded with confidence on the north, east, and south sides. The eastward extent of contamination along the runway is unbounded. The extent of contamination in the C Zone is generally unbounded, although the horizontal extent of C Zone contamination is not expected to be greater than the A and B Zone extent of contamination. The southern extent of TCE and cis-1,2-DCE from MW-1049, -1050, and -1051 (in the A, B, and C Zone, respectively) is unknown. The A, B, and C Zones (south of OU B) should continue to be monitored due to the presence of municipal water supply wells in that area.

Elevated concentrations of PCE, TCE, cis-1,2-DCE, and 1,2-DCA are present in the vicinity of IC 1 and IC 7 of OU B, forming a hot spot at this location. Sampling of MW-201, located just downgradient of the hot spot, and the extraction wells screened in the B Zone produced TCE values of 0.7 μg/l. Concentrations of cis-1,2-DCE and PCE in the A

Zone exhibit significant variation spatially, suggesting that EW-233 and EW-234 may be removing contaminant mass. The abundance of such contaminants in the A and B Zone of OU B indicates either a common source of VOC contamination from IC 1 and IC 7 or some biodegradation of TCE in the subsurface environment. No vinyl chloride has been detected in this region. The TCE plume is bounded with confidence on the north, east, and south sides, but the extent is not known on the west side.

The vertical distribution of contaminants in OU B/C is presented in Figure 4-59. Vertical distribution of TCE in the BC1, BC2, and BC4 cross sections indicate that the bulk of TCE is still in the A zone and there is some contamination in the B, C, and D zones. Wells located on the southeast end of BC4 and BC2, and screened at the top of Monitoring Zone C, contain TCE concentrations above MCLs. This suggests that in some areas of the B/C plume, contamination has migrated from the bottom of Monitoring Zone B to the top of Monitoring Zone C. Cross section BC5 clearly shows TCE and cis-1,2-DCE concentrations decreasing with depth, with the highest concentrations in the A zone decreasing to nondetect in deeper zones. Note that all the wells in Section BC5 are within 100 feet of each other.

The concentrations of the prevalent contaminants in D and E Zone wells are presented in Figure 4-56. The extent of contamination was not delineated because all the wells are oriented in the north-south direction, and it is not possible to delineate or estimate the east-west extent. Of the ten wells located in the deeper zones, four have measured concentrations above MCLs and greater than 10^{-6} risk. The vertical migration of contaminants may be attributed to the strong vertical gradients from BW-18 pumping.

Three lithologic cross sections are cut through the OU B/C Plume. Cross Section 6 is perpendicular to groundwater flow and passes through OU B. Cross Section 7 is parallel to groundwater flow and passes through OUs B and C. Cross Section 8 is oriented north-south and extends from OU D to south of OU C. These cross sections are presented in Chapter 3.

The impacts of the water level decline on the smear zone can be observed in Cross Section 6. MW-158 and MW-235 have measured TCE concentrations at 467 μg/l and 9,500 μg/l, respectively. If the water table continues to decline, MW-158 and MW-235 will become "dry," and a smear zone of elevated VOC concentrations will remain in the vadose zone. This may later be a likely place for a vadose zone remedial action, such as soil vapor extraction.

The representative concentrations of TCE in the monitoring well cluster MW-164, MW-165, and MW-166 are 17 μg/l, 125 μg/l, and 125 μg/l, respectively. TCE concentrations in MW-164 and MW-165 have remained constant since 1989. The concentration in MW-166 is actually an average of fluctuating concentrations measured from November 1989 to August 1991 that ranges from 93 to 180 μg/l. Contamination in the B and C Zone wells is higher than in the A Zone. B and C Zone wells, as well as D Zone wells, should continue to be monitored in this region to estimate the extent of deeper zone contamination. Remedy extraction wells should be installed in this region to contain these relatively high TCE concentrations.

Operable Unit D Plume

In the OU D vicinity, regional groundwater flow is to the south and the southwest. Locally, in the A and B Zones, groundwater flows towards the six OU D extraction wells which are currently in operation.

The OU D source area waste pits are the source of contamination in OU D. High concentrations are measured directly under Sites 2, 3, 5, A, S, and T. TCE concentrations are high in the A Zone but decrease sharply in the B Zone. The decrease is attributed to the VOC mass removal by the extraction wells. No C-Zone monitoring wells exist to discern the presence of C-Zone contamination. The extraction wells have limited the vertical migration of contaminants. The extent of contamination in the A and B Zones is bounded on the northwest, west, south, and southwest sides. The northeast extent is unbounded.

The extraction wells in OU D affect the local groundwater flow directions as well as contain the contaminant plume. The cis-1,2-DCE, PCE, and 1,2-DCA plumes coincide with the TCE plume and also are contained in a localized area due to groundwater extraction. The TCE plumes presented in Figure 4-60 clearly show that these contaminants have maximum concentrations in Monitoring Zone A and have low concentrations at depth. TCE concentrations are significantly higher than those of the other chemicals being monitored. This indicates that TCE is likely the major component of the vadose zone source contributing contaminant mass to groundwater.

The OU D source areas are capped with asphalt to prevent rainfall infiltration and continued leaching of source area contaminants to the groundwater. Vinyl chloride has been detected in the OU D extraction wells as recently as June 1993. As discussed in Section 4.4.4, Biodegradation Potential, the presence of vinyl chloride is a strong indicator of anaerobic conditions and biodegradation. The cap and the extraction wells may contribute to anaerobic conditions.

A large low concentration plume is located in the A Zone to the southwest of OU D. It is defined by MW-1019, MW-1029, and MW-111. Contaminants from the OU D source areas migrated with regional groundwater flow, which was historically in the southwest direction. This offbase plume broke off from the main source area plume when the OU D extraction wells were put into operation. This area should continue to be monitored.

Contamination in OUs E, F, G, and H

In OUs G and H, TCE, PCE, and cis-1,2-DCE have been detected in the A Zone; TCE and PCE have been detected in the B Zone; and only TCE has been detected in the C Zone. The only contaminant detected above MCLs was TCE in the A Zone. Since few monitoring wells exist in this area, the horizontal extent of contamination in the three zones is unknown. The IWL is believed to be a primary source of contamination in this area. Other historical base activities in this area include plating shops, degreasing and wash racks, as well as aircraft maintenance facilities. The approximate locations of PRLs identified by the SVE EE/CA are presented in Figures 4-50 to 4-56. Groundwater flow in this region is generally southwest. No contaminants were detected in wells in OUs E or F.

As detailed investigations of OUs E, F, G, and H are performed, the data collected will be incorporated into the conceptual model. Information regarding source areas, the industrial waste line, and the vadose zone, coupled with water level and water quality data, will help delineate the extent of contamination in those operable units.

4.6.6 Presence of Metals

As discussed previously, it is difficult to analyze metals concentrations to develop a data set of representative current conditions. This issue would be easily resolved by establishing a uniform sampling protocol to ensure consistency of the sampling results. At a minimum, sampling techniques such as filtering and purge rates should be standardized and documented in the field. Monitoring wells Basewide should be sampled using similar sampling techniques during the same time period to ensure spacial comparability of data. Background metals concentrations must be established to evaluate the impact of source area activities on the groundwater system. A consensus statement for background metals concentrations in soils has already been prepared, and a similar document for groundwater metals concentrations should be prepared. The extent of metals contamination cannot be delineated at this time in this Interim RI/FS. Understanding of the presence and extent of metals in the groundwater is regarded as a data gap for the following reasons:

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

Filtered and unfiltered metals samples have been collected, but the different sampling techniques have not been distinguished in the data base. McClellan AFB is aware of the findings by Puls and Powell (1992) that recommend that groundwater metals samples be unfiltered and collected by low purge rates and pump rates. But it is currently difficult to distinguish between unfiltered samples, filtered samples collected at high flow rates, or filtered samples collected at low flow rates. Hence, when elevated metals concentrations are measured, it is impossible to discern if the elevated concentrations reflect contamination as a result of McClellan AFB's operations or are elevated because the sample was unfiltered and collected at high flow rates. Conversely, if results are low or nondetect, it is not possible to distinguish between a filtered sample and an unfiltered sample collected at low flow rates.

The times series of metal samples fluctuates considerably. Elevated metals concentration in groundwater samples can be attributed to at least three factors:

- Mineral dissolution, a natural occurrence, from which background concentrations are established

- Turbidity, which is the result of poor sampling techniques, i.e., high purge or pumping rates

- Contamination from historic Base activities and source areas

Figure 4-61 presents the time series plots of metals concentrations in selected wells. In MW-1000, chromium was sampled consistently at nondetectable levels for 8 years, but then was detected at 1,800 μg/l in January 1993. In MW-10, aluminum was measured at 4,300 μg/l in February 1990, and at 3,000 μg/l in April 1992; Samples collected between these peaks contained between 0 and 195 μg/l. It is unclear whether the peaks are the result of true metals contamination, or due to high purge and pumping rates that result in high turbidity unfiltered samples. It is also unclear whether the low results are due to low levels of contamination in unfiltered samples or reflect filtered samples.

Background metals concentrations in the groundwater have not been established. It is not possible to distinguish between the presence of metals in groundwater that results from mineral dissolution and metals contamination due to historical base activities. MCLs cannot be the only criteria by which the groundwater is evaluated. In some cases, groundwater may exist in natural conditions higher than MCLs. For example, background concentrations for the Sacramento Basin for arsenic and manganese have been recorded as high as 120 μg/l (Johnston, 1985) and 2,300 μg/l (Fogelman, 1979), respectively, whereas the MCLs of both these metals is 50 μg/l. These background groundwater concentrations for the Sacramento Basin have not been accepted for the groundwater beneath McClellan AFB.

One hundred one monitoring and extraction wells were sampled during the second and third quarter of 1993. Forty-nine were located in the A Zone, 35 in the B Zone, 13 in the C Zone, and 4 in the D and E Zones. The most recent results for each of these wells are presented in Figures 4-62, 4-63, 4-64, and 4-65. The distribution of metals contamination has not been delineated for two reasons:

- Many of the wells that were sampled were sampled near source areas resulting from historical Base activities.

- Since background metals concentrations have not been established, it is impossible to distinguish between minerals/metals that occur naturally in the groundwater and metals that are due to historical Base activities.

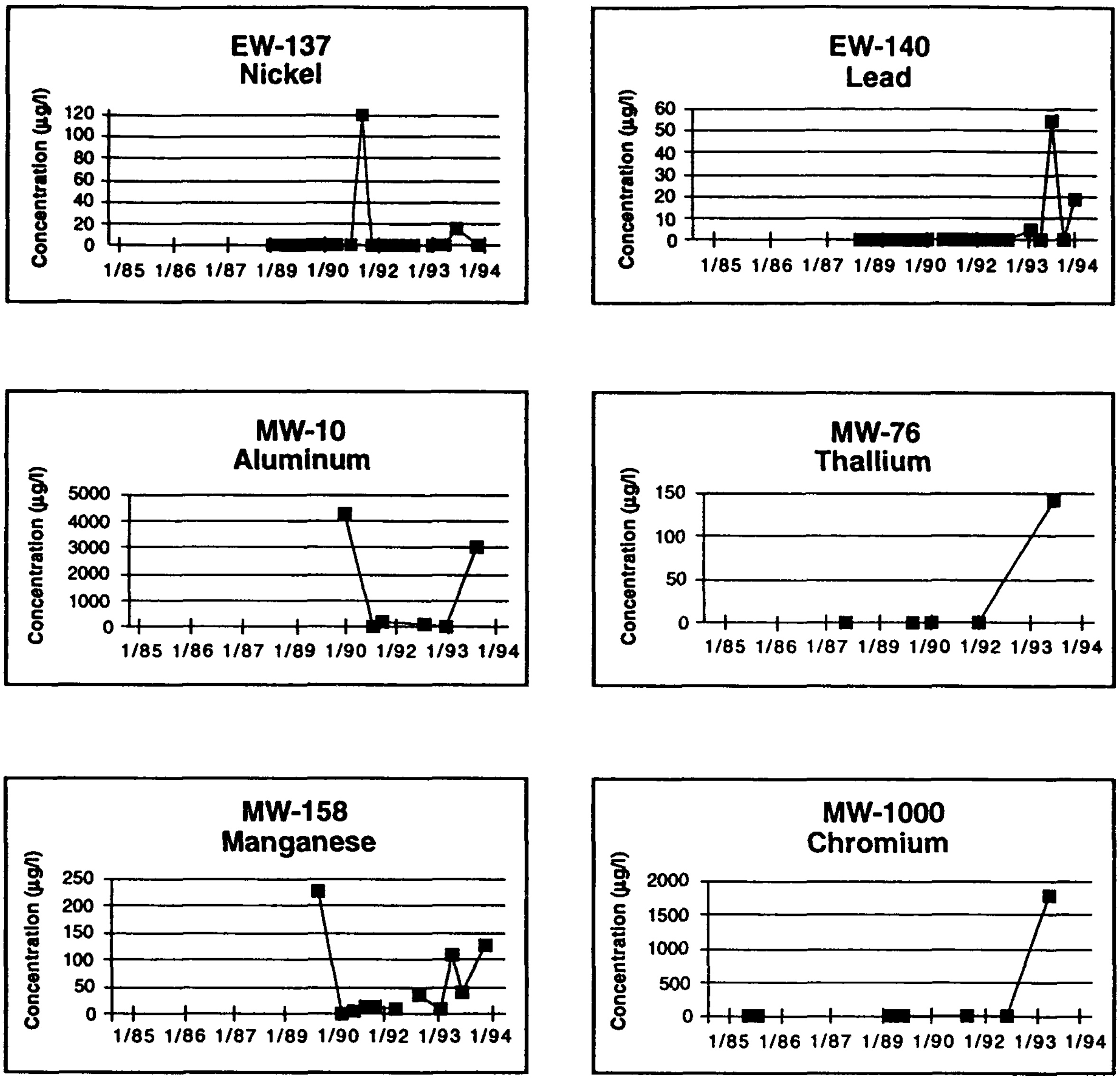


FIGURE 4-61
METALS TIME SERIES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_714

CH2M HILL

It would be misleading to delineate the extent of contamination from the above data set, since most of the wells sampled are within or near historic source areas. Very few wells outside of these locations were sampled. Examining metals concentrations in locations just around the source areas may lead to conclusions about the location of elevated metals concentrations that are not substantiated. Once sampling protocols and background concentrations are established, wells should be sampled Basewide to determine the areal distribution of metals concentration.

At this time, it would be difficult to select metals concentrations that are representative of current conditions. Information of sampling techniques should be assembled, where possible, before conclusions as to the nature and extent of metals contamination can be made. For example, in the groundwater and monitoring wells in McClellan AFB, thallium has been sampled for 286 times up to and including the third quarter 1993 sampling period. It has only been detected 33 times. Ten of those detections were measured during the January 1993 sampling in MW-1000, MW-236, MW-1044, MW-14, MW-183, MW-156, MW-163, MW-57, MW-75, and MW-76. All ten of these wells have been sampled at least five times, but thallium detects were measured only during the January 1993 sampling (MW-176 is presented in Figure 4-61). With the current lack of information regarding the sampling techniques, it would not be possible to conclude if the thallium detects are the result of unfiltered high pumping rates, or reflect actual dissolved concentrations in the groundwater. If the concentrations are true, it would not be possible to distinguish between impacts from the mineral dissolution, turbidity, or impacts from source area contamination.

Groundwater samples are currently collected at McClellan AFB using at least five different methods. These methods include:

- Pneumatic purge and sampling pump. This method typically achieves low flow rate. It is used on shallow wells with smaller well volumes of groundwater.

- Submersible pump. This method typically achieves high flow rate and consequently high turbidity. It is used on deeper wells well with large well volumes of groundwater.

- Dual pumps: submersible purge pump with pneumatic sampling pump. The submersible pump extract groundwater at high flow rates and the pneumatic pump collects samples at lower flow rates. Generally the high purge rates disturb the sediments; this results in turbid samples. This configuration is installed in MW-74 and MW-76 in OU D.

- Purging and sampling using a packer. The purge volumes are reduced by sealing off the pumping area. Hence low purge and pumping rates could be used during sample collection.

- Bailing.

4.7 Mass of Contamination and Target Volumes

This section will present the mass of the prevalent contaminants by zone and by OU followed by a presentation of the target volumes used for evaluation of the remedial action alternatives. The extent of contamination and the mass of the prevalent contaminants were calculated and target volumes were delineated and/or calculated to quantify the extent of VOC contamination in the groundwater. These calculations were performed on the data set presented in Section 4.6.1. This section will present the VOC mass estimates, followed by a discussion of the target volume development. In general, more mass exists in the shallower zones than in the deeper zones. However, the mass and extent of contamination varies widely between different target volumes and different zones.

Mass Estimates

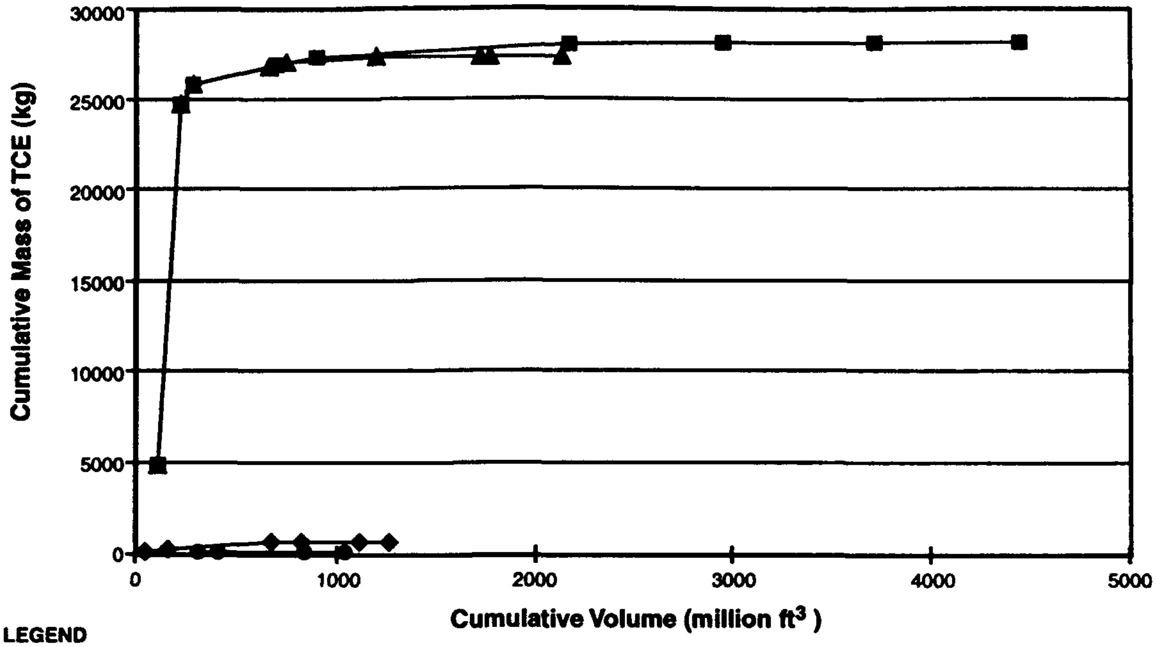
The mass of the VOCs of concern dissolved in the groundwater and sorbed to the soil matrix was estimated based on the data set discussed in Section 4.6.1. Table 4-13 summarizes the mass of TCE, cis-1,2-DCE, 1,2-DCA, and PCE in the saturated zone.

TCE is the most prevalent compound both in mass and by contaminated aquifer volume.

The volumes in which the contamination is present were determined using isopleths, which were based on a linear interpolation of contaminant contour intervals within each groundwater zone. The assumptions made and calculations performed to calculate VOC mass are presented in Appendix K, VOC Mass Estimates. Mass of contaminants and volume of aquifer were calculated for the following concentration intervals: 1, 5, 10, 50, 100, 500, 1,000, and 10,000 μg/l. Figures 4-66, 4-67, 4-68, and 4-69 present the cumulative mass of contaminant versus cumulative volume of aquifer plots for TCE, cis-1,2-DCE, PCE, and 1,2-DCA, respectively. The largest mass of contaminant exists in the >1,000 μg/l areas.

The following assumptions were made in determining the mass of contaminants and the volume of contaminated aquifer:

- Total Porosity = 0.48
- 100 percent saturation
- Saturated water content by weight = 0.34
- Dry bulk density = 1.4 g/cm^3

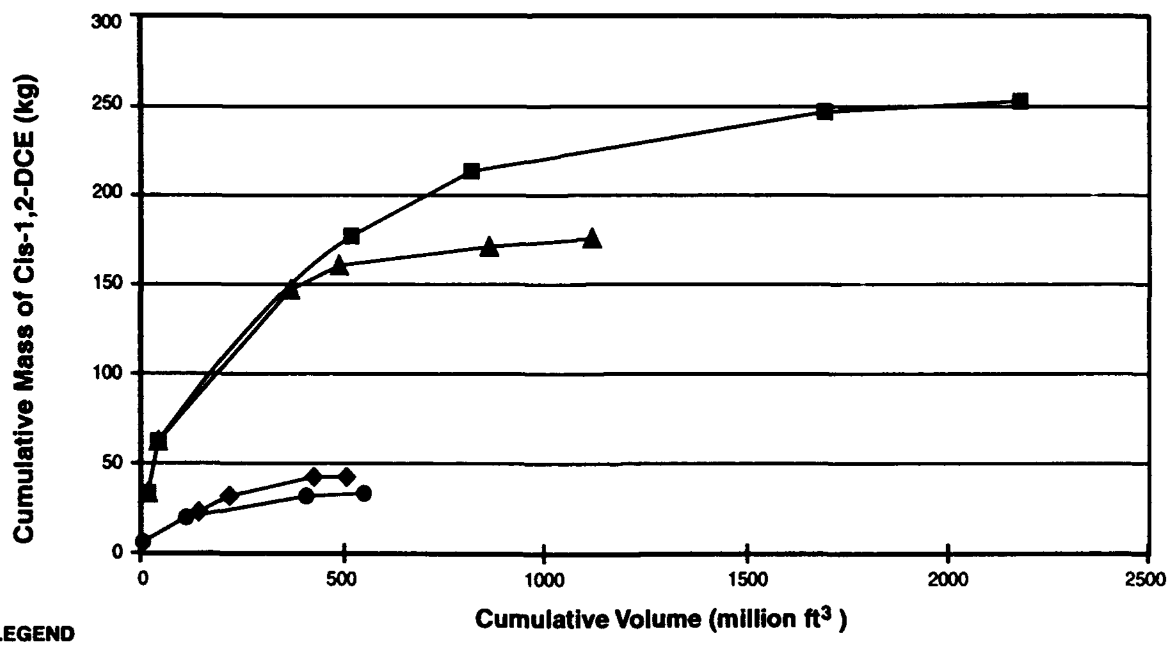


LEGEND

The following TCE isopleths were used in the summation of cumulative mass and cumulative volume:

- ■ Totals: 1,000-10,000; 500-1,000; 100-500; 50-100; 10-50; 5-10; 5 -1; 0.5-1
- ▲ A Zone: 1,000-10,000; 500-1,000; 100-500; 50-100; 10-50; 5-10; 5-1; 0.5-1
- ◆ B Zone: 50-100; 10-50; 5-10; 1-5; 0.5-1
- ● C Zone: 5-10; 1-5; 0.5-1

FIGURE 4-66
CUMULATIVE MASS OF TCE VERSUS VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



LEGEND

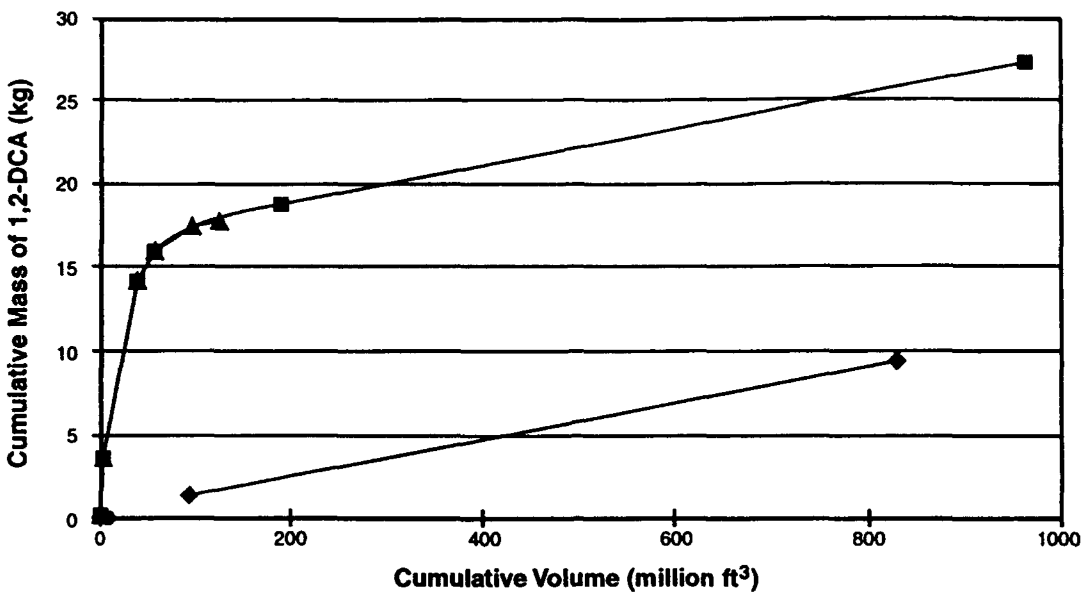
The following cis-1,2-DCE isopleths were used in the summation of cumulative mass and cumulative volume:

- ■ Totals: 50-100; 10-50; 5-10; 1-5; 0.5-1
- ▲ A Zone: 50-100; 10-50; 5-10; 1-5; 0.5-1
- ◆ B Zone: 5-10; 1-5; 0.5-1
- ● C Zone: 5-10; 1-5; 0.5-1

FIGURE 4-67
CUMULATIVE MASS OF cis-1,2-DCE VERSUS VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_116

CH2M HILL

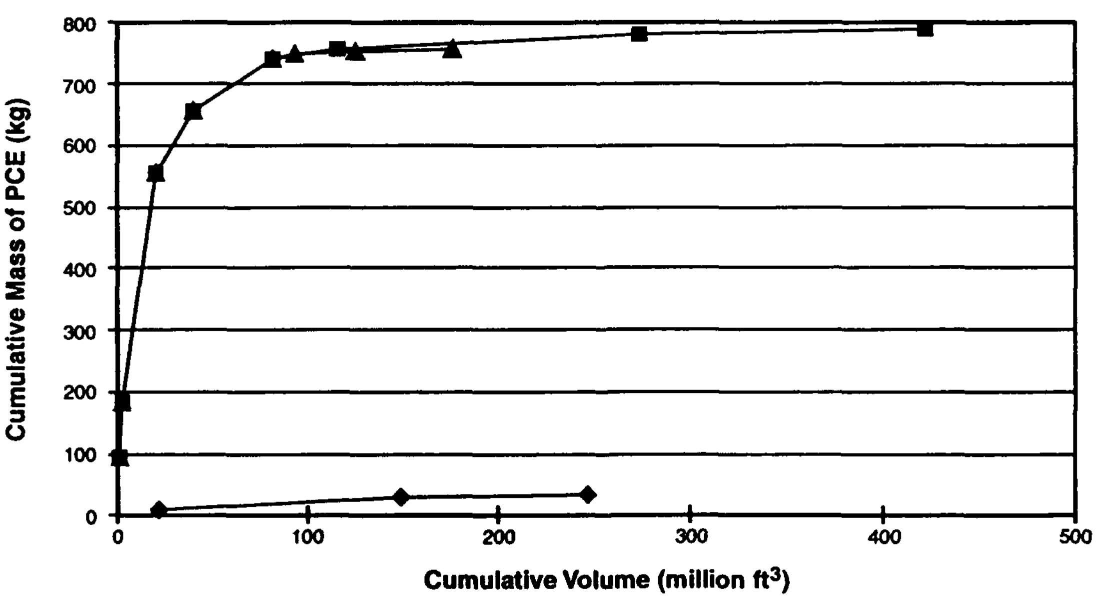


LEGEND

The following 1,2-DCA isopleths were used in the summation of cumulative mass and cumulative volume:

- ■ Totals: 50-100; 10-50; 5-10; 1-5; 0.5-1
- ▲ A Zone: 50-100; 10-50; 5-10; 1-5; 0.5-1
- ◆ B Zone: 0.5-1
- ● C Zone: 0.5

FIGURE 4-68
CUMULATIVE MASS OF 1,2-DCA VERSUS VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



LEGEND

The following PCE isopleths were used in the summation of cumulative mass and cumulative volume:

- ■ Totals: 500-1000; 100-500; 50-100; 10-50; 5-10; 1-5; 0.5-1
- ▲ A Zone: 500-1000; 100-500; 50-100; 10-50; 5-10; 1-5; 0.5-1
- ◆ B Zone: 1-5; 0.5-1

FIGURE 4-69
CUMULATIVE MASS OF PCE VERSUS VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_117

CH2M HILL

Table 4-13
Mass of Prevalent Contaminants and Volume of Contaminated Aquifer By Zone
Groundwater Operable Unit

Prevalent Contaminants	**Zone** A	B	C	**Total**	**Percent of Total Mass**
TCE					
Mass (kg)	7,900	400	170	8,500	
Percent of TCE Mass	93	4.7	2.0		96
Volume (million ft³)	2,200	1,300	4,000	4,600	
Percent of Total Volume	48	29	23		
PCE					
Mass (kg)	760	33	0	790	
Percent of PCE Mass	96	4.0	0		2.7
Volume (million ft³)	180	250	0	420	
Percent of Total Volume	42	58	0		
cis-1,2-DCE					
Mass (kg)	170	43	34	250	
Percent of cis-1,2-DCE Mass	69	17	14		0.90
Volume (million ft³)	1,100	510	550	2,200	
Percent of Total Volume	51	23	25		
1,2-DCA					
Mass (kg)	18	9.5	0.060	27	
Percent of 1,2-DCAMass	65	35	0.00		0.090
Volume (million ft³)	130	830	8.6	970	
Percent of Total Volume	13	86	1.0		
Total Prevalent Contaminant Mass (kg)	8,800	490	200	9,500	100

- Wet bulk density = 1.9 g/cm^3
- Fraction of organic content, f_{oc} = 0.0030
- Contaminants in solution and sorbed to soil are in equilibrium

These physical parameters were either analyzed for during remedial investigations in OU C and OU D or calculated from field sampling results. Saturated water content (by weight) was used to calculate wet bulk density. The data set previously described was used to determine the mass of subsurface VOC contamination. Parameters used in mass estimate calculations are shown in Table 4-14.

Table 4-14 Parameters used in Mass Estimate Calculations			
VOC	K_{oc} (ml/g)	f_{oc} (%)	K_d (ml/g)
TCE	126	0.30	0.38
cis-1,2-DCE	32	0.30	0.096
1,2-DCA	14	0.30	0.042
PCE	661	0.30	2.0
1,1,1-TCA	151	0.30	0.45
1,1-DCE	65	0.30	0.20
Notes: 1. K_{oc} source: U.S. EPA, 1990. 2. $K_d = f_{oc} \times k_{oc}$			

Target Volume

Target volumes were defined to differentiate between the areas where immediate remedial action is necessary, where long-term public health is threatened, and where contaminant concentrations are above background levels. By identifying these areas, alternatives can be developed to maximize containment, extraction, and treatment effectiveness. Four target volumes were identified based on concentration and risk to public health: hot spots, MCLs, risk, and background. These target volumes are presented in Figures 4-70, 4-71, and 4-72. The generation of the data set that these target volumes were created from has been discussed in Section 4.6.1. The areas of the four target volumes are presented in Table 4-15. The following paragraphs describe the four identified target volumes.

Table 4-15 Areas of Target Volumes								
	Hot Spot		MCL		Risk		Background	
Zone	acres	sq ft	acres	sq ft	acres	sq ft	acres	sq ft
A	25.84	1,125,588	663.92	28,922,385	966.45	42,101,564	1,570.29	68,406,331
B	0.00	0	100.87	4,394,208	187.90	8,185,615	474.40	20,666,275
C	0.00	0	52.28	2,277,387	127.84	5,568,954	306.28	13,342,400
Total	25.84	1,125,588	817.07	35,593,980	1,282.19	55,856,133	2,350.96	102,415,006

Hot Spots

The hot spot target volumes are defined as the regions where VOC concentrations are greater than 500 μ/l. Cumulative mass versus cumulative volume shows that the greatest amount of mass is located in the areas of highest concentration, although these areas are small in volume. In addition, the concentrations from these hot spots were significantly greater than from the other target volumes. Aggressive extraction or innovative technologies will be implemented in the hot spot volumes. Hot spot volumes are located below confirmed source areas, suggesting that contaminants have migrated vertically into the groundwater by gravity or though infiltration.

Seven hot spot volumes have been identified in Zone A: two in OU A, three in OU B/C, and two in OU D. None have been identified in any of the other monitoring zones. The potential sources of the seven hot spots are listed as follows:

- The northern OU A hot spot was delineated by MW-224 and MW-172 that had detected TCE at 14,000 μg/l and 17,000 μg/l, respectively. According to the OU A PA Summary Report (Radian, 1990) several spills from maintenance operations, and IWL and underground storage tank leaks have occurred in this region. Contaminants have been detected in the soils in this area. The northern OU A hot spot may be the result of these activities.

- The southern OU A hot spot was delineated by MW-209 that has detected TCE at 3,000 μg/l. This well is located near SA 80 where a spill had occurred (Radian, 1990). Other sites within the vicinity of this well have detected contaminants in the soil.

- The two OU B hot spots are located within IC 1 and IC 7. An open storage area, an abandoned plating shop, and the abandoned industrial water treatment plant and a portion of the IWL comprise IC 1. An open drainage ditch, an abandoned industrial waste treatment plant, degreaseR and solvent spray booths, leaking underground tanks and drains, an oil and storage yard and portions of the IWL comprise IC7. These sites are the probable sources of the hot spots.

- The OU C hot spot is located near CS 22 and CS 42 where priority pollutants have been landfilled and/or burned. CS 22 is a potential site for a cometabolic treatability study.

- The two OU D hot spots are located near CS 2, CS 5, CS A, CS S and CS T. These sites were discharge and burn pits for solvents, sludges and other maintenance wastes. They are the likely source of the OU D hot spots.

Wells with elevated concentrations of the prevalent contaminants were used to define the hot spots. In all wells, if 1,2-DCA, cis-1,2-DCE, or PCE were detected above 500 μg/l, TCE was also detected above 500 μg/l.

MCLs

The MCL target volume is defined as the area where VOC contaminants exist above their MCLs. Since TCE is the most prevalent contaminant, in most areas the MCL target volume is delineated where TCE is greater than or equal to 5 μg/l. In some areas, the MCL target volume was defined by other contaminants. The A Zone OU D MCL (and consequently the risk and background) target volume was extended further east because 1,1-DCE was detected at 210 μg/l in MW-89. The MCL of 1,1-DCE is 6 μg/l. The sample-specific risk in that well does not exceed 10^{-6} because 1,1-DCE is a not a carcinogen. Although TCE was measured at only 2.2 μg/l, MW-228 was included in the A Zone OU A MCL target volume because PCE was measured at 30.5 μg/l.

Risk

The risk target volume was defined as the area where total cancer risk is greater than the 10^{-6} cancer contour. Risk at each well for a given sampling event was calculated by summing the risk contributions of each VOC detected during that sampling event. Since risk is cumulative for all VOC contaminants, in some cases risk exceeding 10^{-6} existed where TCE or other prevalent contaminants were not detected or were detected at low levels. A risk target volume was not drawn around MW-1032; the risk was due to an elevated methylene chloride concentration. Methylene chloride is a common laboratory contaminant.

Background

Concentrations of prevalent contaminants were used to delineate the background target volume. In areas where prevalent contaminant concentrations were below 0.5 μg/l, but risk was elevated, the background target volume was extended to encompass the risk target volume. For example, in MW-150 TCE, cis-1,2-DCE, and 1,2-DCA were non-detect while PCE was measured at 0.1 μg/l. MW-150 was included in the risk and background target volumes because risk was calculated to be greater than 10^{-6} due to elevated concentrations of other VOCs. The northern extent of the A Zone OU G background target volume was extended to MW-102 because TCE was measured at detectable levels MW-103 (B Zone). The northern extent of the OU G background target volumes is unbounded. MW-1005 was not included in the OU D background target volume; TCE was last sampled for at detectable levels in January 1992. It has since gone dry and was replaced by MW-1073, which measured nondetect for all VOCs in October 1993.

MCL target volumes were either the same size or smaller than the risk target volumes because for some VOCs, the MCL really represents the 10^{-4} cancer risk, which would be associated with higher contaminant concentrations than the 10^{-6} cancer risk.

Effects of Fourth Quarter 1993 Data on the Target Volumes. The fourth quarter 1993 data were consulted to determine how the most current data would affect the target volumes. In some areas, incorporating the fourth quarter 1993 data results in larger target volumes, whereas in other areas the target volumes would shrink. This generally occurs in wells along the borders of the target volumes. Since these volume changes are the result of contaminant concentration fluctuations, the target volumes were generally delineated using the more conservative scenario. The fourth quarter 1993 data were not fully incorporated in to the data set because they were not available in electronic format and hence sample-specific risk could not be calculated from the fourth quarter 1993 data. Figures 4-70, 4-71, and 4-72 are annotated with discussions on how the target volumes would change with the fourth quarter 1993 data. A summary of those changes follows.

Target Volume Increases

- A Zone OU A plume: The MCL (and consequently the risk and background) target volume in the eastern portion of the A Zone OU A plume was extended southward because fourth quarter 1993 data revealed that MW-1058 and MW-1067 contained TCE at 27 μg/l and 23 μg/l, respectively. In August 1993 TCE was sampled in MW-1058 and MW-1067 at levels of 0.7 μg/l and 1.4 μg/l, respectively.

- A Zone OU B/C plume: MW-1054 was included in the southwestern portion of the A Zone OU B MCL target volume because fourth quarter 1993 data revealed TCE at 8.4 μg/l. In July 1993, TCE was measured in MW-1054 as 0.4 μg/l.

Target Volume Decreases

- A Zone OU B/C plume: The northern extent of the MCL plume would decrease from north of MW-44S to north of MW-999. In the data set, the TCE concentration in MW-44S was above MCLs; in the fourth quarter 1993, TCE was measured below MCLs in this well.

- A Zone OUs G and H plume: An MCL target volume would not exist using the fourth quarter data. TCE was detected in Wells MW-194 and MW-226 in April 1993 at 8.1 μg/l and 7.5 μg/l, respectively; in fourth quarter 1993, 3 μg/l and 0.38 μg/l, respectively, was detected.

- C Zone OU A plume: The risk and MCL target volumes in OU A would be eliminated with the incorporation of the fourth quarter 1993 result of non detect for MW-180. In the previous data set, TCE was detected in MW-180 at above MCLs.

Generally for wells with fluctuating concentrations, the target volume was increased based on fourth quarter results. Target volumes were not decreased based on fourth quarter 1993 results. The list of possible reductions should be used in prioritizing remedial actions. These areas should continue to be monitored before commitment to a specific remedial action is made.

No target volumes were delineated in Monitoring Zone C of OU D because no OU D monitoring wells are screened in the zones deeper than Monitoring Zone B. This does not necessarily mean that contamination does not exist deeper than the B zone. The delineation of the target volumes is dependent on the monitoring well network. In areas where not enough monitoring wells exist to close the target volumes, source area information and groundwater flow directions were examined to determine the extent of contamination. The following are examples of how the extent of the target volumes in Monitoring Zone A were defined in regions where little information is available:

- Few monitoring wells exist under the runway, and so little water quality information is known about that area. Yet it is believed that there are no sources under the runway and that groundwater flow has generally been in the southwesterly direction. Therefore, the contaminants in the OU A source areas were assumed to have not migrated under the runway.

- Since groundwater flow directions have generally been in the southwesterly direction, contaminants in the OU D source areas have migrated nearly 1 mile offbase. In 1988, when the OU D extraction system started its operation, the plume broke off into two sections. The break in the target volumes defines the extent of contaminant.

- The source of contamination of the background target volume at the northeast section of the Base is believed to be the IWL. Over time, the leakage from the IWL has merged into one low contamination plume. If the IWL were not a potential source, several smaller target volumes would have been delineated with OU-specific activities as the primary source of contamination.

No D or E Zone Target Areas

Target areas were not identified in the D and E zone because the monitoring well network in these zones is not dense enough to delineate an east or west extent of contamination. The existing wells are oriented in a north-south line. Current sampling indicates that contamination is present in these zones. New monitoring wells should be installed to the east and west of the existing wells and sampled to further define the lateral extent of contamination.

4.8 Future Conditions

Future contaminant distributions and groundwater flow directions can be predicted by understanding how site conditions, source areas, contaminant transport mechanisms, and physical transport mechanisms have lead to the current groundwater conditions. This section will identify data gaps and areas of future monitoring, identify trends in contaminant and water level trends, and predict future conditions

Data Gaps

Spacial and temporal holes in the groundwater database are data gaps. Spacial data gaps were identified by examining the horizontal and vertical extent of contamination. Areas where the extent is not bounded (i.e., where the extent cannot be delineated) are considered spacial data gaps. Temporal data gaps were identified as time periods when the sampling of wells that were not sampled could have served to better define the extent of contamination.

Between 1991 and 1993, several wells were not sampled through GSAP. Sample intervals were selected based primarily on the wells' past contaminant concentration history and proximity to groundwater plumes. Some wells were not sampled because results measured from these wells had consistent nondetect VOC results. Spatial and temporal data gaps were not created in this case. Other wells had VOC results above detectable levels, but were still not sampled. Temporal data gaps were created from not sampling these wells since the extent of contamination was unbound in their vicinity.

The vertical extent of contamination in the 60- to 90-foot region between the bottom of Monitoring Zones A and B is not well defined because few wells are screened in that area. Monitoring Zone A wells are typically screened at the bottom of the A zone, and Monitoring Zone B well are typically screened at the bottom of the B zone. The average screen interval of an A-zone well is located -35 to -47 feet msl, whereas the average screen interval of a B-zone well is located -90 to -100 feet msl. Therefore, the A-zone contamination appears considerably higher than the B-zone contamination because of the large unsampled vertical distance between the screened intervals. For example, the average OU A A-zone TCE concentration is greater than 1,000 μg/l, yet the average B-zone TCE concentration is less than 20 μg/l. The top of the A Zone is not accounted for in the same manner as the top of the B Zone. Water levels have declined Basewide, leaving a shallow A Zone with approximately 10-feet thickness in OU A and a thickness of no more than 40 to 50 feet in OUs B, C, and D. The regions between the bottom of the A zone and the bottom of the B zone should be sampled to monitor the vertical migration of contaminants and to delineate the vertical extent of contamination. During the installation of new monitoring wells, vertical hydropunching should be performed to determine a vertical contaminant profile and to optimize the placement of screened intervals.

This section identifies, by Operable Unit, areas where data gaps exist either because monitoring wells are not present laterally or vertically, or because existing wells were not sampled within the last 2 years and consequently the current extent of contamination is undefinable. Water quality data gaps can be resolved with the installation of new wells or by performing vertical profiling. Refer to Figures 4-43 TO 4-46 for current well locations and most recent sampling information. Locations of new monitoring wells, necessary to measure water quality and monitor hydraulic control, are presented in Chapter 7, Data Collection and Management. These locations were selected to further define the MCL, risk, and background target areas.

Operable Unit A

The following paragraphs summarize the areas in the A and B zones where spacial data gaps (where additional wells are needed) and temporal data gaps (where additional sampling of existing wells may be needed) exist.

North and Northwest of A- and B-Zone Contamination. The extent of contamination in the north and northwest sides of the OU A plume in the A and B zones could be better defined with the installation and sampling of wells in those regions. Several of the outermost wells have detected contamination above background levels.

Offbase Migration to the Southeast. The extent of A-zone offbase migration could be further delineated with the installation and sampling of offbase wells on the southeast side of the OU A plume.

B Zone Underneath Hot Spots. The B-zone areas underneath the A-zone hot spots should be sampled to monitor the potential downward migration of contaminants from these highly concentrated areas. MW-173 should be added to the monitoring program. It is located directly underneath an A-zone hot spot. Concentrations in this well have generally been increasing with time; it was last sampled in 1991 at levels considerably higher than MCLs.

Operable Units B and C

The following paragraphs describe the areas where spacial and temporal data gaps exist in OUs B and C:

East Extent of A-Zone Contamination. The extent of contamination in the A zone along the east side of the OU B/C plume could be better delineated with the installation and sampling of wells in that region. MW-61, one of the easternmost wells in the central section of the plume, was sampled in 1993 with results above MCLs.

Northern Extent of the C-Zone Contamination. At least one well should be installed between EW-144 and MW-190 to determine the northern extent of contamination in the C zone.

Southeast and Southern Extent of C-Zone Contamination. Wells should be installed in southeastern and southern portions of OU B/C to attempt to close the risk and background target areas and to monitor offbase migration to the city wells and the Caltrans wells.

East and West Extent of D- and E-Zone Contamination. The wells that are currently in the D and E zones are oriented north to south. The east and west extent of contamination in the D and E zones would be better defined with the installation and sampling of wells on the east and west sides of existing wells in the D and E zones. The extent of vertical hydraulic control could also be monitored with the installation of additional wells if they are located near an existing C-Zone well. MW-141, MW-162, MW-163, and MW-167 have been sampled between 1992 and 1993 and have had measured concentrations above MCLs. These wells should continue to be sampled for VOCs to monitor the downward migration of contamination.

Operable Unit D

The following paragraphs describe areas in OU D where spacial and temporal data gaps exist:

Northeastern Extent of A-Zone Contamination. The northeastern extent of the OU D plume could be better defined with the installation and sampling of wells in that region.

Southern Extent of the B-Zone Contamination. The southern extent of contamination could be further delineated with the installation and sampling of at least one monitoring well south of MW-19D. This well could also serve to determine the extent of hydraulic influence of the OU D extraction wells.

Downward Migration into C and D Zones. There are no target areas in the C and D zones of OU D because no monitoring wells are screened in these zones. Deeper monitoring wells should be installed to monitor the downward migration of contaminants and to monitor the effectiveness of the OU D extraction wells.

Data Trends

VOC concentrations and water levels have been measured from the Base monitoring wells since the early 1980s. Several remedial actions have been put into place since monitoring began. These remedial actions include the excavation of source pits; the capping of source pits; the installation and operation of the OU B, OU C and OU D extraction wells; and the disconnection of residents from groundwater sources and reconnection to city water. Along with groundwater flow due to Base and regional pumping, and natural attenuation, these remedial actions have contributed to the change in concentrations at the wells over the monitoring period.

This section will first discuss in generalities how the concentrations of VOCs of concern have been changing with time. Following that discussion, the concentration trends of Basewide wells will be presented.

Generally, the concentrations of the VOCs of concern have decreased with time, whereas the number of wells sampled that have detected these VOCs has increased with time. (Figure 4-42 shows how the frequency of detects for selected VOCs has increased with time, whereas the mean concentrations have decreased with time.) For most contaminants, the frequency of detections has been increasing with time, but their maximum and mean concentrations have been decreasing. This may be the result of the following:

- Because of regional, Base, and extraction well pumpage, contaminant plumes have been migrating.

- Contaminant mass has been removed by extraction wells installed for remedial actions.

- Several wells that have been sampled consistently at non-detect levels have been dropped from the monitoring program.

- New wells have been added to the program to further define the plumes. This has led to the addition of numerous wells in areas with relatively low levels of groundwater contamination.

Hence, compounds have been detected in more sampled wells, but at lower concentrations.

TCE is the most prevalent VOC of concern both in number of detects and in mass of contaminant. TCE time series were examined to determine the general data trend of wells in various parts of the Base. The following trend analysis, observations, and conclusions were made:

- Monitoring wells in close proximity to the extraction wells generally experience a slight increase in concentrations when the neighboring extraction well begins pumping. This increase is followed by a decrease in concentrations. This trend is observed in wells near the OUs B, C, and D extraction wells. Figure 4-73 show how concentrations in MW-41S, MW-136, and MW-10 all experience slight increases and then decreases in concentrations related to the extraction well operations. This may be due to increased concentration gradients from increased groundwater flow. Contaminants that were sorbed to the soil matrix or trapped in immobile pores were mobilized by increased concentration gradients and extracted by the extraction wells.

- If TCE is detected in offbase monitoring wells, the concentrations generally fluctuate between background and MCLs. In some wells, concentrations eventually drop to nondetectable levels because of flushing and dilution and/or natural attenuation. Figure 4-74 presents the TCE time series plots of offbase wells MW-1019, MW-1032, MW-1036, MW-1053, MW-1056, and MW-1067. There are also several offbase wells that have consistently shown non-detect levels of TCE contamination.

- Monitoring wells that are screened within the source areas do not experience a sharp decline in TCE concentrations after extraction wells are put into operation. This may be due to the presence of DNAPLs in the source areas or a large mass of contamination adsorbed to the aquifer materials, or both. Concentration gradients are induced by groundwater extraction that drives adsorbed mass into the

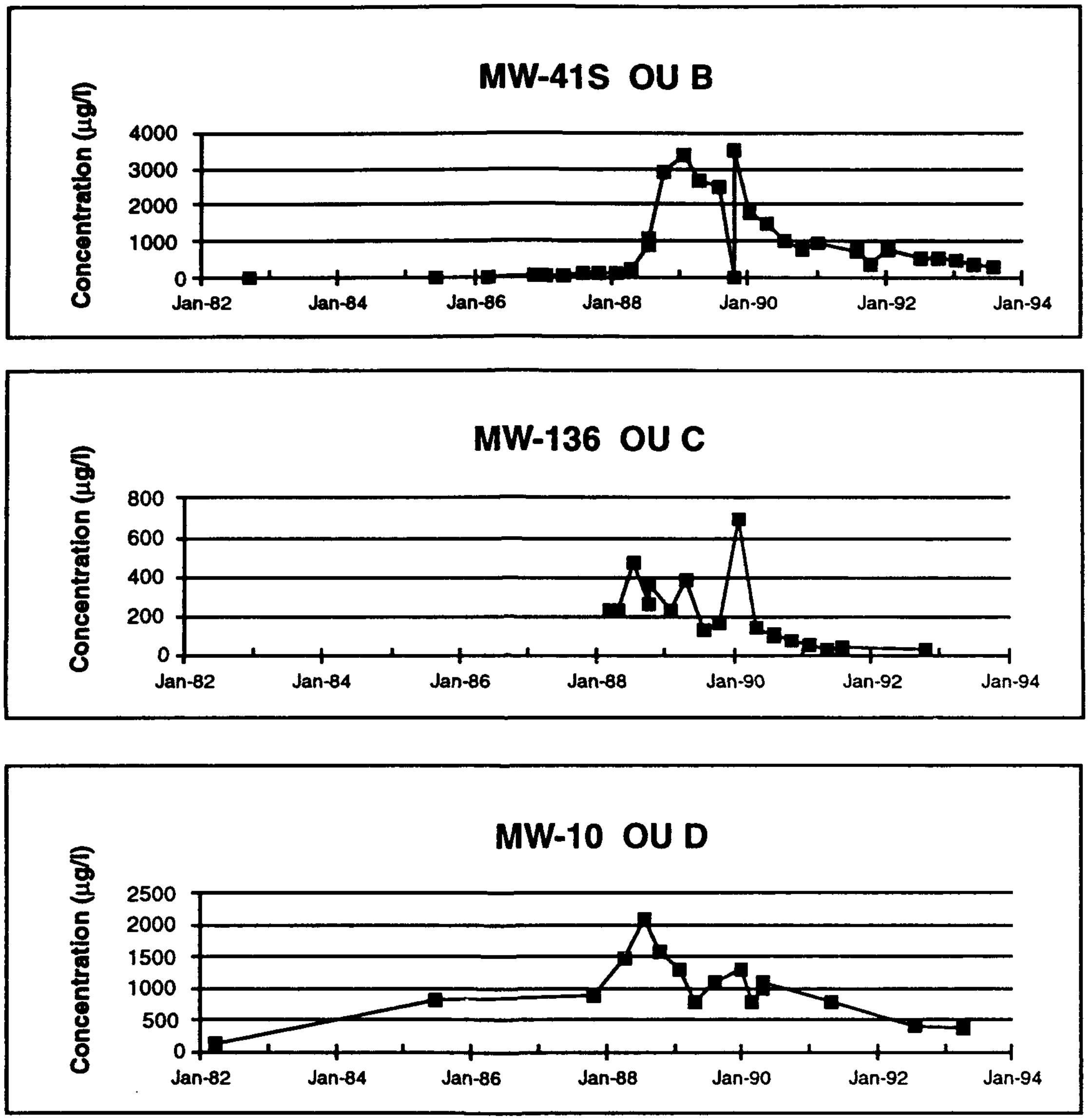


FIGURE 4-73
TCE TIME SERIES OF MONITORING WELLS LOCATED NEAR BASE EXTRACTION WELLS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_150

CH2M HILL

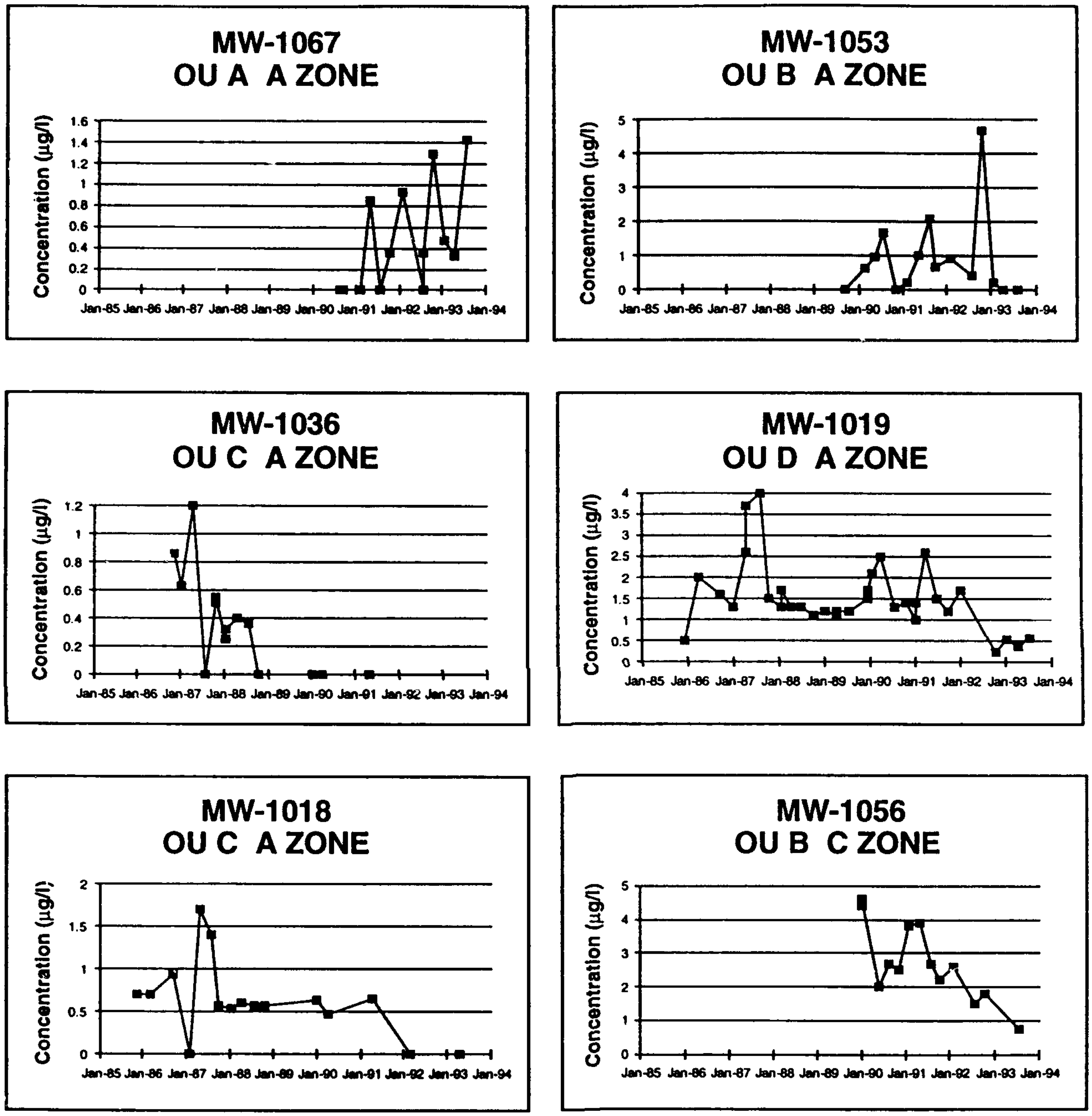


FIGURE 4-74
TCE TIME SERIES OF OFF BASE MONITORING WELLS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_158

CH2M HILL

groundwater or induces DNAPLs to dissolve into groundwater and replace the aqueous-phase contamination removed by the extraction wells. Time series plots of A-zone monitoring wells screened directly through the source areas are presented in Figure 4-75.

- In areas of the A zone, where extraction wells do not exist, there appears to be vertical downward migration of contamination from the A-zone hot spot areas to the B zone. The time series plots for the A-zone/B-zone clusters of MW-172/MW-173 and MW-224/MW-225 in Figure 4-76 show that B-zone contaminant concentrations are increasing with time. This slow but steady vertical migration is due to downward vertical gradients induced by regional and municipal pumpage in vicinity of the Base.

- The concentrations of vinyl chloride in OU D monitoring wells have dropped significantly to nondetectable levels since the operation of the OU D extraction system. Figure 4-77 presents the vinyl chloride time series of MW-10 and MW-54 as well as EW-73 and EW-83. Vinyl chloride has not been detected in any monitoring wells since April 1990.

Contaminant Trend Analysis

A trend analysis of VOC contamination in groundwater was performed using the monitoring data collected from 1986 to 1993. This trend analysis was used to identify areas of the site where uncertainties in groundwater contaminant concentrations may exist, and to aid in characterizing the relationships between contaminant sources in soil and contaminant concentrations in groundwater. The trend analysis identified wells where contaminant concentrations were increasing over time, decreasing, remaining static, or exhibited "boundary" characteristics. Boundary wells were those where contaminant concentrations fluctuated over time. There may be different reasons for these fluctuations, such as changes in contaminant concentrations in response to changing flow directions and water levels, or high variability in sampling and analytical QA/QC. Fluctuations in contaminant trends in some wells may be anomalous, or not clearly understandable, given the current knowledge in site conditions.

The trend analysis summarizes observations of contaminant trends over time, but does not directly provide a rationale that explains those trends. However, the trend analysis aids in identifying wells or areas at the Base where obtaining a better understanding of contaminant fate and transport, and contaminant spatial distribution, would contribute to a refined estimate of the extent of the target volumes for remediation. In particular, wells identified as boundary wells in the trend analysis contribute significantly to the uncertainty in the estimated target volumes. Collection of additional data from these wells could result in a reduction in the extent of the target volumes.

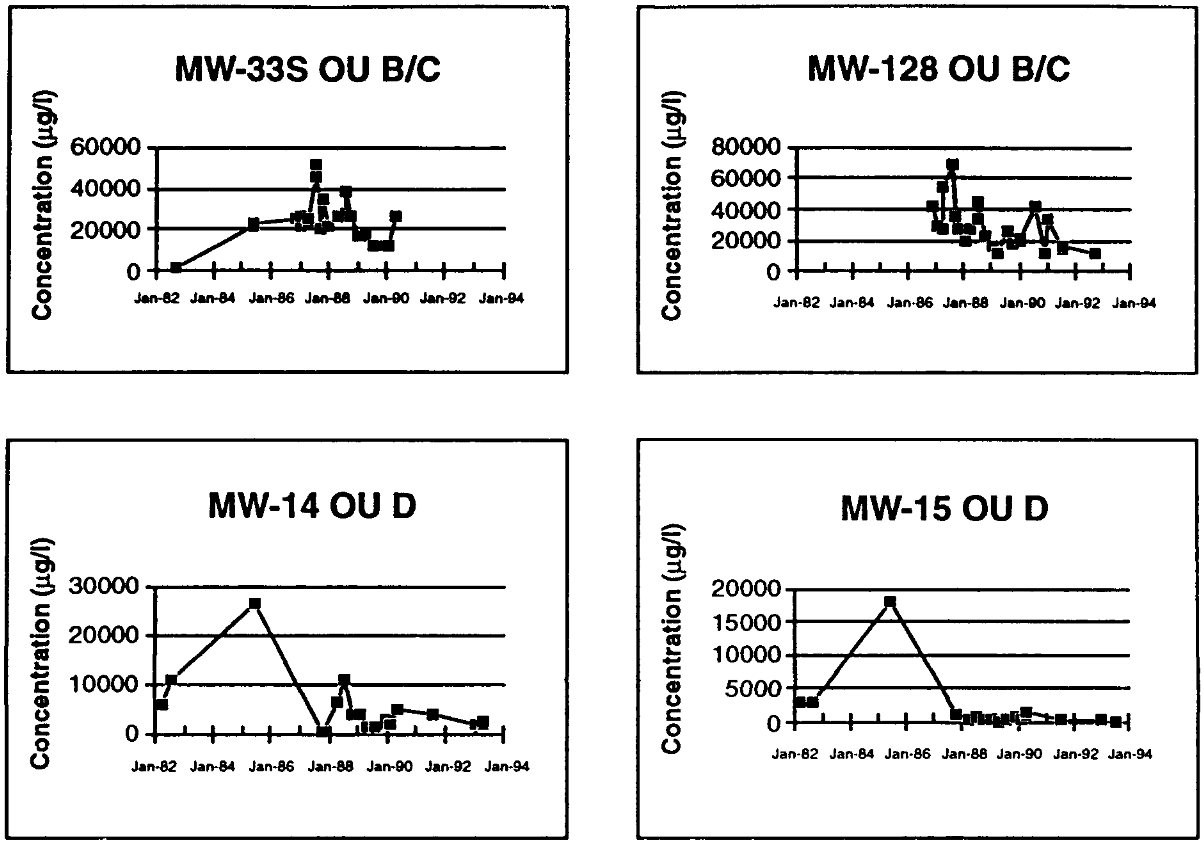


FIGURE 4-75
TCE TIME SERIES OF A ZONE MONITORING WELLS LOCATED IN OR WITHIN SOURCE AREAS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENT, CALIFORNIA

RDD1454_160

CH2M HILL

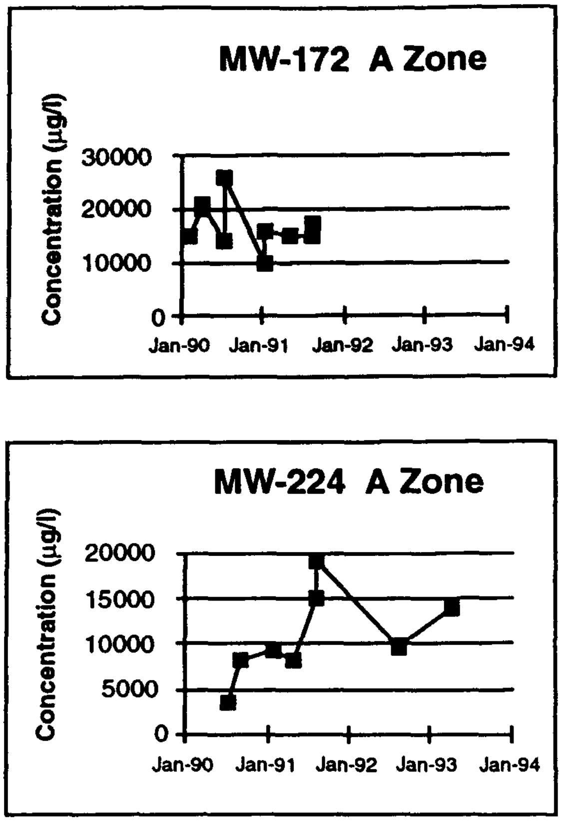


FIGURE 4-76
TCE TIME SERIES OF OU A MONITORING WELL CLUSTERS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_153

CH2M HILL

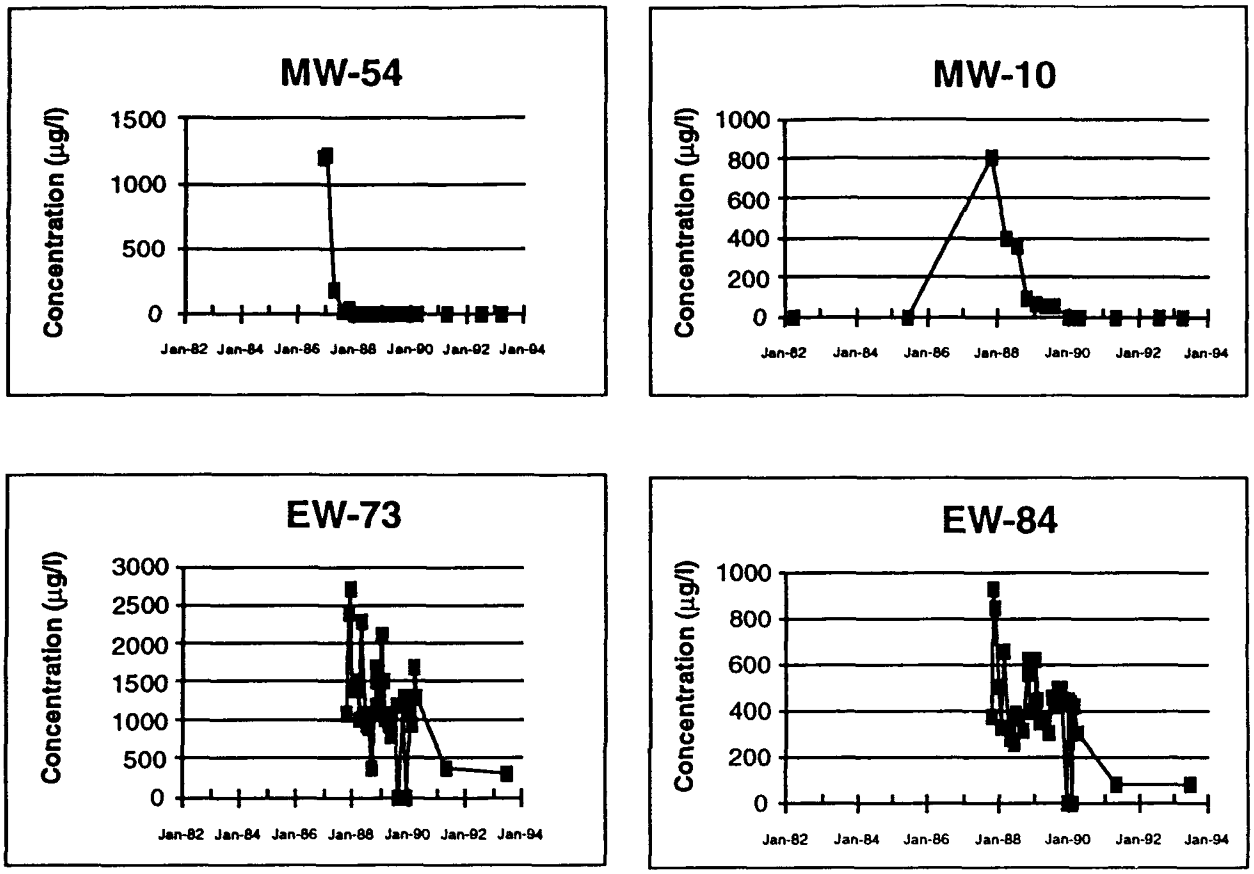


FIGURE 4-77
VINYL CHLORIDE TIME SERIES FOR WELLS IN OU D
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

For purposes of the trend analysis, contaminant concentrations were first converted to estimates of increased lifetime cancer risk using risk assessment methods. This was done to simplify the analysis of trends in wells with multiple contaminants. The risk assessment methodology and the rationale for using increased lifetime cancer risk as an indicator of the magnitude of contaminant impacts to groundwater are presented in the risk assessment, Appendix B. Plots of the trends of risk over time for each well are provided as an attachment to the risk assessment. Trends for the wells at the Base are presented in Figures 4-78 through 4-81.

Trends in Monitoring Zone A

As shown in Figure 4-78, most of the A-Zone wells within OUs A and B exhibit little change in groundwater concentrations over time. Wells where groundwater concentrations increase over time indicate contaminant releases to groundwater in the A zone in OU A. There does not appear to be a consistent pattern of trends in OU B wells in the A zone. This suggests a complex pattern of contaminant releases and groundwater extraction within OU B, resulting in wells with increasing trends in proximity to wells with no consistent or decreasing trends. As in OUs A and B, the largest proportion of A-zone wells within OU C exhibit no consistent trends. Compared with OU B, a larger proportion of OU C wells in the A zone exhibit increasing trends, suggesting continuing contaminant releases to the A zone. In other words, it is reasonable to predict that contaminant impacts to groundwater could increase over time in OUs A and C, though the magnitude of those impacts is greater in OU A, as shown in the risk assessment in Chapter 3. Contaminant trends in OU D generally are decreasing over time in the A zone.

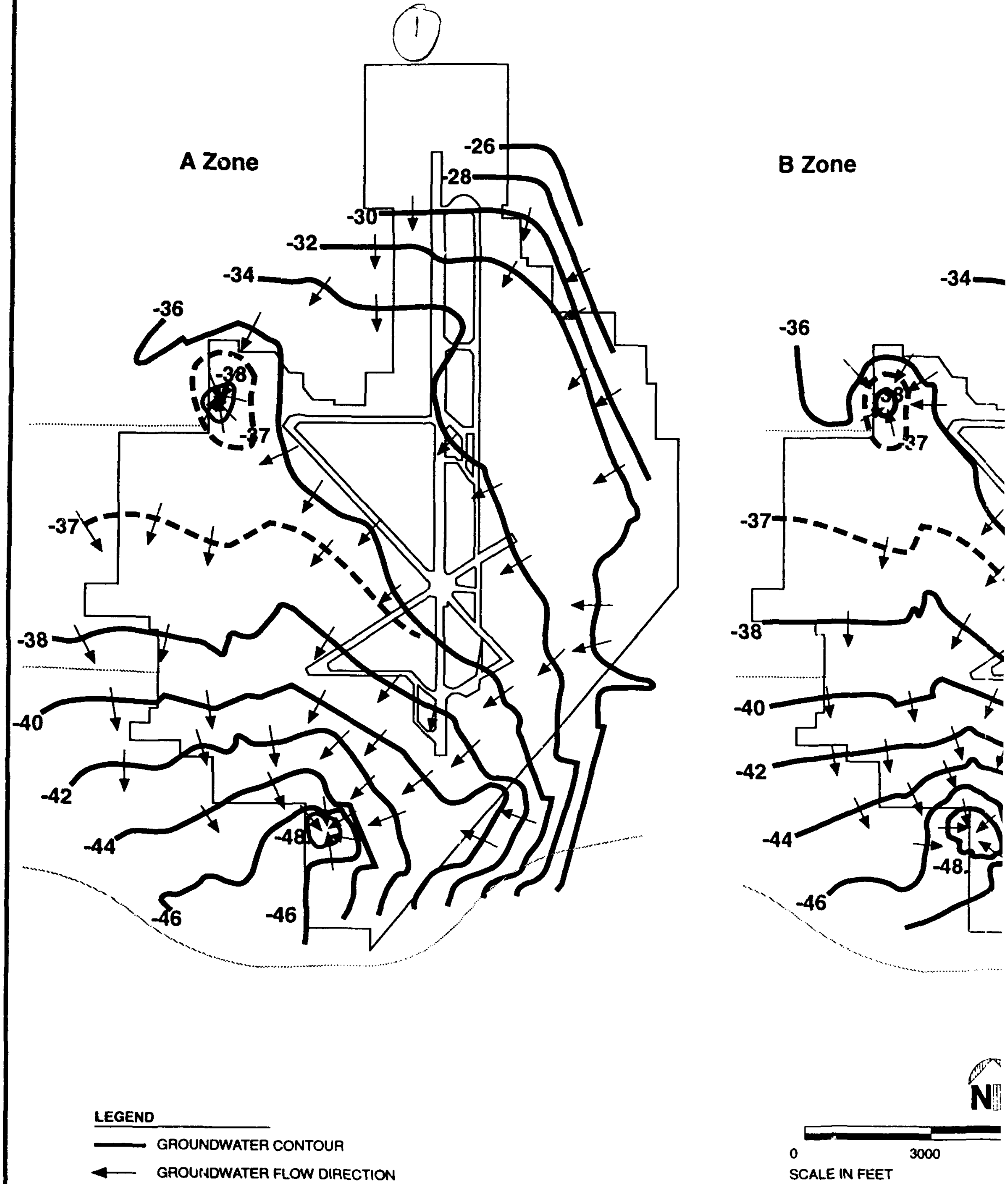
Trends in Monitoring Zones B through D

Trends within the B-zone generally show fluctuations in concentrations. The largest uncertainties in contaminant trends are in B-zone wells within OUs A, B, and D. The large proportion of wells with no consistent trends suggests that groundwater impacts within the deeper monitoring zones are relatively localized. One reasonable explanation, as suggested by DTSC, is that several deeper wells have incompetent annular seals that leak and allow shallow contaminated groundwater to migrate down to deeper zones along the well annulus. Within the C zone, there are more wells with increasing trends compared with B-zone wells. For OU C, this could be due to contaminant migration from sources within OU D, rather than vertical migration from shallower zones within OU C. D-zone wells within OU B show significant uncertainty in contaminant trends. D-zone wells within OU C generally show no consistent or decreasing trends in concentration in groundwater.

Future Conditions

This section discusses the future conditions that will develop regarding the distribution of contamination if no remedial action is implemented at the Base. These conclusions are based on a No-Action Alternative simulation performed using the groundwater flow model (Chapter 8). BW-18 was assumed to be abandoned in this simulation as the agencies have stated their concern that it is a potential conduit for contamination to move into deeper zones and that it should be abandoned. In actuality, BW-18 will be in operation until 1997 or 1998. BW-18 will not be decommissioned until adequate remedy extraction wells are in operation to prevent offbase migration of the southern section of the OU B/C plume.

The groundwater flow simulations indicate that groundwater in Monitoring Zones A, B, and C will move south to southwesterly if no remedial action is implemented. A downward gradient will also prevail between all of the monitoring zones at the Base except in areas of existing shallow extraction. The result of these hydrologic conditions is that contamination currently residing at OU A and OU B/C will move south/southwest toward the municipal production wells located south of the Base. The predominant downward gradient will also continue to move contamination downward into deeper units as the plume travels southwesterly. Although contamination in the background target volume below 0.55 μg/l will arrive at the municipal wells in a fairly short amount of time, higher concentrations of contaminants in the risk and MCL target volumes have a relatively long distance remaining to travel and will not reach municipal wells for a decade or more. Finally, most of the contamination at OU D is currently contained by the existing extraction system, and only low concentrations of contaminants are expected to migrate away from that OU.



LEGEND

GROUNDWATER CONTOUR

GROUNDWATER FLOW DIRECTION

ADDITIONAL CONTOURS TO SHOW FLOW DIRECTION

Contours based on January 1993 Water Levels.
Data available on Figures 4-35, 4-36, and 4-37.

RDD1454_118

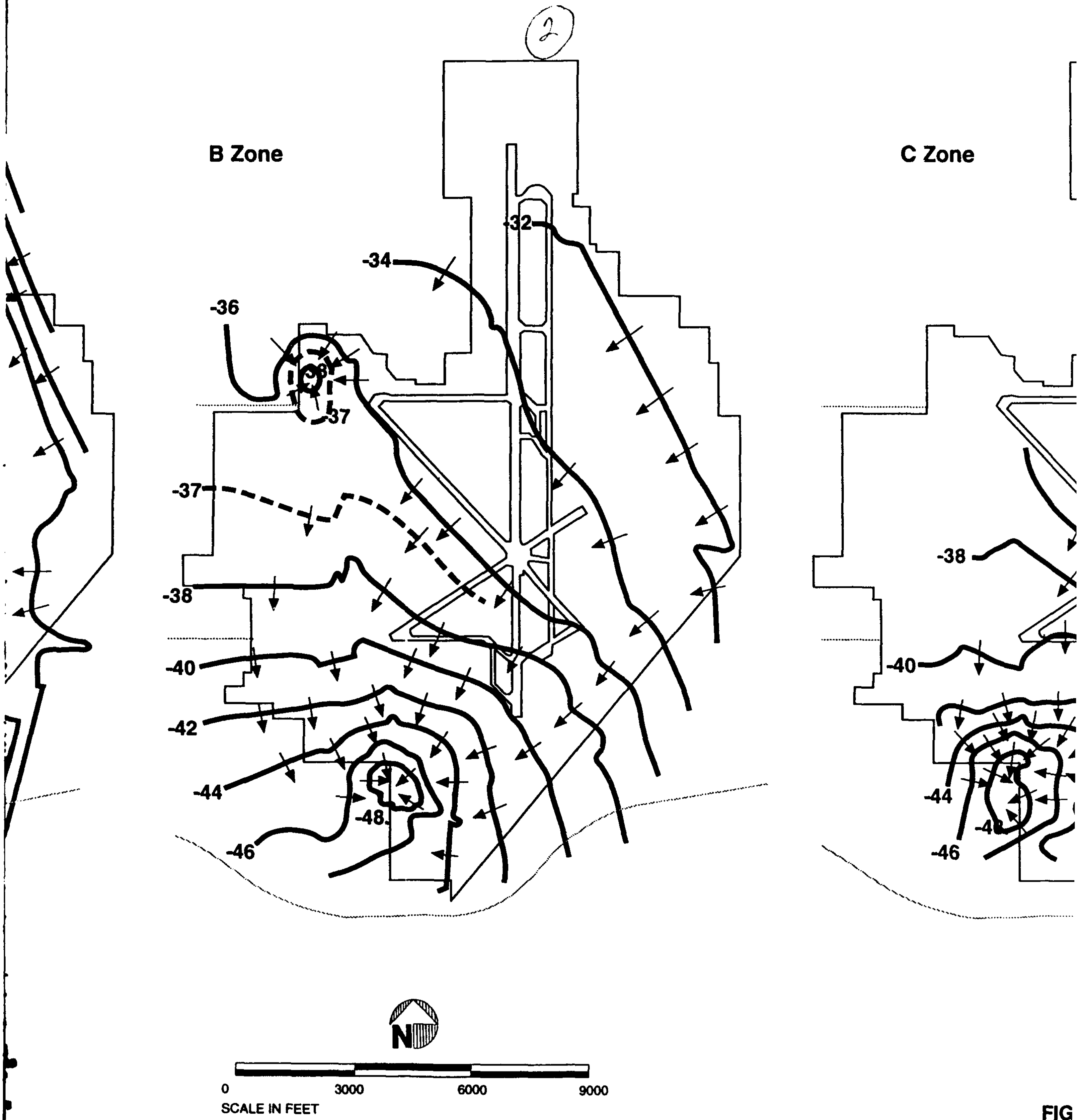


FIG
FL
B, A
GRO
McCl
SACI

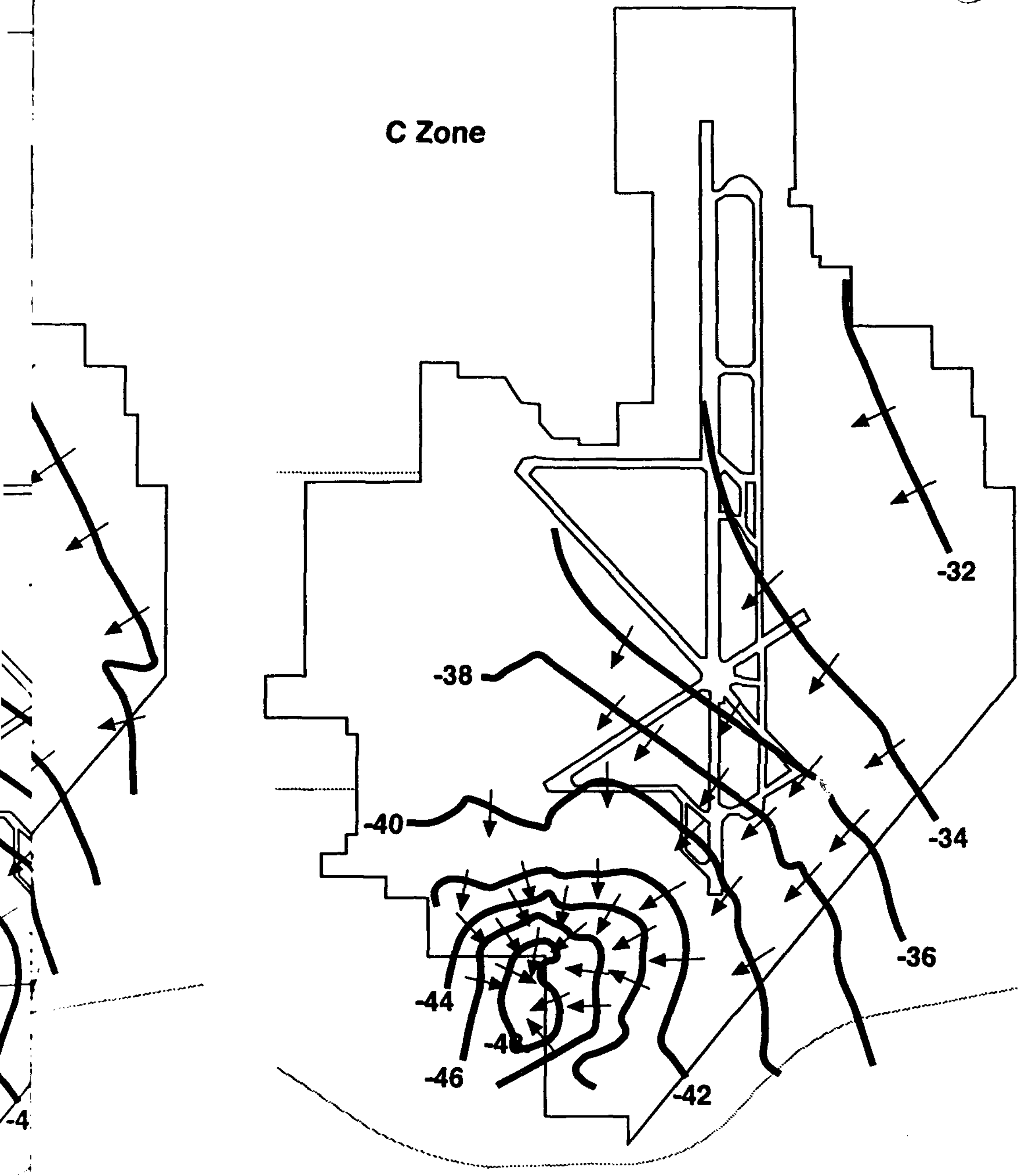
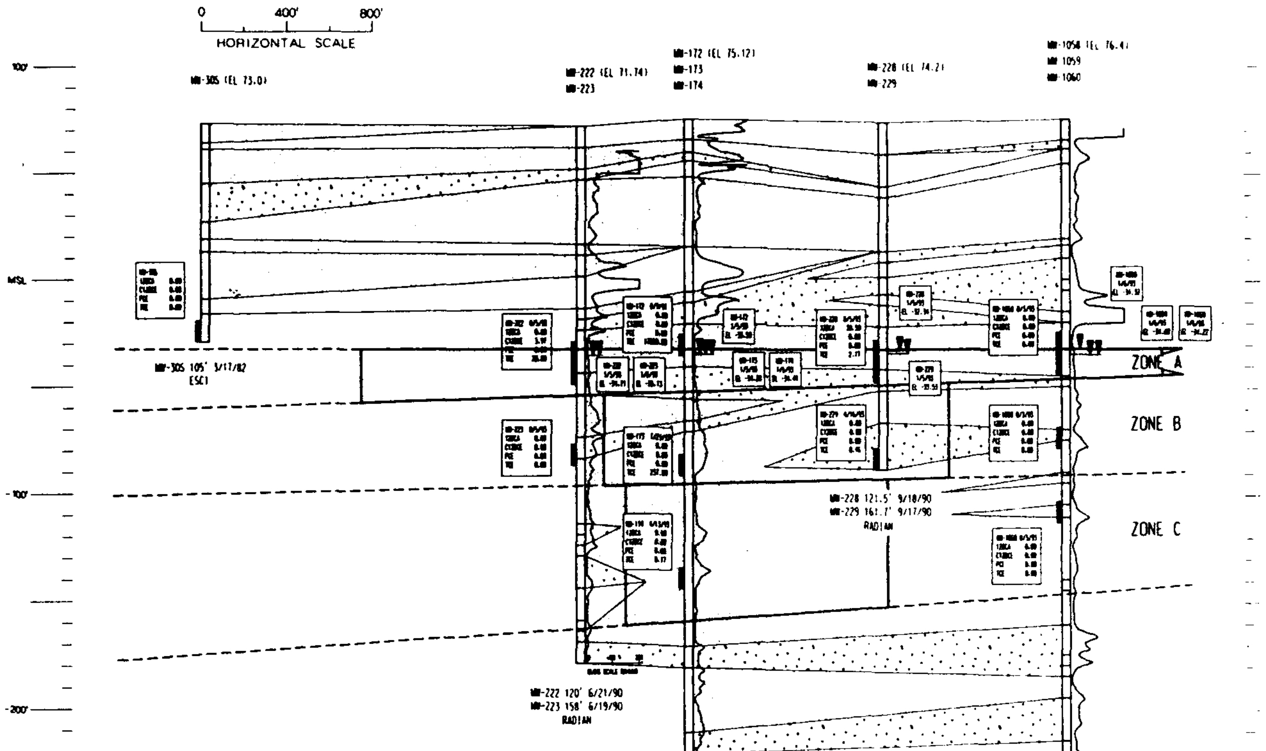


FIGURE 4-3
FLOW DIRECTIONS IN THE A, B, AND C ZONES (JANUARY, 1993)
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

(1)

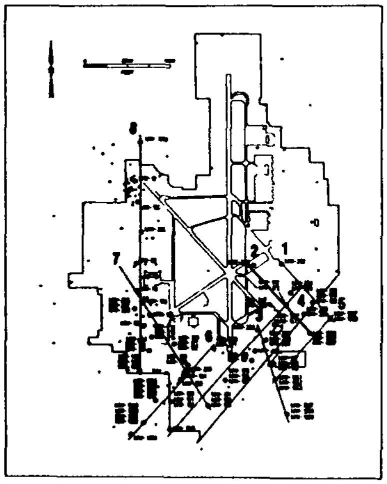
CROSS SECTION 2



NOTES

1. Flow direction of depositional channels is approximately perpendicular to the cross section. Groundwater generally follows the course of the channel deposits, but is strongly influenced by regional pumping south of the Base.

2. Groundwater levels in MW-1058 and MW-1060 have dropped more than 30 feet between first and third quarter measurements, while other wells in the cross section show no seasonal extremes.

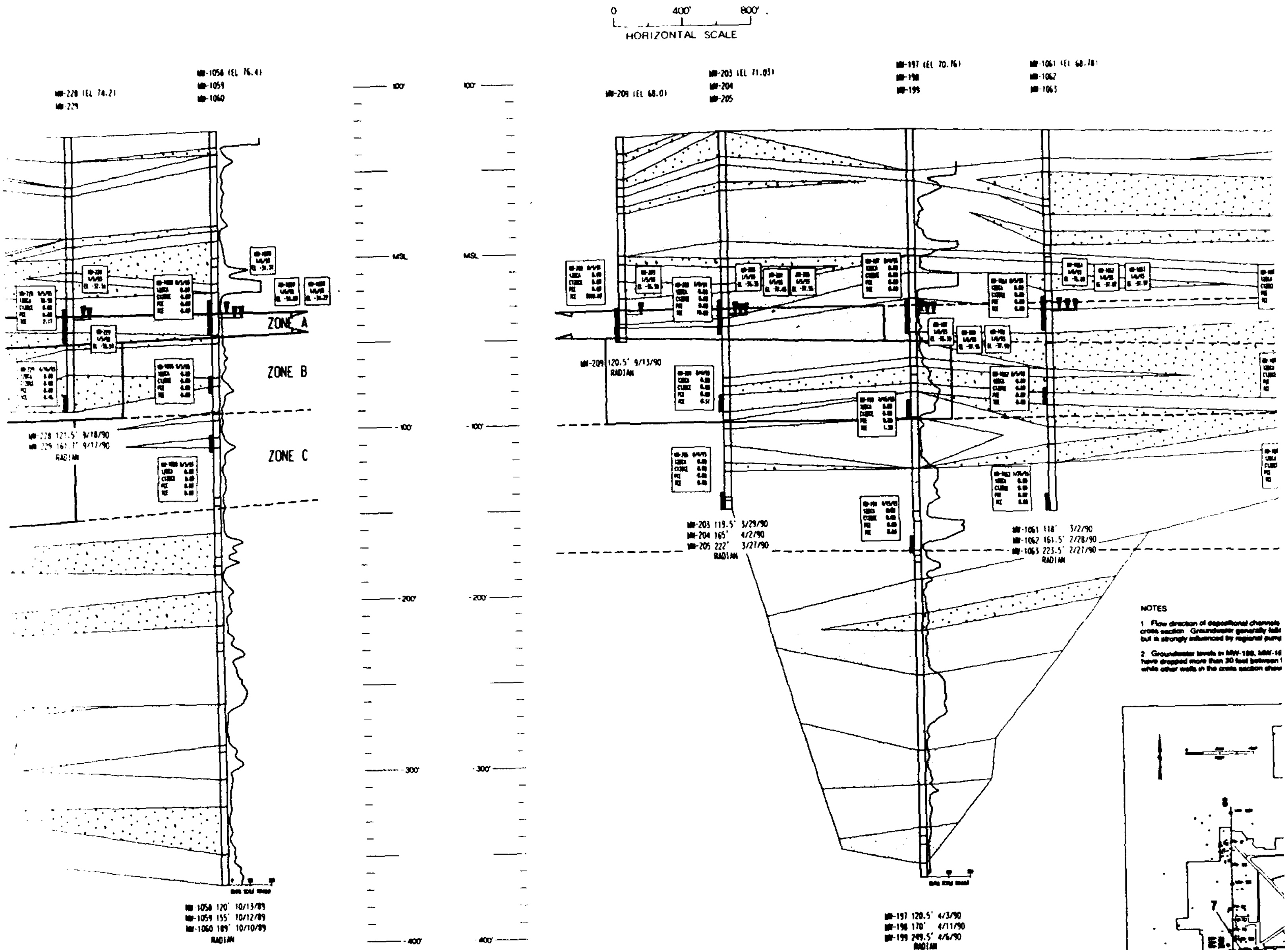


SITE MAP

SWE 28722.84.

(2)

CROSS SECTION 3



LEGEND

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

NOTES

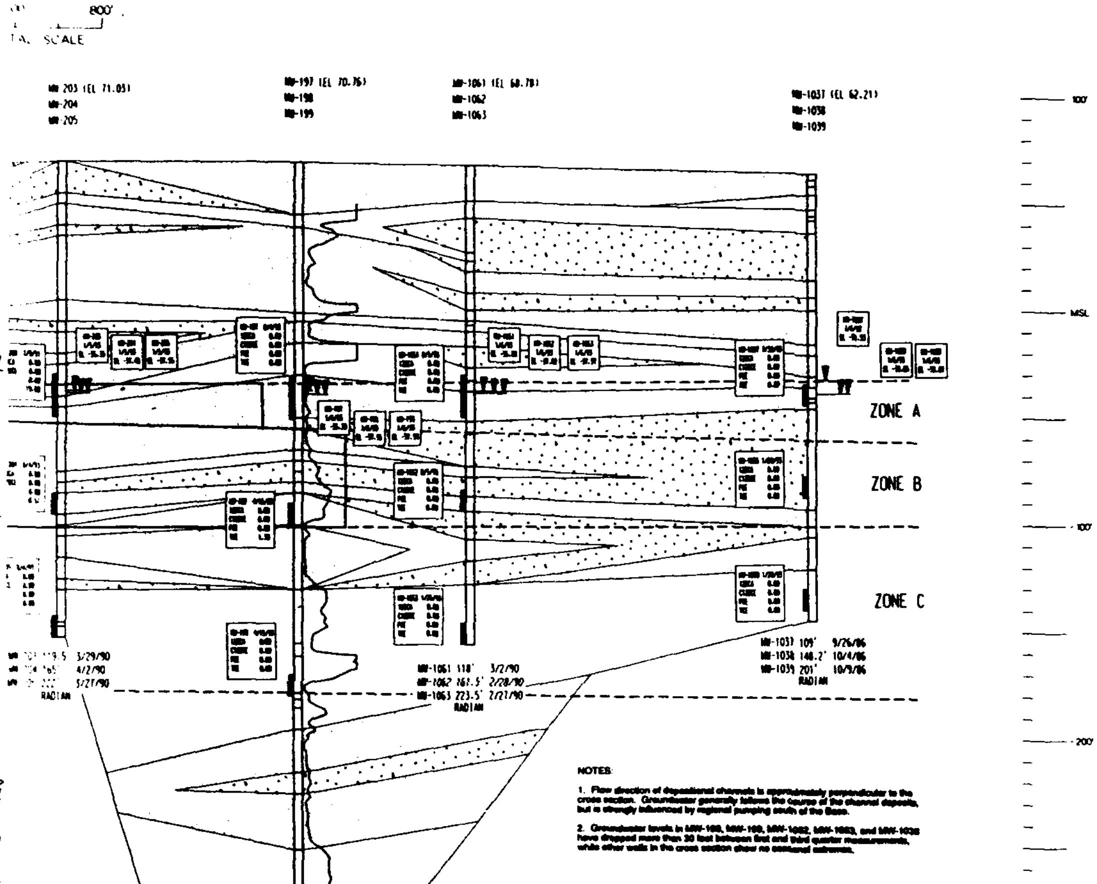
1. Flow direction of depositional channels ... cross section. Groundwater generally ... but is strongly influenced by regional pum...

2. Groundwater levels in MW-198, MW-1... have dropped more than 30 feet between ... while other wells in the cross section show...

SITE M...

FIGU...
CRO...
IN T...
GROU...
McCLE...
SACR...

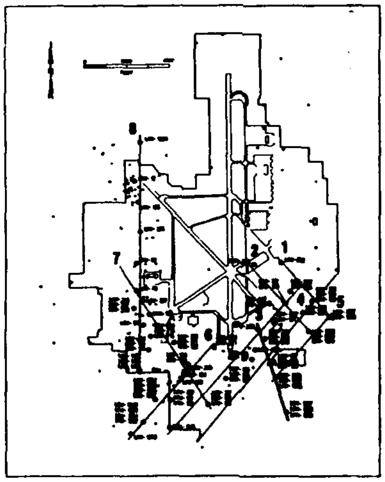
CROSS SECTION 3



NOTES:

1. Flow direction of depositional channels is approximately perpendicular to the cross section. Groundwater generally follows the course of the channel deposits, but is strongly influenced by regional pumping south of the Base.

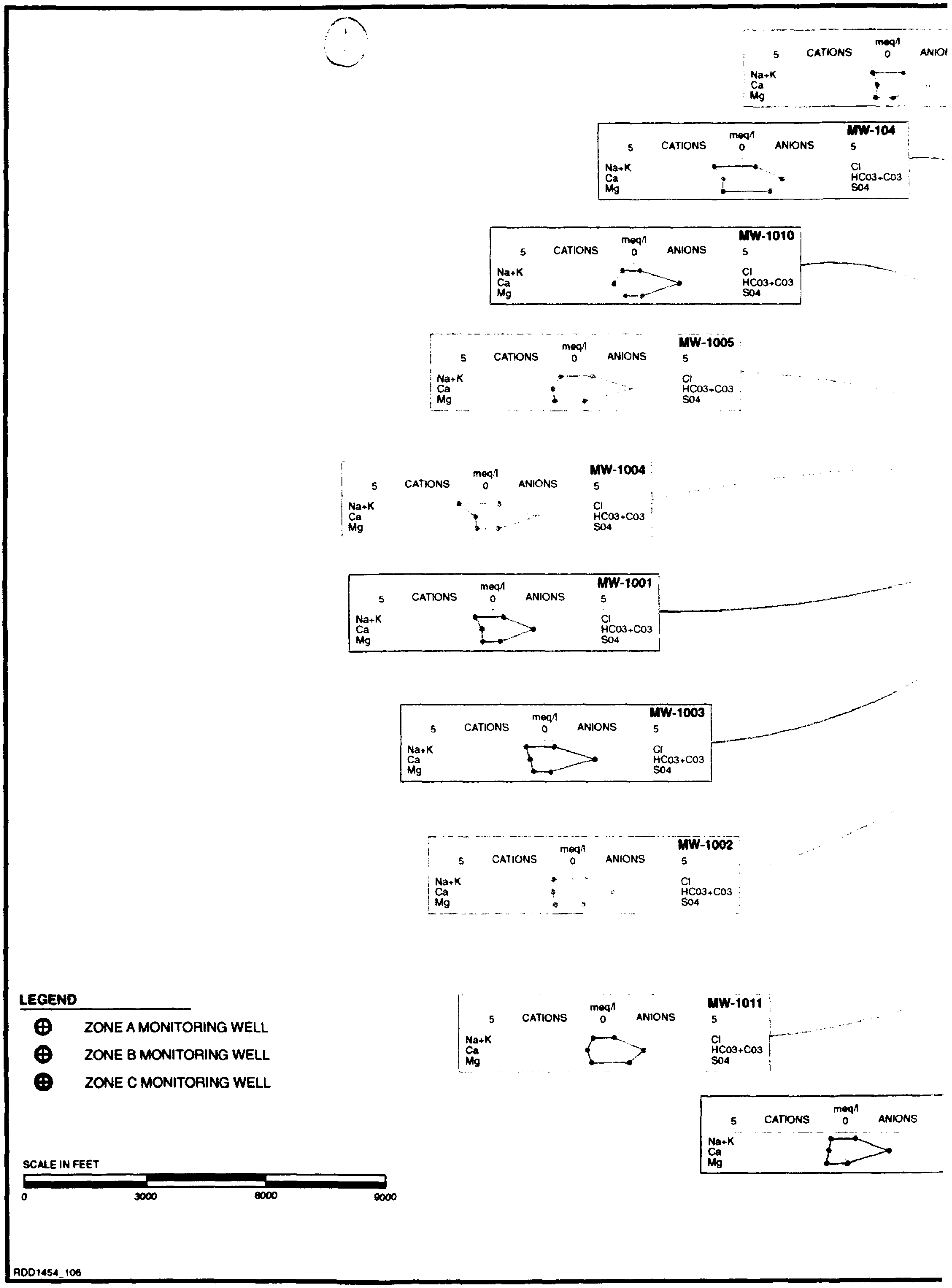
2. Groundwater levels in MW-198, MW-199, MW-1062, MW-1063, and MW-1038 have dropped more than 30 feet between first and third quarter measurements, while other wells in the cross section show no seasonal extremes.



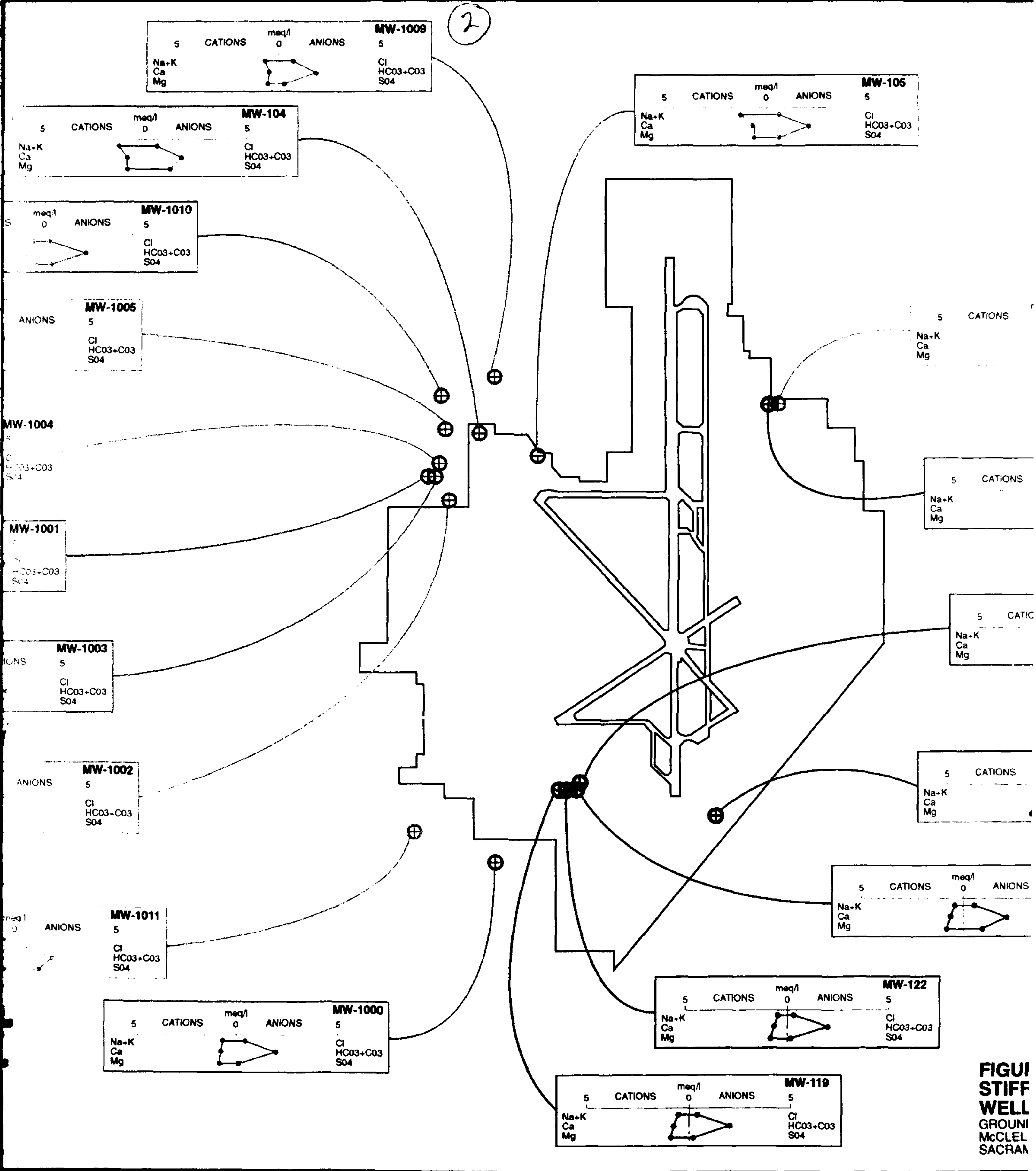
SITE MAP

FIGURE 4-4
CROSS SECTIONS
IN THE VICINITY OF OU A
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


MW-104
MW-1010
MW-1005
MW-1004
MW-1001
MW-1003
MW-1002
MW-1011
5 CATIONS meq/l 0 ANIONS 5
Na+K
Ca
Mg
Cl
HC03+C03
S04
LEGEND
ZONE A MONITORING WELL
ZONE B MONITORING WELL
ZONE C MONITORING WELL
SCALE IN FEET
0
3000
9000
RDD1454_106

(2)



FIGU
STIFF
WELL
GROUN
McCLEL
SACRAM

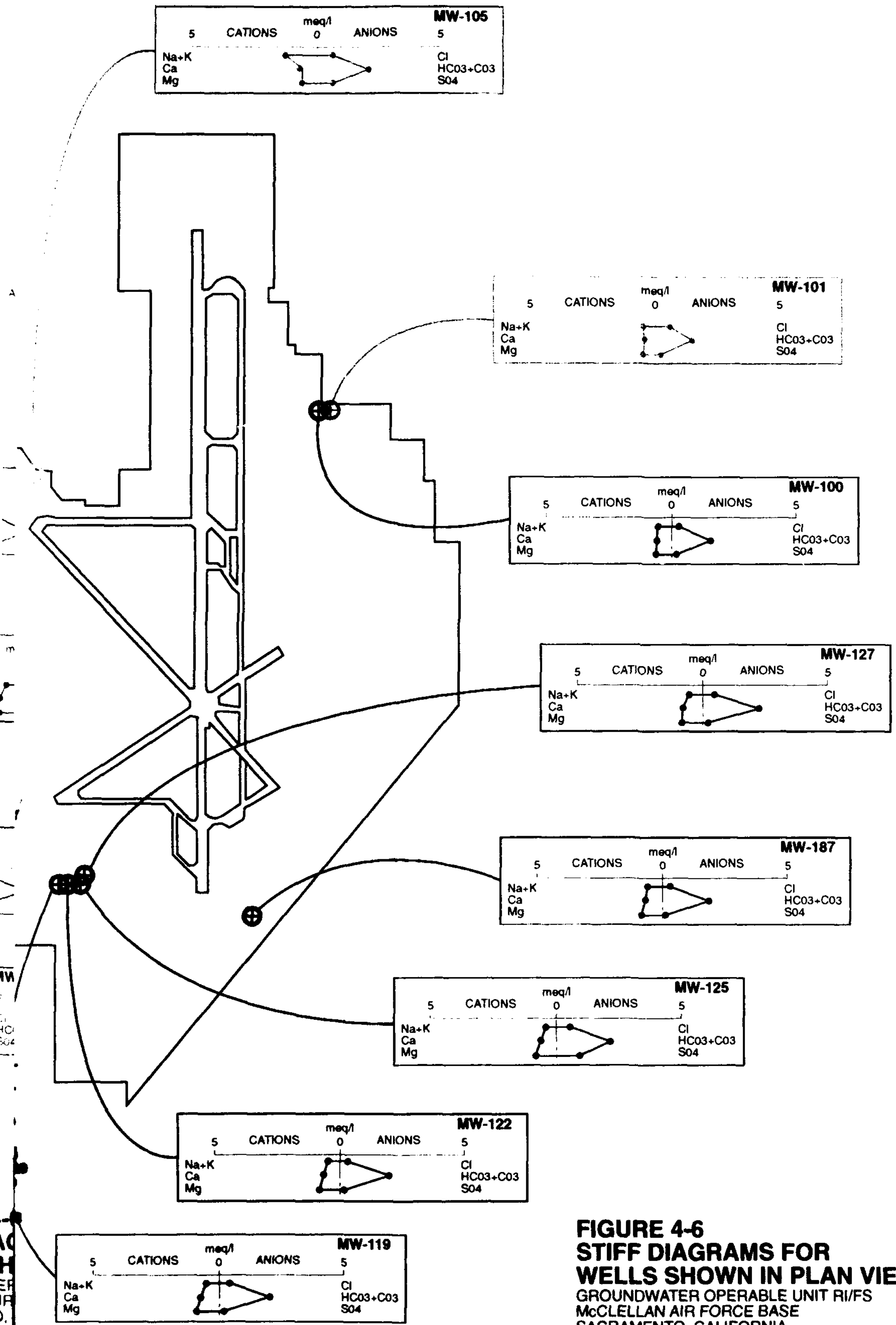
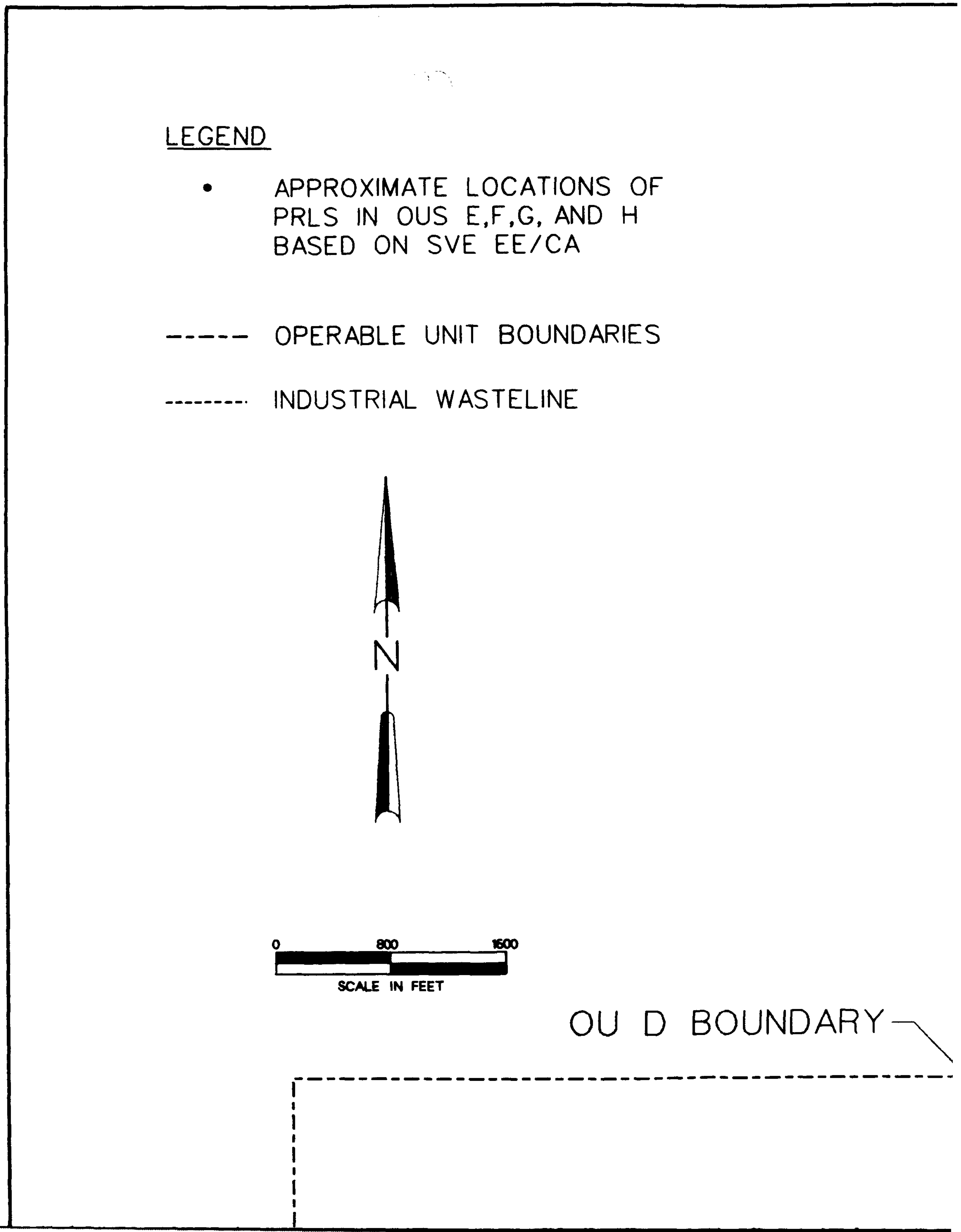
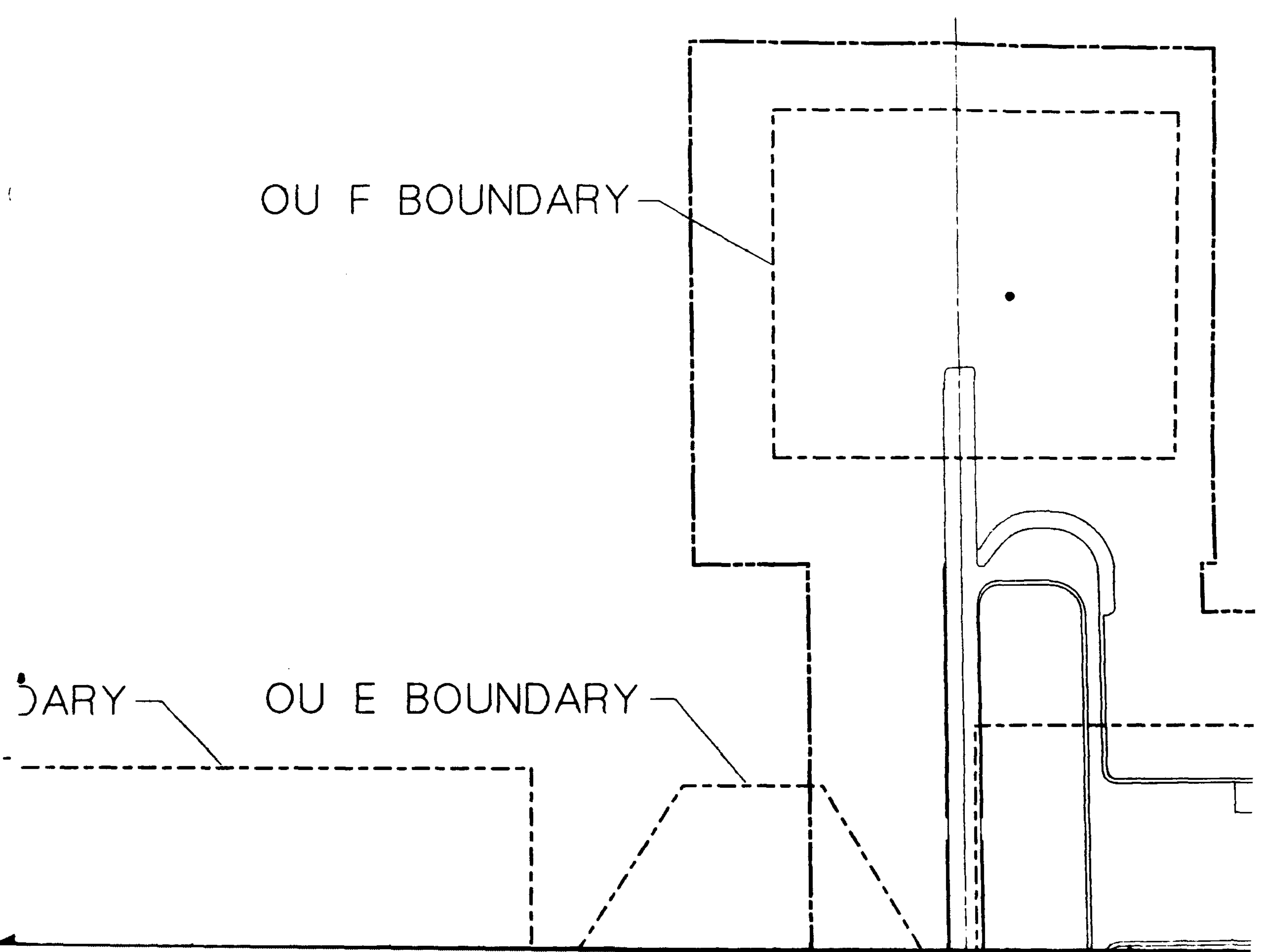
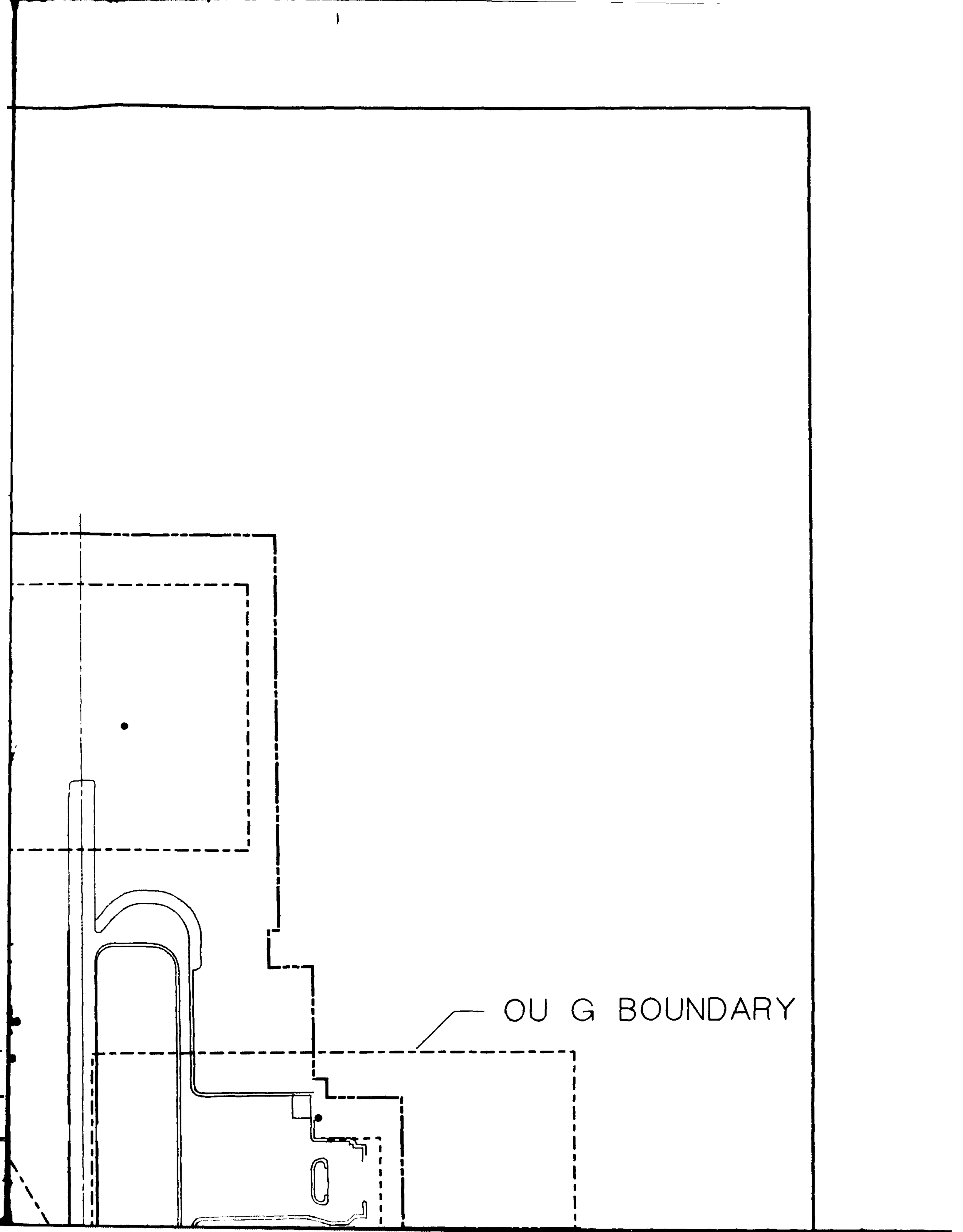


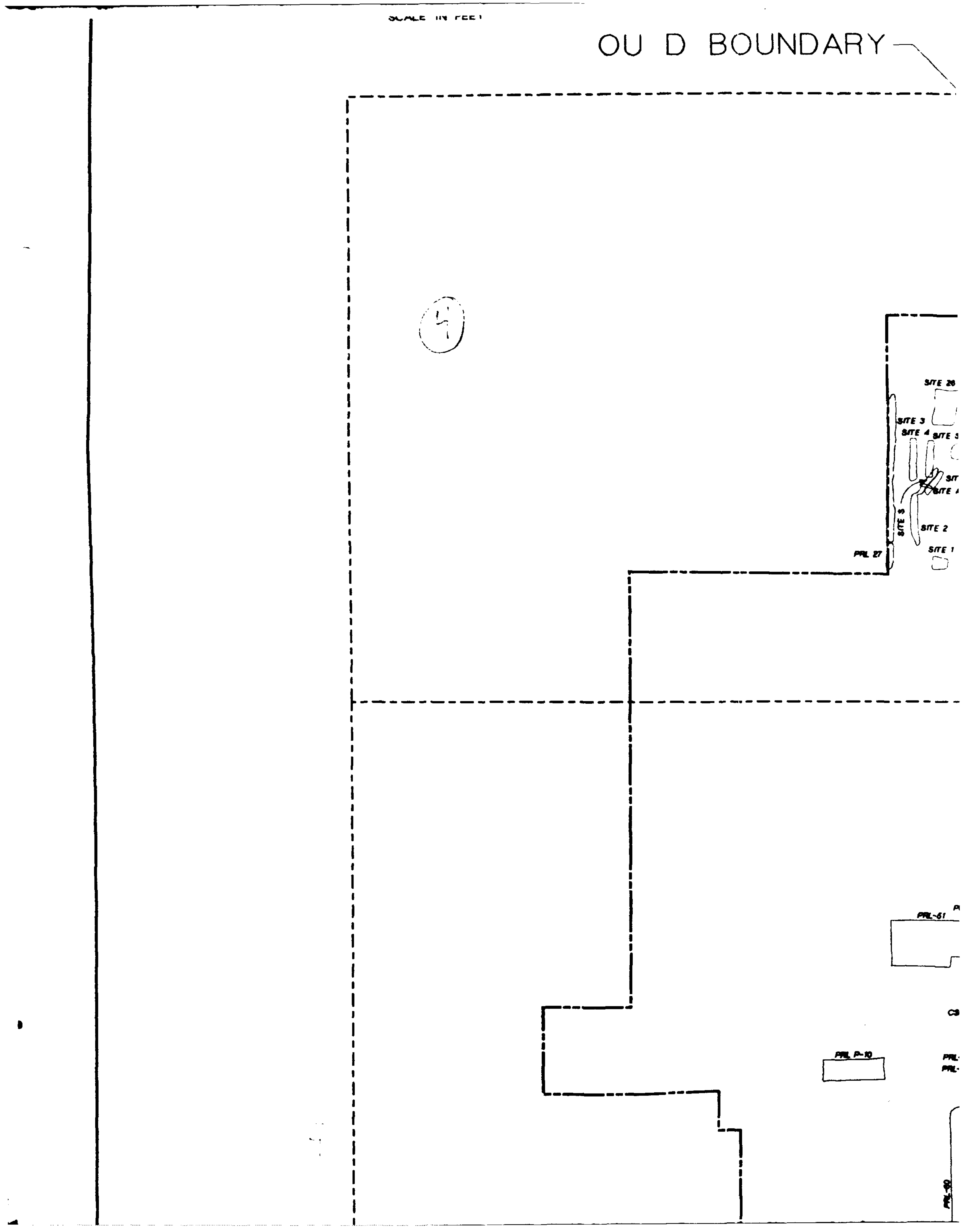
FIGURE 4-6
STIFF DIAGRAMS FOR WELLS SHOWN IN PLAN VIEW
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

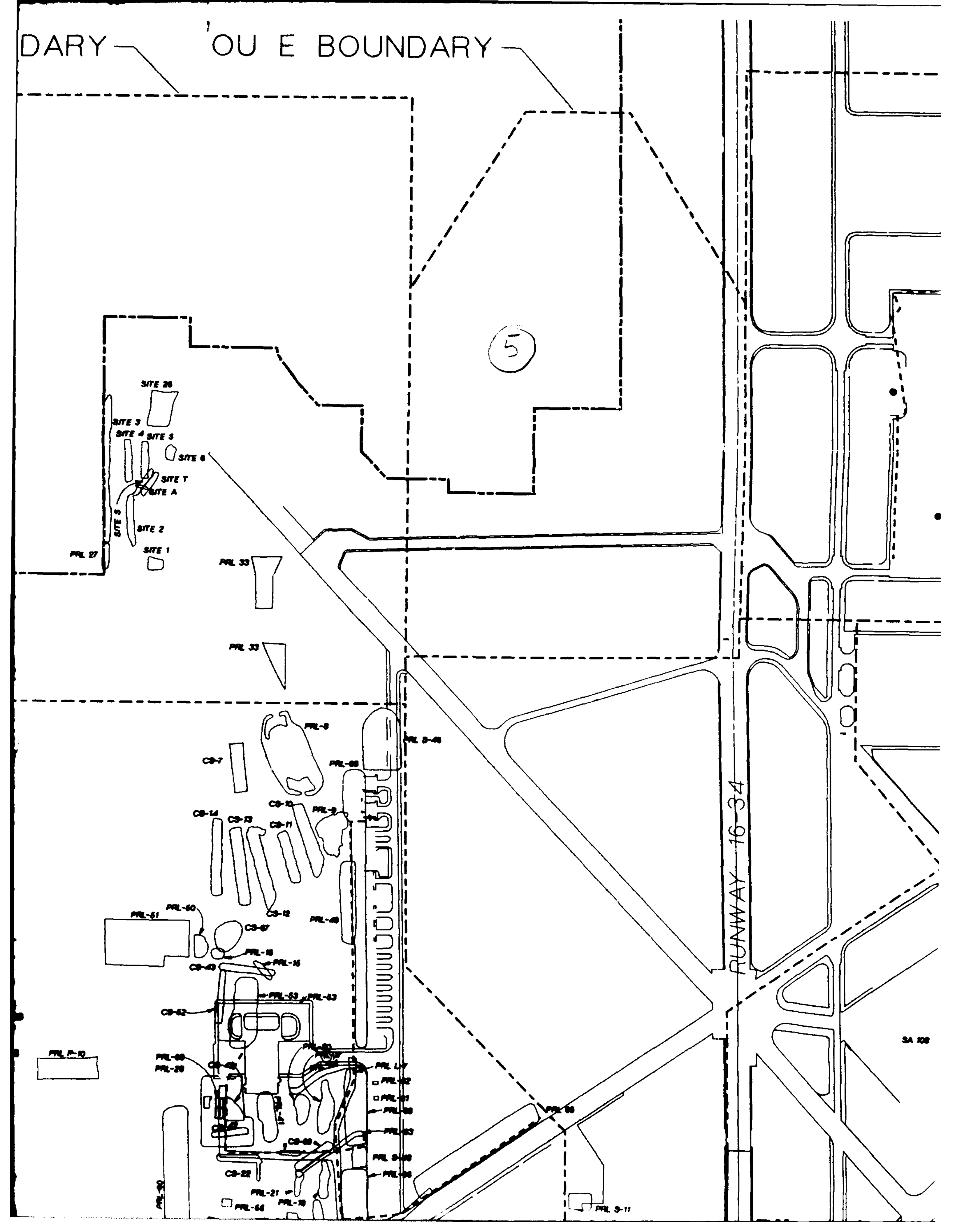

LEGEND
• APPROXIMATE LOCATIONS OF PRLS IN OUS E,F,G, AND H BASED ON SVE EE/CA
----- OPERABLE UNIT BOUNDARIES
--------- INDUSTRIAL WASTELINE
N
0
800
1600
SCALE IN FEET
OU D BOUNDARY

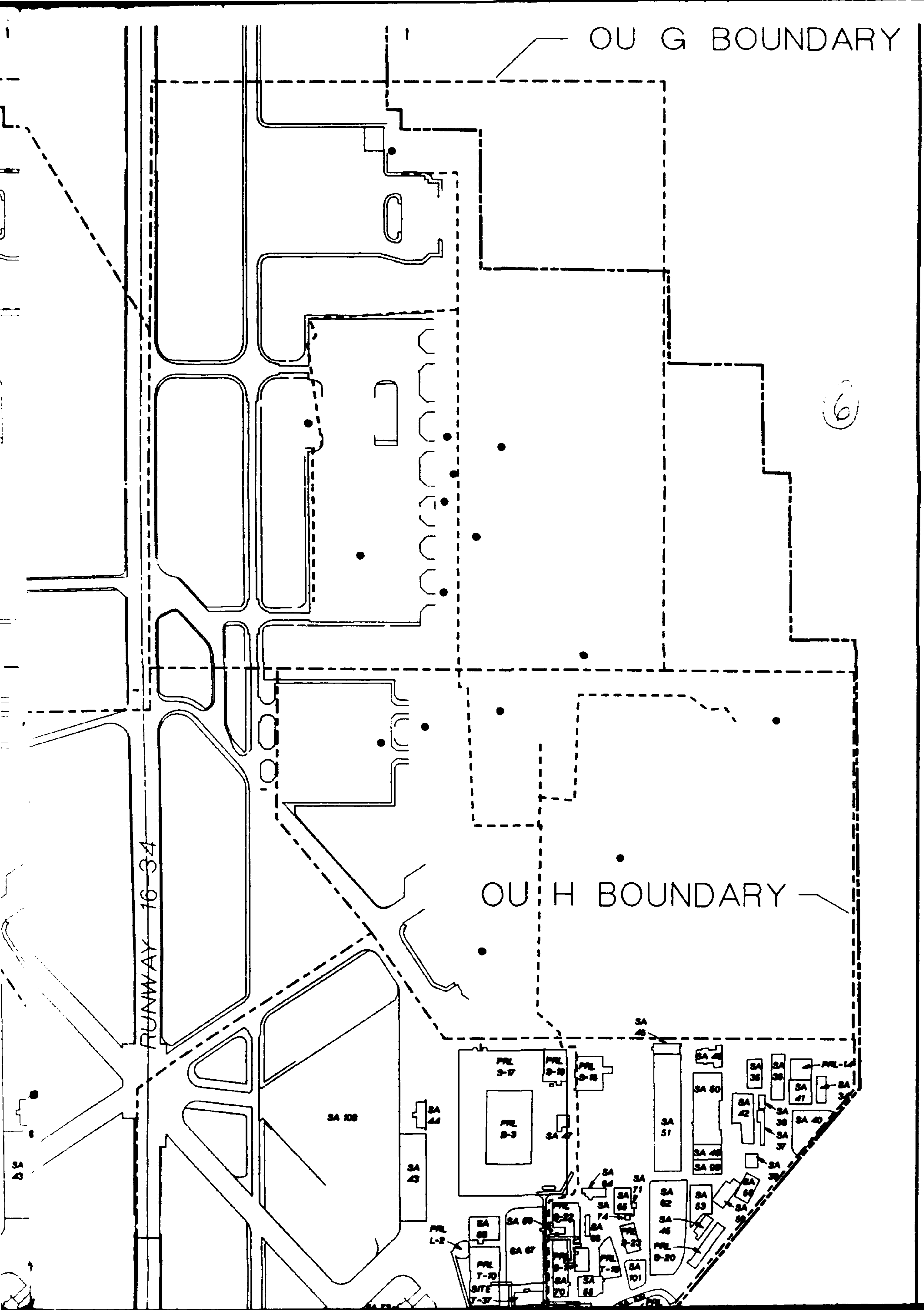

OU F BOUNDARY
ARY
OU E BOUNDARY


OU G BOUNDARY

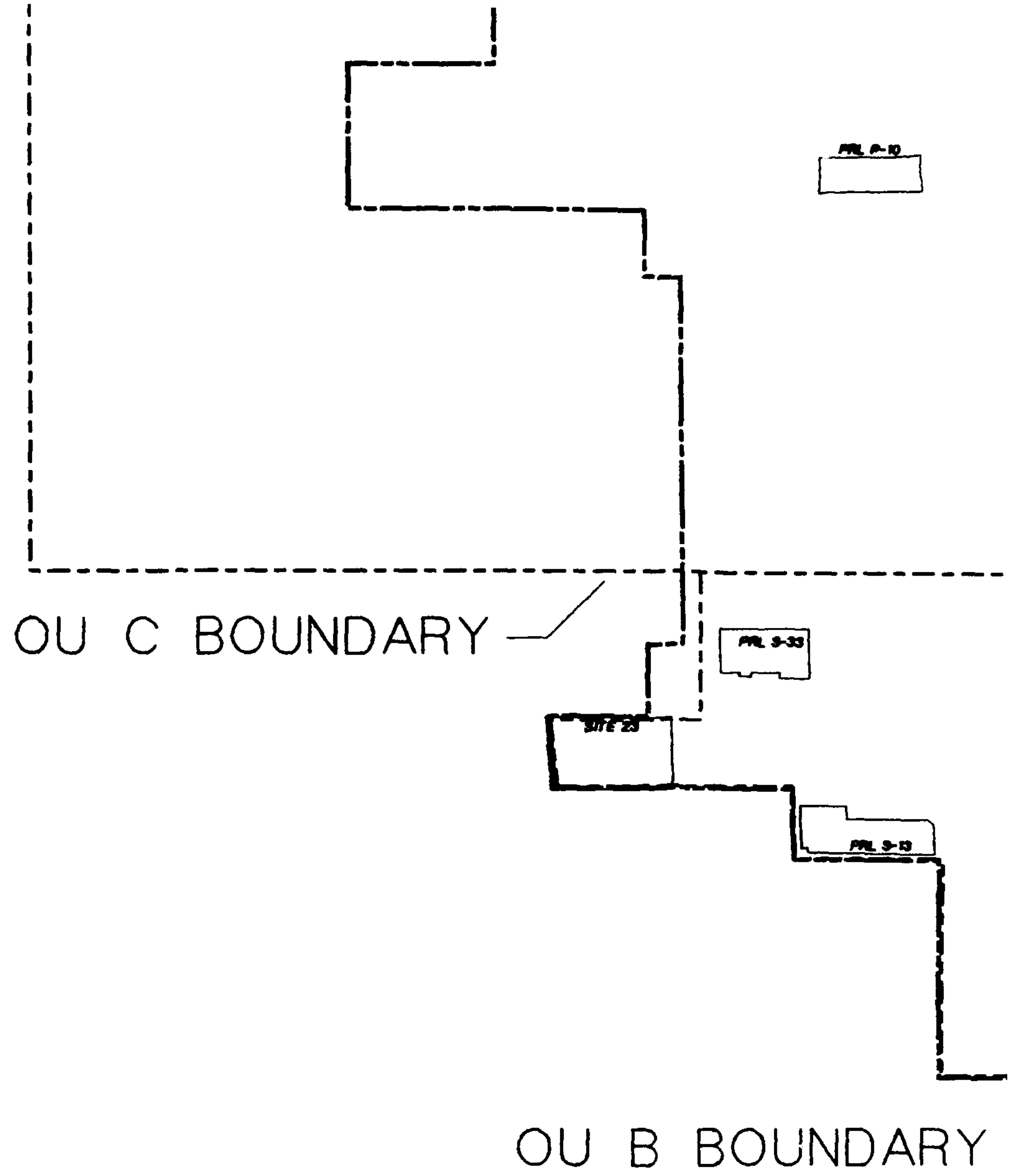


OU D BOUNDARY
SITE 20
SITE 3
SITE 4
SITE 2
SITE 1
PRL 27
PRL-61
PRL P-10


DARY
OU E BOUNDARY
5
SITE 26
SITE 3
SITE 4
SITE 5
SITE 6
SITE T
SITE A
SITE 2
SITE 1
PRL 27
PRL 33
PRL 33
PRL-8
CS-7
CS-10
PRL-9
CS-14
CS-13
CS-11
CS-12
PRL-60
PRL-61
CS-67
PRL-18
PRL-15
CS-43
CS-52
PRL P-10
CS-22
PRL-21
PRL S-11
RUNWAY 16-34
SA 108


OU G BOUNDARY
OU H BOUNDARY
RUNWAY 16-34
SA 108
SA 44
SA 43
PRL S-17
PRL S-16
PRL B-3
SA 47
SA 48
SA 51
SA 50
SA 49
SA 36
SA 41
SA 42
SA 40
PRL L-2
PRL T-10
SITE T-37
SA 67
SA 62
SA 53
SA 101

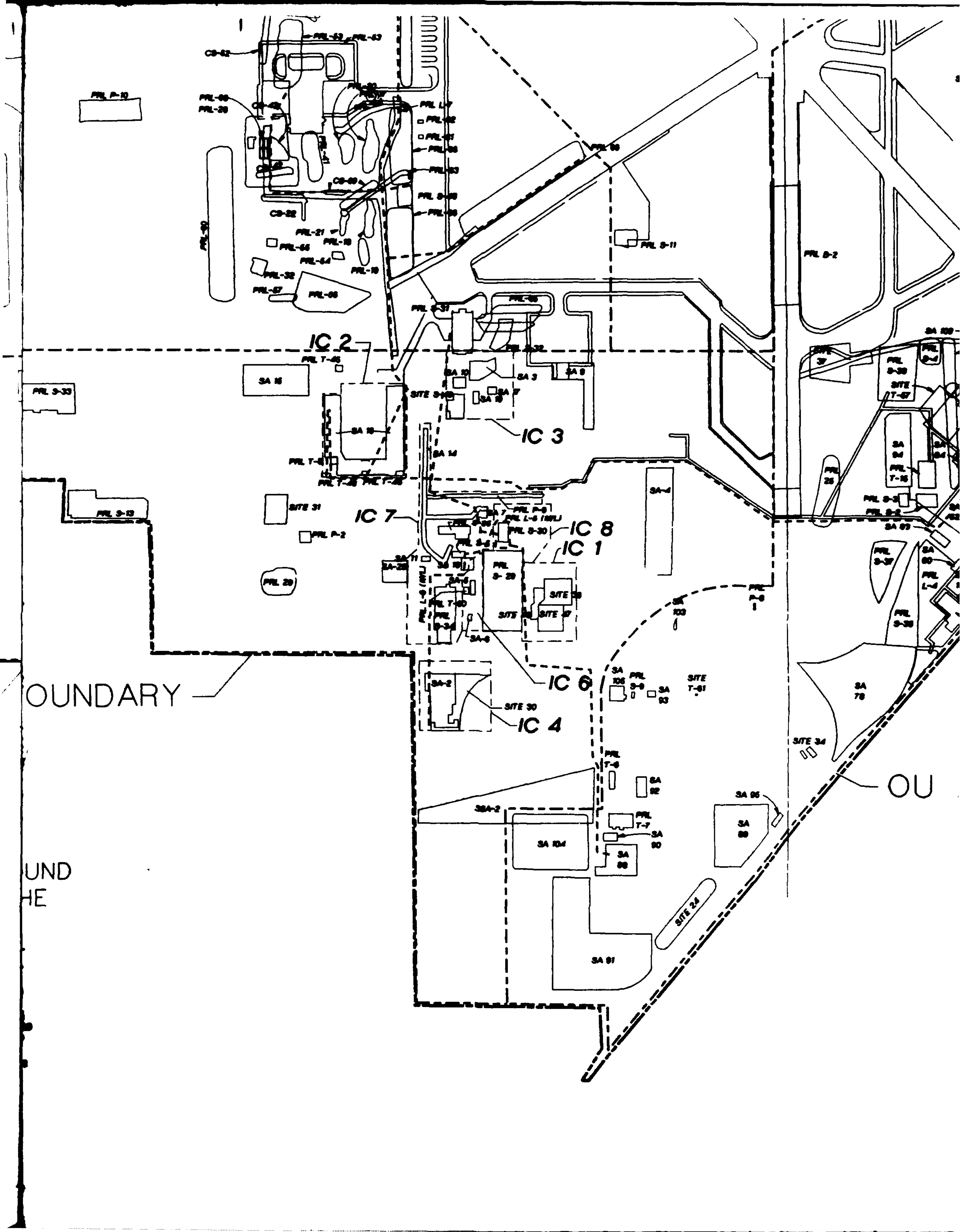
6



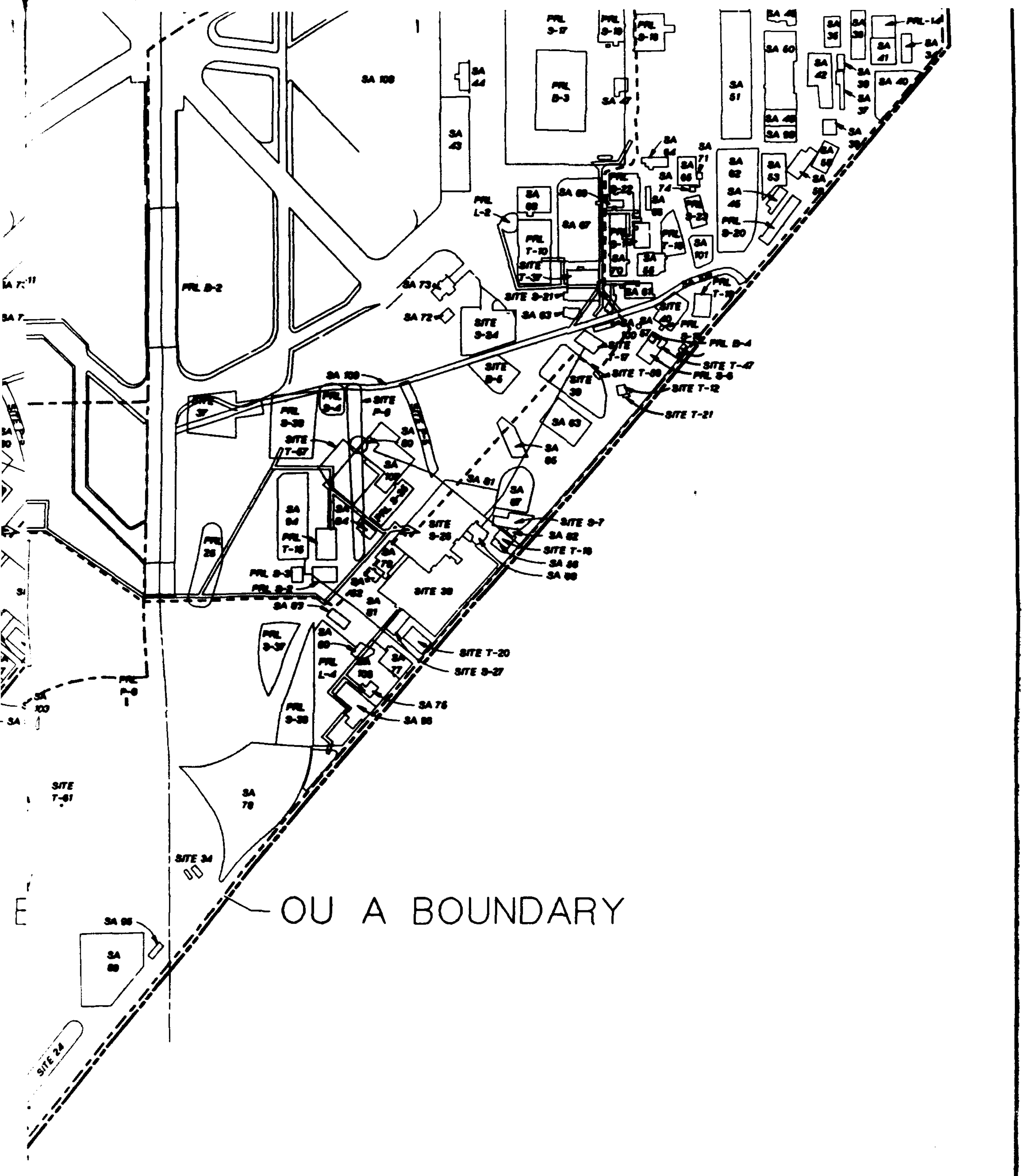
7

NOTE:

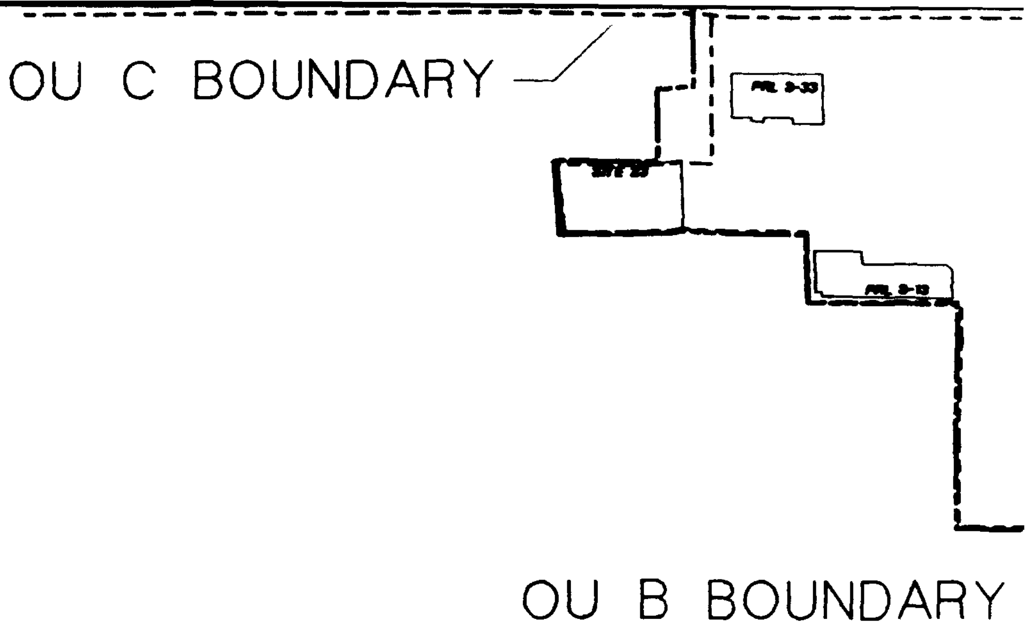
SOURCE AREA LABELS CAN BE FOUND IN THE CONCEPTUAL MODEL OF THE GWOU RI/FS (CH2M HILL, 1994)



IC 2
IC 3
IC 7
IC 8
IC 1
IC 6
IC 4
OUNDARY
UND
HE
OU
SA 16
SA 91
SA 104
SA-4
SA 78
SITE 31
SITE 30
SITE 34
SITE 24
PRL 28
PRL 8-2
PRL S-11
PRL S-13
PRL S-33
PRL P-10
PRL P-2



OU A BOUNDARY
PRL B-2
PRL B-3
PRL S-17
SA 43
SA 44
SA 51
SA 60
SA 40
SA 67
SA 63
SA 72
SA 73
SITE S-34
SITE S-21
SITE T-37
PRL T-10
PRL L-2
SA 109
SITE 37
PRL S-39
SITE T-57
SITE P-6
PRL 26
PRL T-15
SITE S-26
SITE 38
SITE T-20
SITE S-27
SA 76
SA 78
PRL S-37
PRL S-38
PRL L-4
SITE 34
SITE 24
SITE T-61
SITE S-7
SITE T-16
SITE T-12
SITE T-21
SITE T-47
PRL S-20
PRL B-4
SA 101
SA 53
SA 100



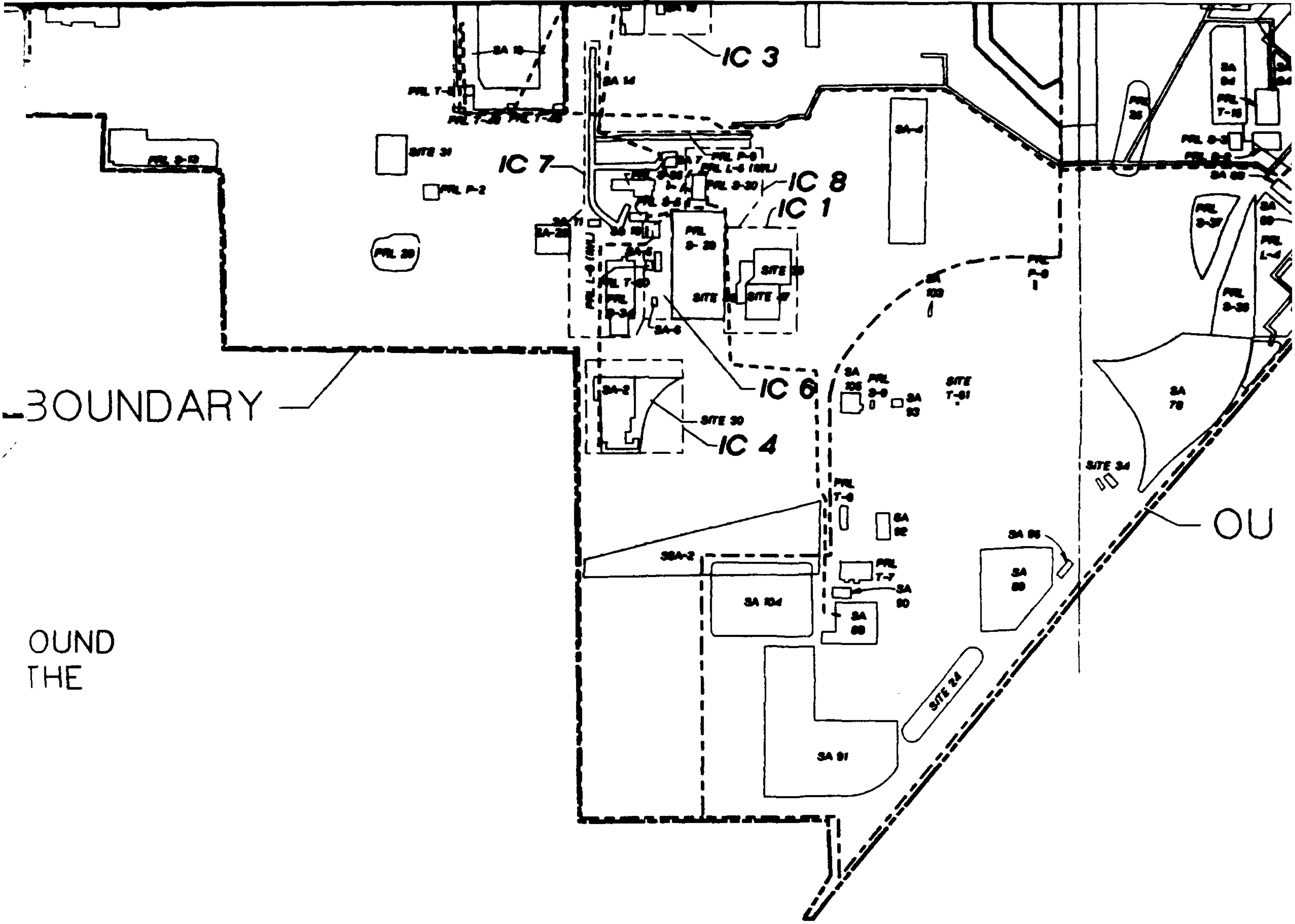
NOTE:

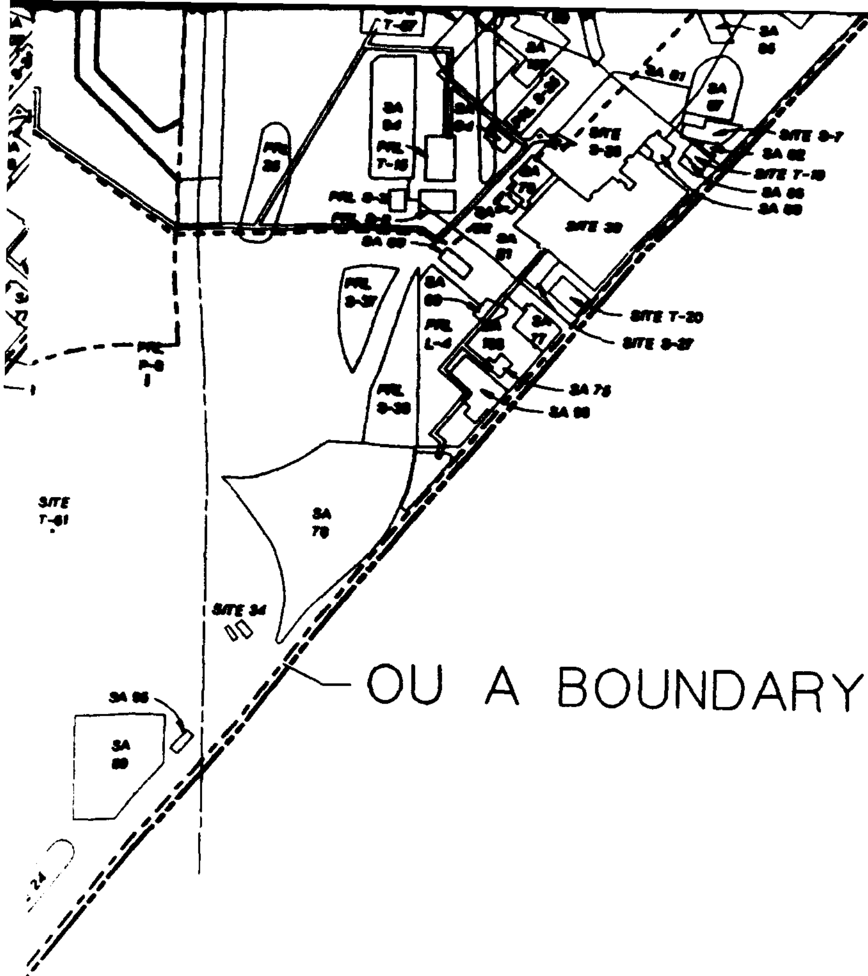
SOURCE AREA LABELS CAN BE FOUND IN THE CONCEPTUAL MODEL OF THE GWOU RI/FS (CH2M HILL, 1994)

10

RDD 1454

MEY94/4-11.DGN

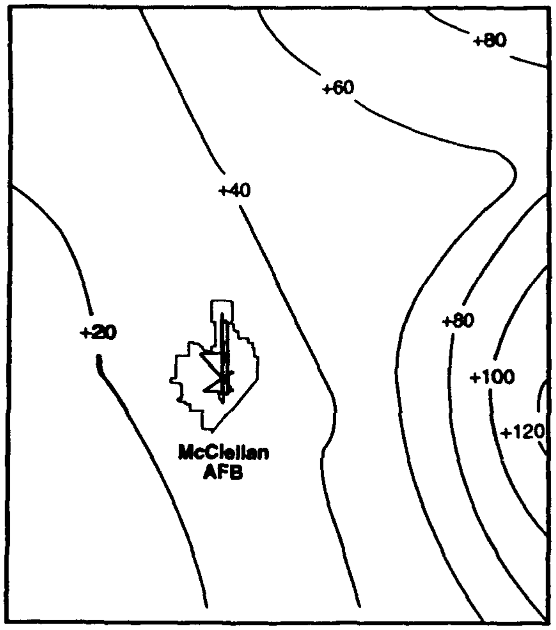

IC 3
IC 7
IC 8
IC 1
IC 6
IC 4
BOUNDARY
OU
OUND
THE
SITE 31
FRL P-2
FRL 28
SA-4
SA-2
SITE 30
SSA-2
SA 104
SA 91
SITE 24
SITE 34
SA 78
SA 89
SA 92
SA 88



12

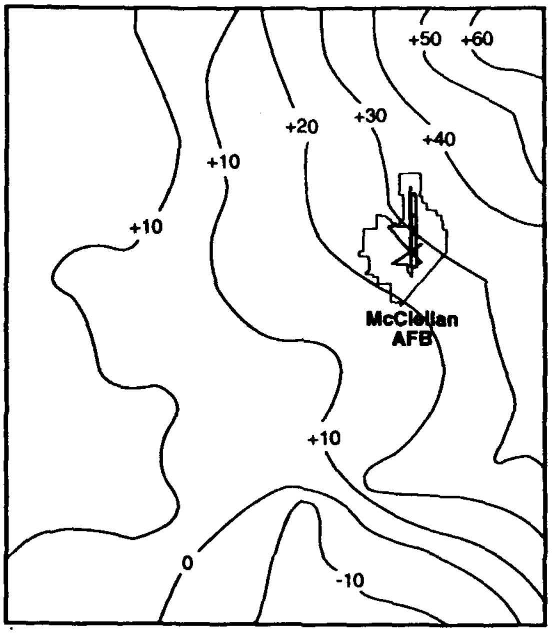
FIGURE 4-11
MAP OF OU BOUNDARIES SOURCE AREASAND IWL
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



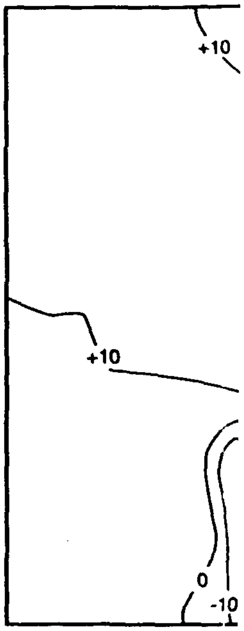
Spring 1912

SOURCE: CH2M HILL, July 1981



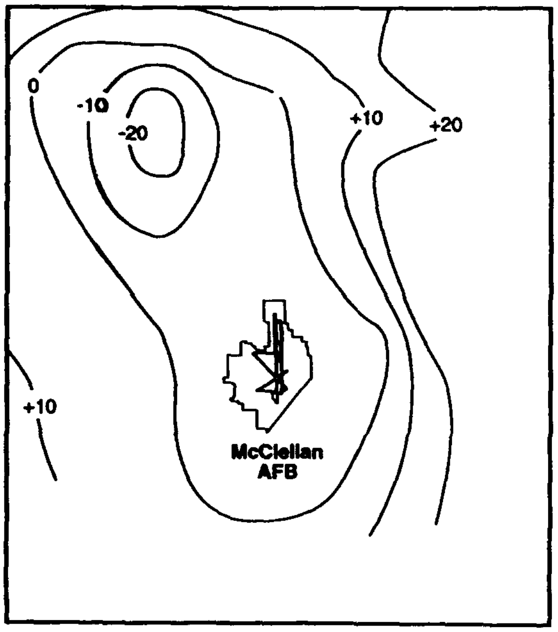
Spring 1953

SOURCE: County of Sacramento Dept. of Public Works, Water Resources Division, 1989



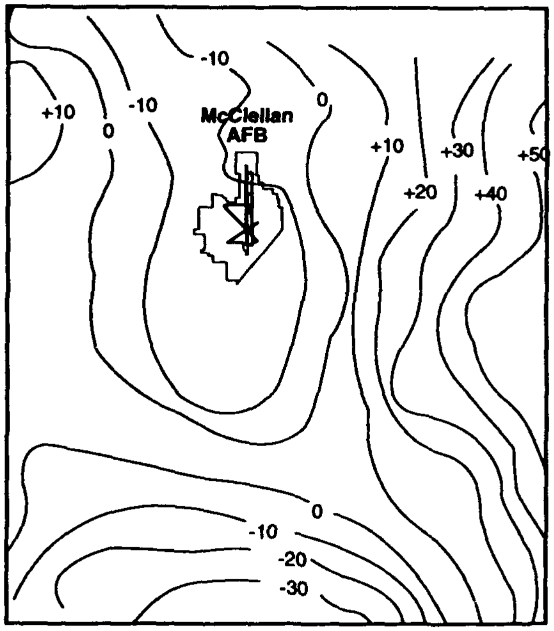
Sprin

SOURCE: County of Sacra Water Resource



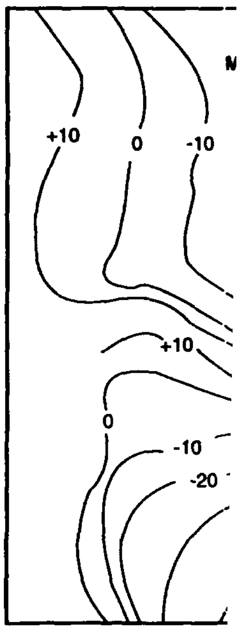
Spring 1971

SOURCE: CH2M HILL, July 1981



Spring 1975

SOURCE: County of Sacramento Dept. of Public Works, Water Resources Division, 1989



Sprin

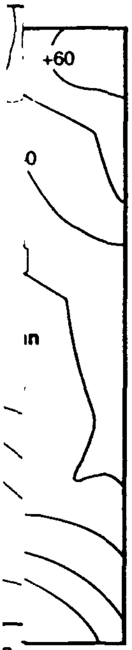
SOURCE: County of Sacr Water Resourc

LEGEND

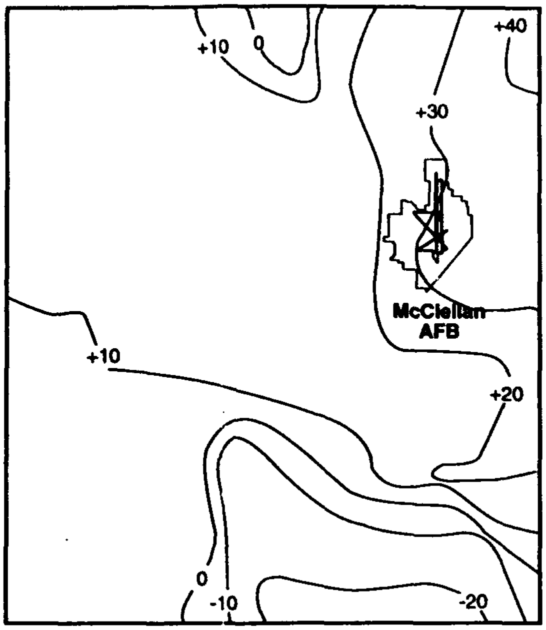
GROUNDWATER CONTOURS (ft msl)

RDD1454_134

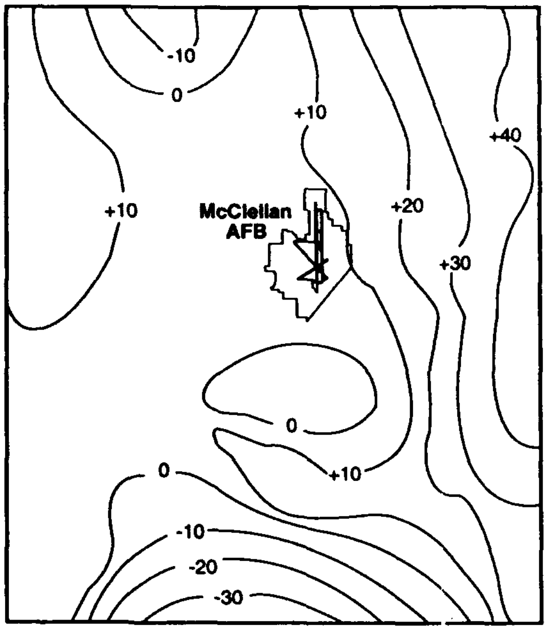
(1)



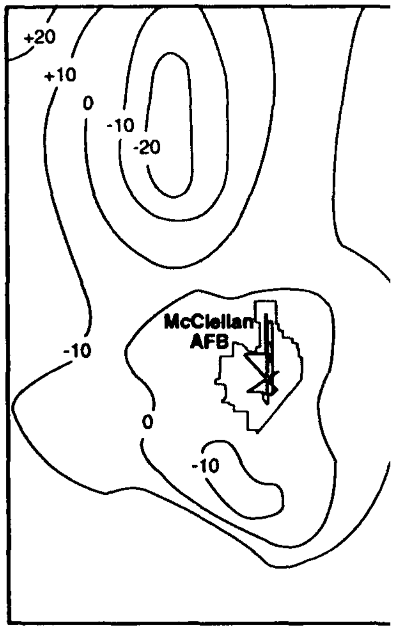
8
sicVorks,



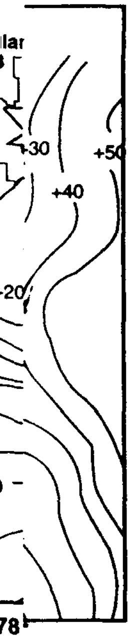
Spring 1958
SOURCE: County of Sacramento Dept. of Public Works, Water Resources Division, 1989



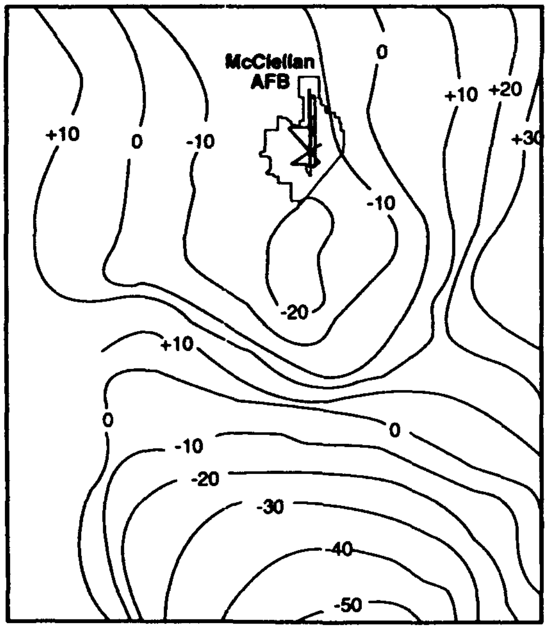
Spring 1963
SOURCE: County of Sacramento Dept. of Public Works, Water Resources Division, 1989



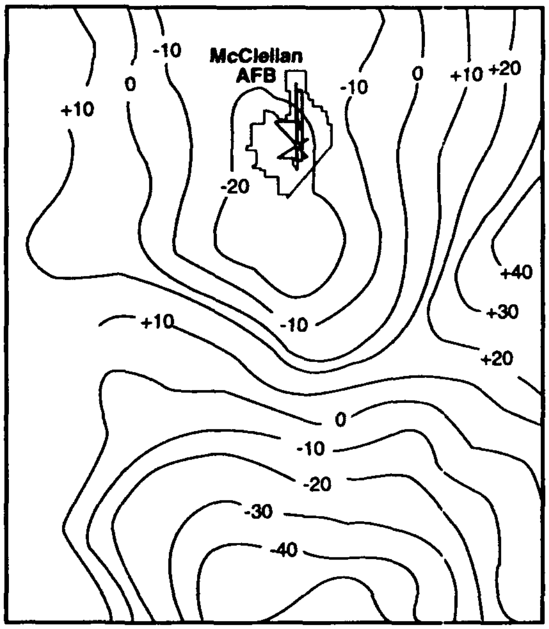
Spring 1968
SOURCE: CH2M HILL, July 1981



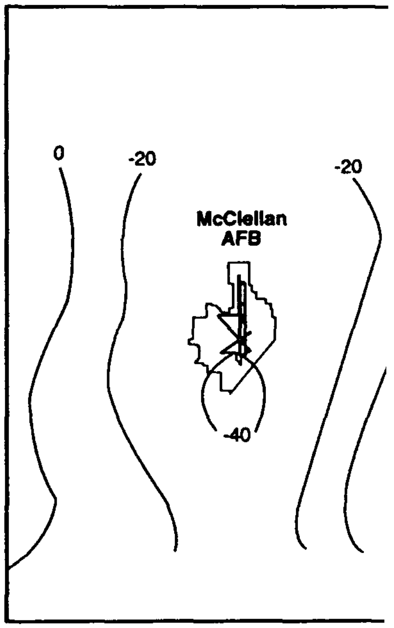
78
Vorks,



Spring 1978
SOURCE: County of Sacramento Dept. of Public Works, Water Resources Division, 1989



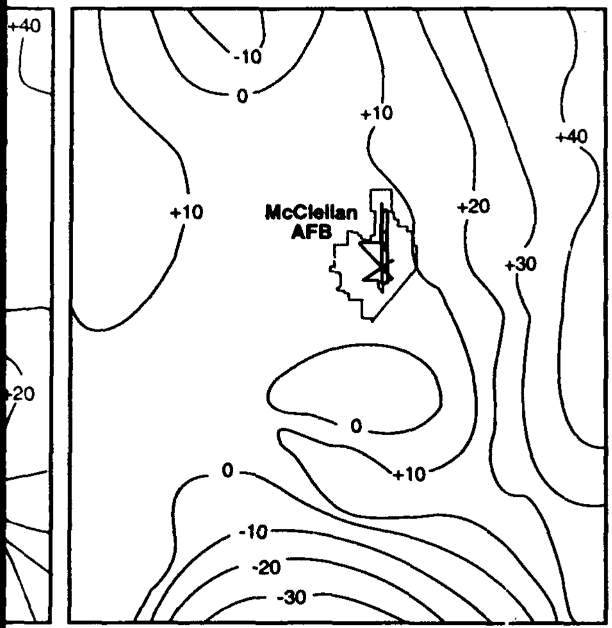
Spring 1980
SOURCE: County of Sacramento Dept. of Public Works, Water Resources Division, 1989



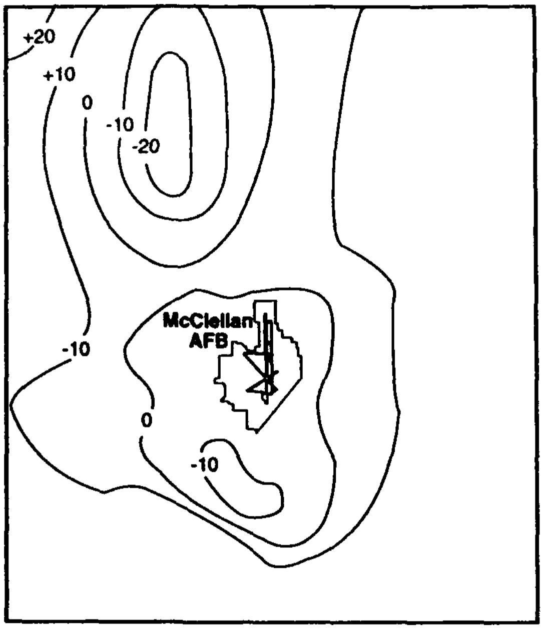
Fall 1989
SOURCE: County of Sacramento Dept. of P Water Resources Division, 1989

FIGURE 4-19
GROUNDWATER CONTOURS IN THE VI OF McCLELLAN AIR F
GROUNDWATER OPERABLE UNIT
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

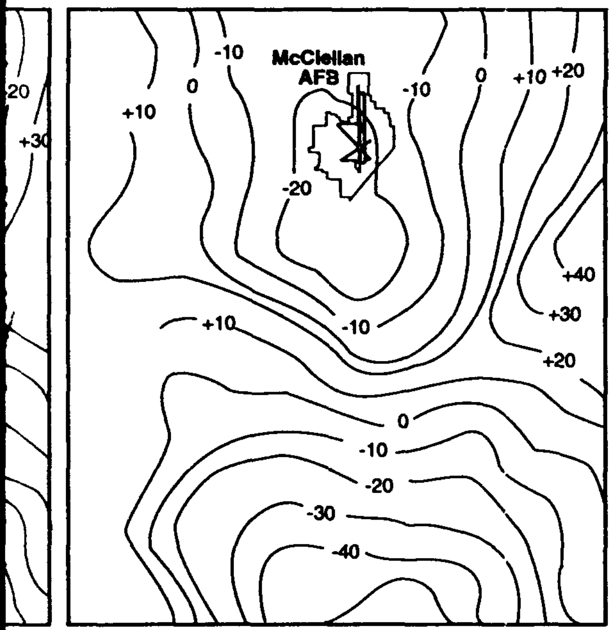
(2)



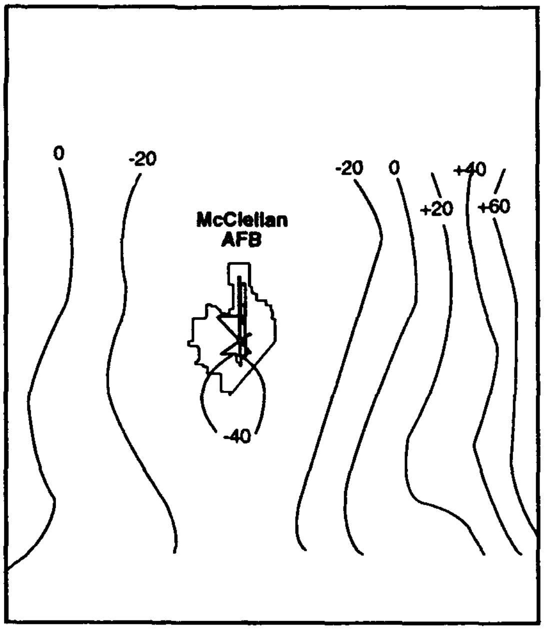
Spring 1963
SOURCE: *County of Sacramento Dept. of Public Works, Water Resources Division, 1989*



Spring 1968
SOURCE: CH2M HILL, July 1981



Spring 1980
SOURCE: County of Sacramento Dept. of Public Works, Water Resources Division, 1989

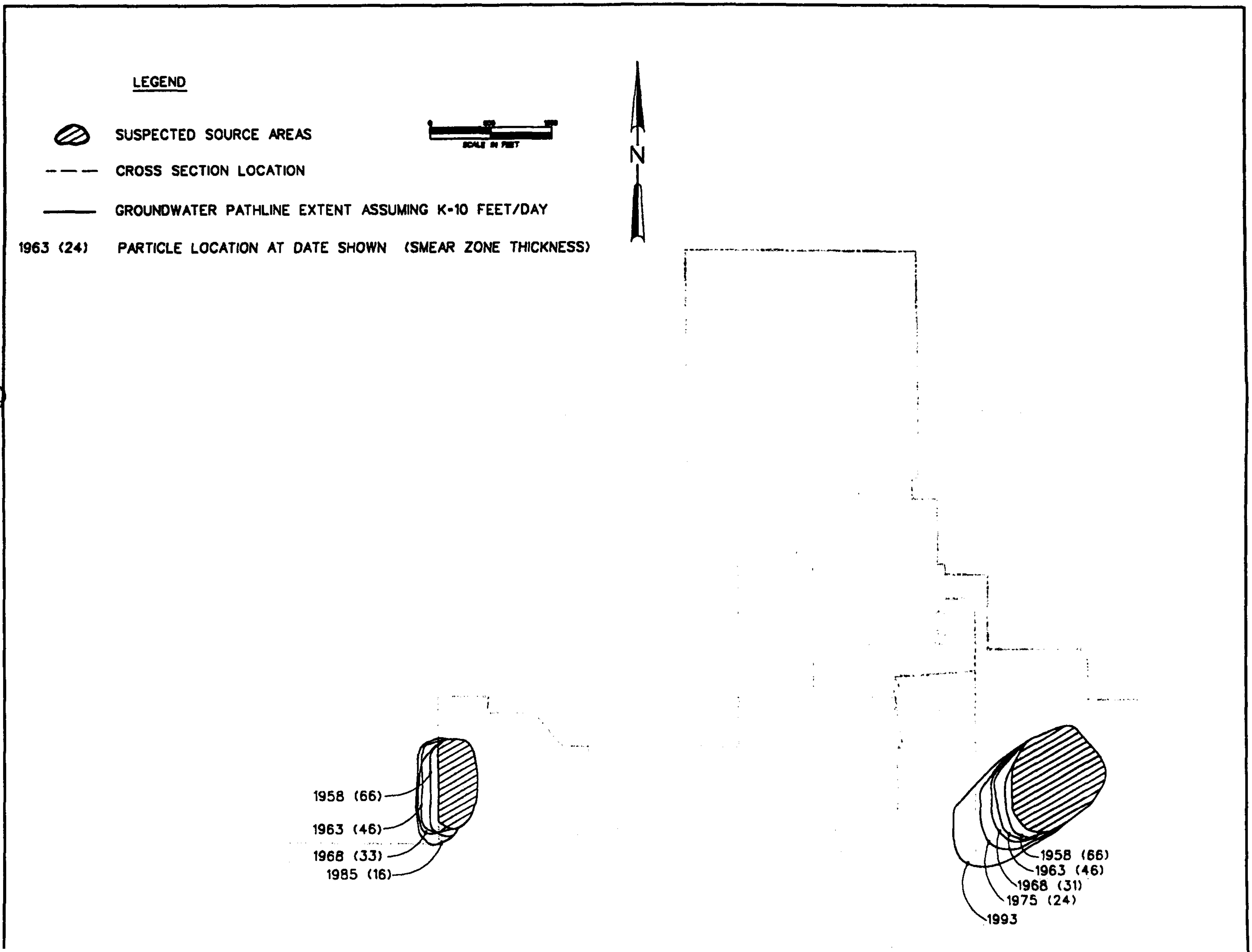


Fall 1989
SOURCE: County of Sacramento Dept. of Public Works, Water Resources Division, 1989

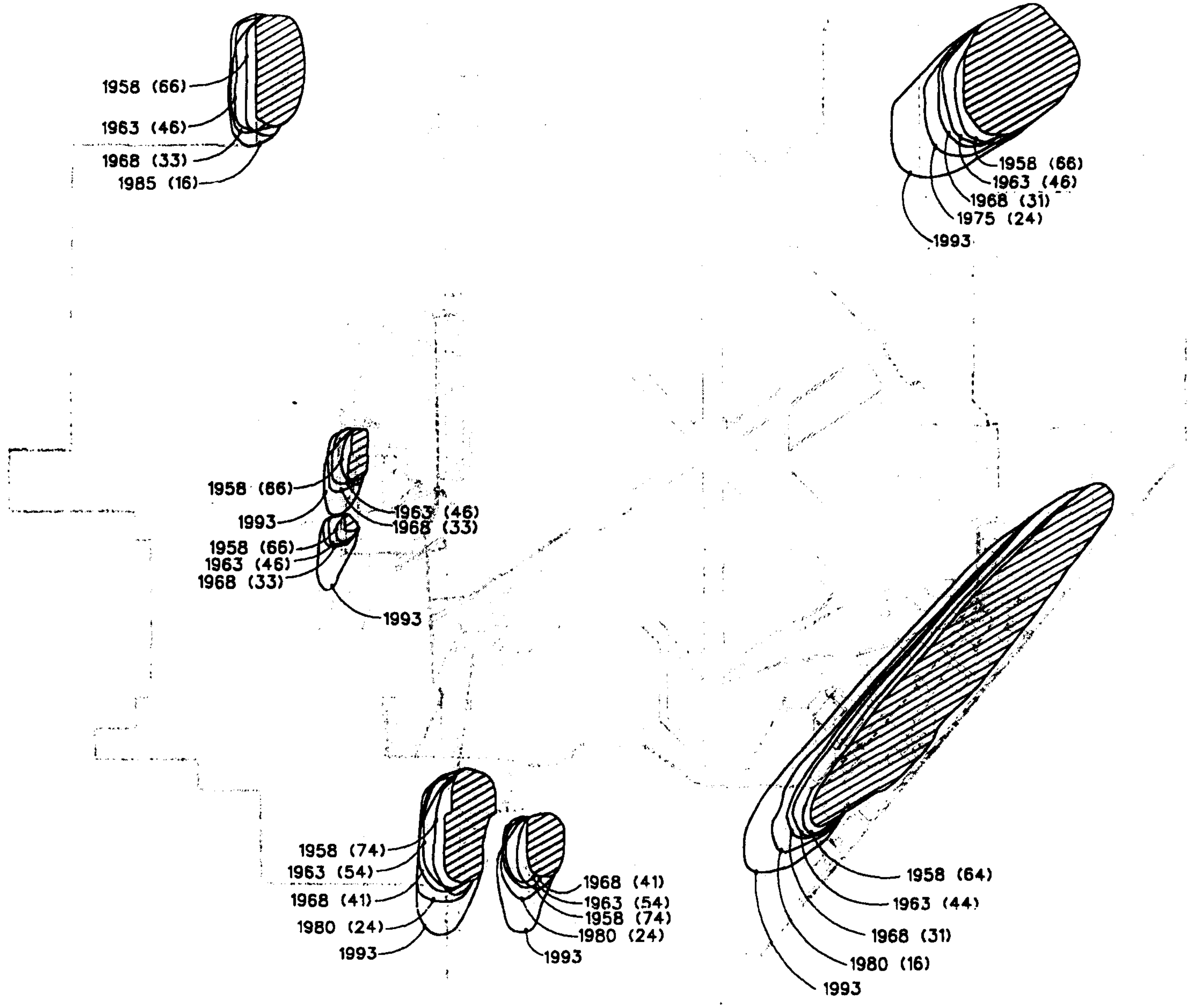
FIGURE 4-19
GROUNDWATER CONTOURS IN THE VICINITY OF McCLELLAN AIR FORCE BASE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

3



LEGEND
SUSPECTED SOURCE AREAS
CROSS SECTION LOCATION
GROUNDWATER PATHLINE EXTENT ASSUMING K=10 FEET/DAY
1963 (24) PARTICLE LOCATION AT DATE SHOWN (SMEAR ZONE THICKNESS)
SCALE IN FEET
N
1958 (66)
1963 (46)
1968 (33)
1985 (16)
1958 (66)
1963 (46)
1968 (31)
1975 (24)
1993



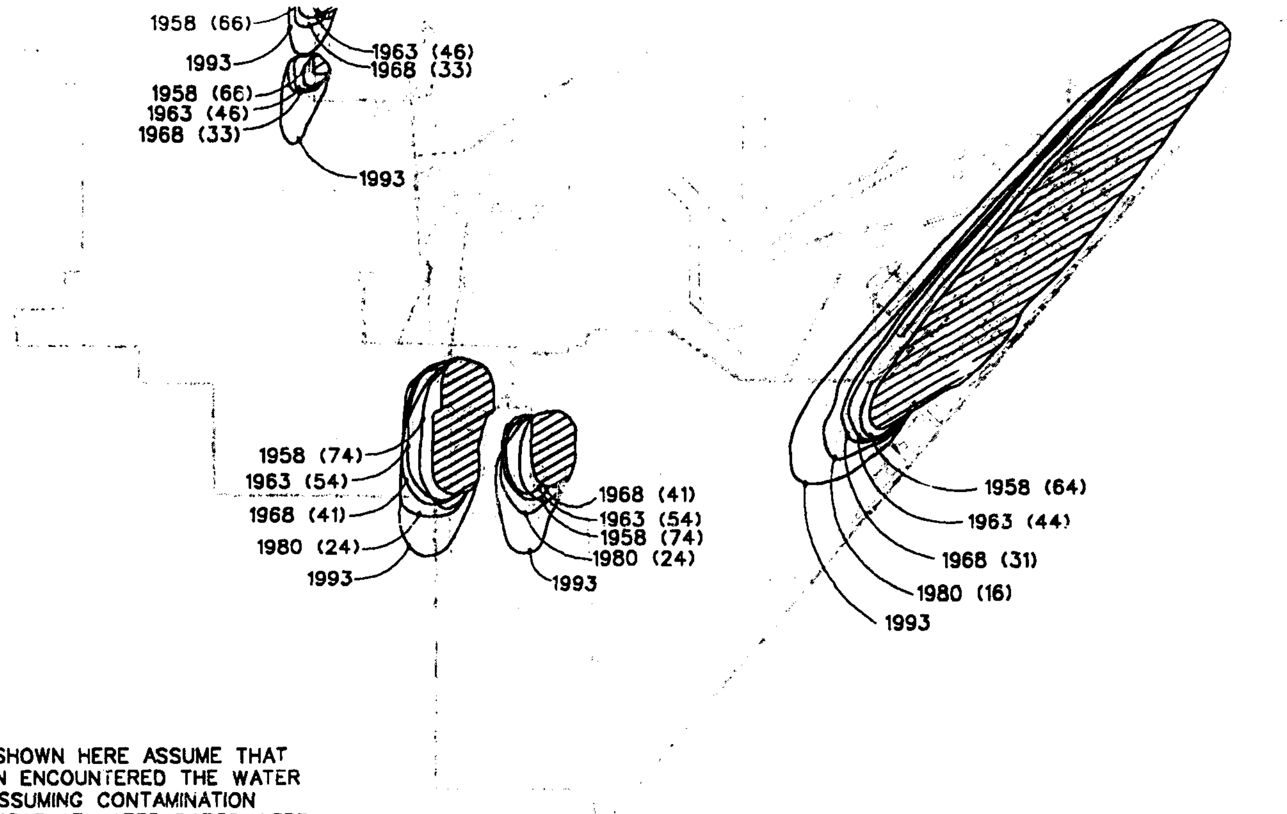
NOTES:

1. THE GROUNDWATER PATHLINES SHOWN HERE ASSUME THAT VADOSE ZONE CONTAMINATION ENCOUNTERED THE WATER TABLE IN 1950. PATHLINES ASSUMING CONTAMINATION ENCOUNTERED THE WATER TABLE AT LATER DATES WERE CALCULATED, BUT ARE NOT SHOWN HERE BECAUSE THEY DO NOT SIGNIFICANTLY ALTER THE ESTIMATED SMEAR ZONE EXTENT.

2. THESE PATHLINES WERE CALCULATED USING DARCY'S LAW. HYDRAULIC GRADIENTS WERE OBTAINED FROM REGIONAL WATER LEVEL CONTOUR MAPS. GROUNDWATER VELOCITIES ARE BASED ON AN ASSUMED TRANSPORT POROSITY OF 0.15 AND THE HYDRAULIC CONDUCTIVITY SHOWN.

FIGURE 4-28
ESTIMATED SMEAR ZONE EXTENT

(2)



NOTES:

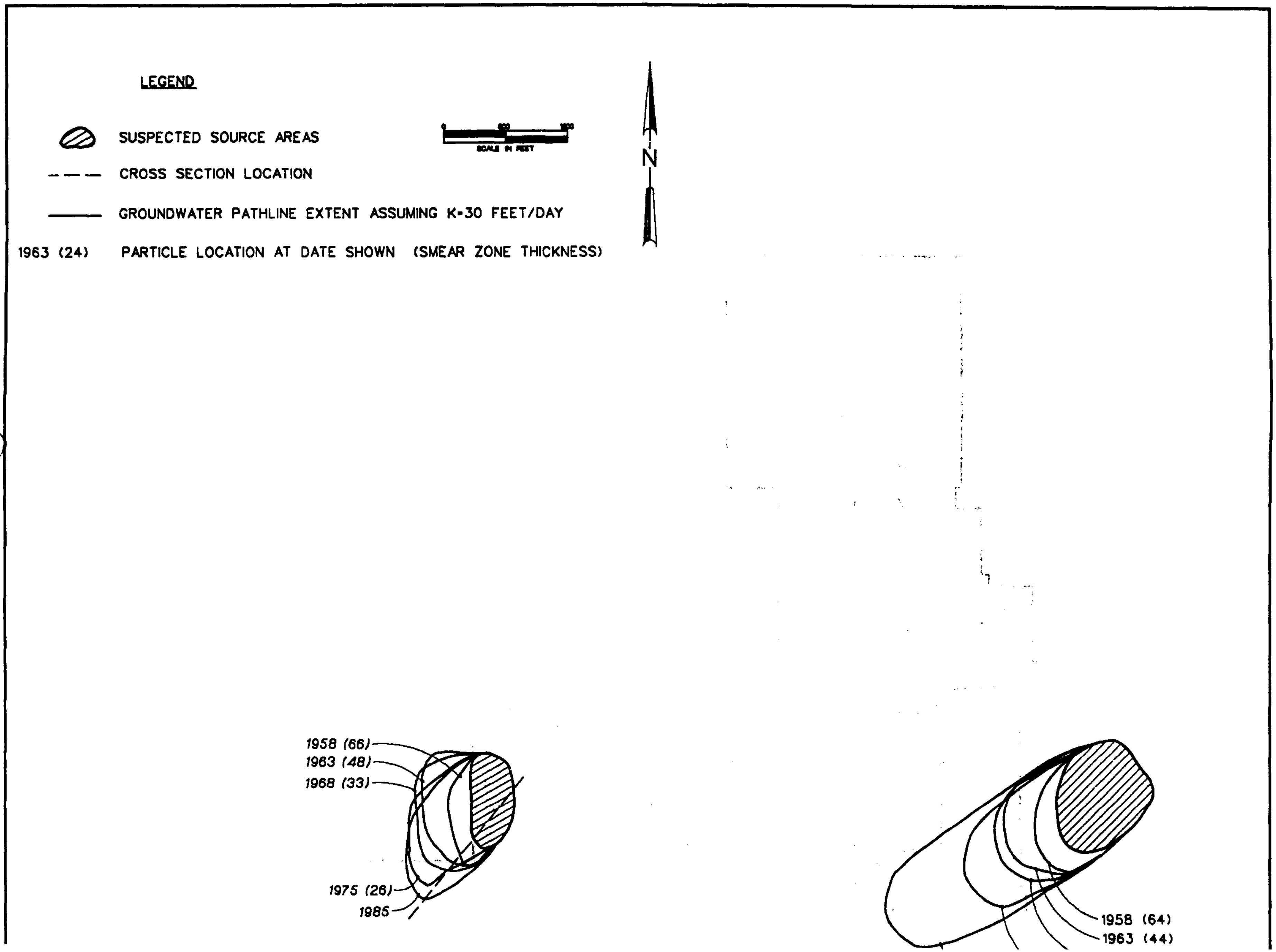
1. THE GROUNDWATER PATHLINES SHOWN HERE ASSUME THAT VADOSE ZONE CONTAMINATION ENCOUNTERED THE WATER TABLE IN 1950. PATHLINES ASSUMING CONTAMINATION ENCOUNTERED THE WATER TABLE AT LATER DATES WERE CALCULATED, BUT ARE NOT SHOWN HERE BECAUSE THEY DO NOT SIGNIFICANTLY ALTER THE ESTIMATED SMEAR ZONE EXTENT.

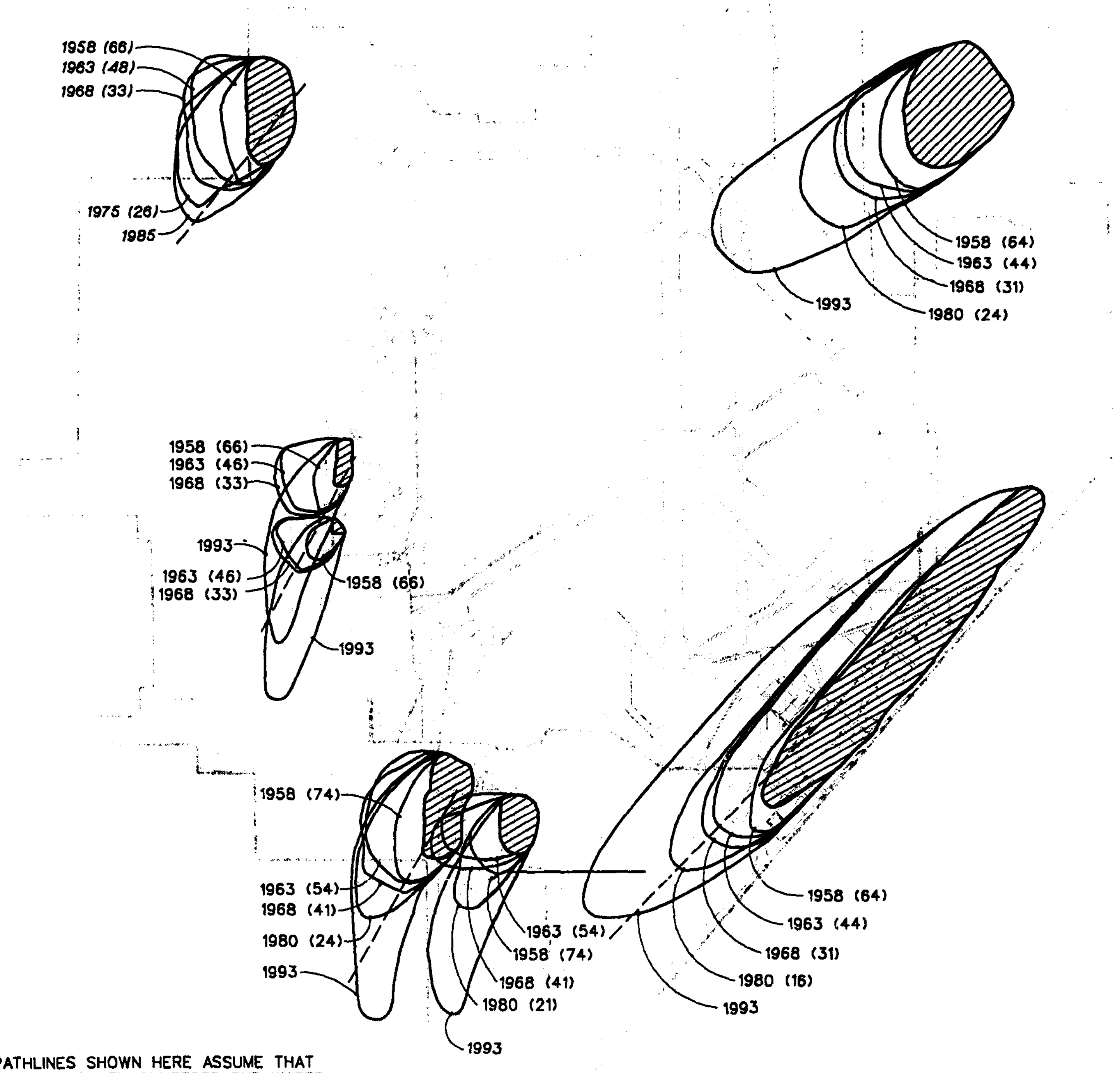
2. THESE PATHLINES WERE CALCULATED USING DARCY'S LAW. HYDRAULIC GRADIENTS WERE OBTAINED FROM REGIONAL WATER LEVEL CONTOUR MAPS. GROUNDWATER VELOCITIES ARE BASED ON AN ASSUMED TRANSPORT POROSITY OF 0.15 AND THE HYDRAULIC CONDUCTIVITY SHOWN.

FIGURE 4-28
ESTIMATED SMEAR ZONE EXTENT ASSUMING AN AQUIFER HYDRAULIC CONDUCTIVITY OF 10 FEET/DAY
GROUNDWATER OPERBLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1464
MEY94/4-28.DGN

CH2M HILL

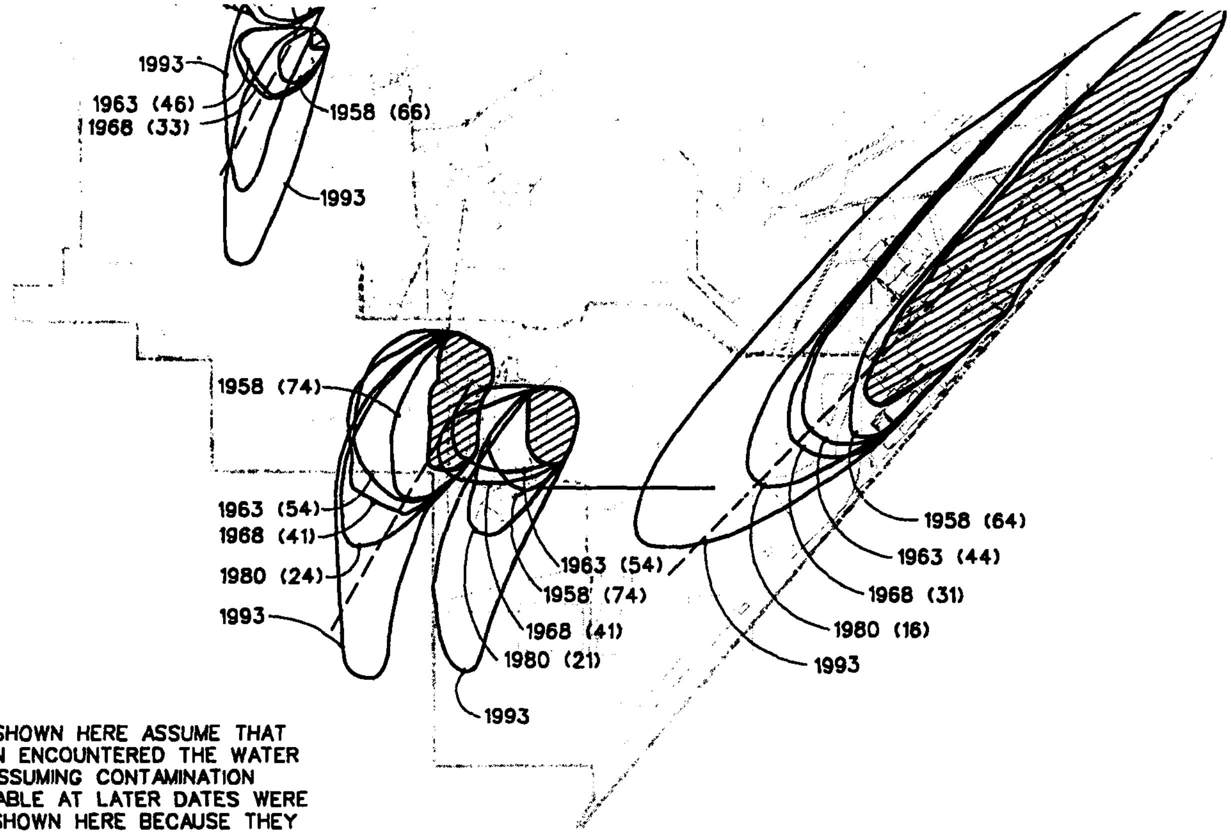

LEGEND
SUSPECTED SOURCE AREAS
CROSS SECTION LOCATION
GROUNDWATER PATHLINE EXTENT ASSUMING K=30 FEET/DAY
1963 (24) PARTICLE LOCATION AT DATE SHOWN (SMEAR ZONE THICKNESS)
N
1958 (66)
1963 (48)
1968 (33)
1975 (26)
1985
1958 (64)
1963 (44)



NOTES:

1. THE GROUNDWATER PATHLINES SHOWN HERE ASSUME THAT VADOSE ZONE CONTAMINATION ENCOUNTERED THE WATER TABLE IN 1950. PATHLINES ASSUMING CONTAMINATION ENCOUNTERED THE WATER TABLE AT LATER DATES WERE CALCULATED, BUT ARE NOT SHOWN HERE BECAUSE THEY

2. THESE PATHLINES WERE CALCULATED USING DARCY'S LAW.



NOTES:

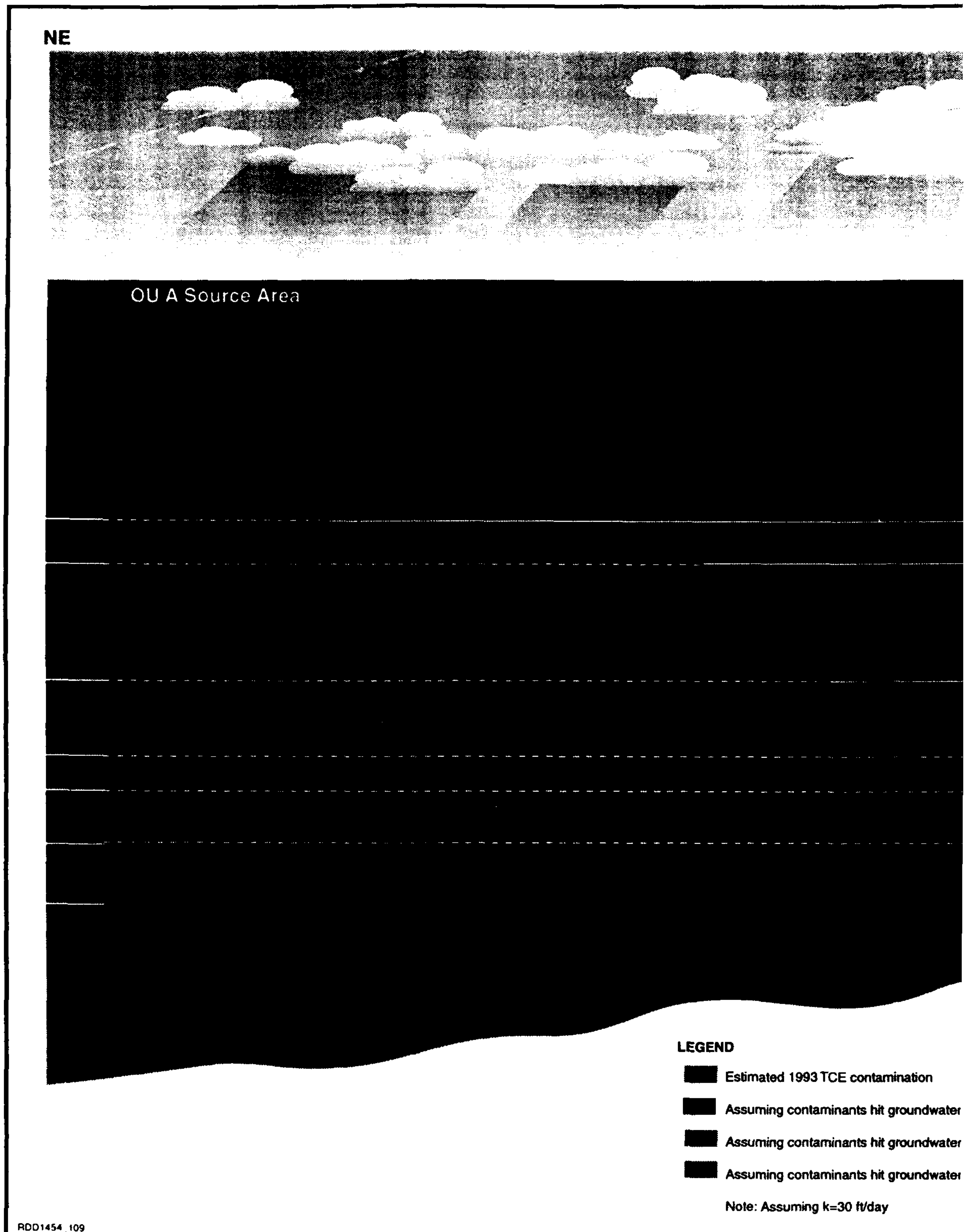
1. THE GROUNDWATER PATHLINES SHOWN HERE ASSUME THAT VADOSE ZONE CONTAMINATION ENCOUNTERED THE WATER TABLE IN 1950. PATHLINES ASSUMING CONTAMINATION ENCOUNTERED THE WATER TABLE AT LATER DATES WERE CALCULATED, BUT ARE NOT SHOWN HERE BECAUSE THEY DO NOT SIGNIFICANTLY ALTER THE ESTIMATED SMEAR ZONE EXTENT.

2. THESE PATHLINES WERE CALCULATED USING DARCY'S LAW. HYDRAULIC GRADIENTS WERE OBTAINED FROM REGIONAL WATER LEVEL CONTOUR MAPS. GROUNDWATER VELOCITIES ARE BASED ON AN ASSUMED TRANSPORT POROSITY OF 0.15 AND THE HYDRAULIC CONDUCTIVITY SHOWN.

FIGURE 4-29
ESTIMATED SMEAR ZONE EXTENT ASSUMING AN AQUIFER HYDRAULIC CONDUCTIVITY OF 30 FEET/DAY
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454
MEY/4-29.DGN

CH2M HILL


NE
OU A Source Area
LEGEND
Estimated 1993 TCE contamination
Assuming contaminants hit groundwater
Assuming contaminants hit groundwater
Assuming contaminants hit groundwater
Note: Assuming k=30 ft/day
RDD1454.109

RI/FS

ated 1993 TCE contamination

50 uming contaminants hit groundwater in 1950

58 uming contaminants hit groundwater in 1958

68 uming contaminants hit groundwater in 1968

e: Assuming k=30 ft/day

0 200 400 600

HORIZONTAL SCALE, IN FEET

FIGURE 4-30
SMEAR ZONE EX
CROSS SECTION
GROUNDWATER OPERAB
McCLELLAN AIR FORCE B
SACRAMENTO, CALIFORN

CH

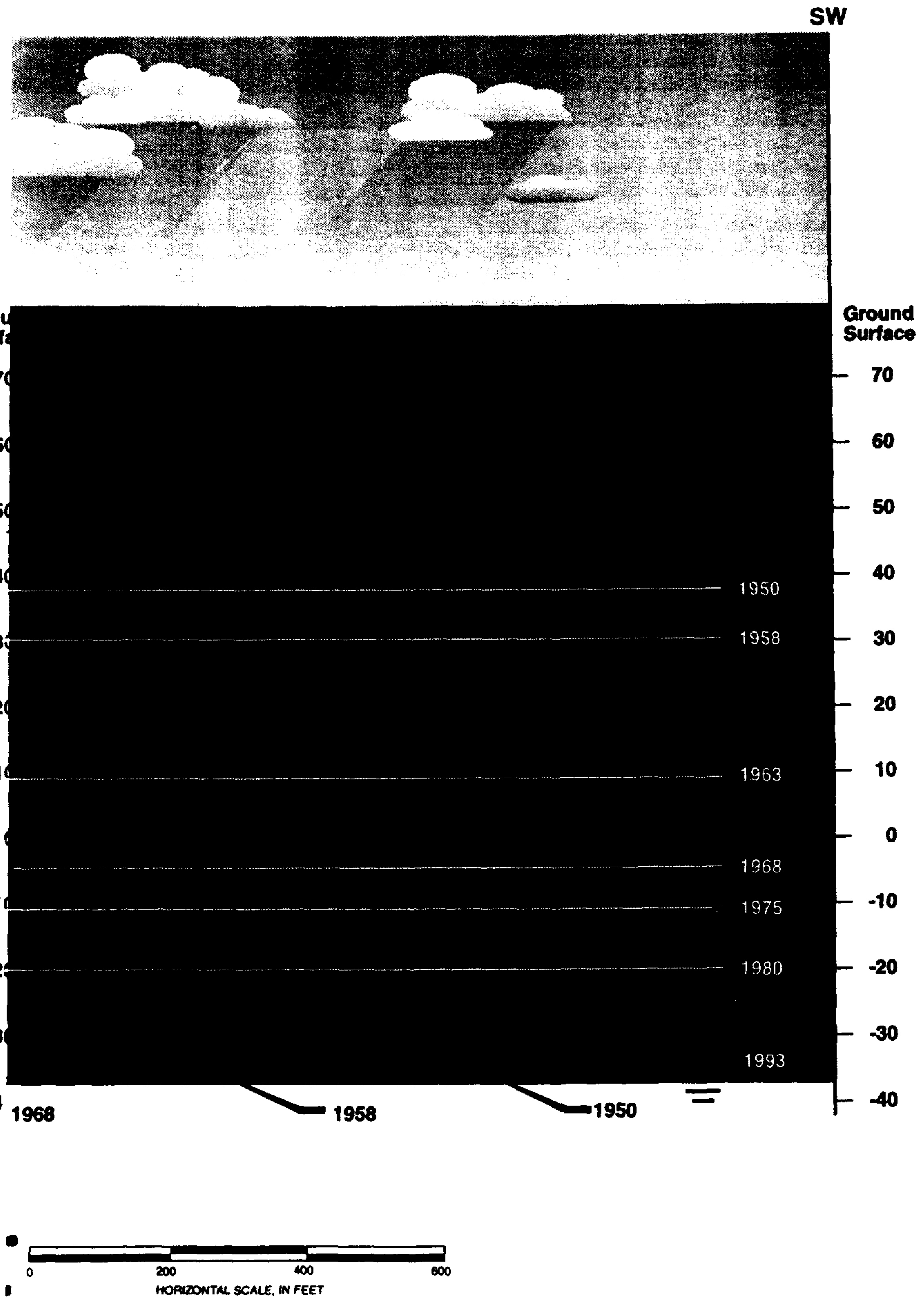
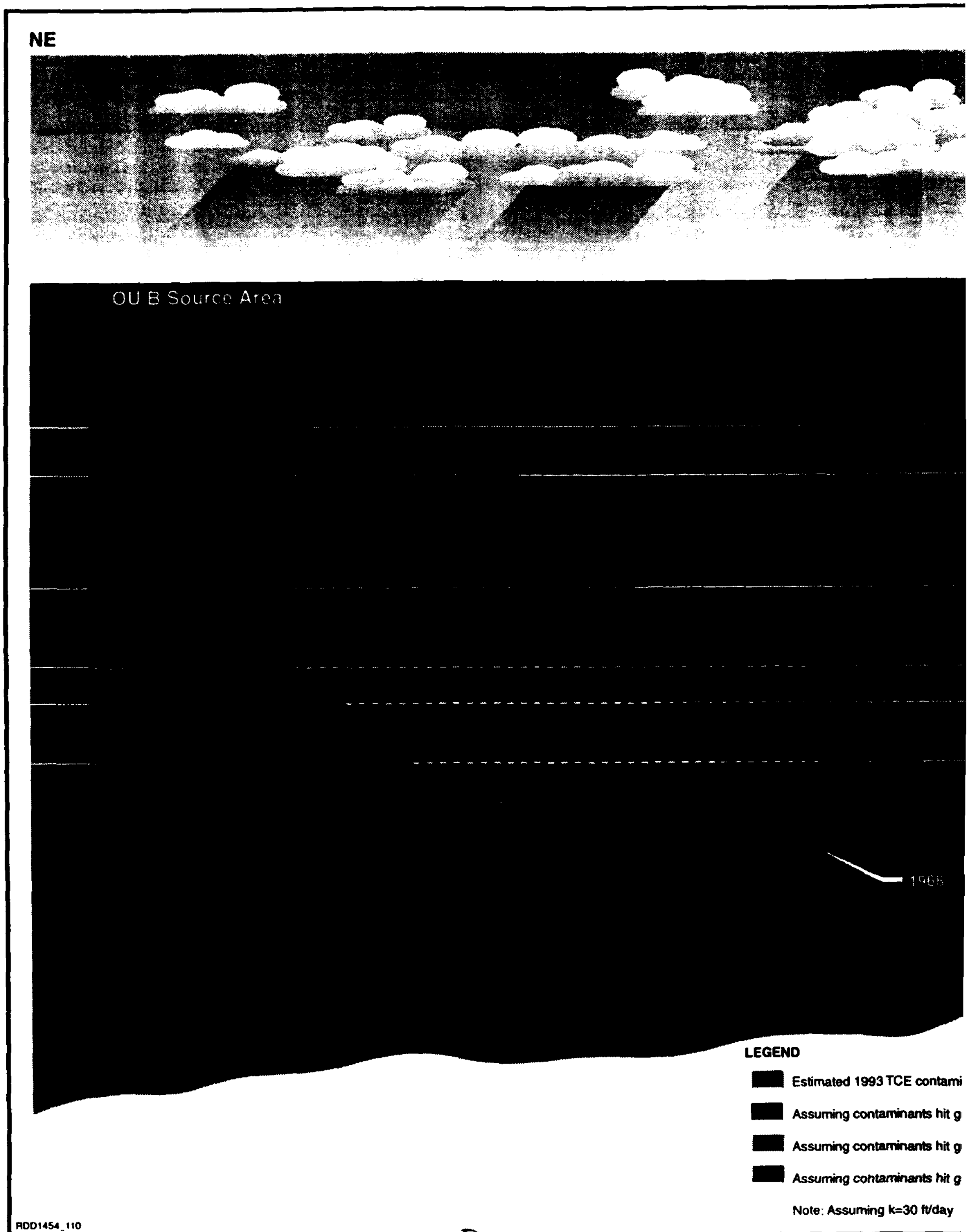
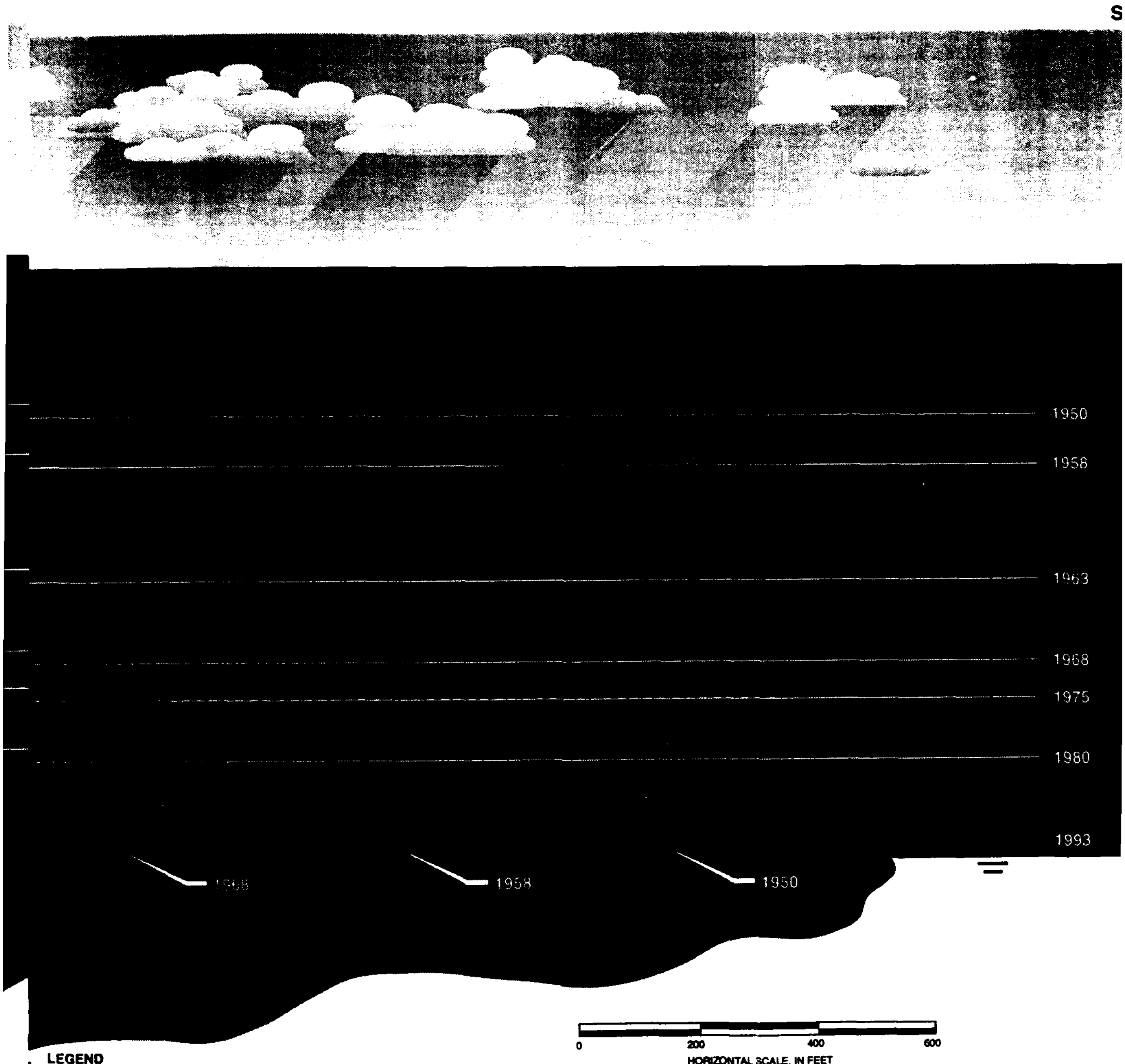


FIGURE 4-30
SMEAR ZONE EXTENT
CROSS SECTION OF OU A
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


NE
OU B Source Area
LEGEND
Estimated 1993 TCE contami
Assuming contaminants hit g
Assuming contaminants hit g
Assuming contaminants hit g
Note: Assuming k=30 ft/day
RDD1454_110



LEGEND

- Estimated 1993 TCE contamination
- Assuming contaminants hit groundwater in 1950
- Assuming contaminants hit groundwater in 1958
- Assuming contaminants hit groundwater in 1968

Note: Assuming k=30 ft/day

FIGURE 4-31
SMEAR ZONE E
CROSS SECTIO
GROUNDWATER OPERA
McCLELLAN AIR FORCE
SACRAMENTO, CALIFOR

CH

2

RDD1454_134

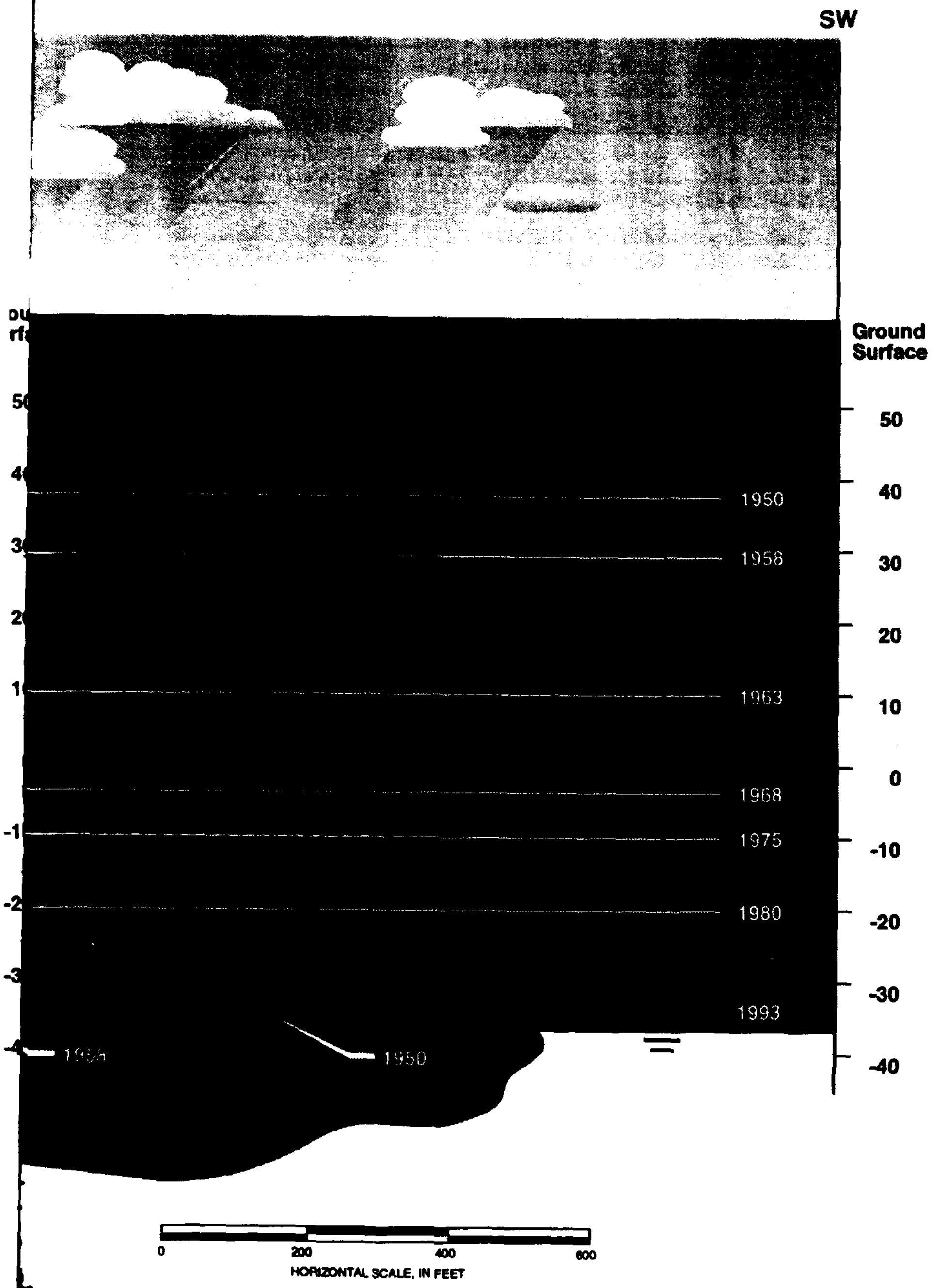
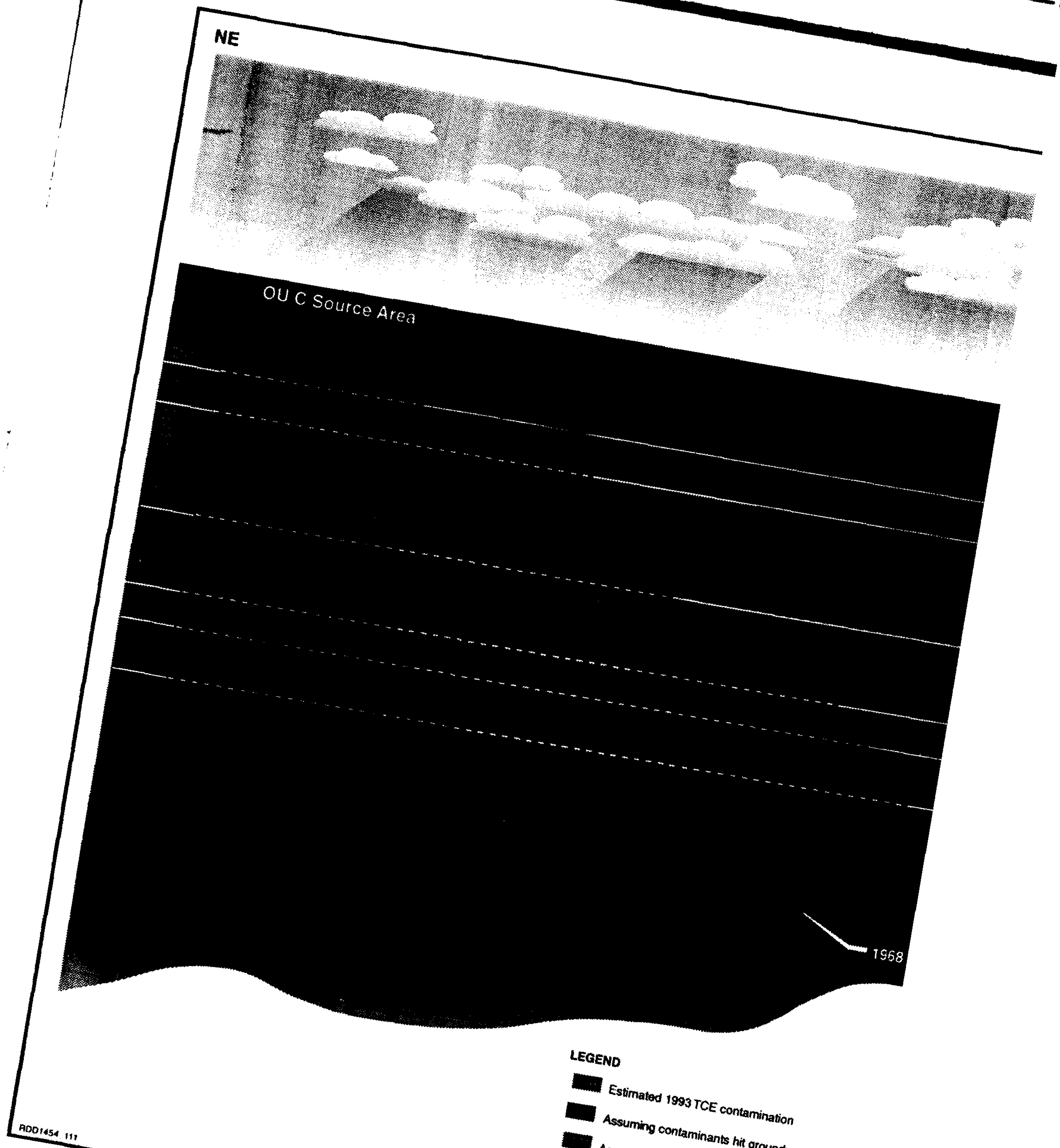


FIGURE 4-31
SMEAR ZONE EXTENT
CROSS SECTION OF OU B
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

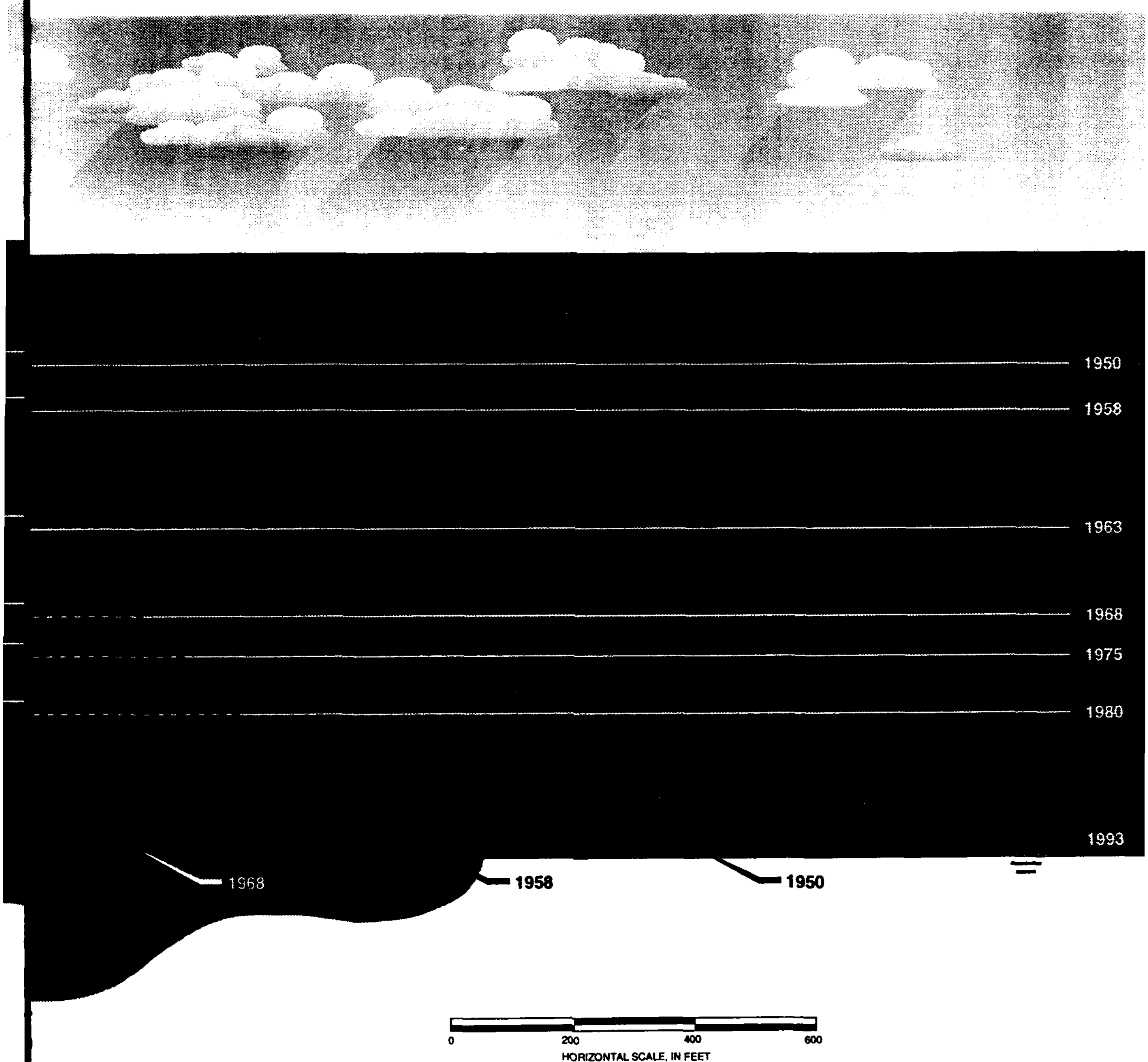
CH2M HILL

(2)


NE
OU C Source Area
1968
LEGEND
Estimated 1993 TCE contamination
Assuming contaminants hit groundwater in 1950
Assuming contaminants hit groundwater in 1958
Assuming contaminants hit groundwater in 1968
Note: Assuming k=30 ft/day
RDD1454_111

(1)

RI/FS



3 TCE contamination

ontaminants hit groundwater in 1950

ontaminants hit groundwater in 1958

ontaminants hit groundwater in 1968

ning k=30 ft/day

FIGURE 4-32
SMEAR ZONE E
CROSS SECTIO
GROUNDWATER OPER.
McCLELLAN AIR FORCI
SACRAMENTO, CALIFO

(2)

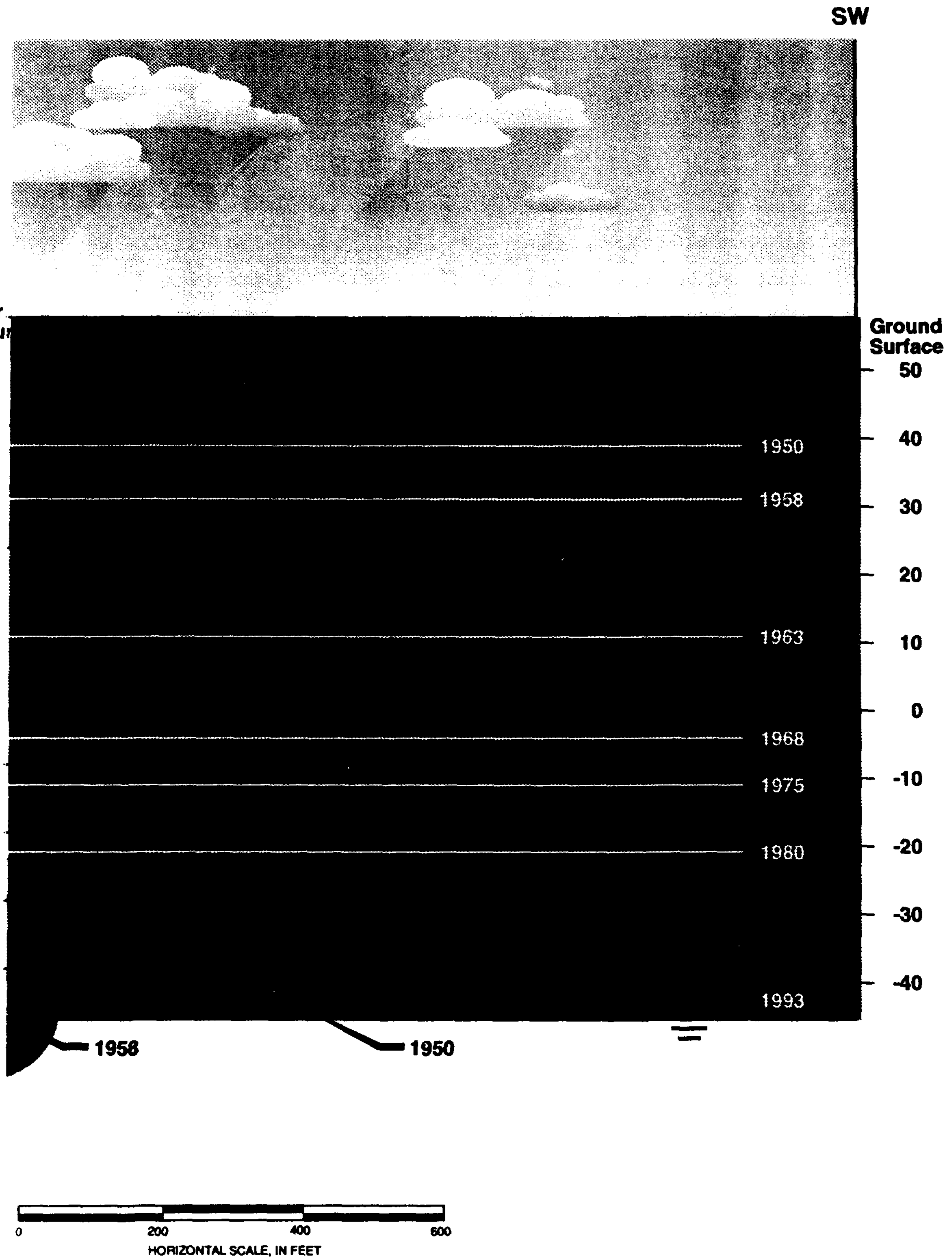
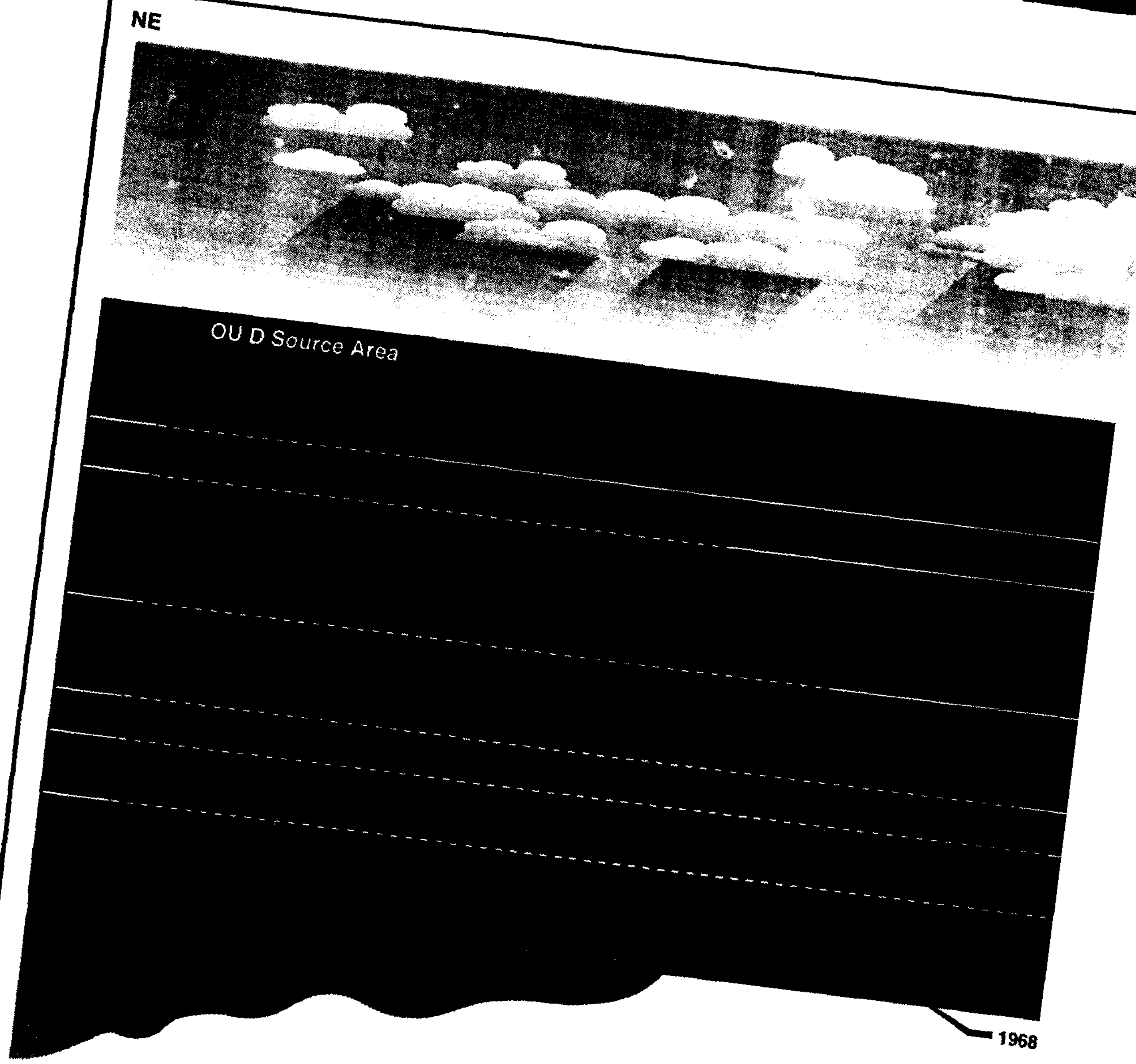


FIGURE 4-32
SMEAR ZONE EXTENT
CROSS SECTION OF OU C
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



LEGEND

- Estimated 1993 TCE contamination
- Assuming contaminants hit groundwater in 1950
- Assuming contaminants hit groundwater in 1958
- Assuming contaminants hit groundwater in 1968

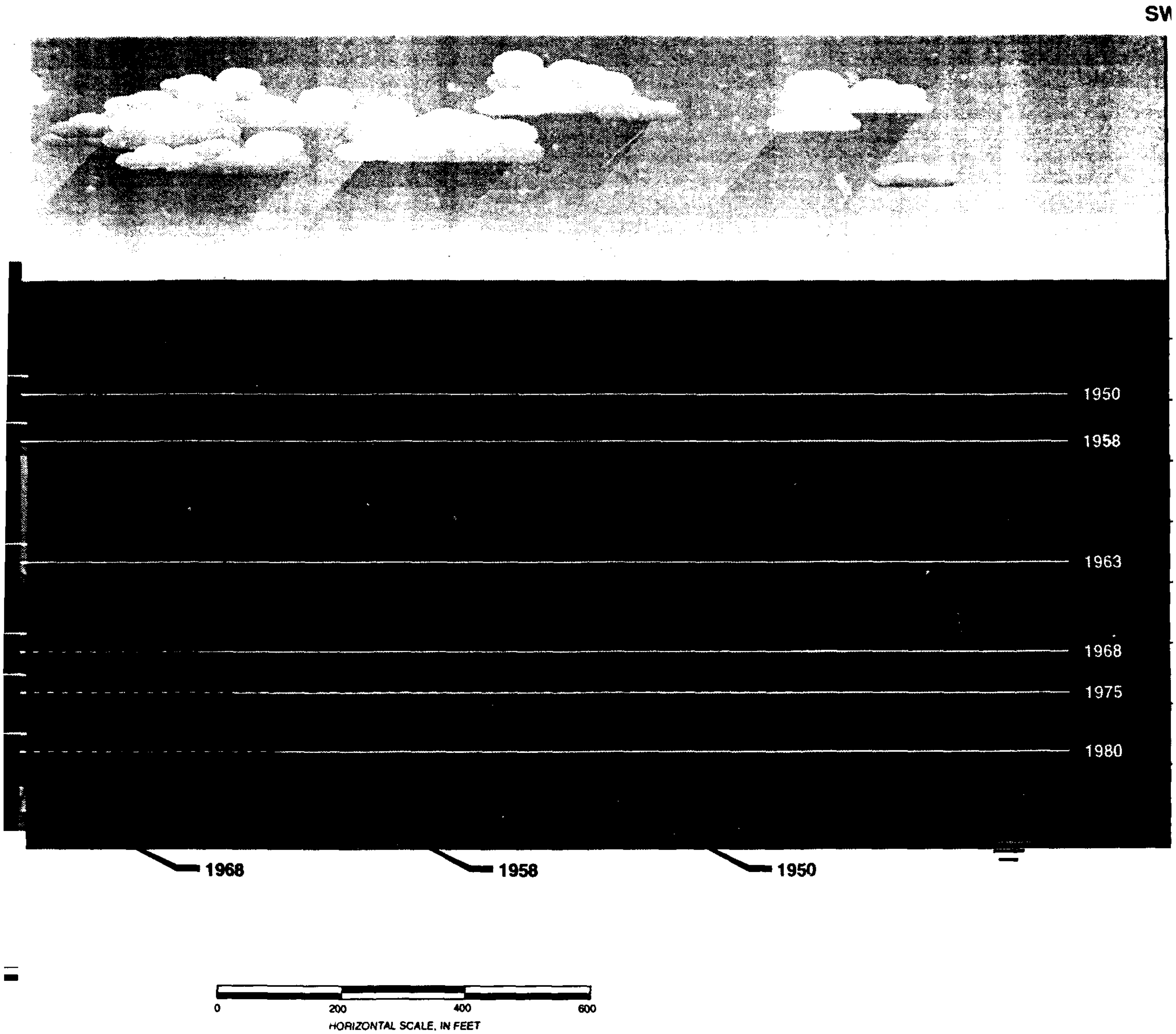
Note: Assuming k=30 ft/day

NOTE:

The discrepancy between the smear zone extent and the extent of groundwater contamination may be caused by one or more of the following:

1. The hydraulic conductivity in the region is less than the assumed 30 ft/day.
2. The contamination encountered water table later than 1950 because of low vertical hydraulic conductivity.
3. The ongoing groundwater extraction at OU D has limited the extent of the groundwater contamination.

RDD1454 .112



er
nductivity.
as limited

FIGURE 4-33
SMEAR ZONE EXT
CROSS SECTION (
GROUNDWATER OPERABLI
McCLELLAN AIR FORCE BA
SACRAMENTO, CALIFORNI

CH2M

(2)

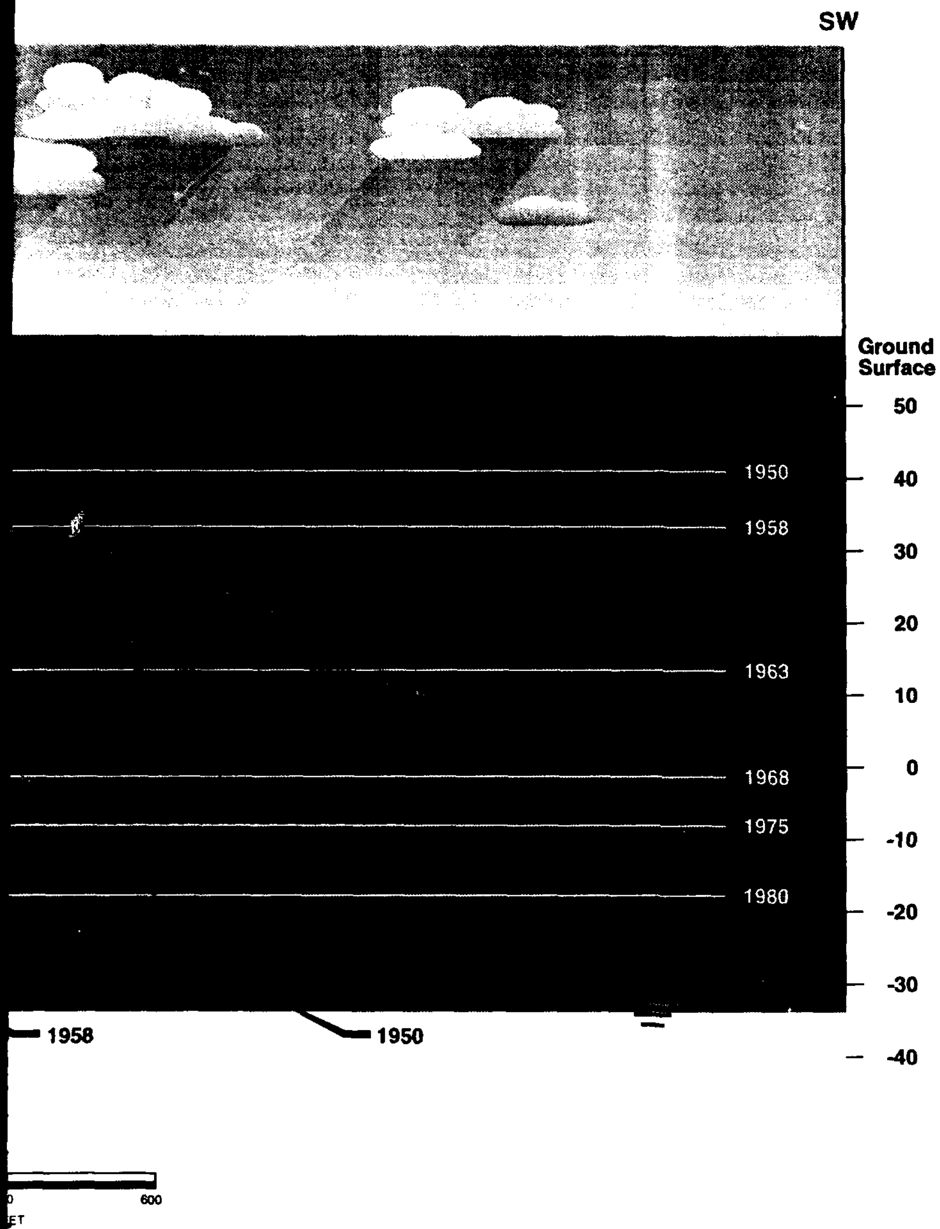
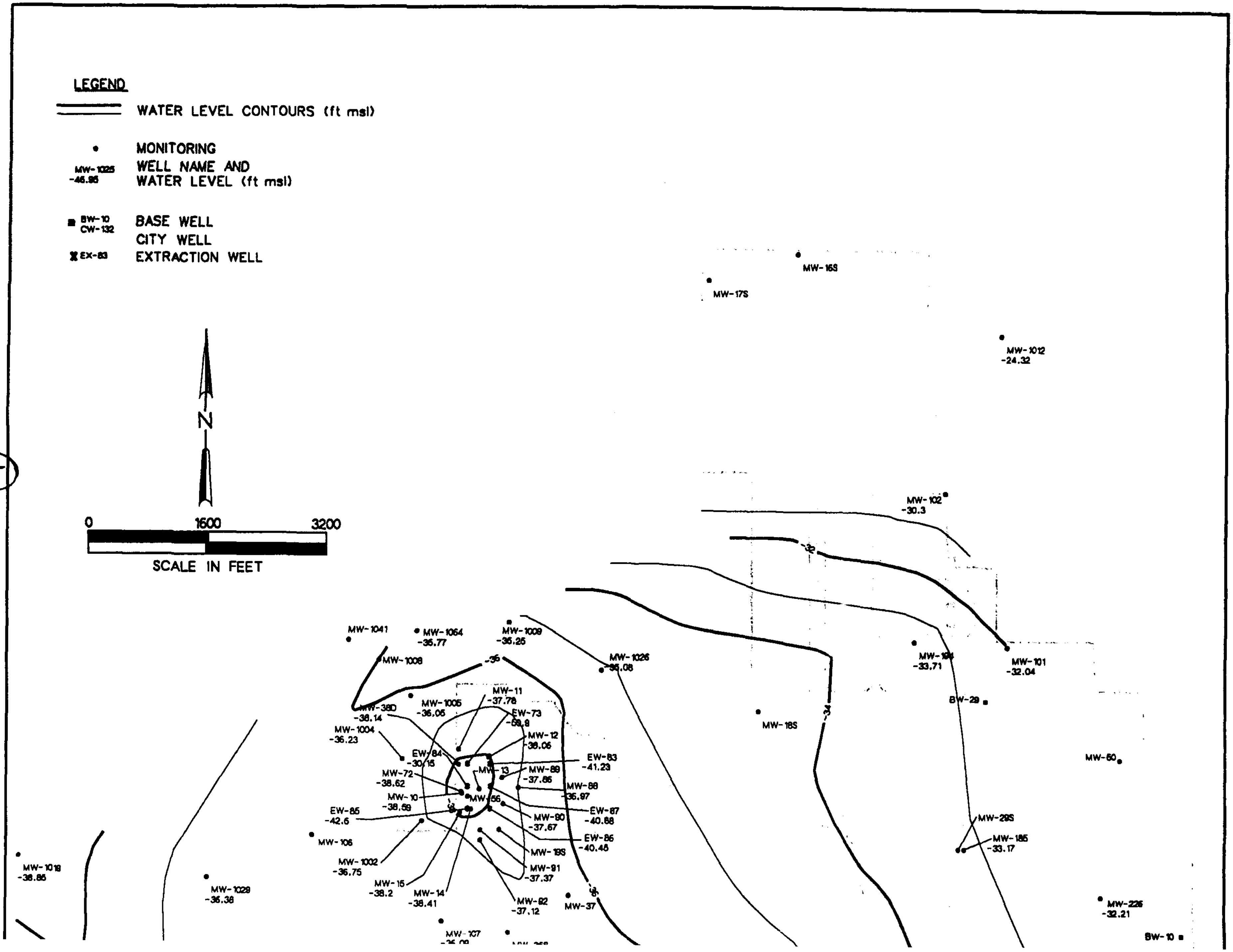


FIGURE 4-33
SMEAR ZONE EXTENT
CROSS SECTION OF OU D
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



LEGEND
WATER LEVEL CONTOURS (ft msl)
MONITORING
MW-1025 -46.86
WELL NAME AND
WATER LEVEL (ft msl)
BW-10
CW-132
BASE WELL
CITY WELL
EX-83
EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
MW-16S
MW-17S
MW-1012 -24.32
MW-102 -30.3
-32
-34
-36
MW-101 -32.04
MW-18S
BW-29
MW-60
MW-29S
MW-185 -33.17
MW-226 -32.21
BW-10
MW-1041
MW-1064 -36.77
MW-1009 -36.25
MW-1026 -36.08
MW-1008
MW-11 -37.78
MW-1005 -36.05
EW-73 -59.8
MW-38D -38.14
MW-1004 -36.23
MW-12 -36.06
EW-84 -30.15
EW-83 -41.23
MW-72 -38.62
MW-13
MW-89 -37.86
MW-88 -36.97
MW-10 -38.59
MW-56
EW-87 -40.88
EW-85 -42.6
MW-90 -37.67
EW-86 -40.48
MW-106
MW-19S
MW-1002 -36.75
MW-91 -37.37
MW-1019 -36.86
MW-1029 -36.38
MW-15 -38.2
MW-14 -38.41
MW-92 -37.12
MW-37
MW-107

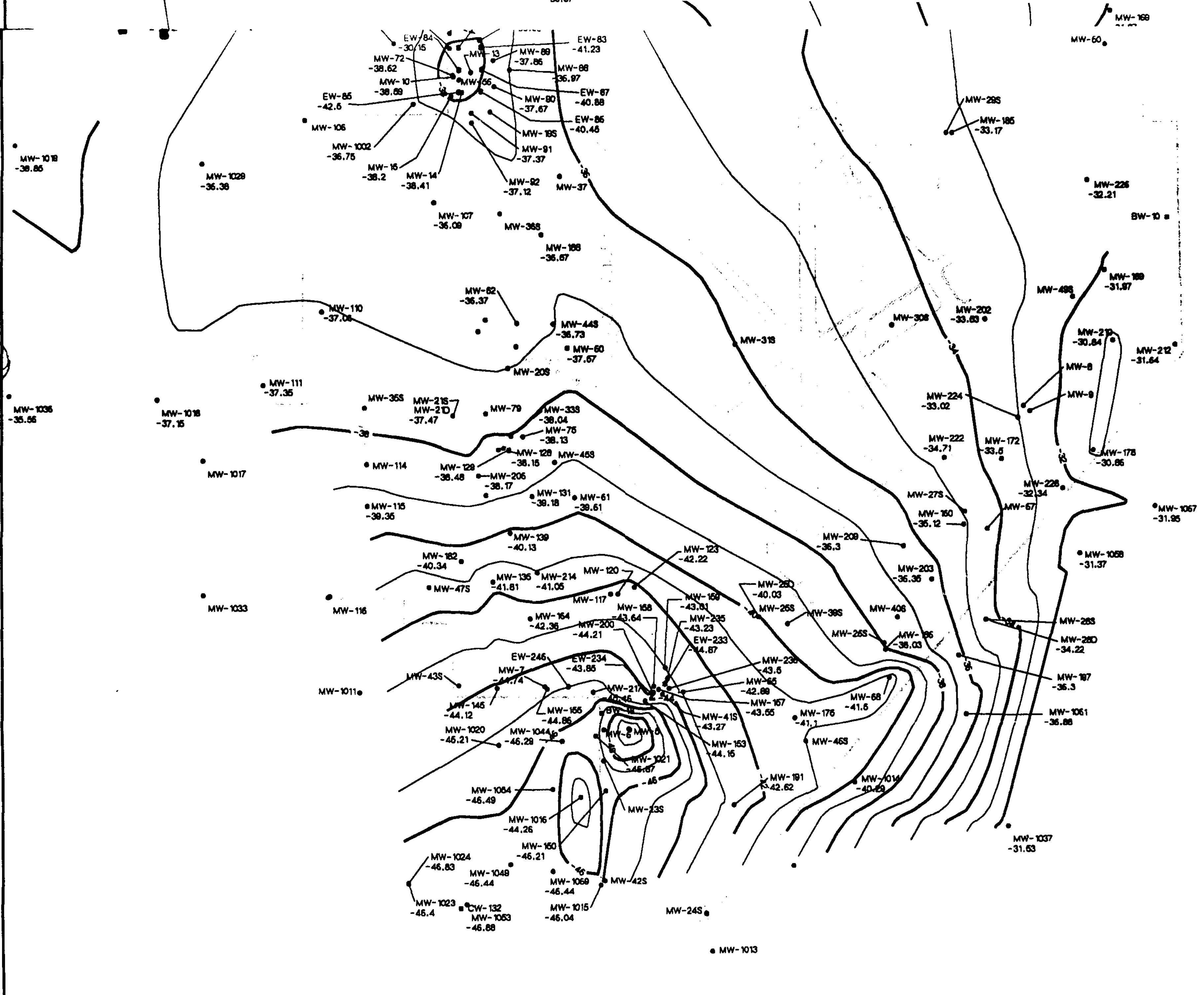


FIGURE 4-35
WATER LEVELS IN
MONITORING ZONE A.

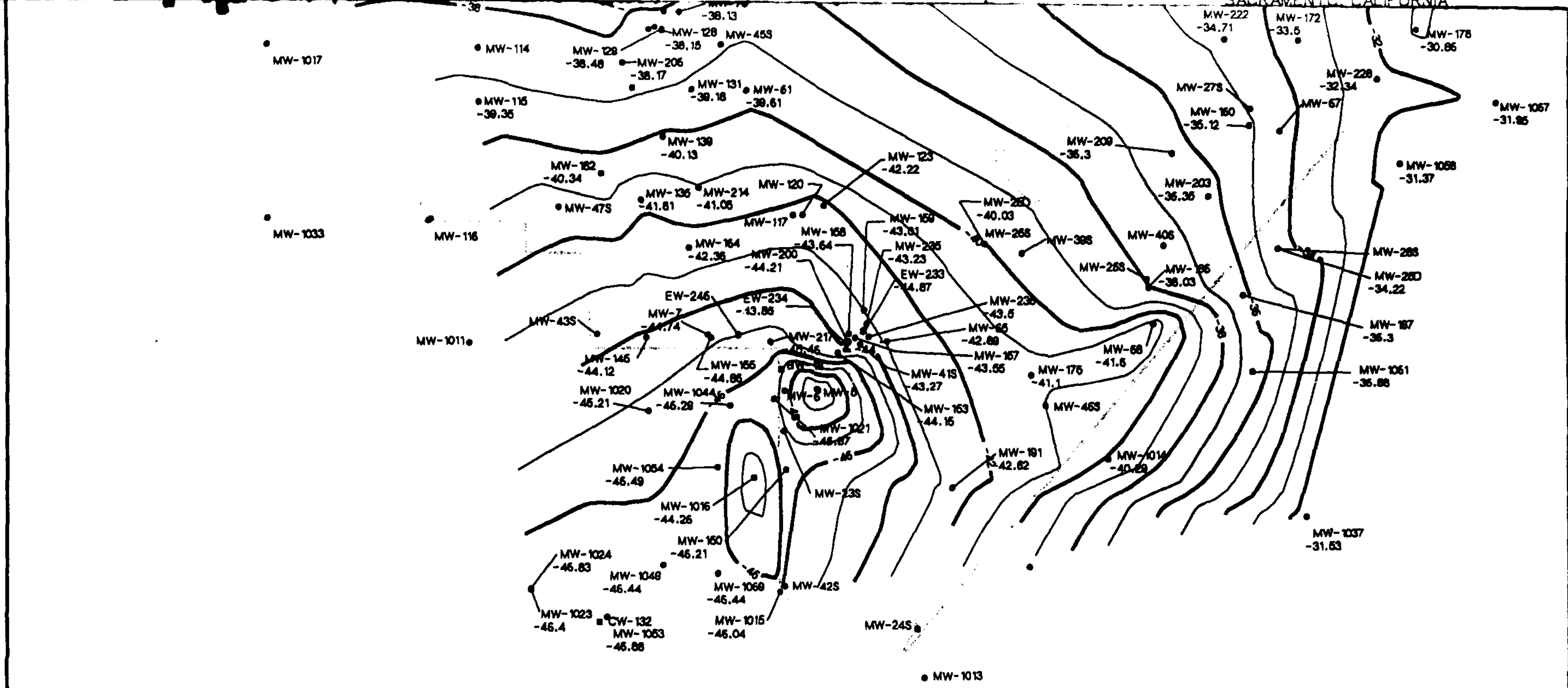
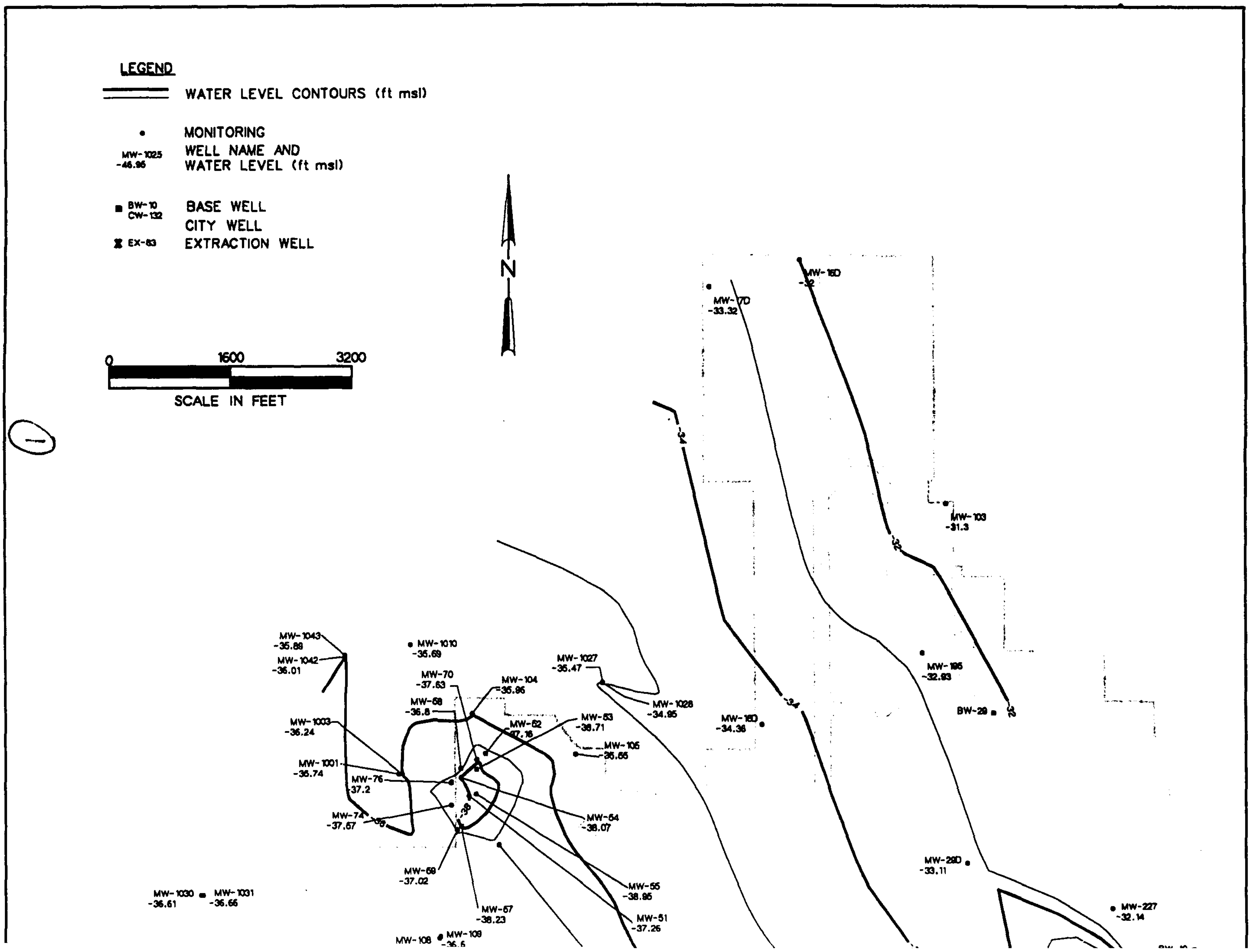


FIGURE 4-35
WATER LEVELS IN MONITORING ZONE A, JANUARY 1993
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1464
GWOU/4-35.DGN



LEGEND
WATER LEVEL CONTOURS (ft msl)
MONITORING
MW-1025
-46.96
WELL NAME AND
WATER LEVEL (ft msl)
BW-10
CW-132
BASE WELL
CITY WELL
EX-83
EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
MW-16D
-32
MW-7D
-33.32
-34
MW-103
-31.3
-32
MW-19S
-32.93
BW-29
-32
MW-18D
-34.36
-34
MW-1043
-35.89
MW-1042
-36.01
MW-1010
-35.69
MW-1027
-35.47
MW-70
-37.63
MW-104
-35.86
MW-1028
-34.95
MW-68
-36.8
MW-62
-37.16
MW-53
-36.71
MW-1003
-36.24
MW-105
-36.66
MW-1001
-36.74
MW-76
-37.2
MW-74
-37.67
MW-54
-38.07
MW-69
-37.02
MW-29D
-33.11
MW-55
-38.95
MW-1030
-36.61
MW-1031
-36.66
MW-67
-38.23
MW-51
-37.26
MW-227
-32.14
MW-108
MW-109
-36.6

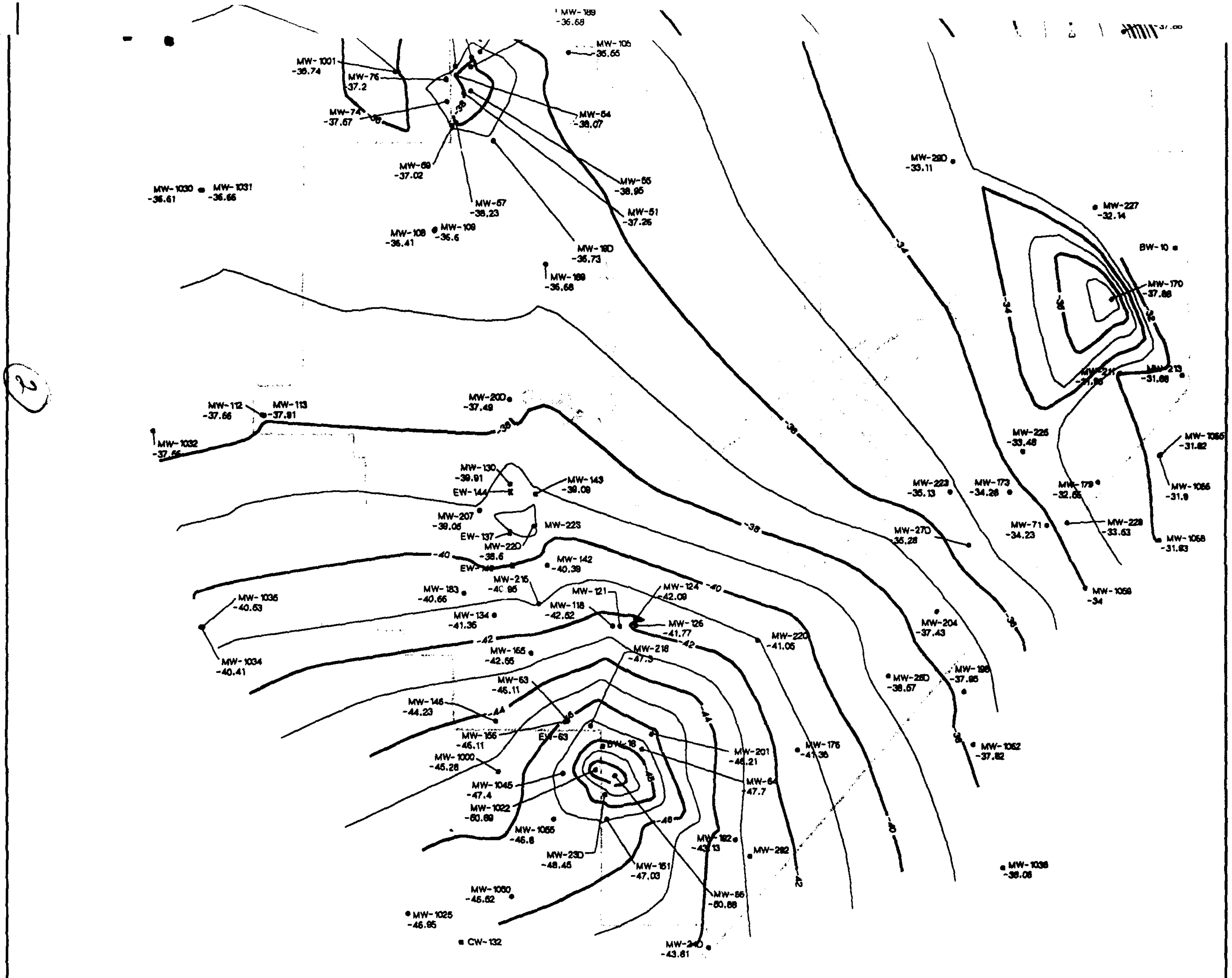


FIGURE 4-36
WATER LEVELS IN

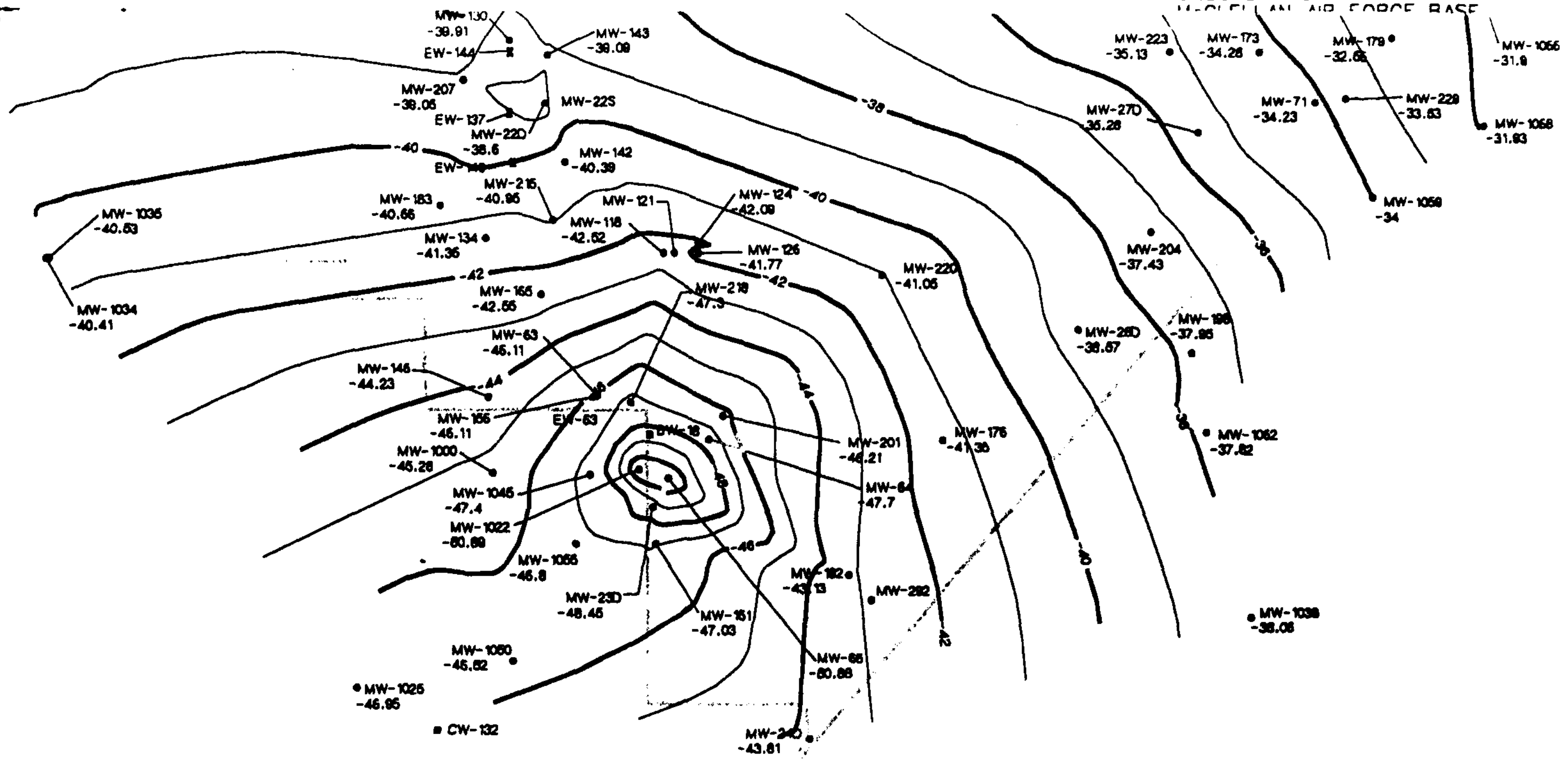
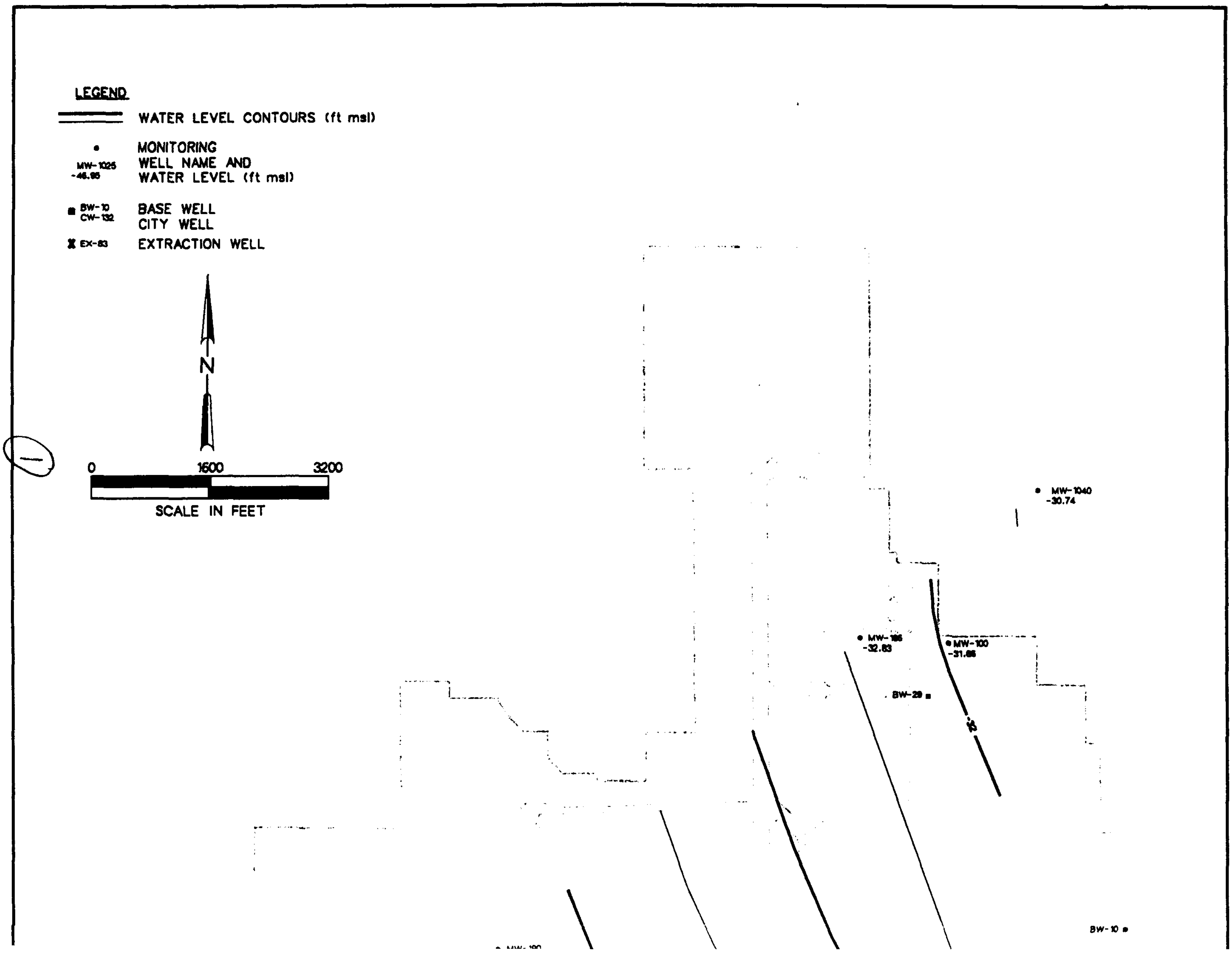


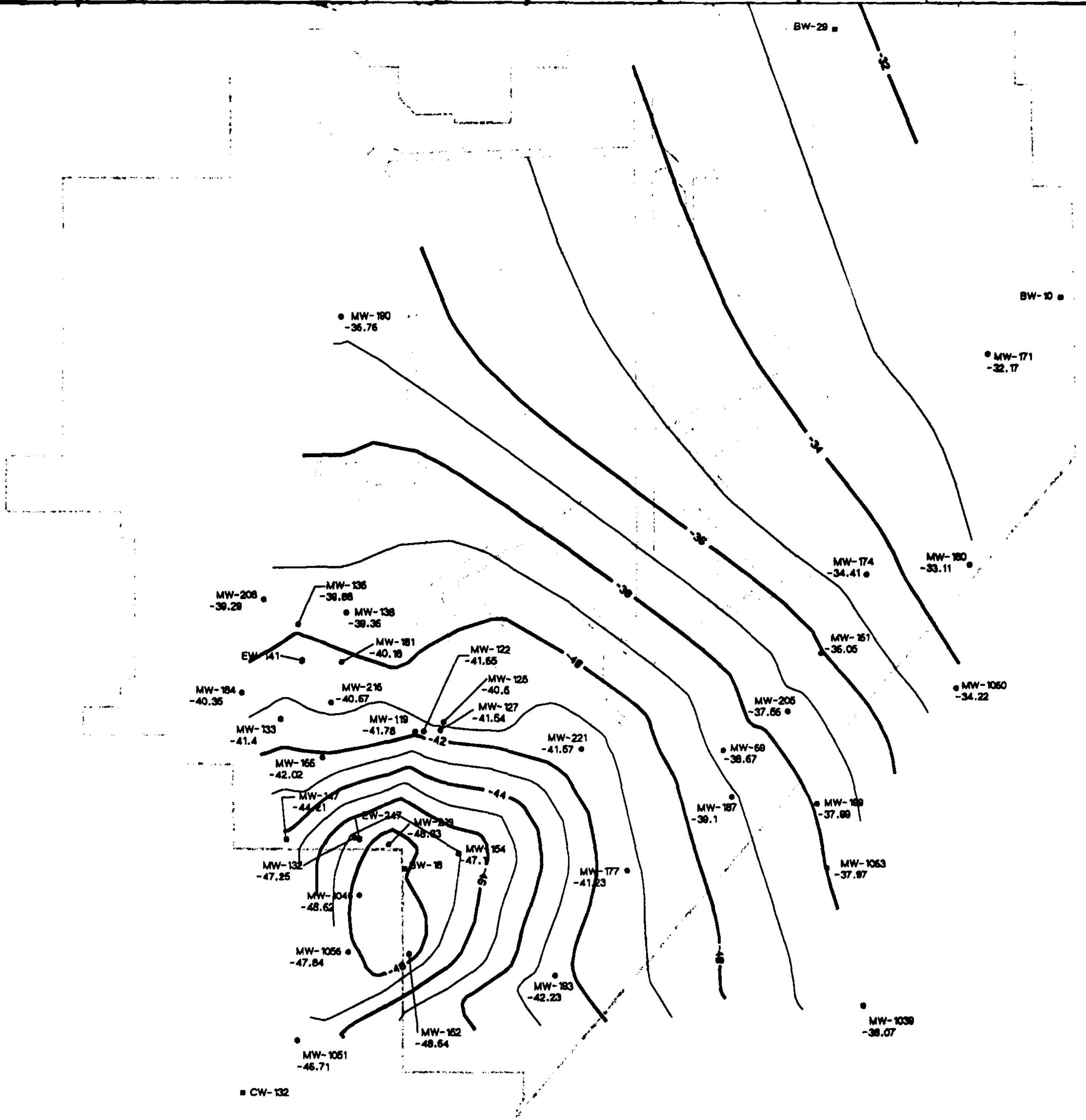
FIGURE 4-36
WATER LEVELS IN MONITORING ZONE B, JANUARY 1993
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1464
GWOU/4-36.DGN


LEGEND
WATER LEVEL CONTOURS (ft msl)
MONITORING
WELL NAME AND
WATER LEVEL (ft msl)
MW-1025
-46.95
BW-10
CW-132
BASE WELL
CITY WELL
EX-83
EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
MW-1040
-30.74
MW-186
-32.83
MW-100
-31.86
BW-29
-32
BW-10

2



BW-29
BW-10
MW-171 -32.17
MW-180 -33.11
MW-1060 -34.22
MW-174 -34.41
MW-161 -35.05
MW-205 -37.56
MW-199 -37.89
MW-1063 -37.97
MW-1039 -38.07
MW-69 -38.67
MW-187 -39.1
MW-190 -36.76
MW-208 -39.29
MW-135 -39.88
MW-136 -39.36
MW-181 -40.16
EW-141
MW-184 -40.35
MW-216 -40.57
MW-122 -41.65
MW-125 -40.6
MW-127 -41.54
MW-119 -41.78
MW-133 -41.4
MW-221 -41.57
MW-155 -42.02
MW-177 -41.23
MW-183 -42.23
MW-132 -47.25
EW-247
MW-154 -47.1
BW-16
MW-1056 -47.84
MW-162 -48.54
MW-1051 -46.71
CW-132
-32
-34
-36
-38
-40
-42
-44
-46
-48

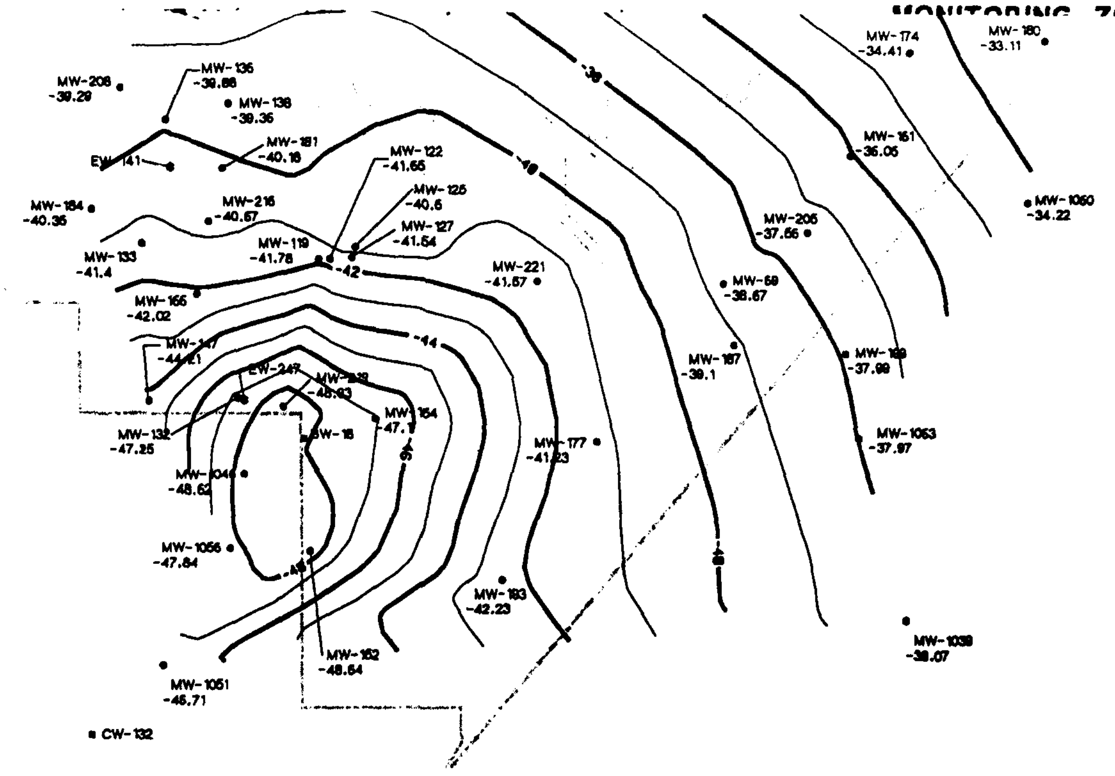
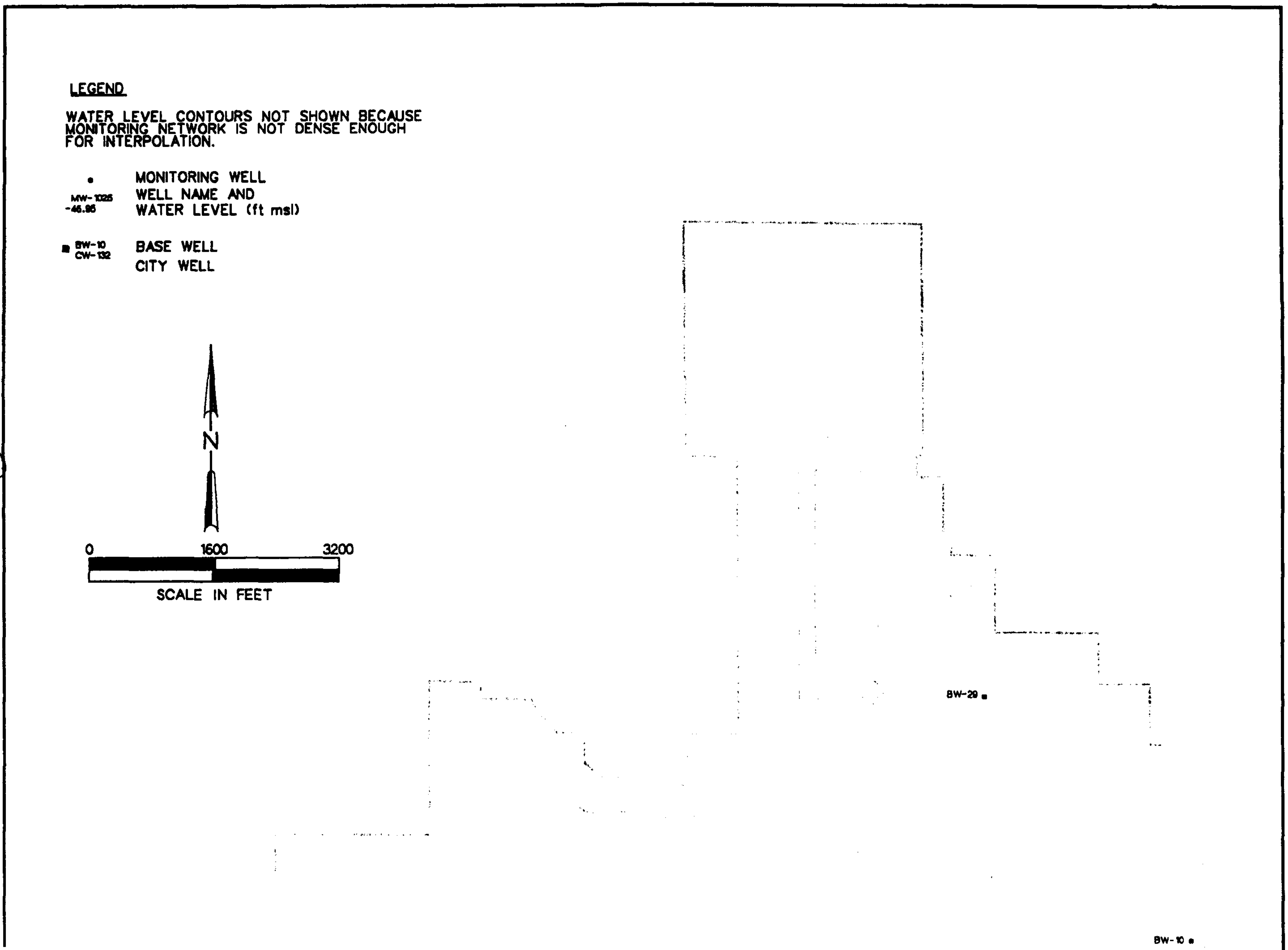


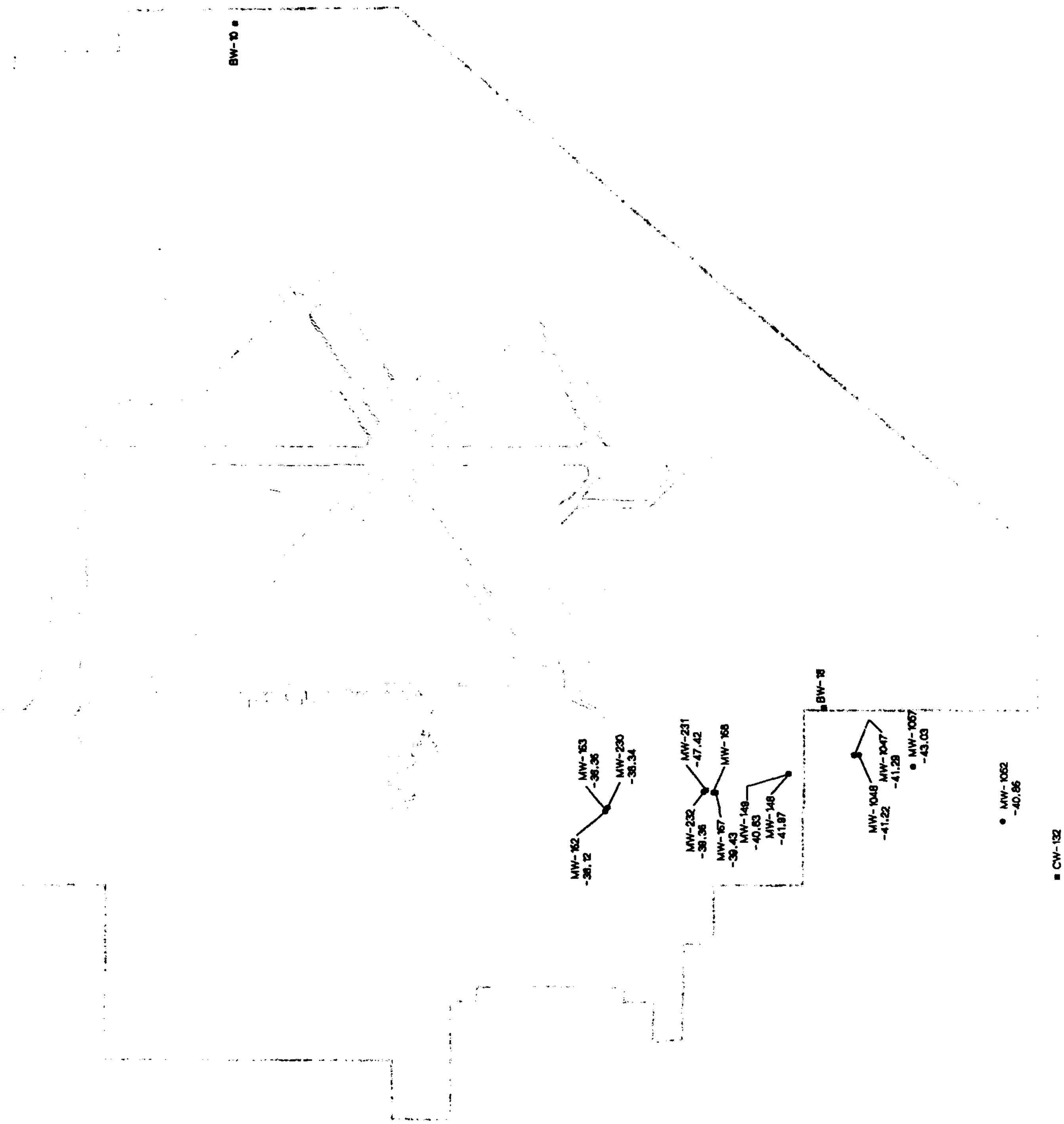
FIGURE 4-37
WATER LEVELS IN MONITORING ZONE C, JANUARY 1993
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454
GWOU/4-37.DGN


LEGEND
WATER LEVEL CONTOURS NOT SHOWN BECAUSE MONITORING NETWORK IS NOT DENSE ENOUGH FOR INTERPOLATION.
MONITORING WELL
MW-1026 -46.86
WELL NAME AND WATER LEVEL (ft msl)
BW-10 CW-132
BASE WELL
CITY WELL
N
0
1600
3200
SCALE IN FEET
BW-29
BW-10

(1)


BW-10
BW-18
MW-163
-38.36
MW-230
-38.34
MW-162
-38.12
MW-231
-47.42
MW-168
MW-232
-39.36
MW-167
-39.43
MW-149
-40.63
MW-148
-41.97
MW-1048
-41.22
MW-1047
-41.29
MW-1057
-43.03
MW-1062
-40.86
CW-132

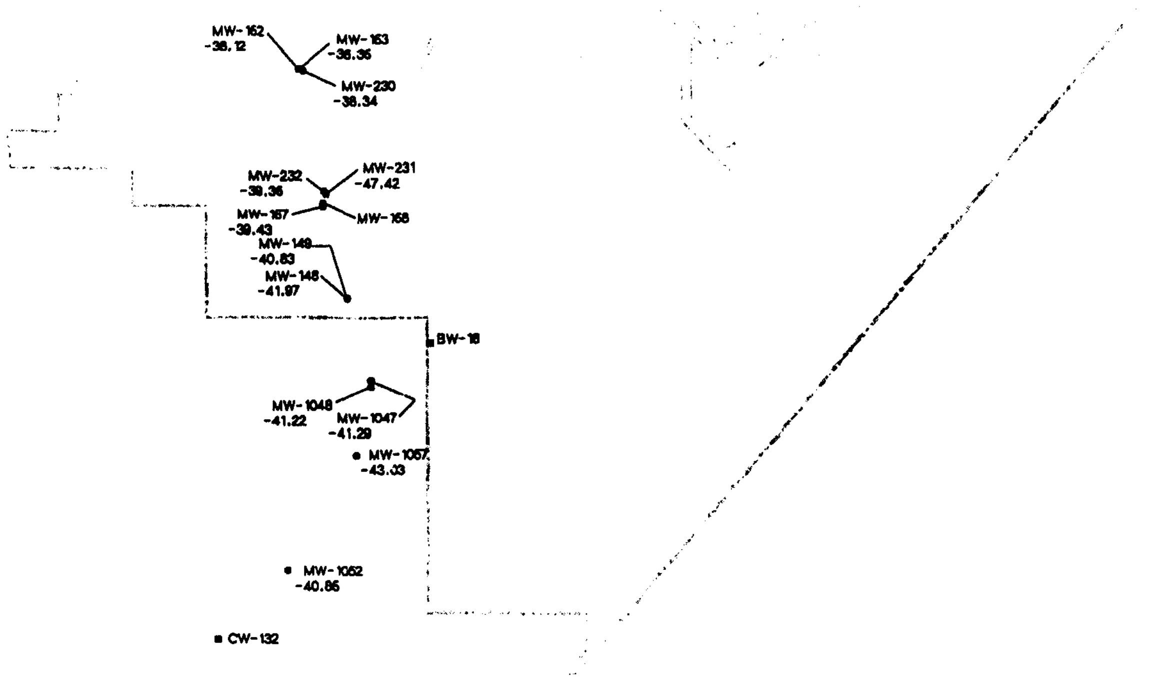
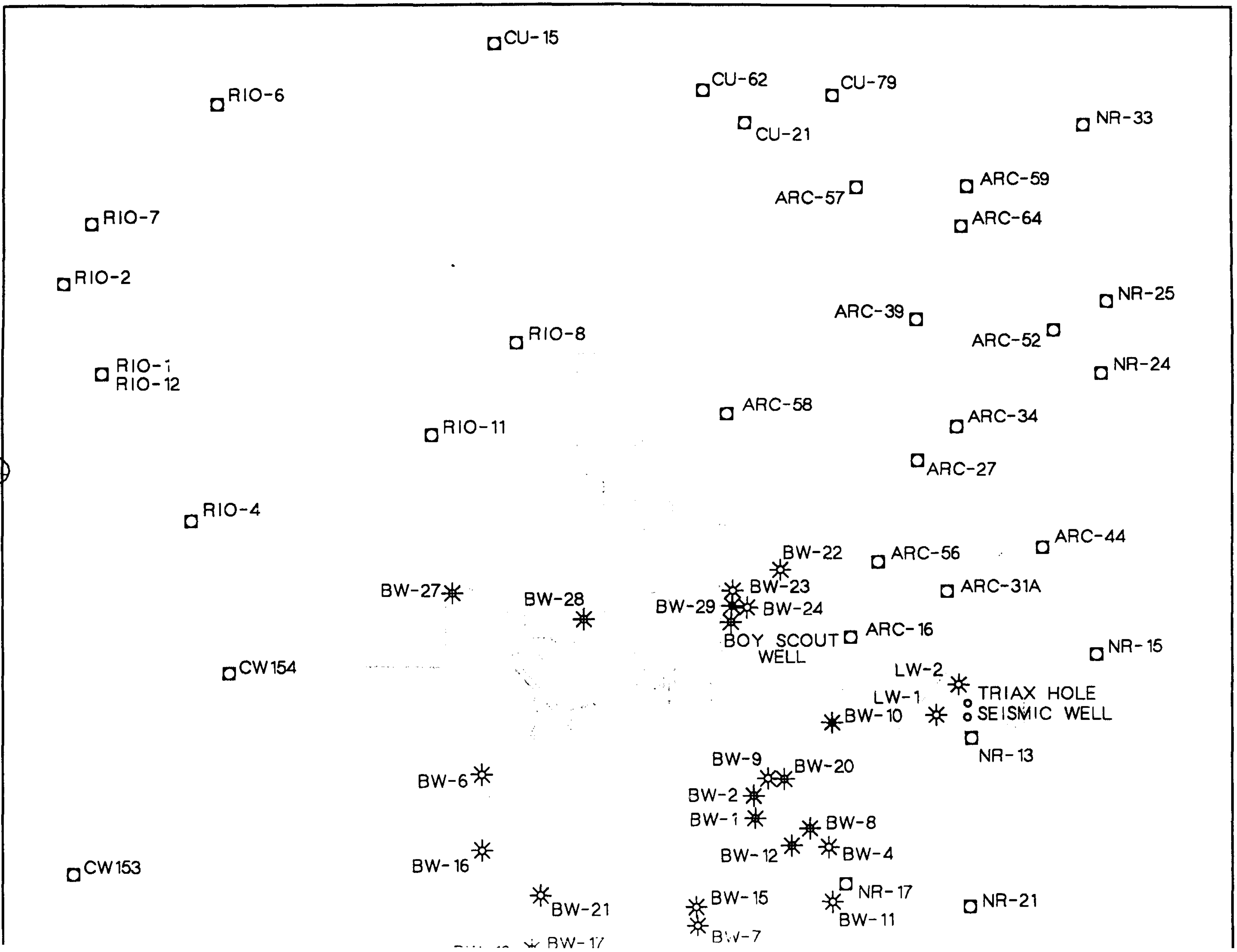
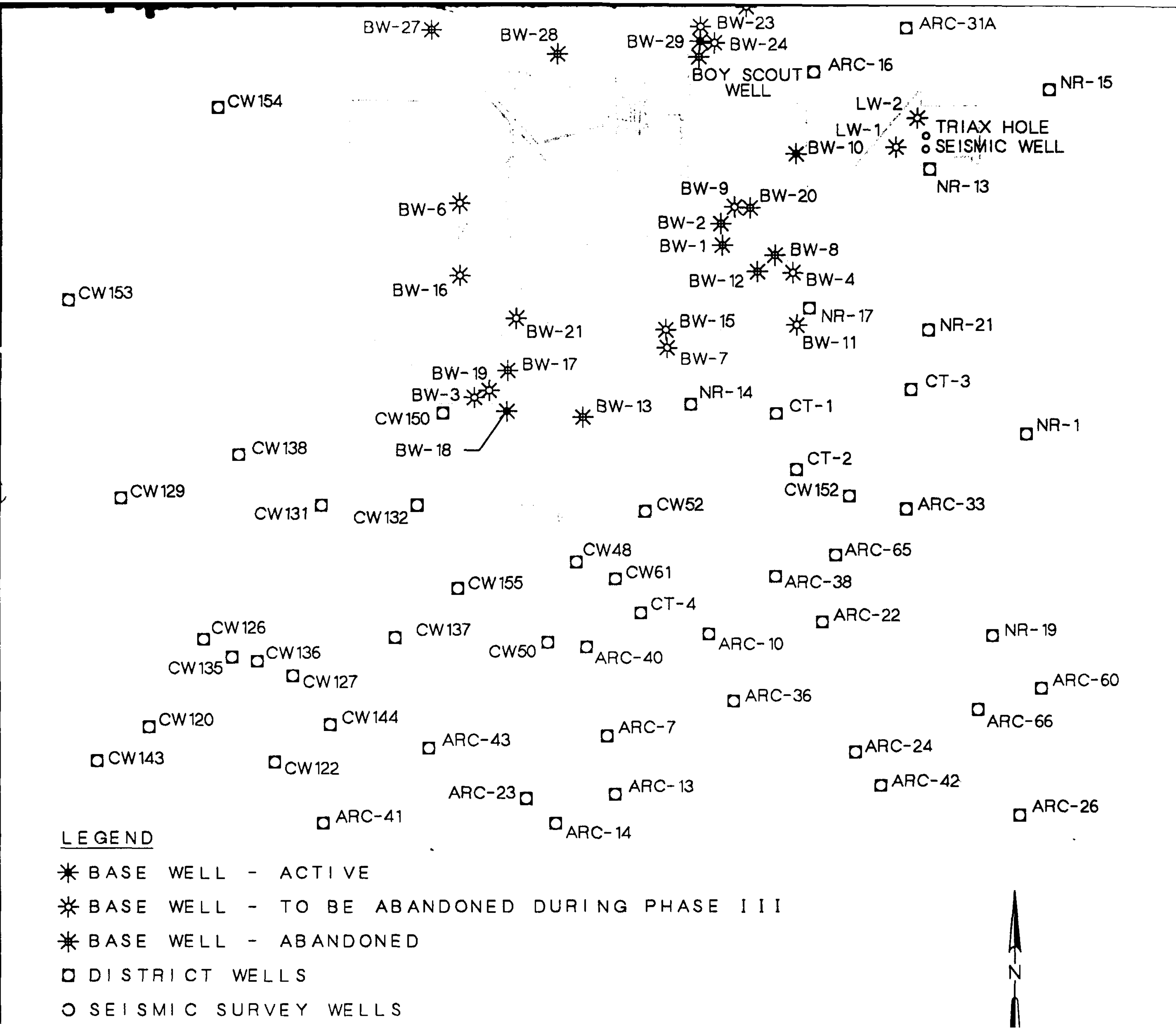


FIGURE 4-38
WATER LEVELS IN MONITORING ZONES D AND E, JANUARY 1993
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

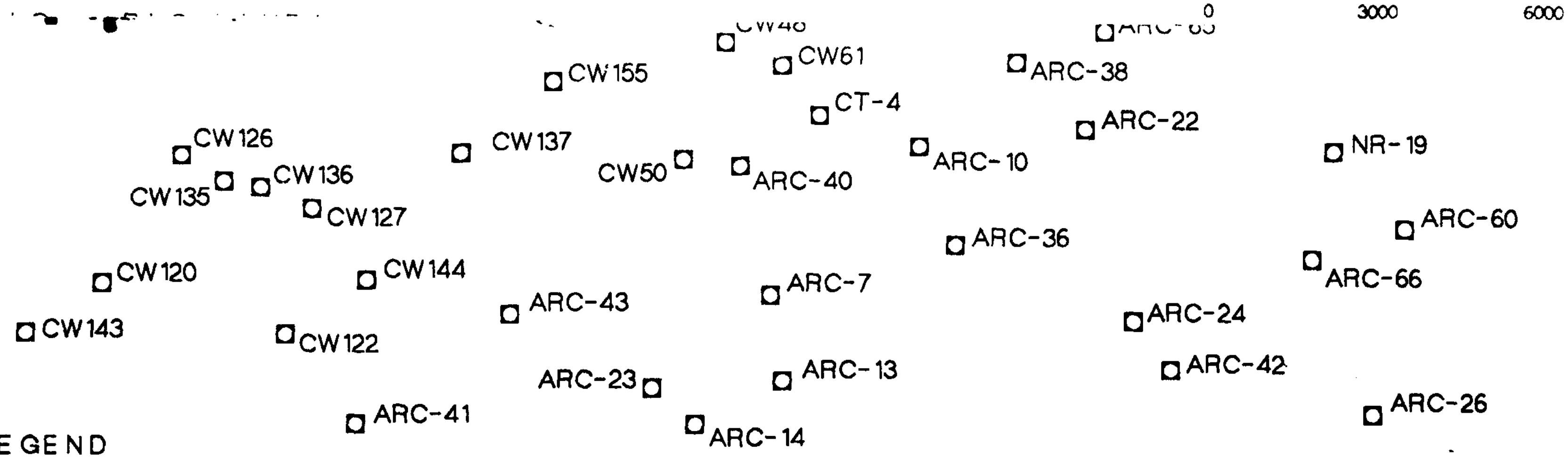
CH2M HILL

RDD1464
GWOU/4-38.DGN


CU-15
CU-62
CU-79
CU-21
NR-33
RIO-6
ARC-57
ARC-59
ARC-64
RIO-7
RIO-2
ARC-39
NR-25
ARC-52
RIO-8
NR-24
RIO-1
RIO-12
ARC-58
ARC-34
RIO-11
ARC-27
RIO-4
BW-22
ARC-56
ARC-44
BW-27
BW-28
BW-23
BW-29
BW-24
ARC-31A
BOY SCOUT
WELL
ARC-16
NR-15
CW154
LW-2
LW-1
TRIAX HOLE
SEISMIC WELL
BW-10
NR-13
BW-9
BW-20
BW-6
BW-2
BW-1
BW-8
BW-12
BW-4
BW-16
CW153
BW-21
BW-15
NR-17
NR-21
BW-11
BW-7


BW-27
BW-28
BW-23
BW-29
BW-24
BOY SCOUT WELL
ARC-31A
ARC-16
NR-15
CW154
LW-2
LW-1
TRIAX HOLE
SEISMIC WELL
BW-10
NR-13
BW-9
BW-20
BW-6
BW-2
BW-1
BW-8
BW-12
BW-4
CW153
BW-16
NR-17
BW-11
NR-21
BW-21
BW-15
BW-7
BW-19
BW-17
BW-3
CW150
BW-18
BW-13
NR-14
CT-1
CT-3
NR-1
CW138
CT-2
CW152
ARC-33
CW129
CW131
CW132
CW52
CW48
ARC-65
CW61
ARC-38
CW155
CT-4
ARC-22
CW126
CW137
CW50
ARC-40
ARC-10
NR-19
CW135
CW136
CW127
ARC-36
ARC-60
ARC-66
CW120
CW144
ARC-7
ARC-43
ARC-24
CW143
CW122
ARC-13
ARC-42
ARC-23
ARC-26
ARC-41
ARC-14
LEGEND
BASE WELL - ACTIVE
BASE WELL - TO BE ABANDONED DURING PHASE III
BASE WELL - ABANDONED
DISTRICT WELLS
SEISMIC SURVEY WELLS
N

CT - CALTRANS



LEGEND

✱ BASE WELL - ACTIVE

✱ BASE WELL - TO BE ABANDONED DURING PHASE III

✱ BASE WELL - ABANDONED

□ DISTRICT WELLS

O SEISMIC SURVEY WELLS

BW - BASE WELL
CT - CALTRANS
RIO - RIO LINDA
CU - CITIZENS UTILITIES
ARC - ARCADE
NR - NORTHRIDGE
CW - CITY WELL

NOTES
1. BW-25 IS LOCATED AT THE LINCOLN COMMUNICATION SITE.
2. BW-26 IS LOCATED AT THE DAVIS COMMUNICATIONS SITE.
3. CW-150 HAS BEEN DECOMISSIONED.

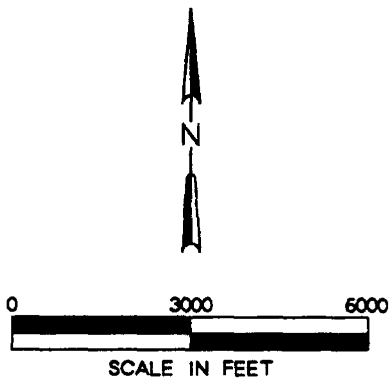
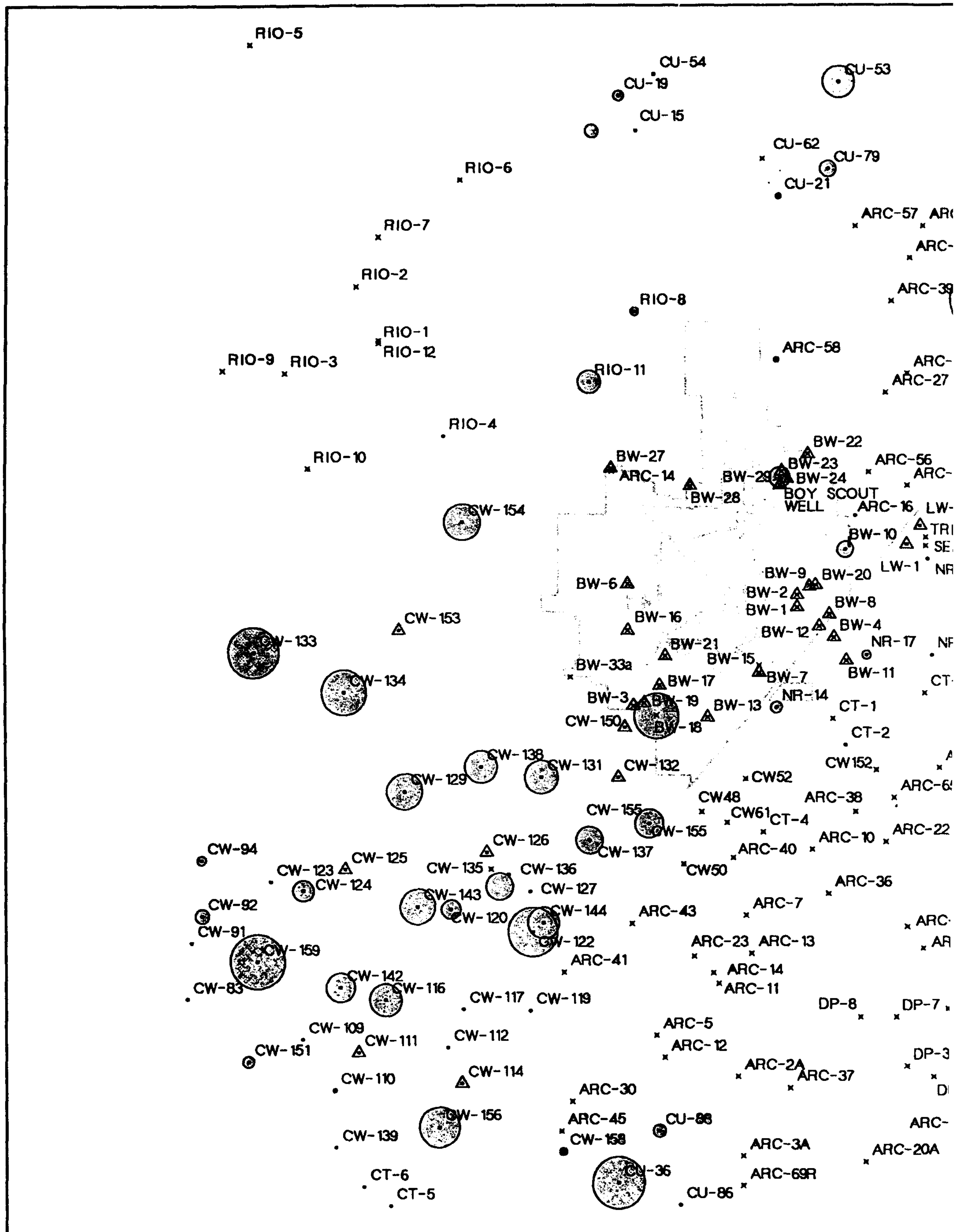


FIGURE 4-40
PRODUCTION, MUNICIPAL, AND BASE WELLS IN THE VICINITY OF MCCLELLAN AIR FORCE BASE

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD 1464
MEY84/4-40.DGN

CH2M HILL



RDD 1454

MEY94/4-41.dgn

(1)

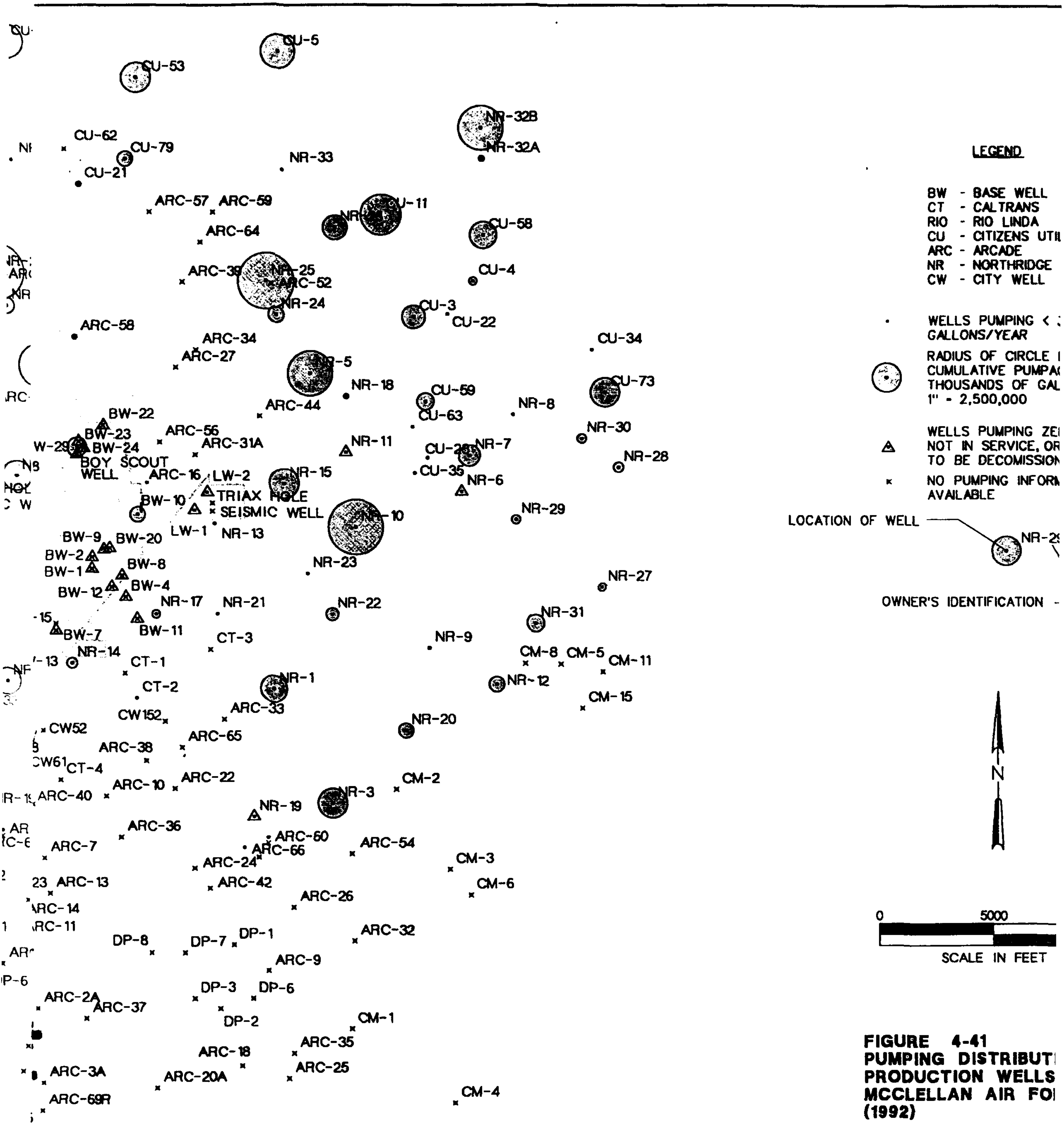
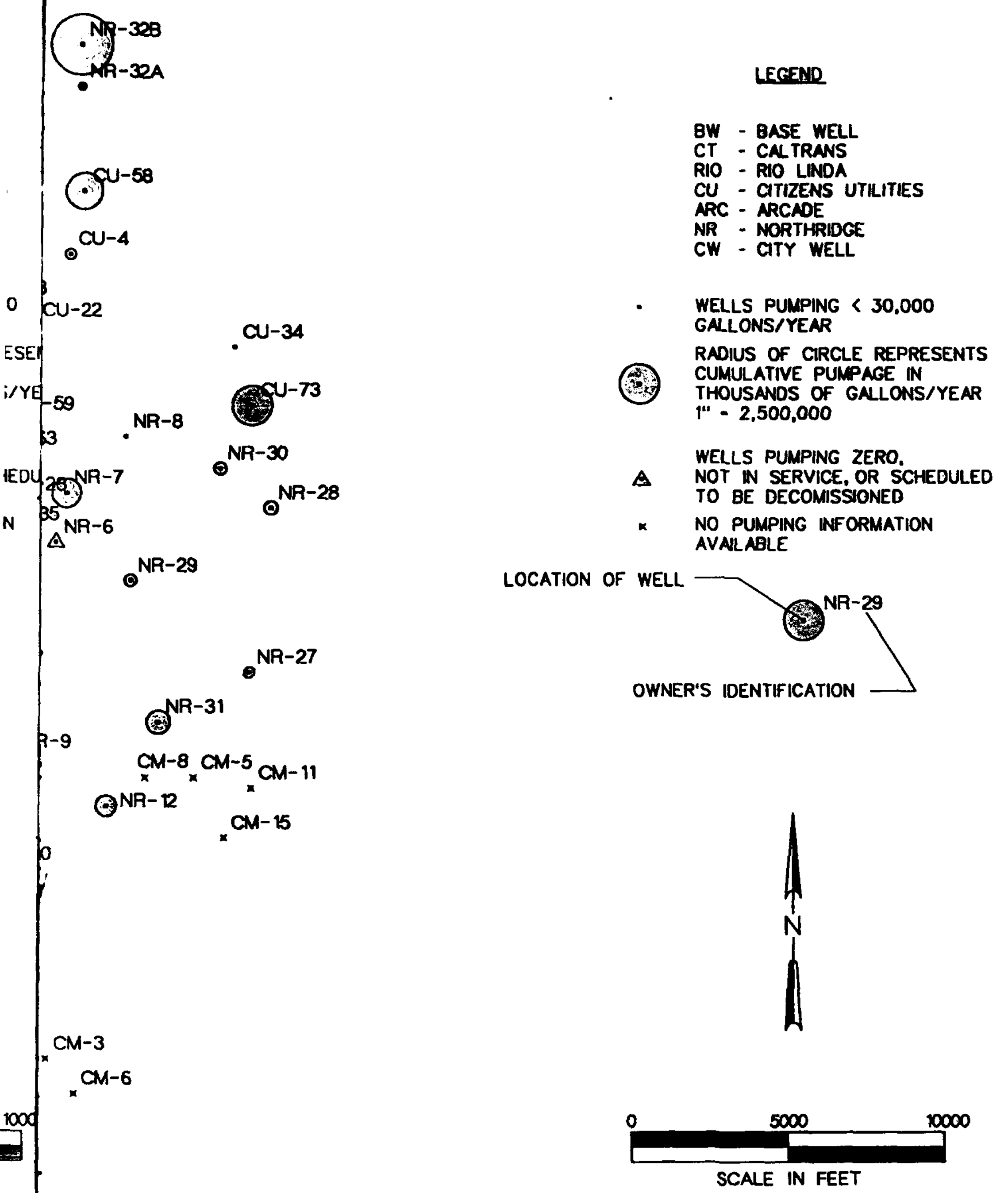


FIGURE 4-41
PUMPING DISTRIBUT
PRODUCTION WELLS
MCCLELLAN AIR FO
(1992)

GROUNDWATER OPERABLE U
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

2

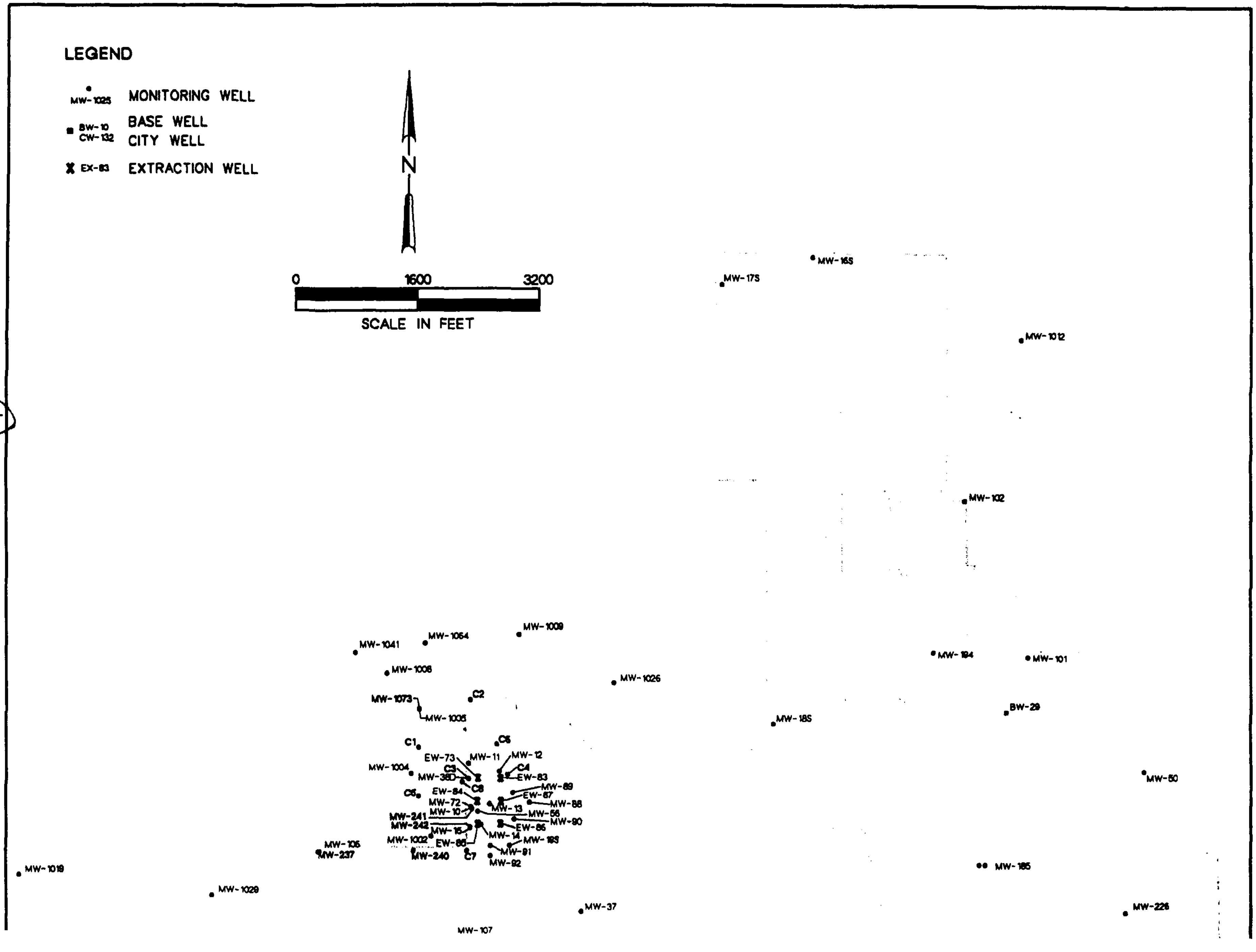


CM-4

FIGURE 4-41
PUMPING DISTRIBUTION OF PRODUCTION WELLS AROUND MCCLELLAN AIR FORCE BASE (1992)

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


LEGEND
MW-1025 MONITORING WELL
BW-10 BASE WELL
CW-132 CITY WELL
EX-83 EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
MW-16S
MW-17S
MW-1012
MW-102
MW-1009
MW-1041
MW-1064
MW-1006
MW-1026
MW-194
MW-101
MW-1073
MW-1005
C2
BW-29
MW-18S
C1
C5
EW-73
MW-11
MW-12
MW-1004
C3
C4
MW-38D
EW-83
C8
C6
EW-84
MW-89
EW-87
MW-72
MW-88
MW-13
MW-241
MW-10
MW-56
MW-242
MW-90
MW-15
EW-86
MW-14
MW-1002
MW-183
EW-85
MW-106
MW-91
MW-237
MW-240
C7
MW-92
MW-50
MW-1019
MW-185
MW-1029
MW-37
MW-226
MW-107
1

C1
C6
EW-73
MW-11
MW-12
C3
C4
MW-1004
MW-38D
EW-63
C8
C5
EW-64
MW-69
EW-67
MW-72
MW-88
MW-13
MW-241
MW-55
MW-242
MW-90
MW-16
EW-66
MW-14
MW-193
MW-1002
EW-65
MW-91
MW-105
MW-237
MW-240
C7
MW-92
MW-1019
MW-1029
MW-37
MW-107
MW-363
MW-188
MW-185
MW-226
BW-10
MW-169
MW-466
MW-202
MW-110
MW-82
MW-62
MW-44S
MW-305
MW-210
MW-212
MW-81
MW-60
MW-31S
MW-111
MW-1036
MW-1018
MW-35S
MW-21D
MW-79
MW-8
MW-9
MW-224
MW-33S
MW-76
MW-80
MW-129
MW-77
MW-126
MW-45S
MW-176
MW-222
MW-172
MW-1017
MW-114
MW-206
MW-228
MW-115
MW-78
MW-131
MW-61
MW-1057
MW-273
MW-160
MW-67
MW-139
MW-286
MW-209
MW-1058
MW-182
MW-214
MW-203
MW-47S
MW-135
MW-123
MW-283
MW-1033
MW-48S
MW-261
MW-117
MW-120
MW-116
MW-25D
MW-40S
MW-269
MW-284
MW-164
MW-386
MW-200
MW-155
MW-268
MW-166
MW-270
MW-169
MW-272
MW-197
MW-271
MW-235
EW-233
MW-68
MW-7
EW-246
MW-43S
MW-146
MW-236
MW-56
MW-1011
MW-217
MW-157
MW-165
EW-234
MW-175
MW-1061
BW-18
MW-153
MW-41S
MW-287
MW-46S
MW-6
MW-5
MW-1020
MW-1021
MW-292
MW-1044
MW-23S
MW-1014
MW-285
MW-1054
MW-150
MW-191
MW-1016
MW-282
MW-281
MW-1037
MW-289
MW-290
MW-1075
MW-1049
MW-1059
MW-1024
MW-42S
MW-1015
MW-1023
MW-1053
CW-132
MW-243
MW-1013

2

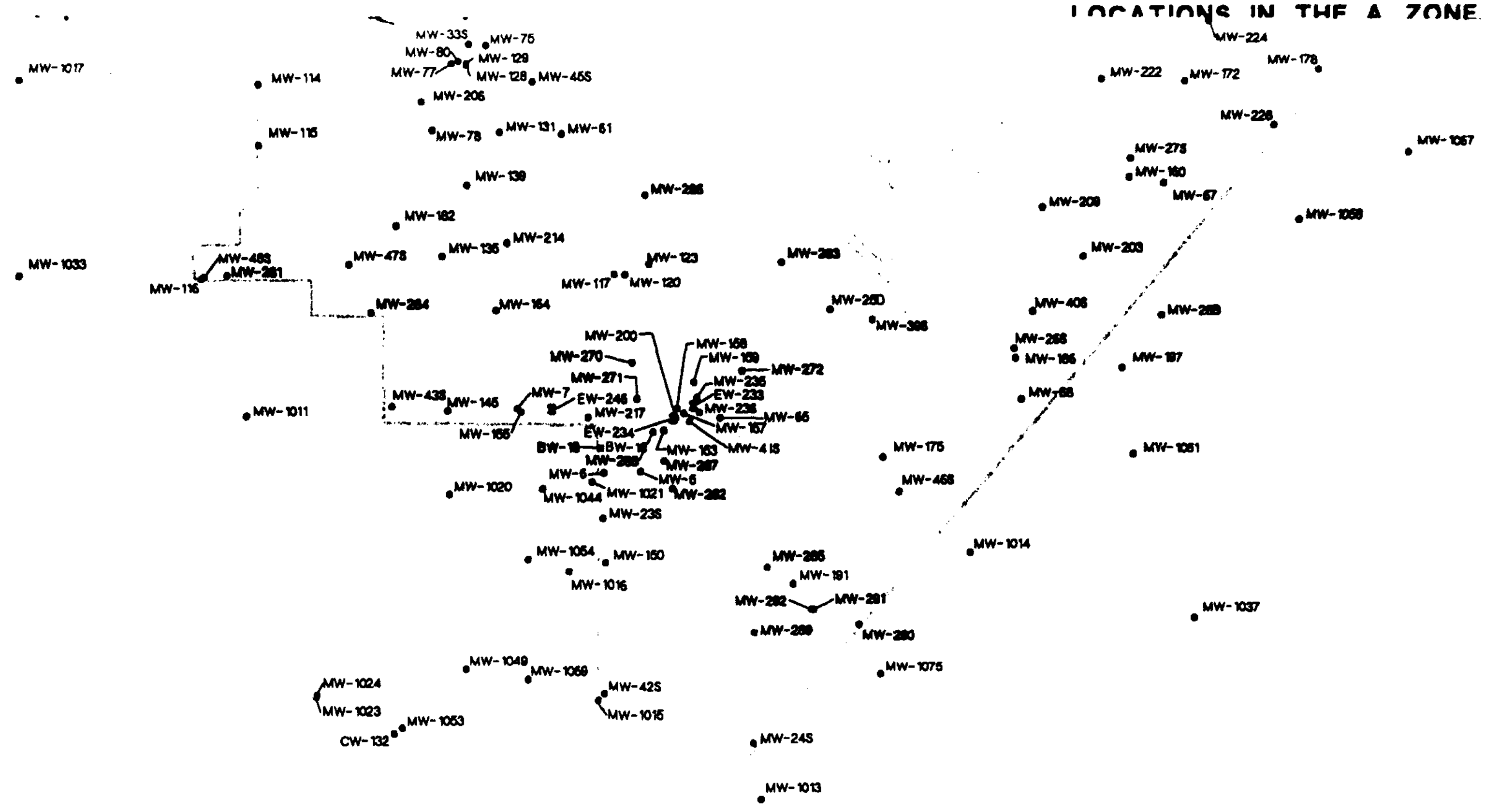
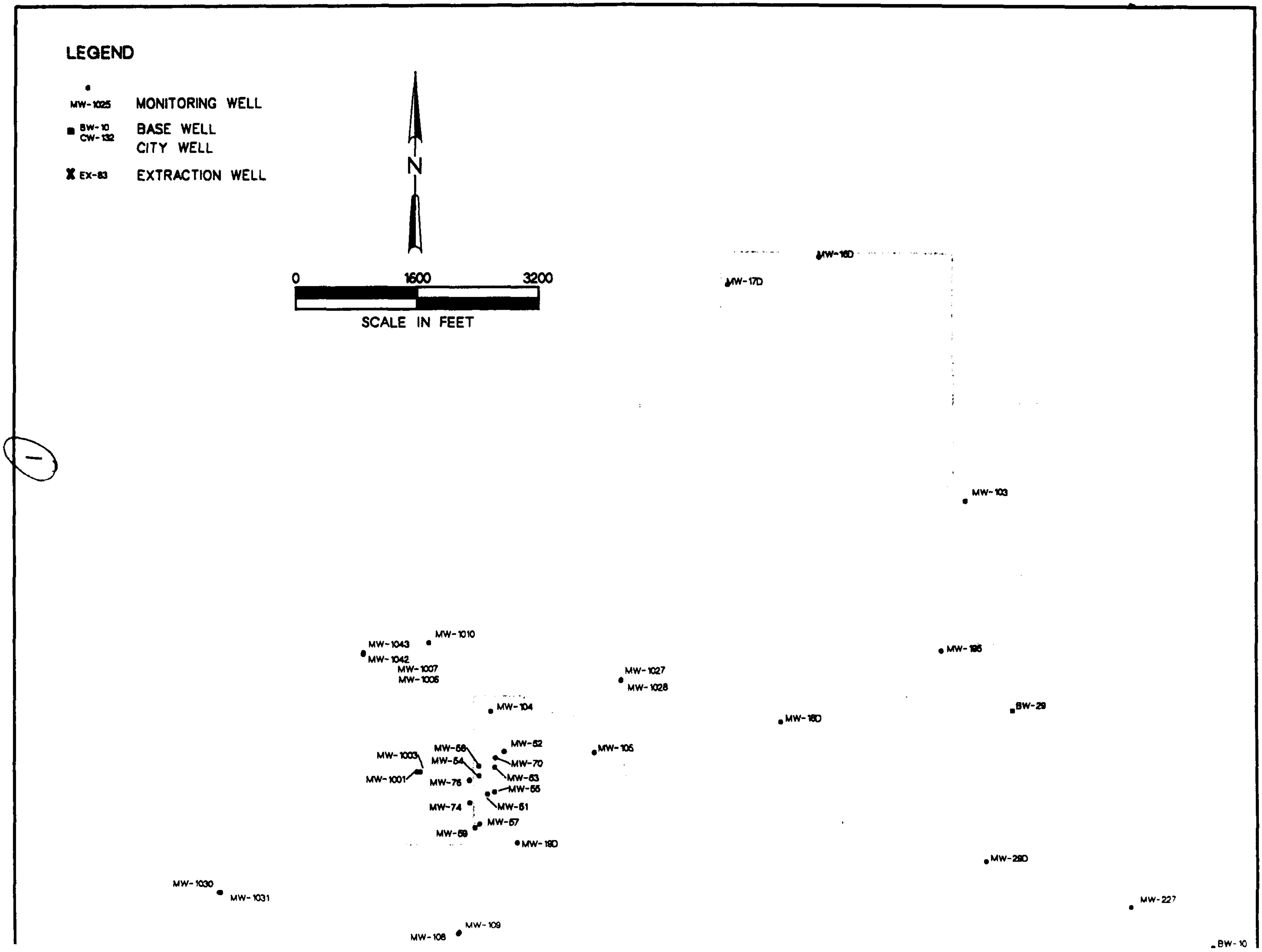


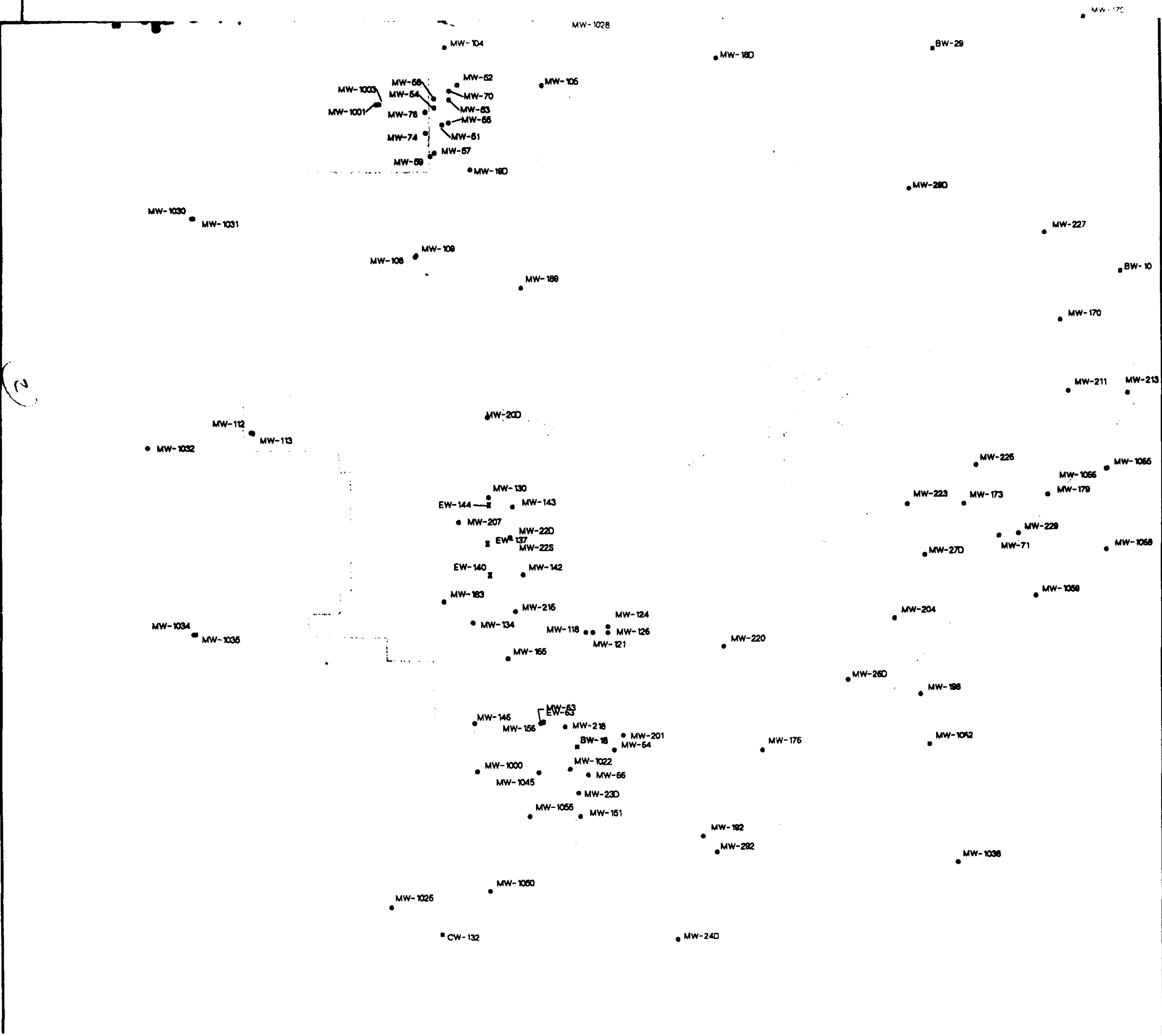
FIGURE 4-43
MONITORING WELL LOCATIONS IN THE A ZONE

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454
MEY94/4-43.DGN


LEGEND
MW-1025 MONITORING WELL
BW-10 BASE WELL
CW-132 CITY WELL
EX-83 EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
MW-16D
MW-17D
MW-103
MW-1010
MW-1043
MW-1042
MW-1007
MW-1006
MW-1027
MW-1028
MW-104
MW-18D
BW-29
MW-105
MW-1003
MW-1001
MW-62
MW-70
MW-63
MW-55
MW-51
MW-57
MW-69
MW-74
MW-76
MW-19D
MW-28D
MW-1030
MW-1031
MW-227
MW-109
MW-108
BW-10



MW-1028
MW-104
MW-18D
BW-29
MW-58
MW-62
MW-1003
MW-54
MW-70
MW-105
MW-1001
MW-76
MW-63
MW-65
MW-74
MW-61
MW-57
MW-59
MW-19D
MW-28D
MW-1030
MW-1031
MW-227
MW-109
MW-108
BW-10
MW-189
MW-170
MW-211
MW-213
MW-20D
MW-112
MW-113
MW-1032
MW-226
MW-1065
MW-1066
MW-130
MW-223
MW-173
MW-179
EW-144
MW-143
MW-207
MW-22D
MW-229
EW-137
MW-22S
MW-27D
MW-71
MW-1058
EW-140
MW-142
MW-183
MW-1059
MW-216
MW-204
MW-124
MW-1034
MW-134
MW-118
MW-126
MW-1035
MW-121
MW-220
MW-165
MW-26D
MW-198
MW-63
EW-63
MW-146
MW-156
MW-218
MW-201
BW-18
MW-64
MW-175
MW-1052
MW-1000
MW-1022
MW-1045
MW-66
MW-23D
MW-1055
MW-151
MW-192
MW-292
MW-1036
MW-1060
MW-1025
CW-132
MW-24D

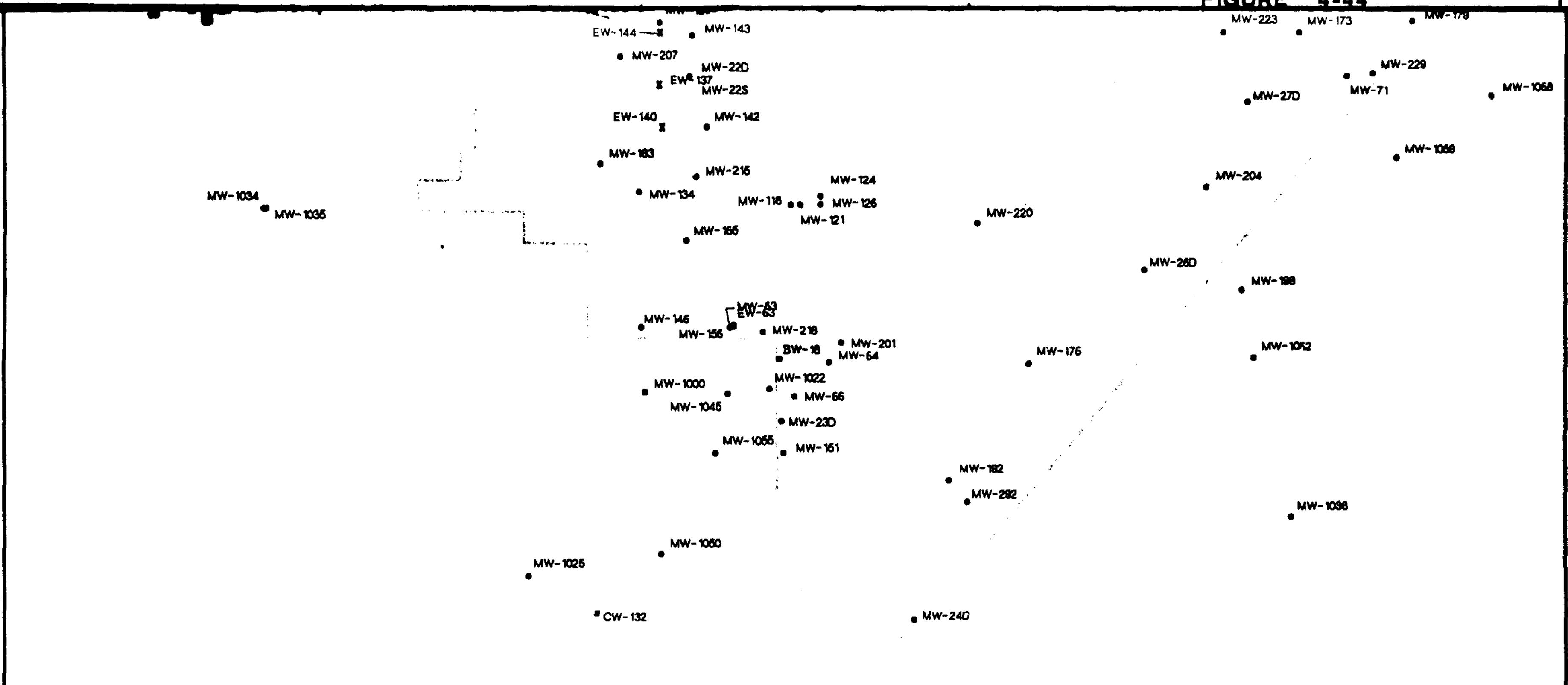
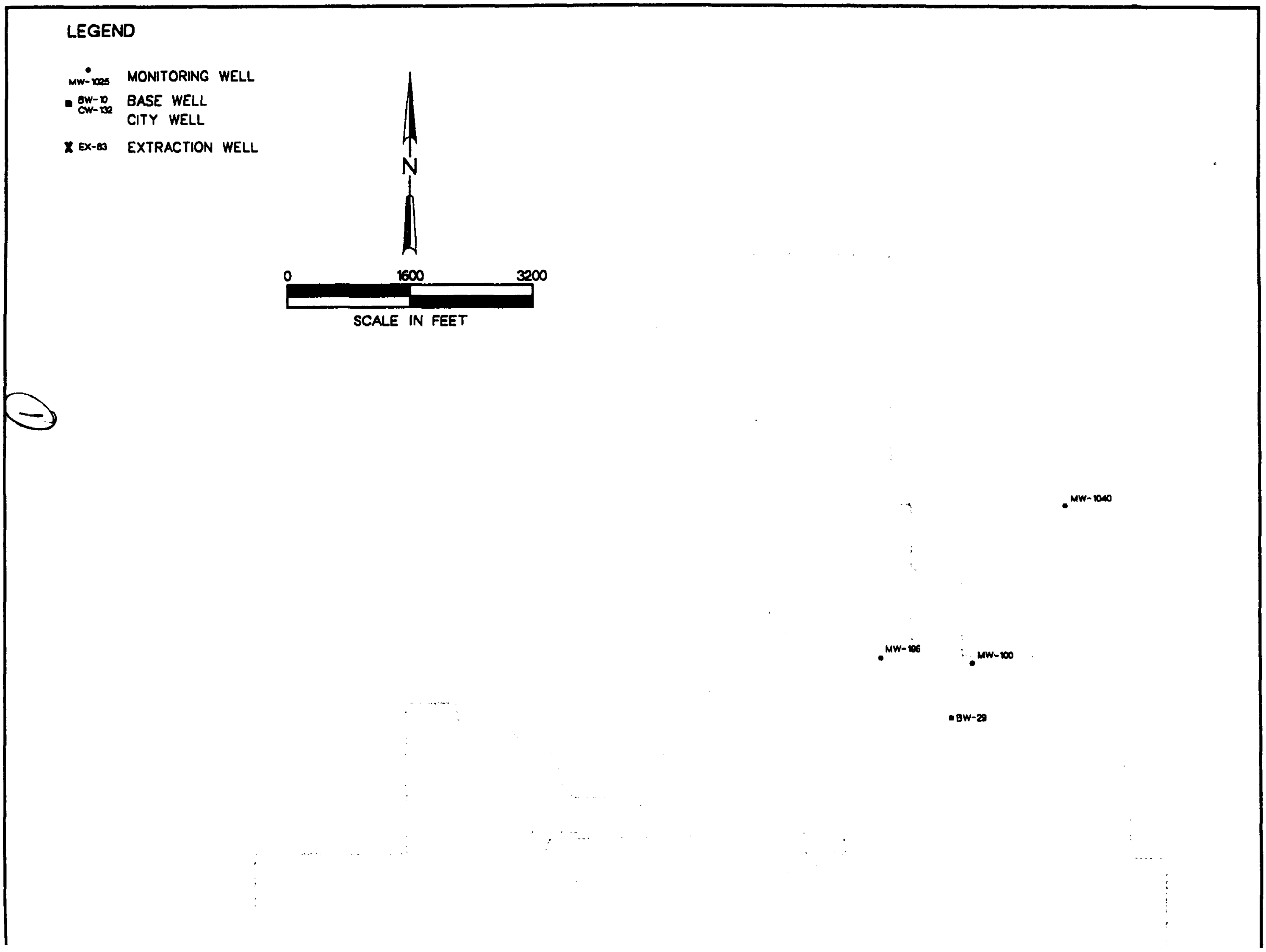


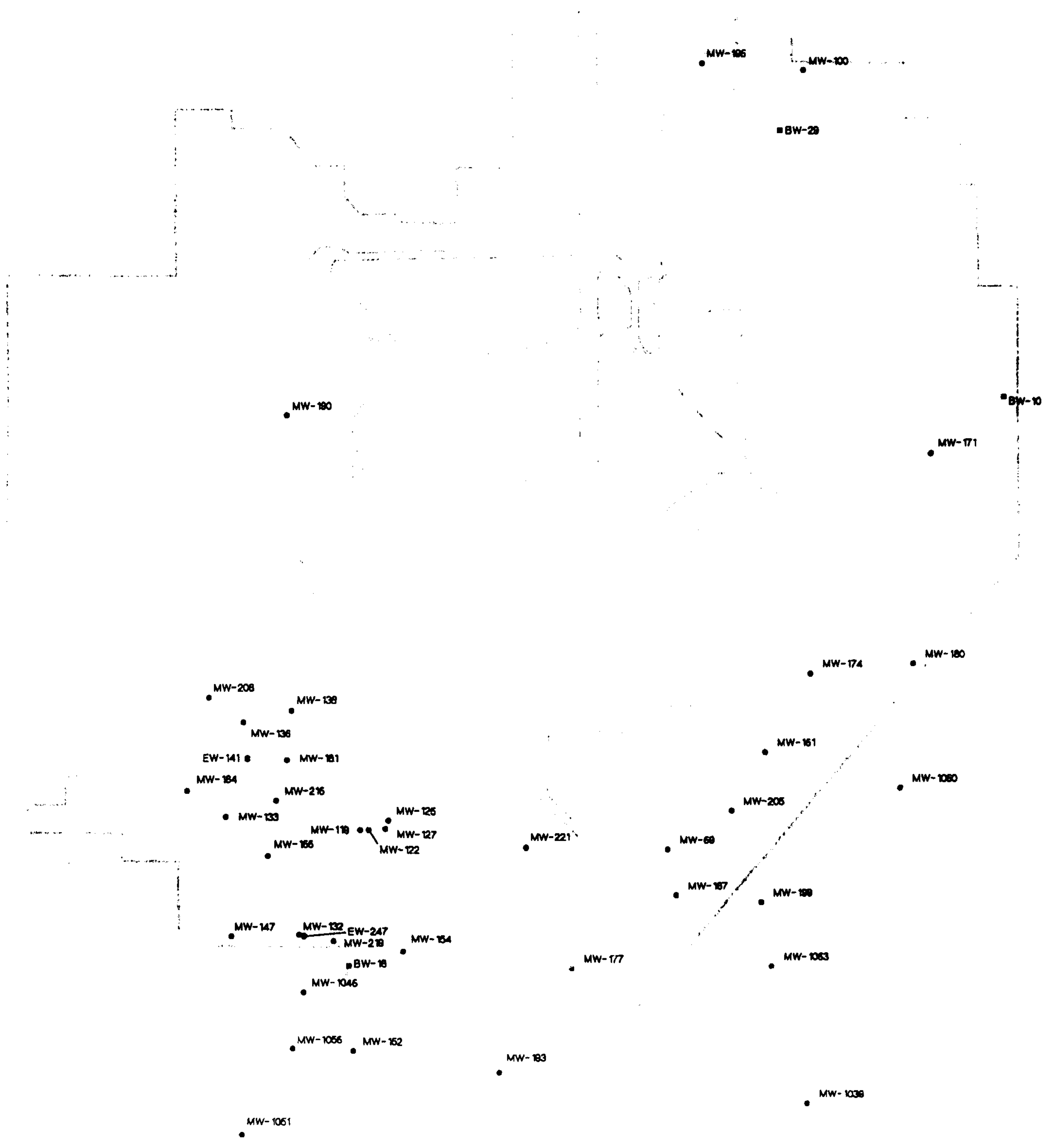
FIGURE 4-44
MONITORING WELL LOCATIONS IN THE B ZONE
GROUNDWATER OPERABLE UNIT /FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD 1454
GWOU/4-44.DGN



LEGEND
MW-1025 MONITORING WELL
BW-10 BASE WELL
CW-132 CITY WELL
EX-83 EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
MW-1040
MW-196
MW-100
BW-29


MW-171
MW-196
MW-100
BW-29
BW-10
MW-190
MW-171
MW-174
MW-180
MW-161
MW-1060
MW-208
MW-138
MW-136
EW-141
MW-181
MW-184
MW-216
MW-205
MW-125
MW-133
MW-119
MW-127
MW-221
MW-69
MW-166
MW-122
MW-167
MW-199
MW-147
MW-132
EW-247
MW-219
MW-154
MW-177
MW-1063
BW-16
MW-1046
MW-1056
MW-152
MW-193
MW-1039
MW-1051

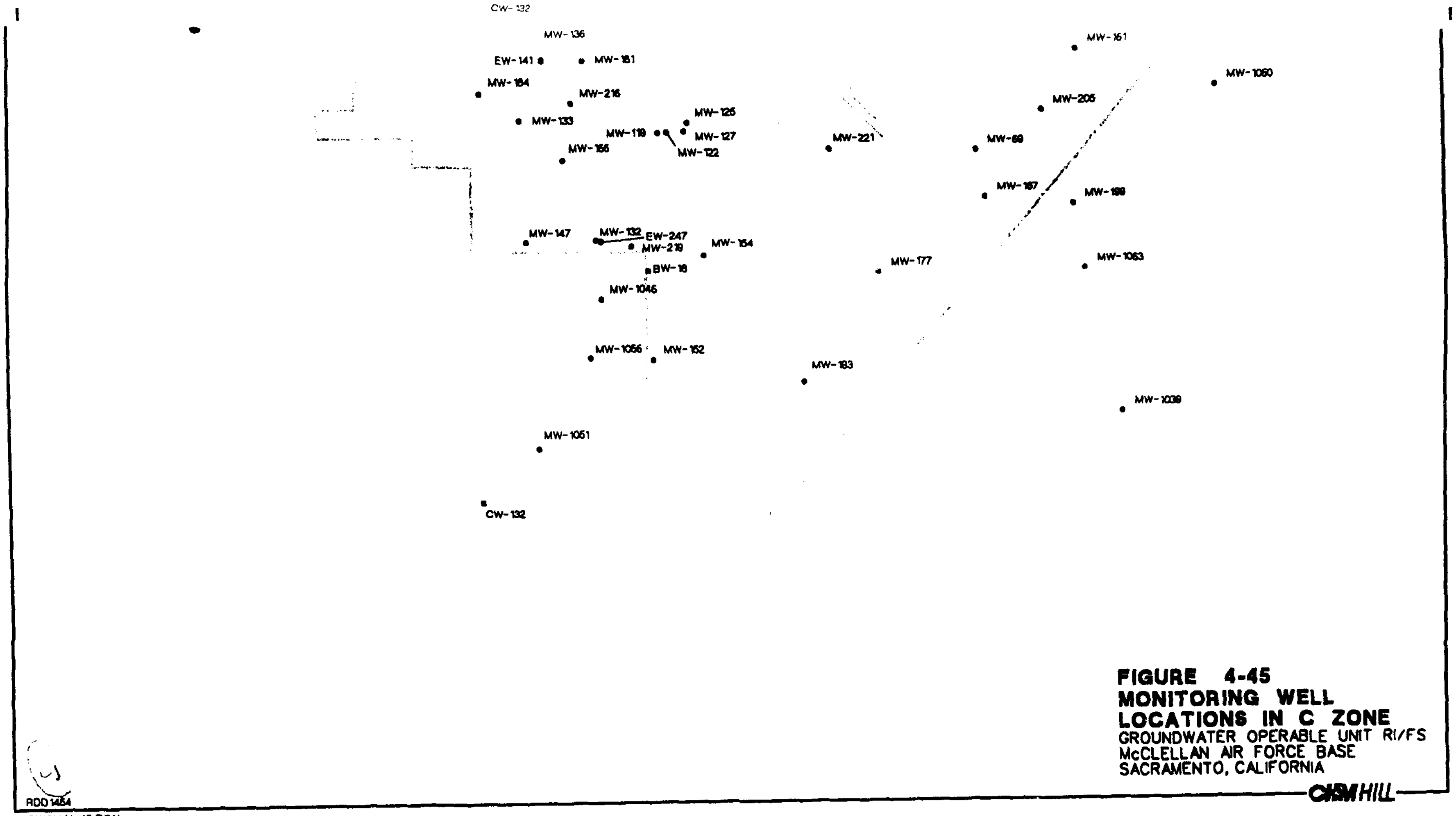
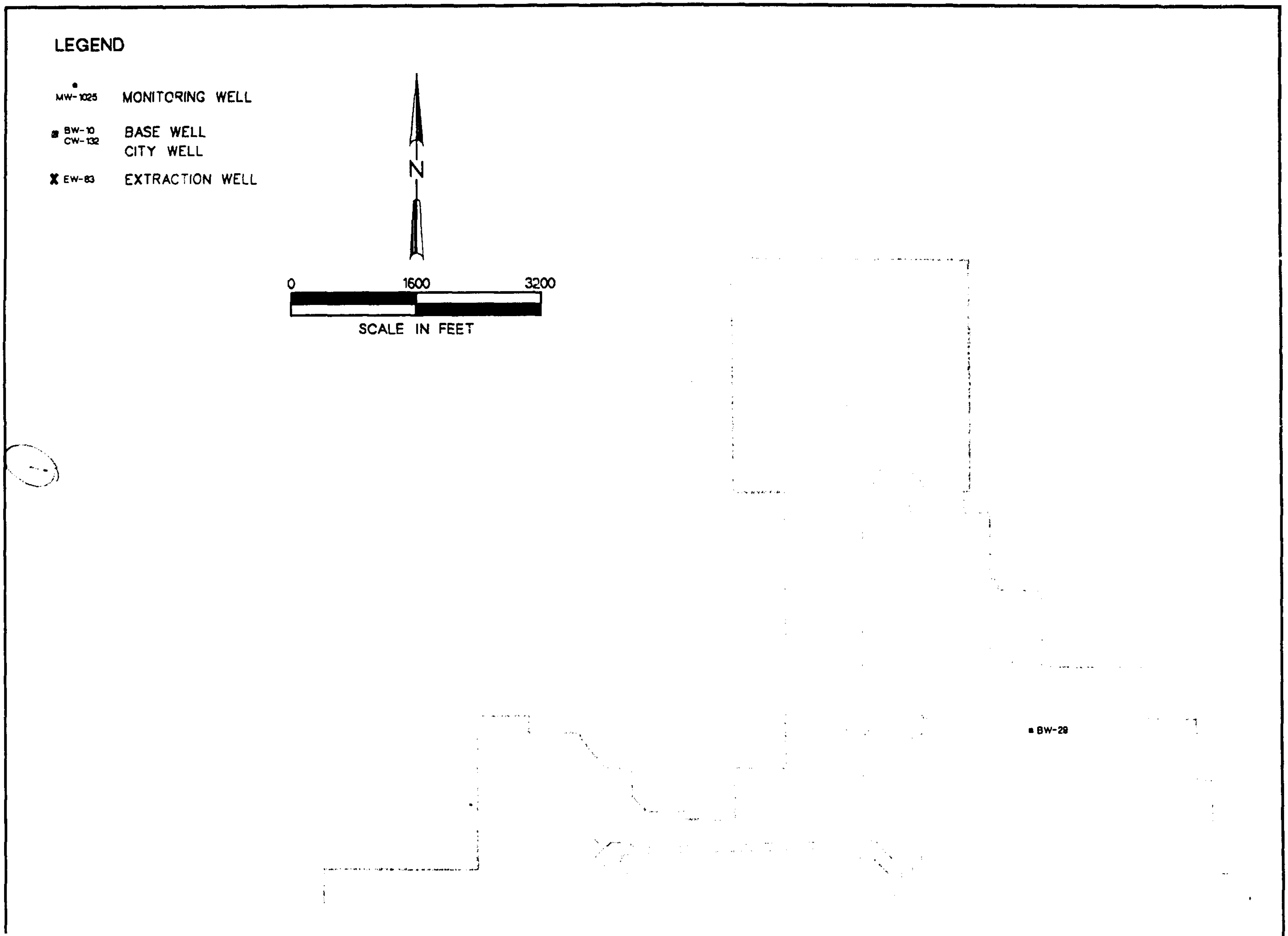
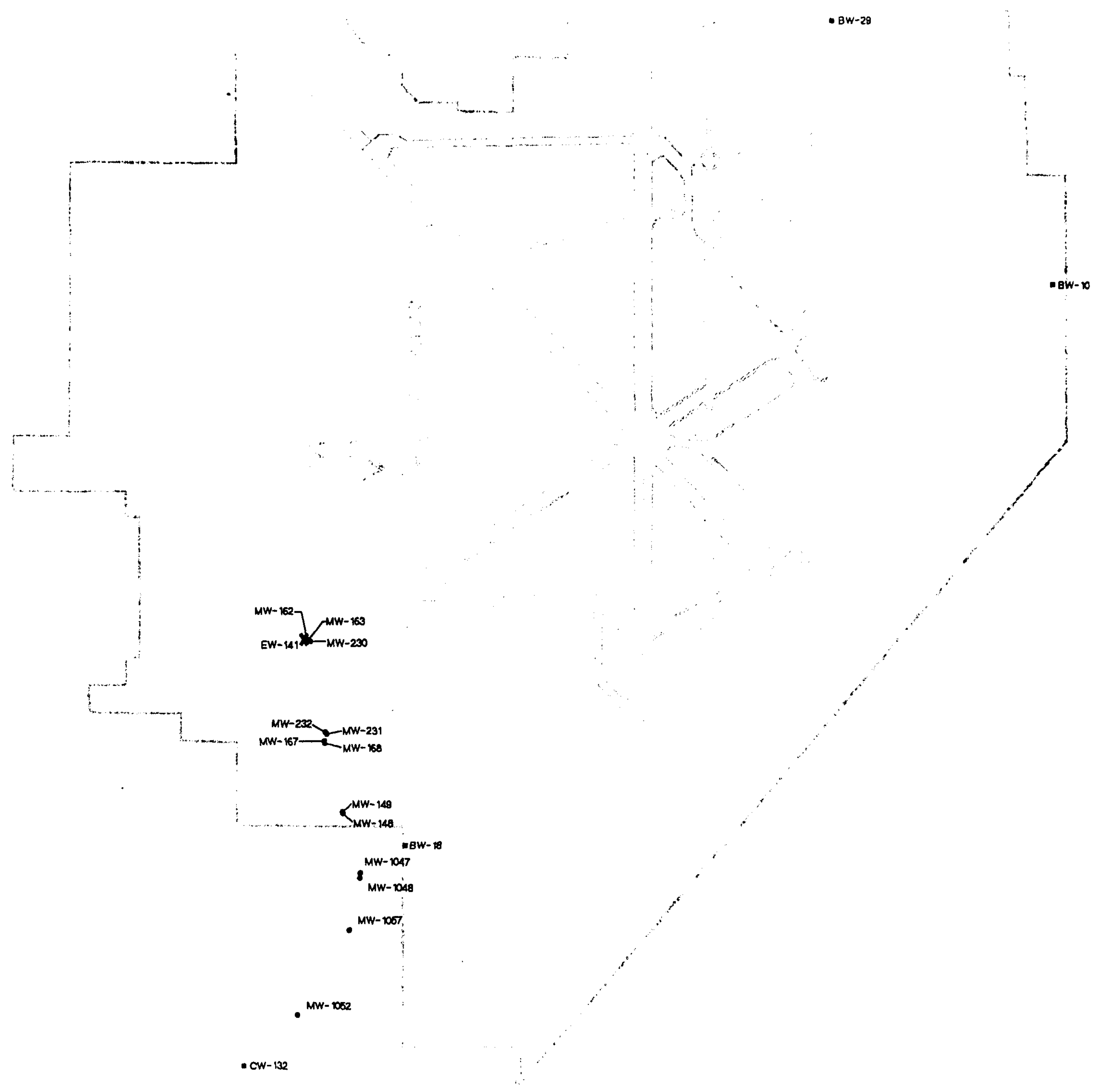


FIGURE 4-45
MONITORING WELL LOCATIONS IN C ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454
GWOU/4-45.DGN


LEGEND
MW-1025 MONITORING WELL
BW-10 BASE WELL
CW-132 CITY WELL
EW-83 EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
BW-29


BW-29
BW-10
MW-162
MW-163
EW-141
MW-230
MW-232
MW-231
MW-167
MW-168
MW-149
MW-148
BW-18
MW-1047
MW-1048
MW-1057
MW-1052
CW-132

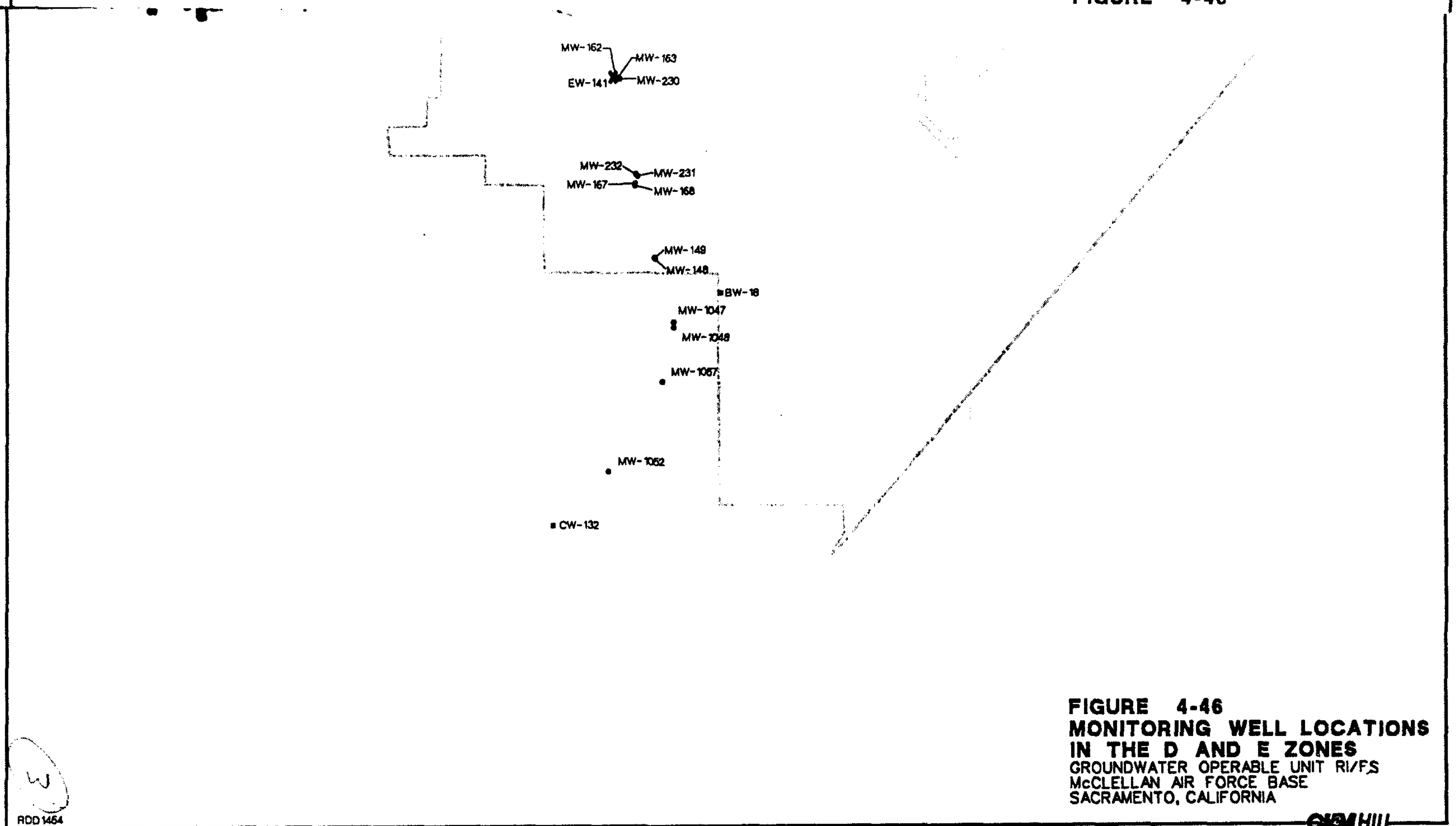
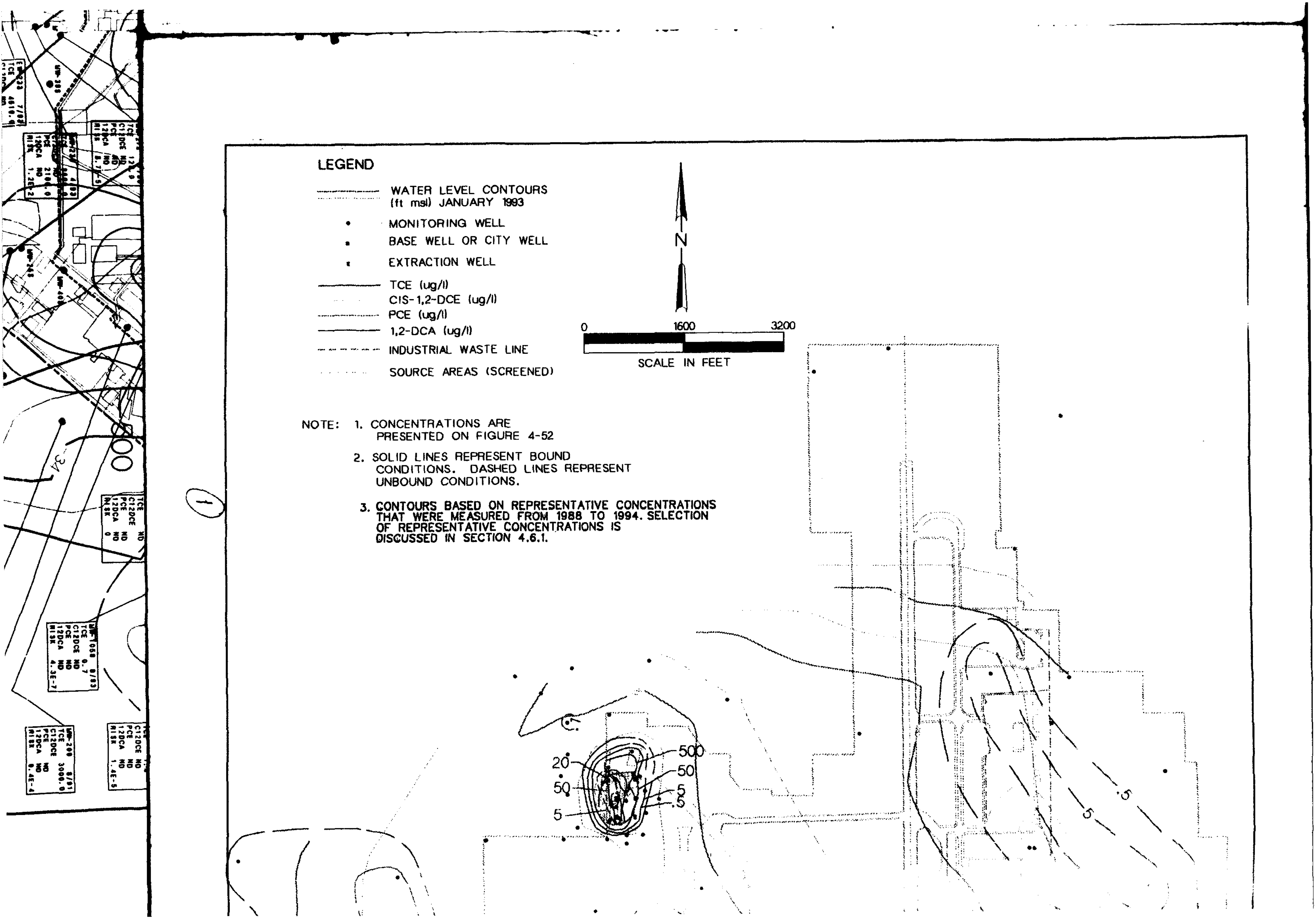


FIGURE 4-46
MONITORING WELL LOCATIONS IN THE D AND E ZONES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD 1454
MEY94/4-46.DGN



LEGEND
WATER LEVEL CONTOURS (ft msl) JANUARY 1993
MONITORING WELL
BASE WELL OR CITY WELL
EXTRACTION WELL
TCE (ug/l)
CIS-1,2-DCE (ug/l)
PCE (ug/l)
1,2-DCA (ug/l)
INDUSTRIAL WASTE LINE
SOURCE AREAS (SCREENED)
N
0
1600
3200
SCALE IN FEET
NOTE: 1. CONCENTRATIONS ARE PRESENTED ON FIGURE 4-52
2. SOLID LINES REPRESENT BOUND CONDITIONS. DASHED LINES REPRESENT UNBOUND CONDITIONS.
3. CONTOURS BASED ON REPRESENTATIVE CONCENTRATIONS THAT WERE MEASURED FROM 1988 TO 1994. SELECTION OF REPRESENTATIVE CONCENTRATIONS IS DISCUSSED IN SECTION 4.6.1.
500
50
5
5
20
50
5
5
5

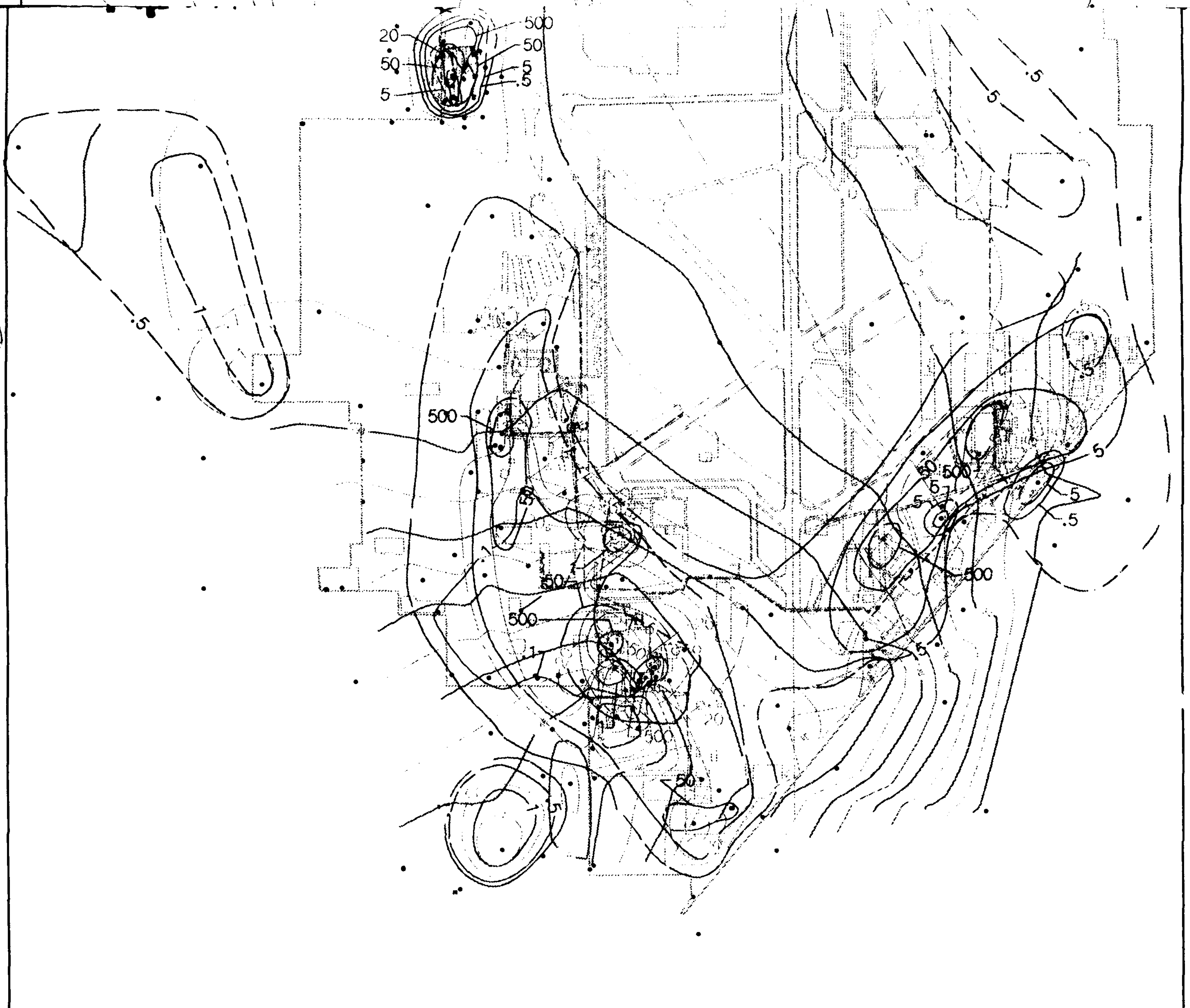


FIGURE 4-50

MONITORING ZONE A

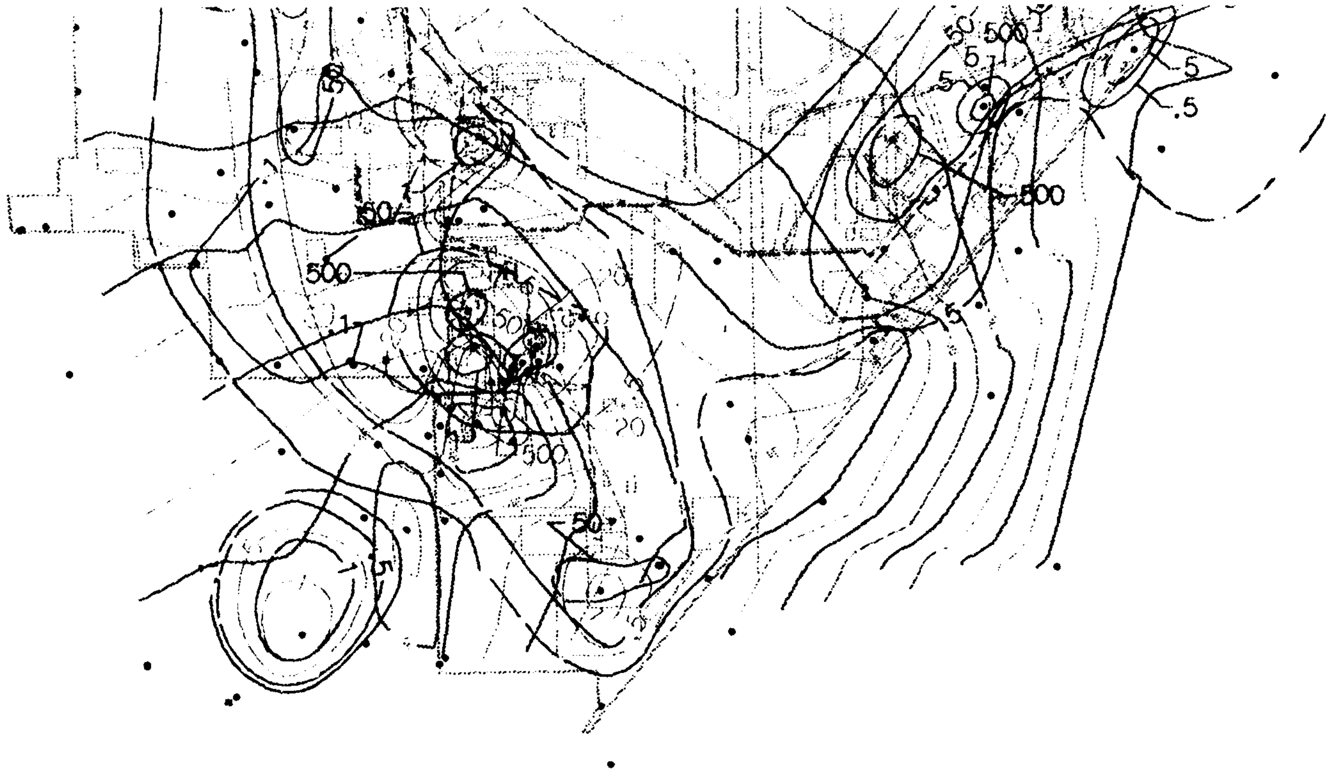


FIGURE 4-50
EXTENT OF VOC
CONTAMINATION IN
MONITORING ZONE A
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454 Mar 28, 1994
MEY/4-50.DGN

LEGEND

MW-11 7/93
TCE 1400.0
C12DCE ND
PCE ND
12DCA ND
RISK 1.E-3

WELL NAME, MONTH AND YEAR OF
VOC CONCENTRATION (ug/l), AND C
RISK VALUE.

WATER LEVEL CONTOURS (ft msl) JANUARY 1993

• MONITORING WELL

⊠ BASE WELL OR CITY WELL

x EXTRACTION WELL

TCE (ug/l)

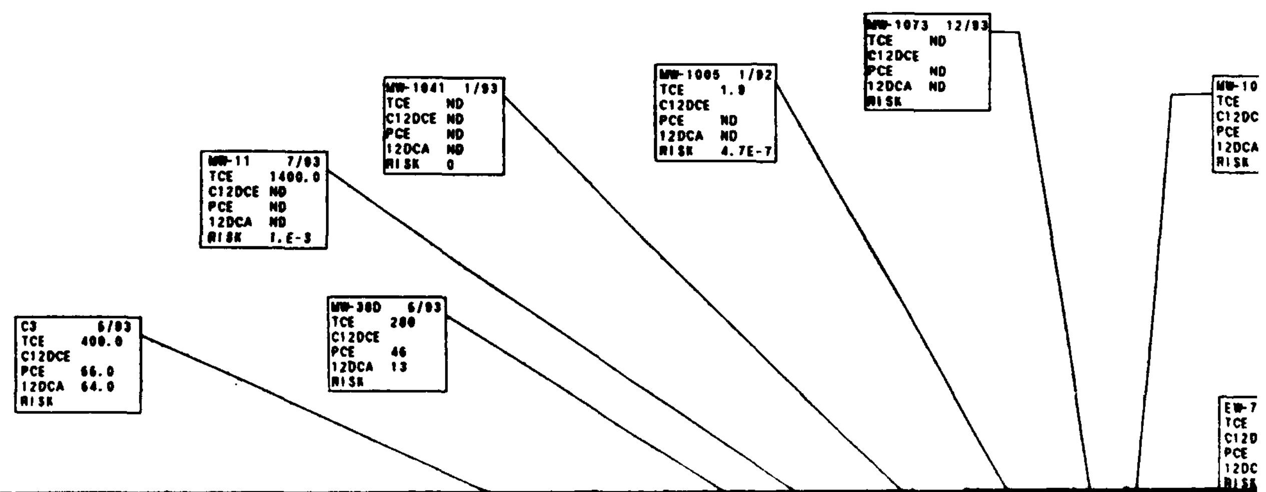
INDUSTRIAL WASTE LINE

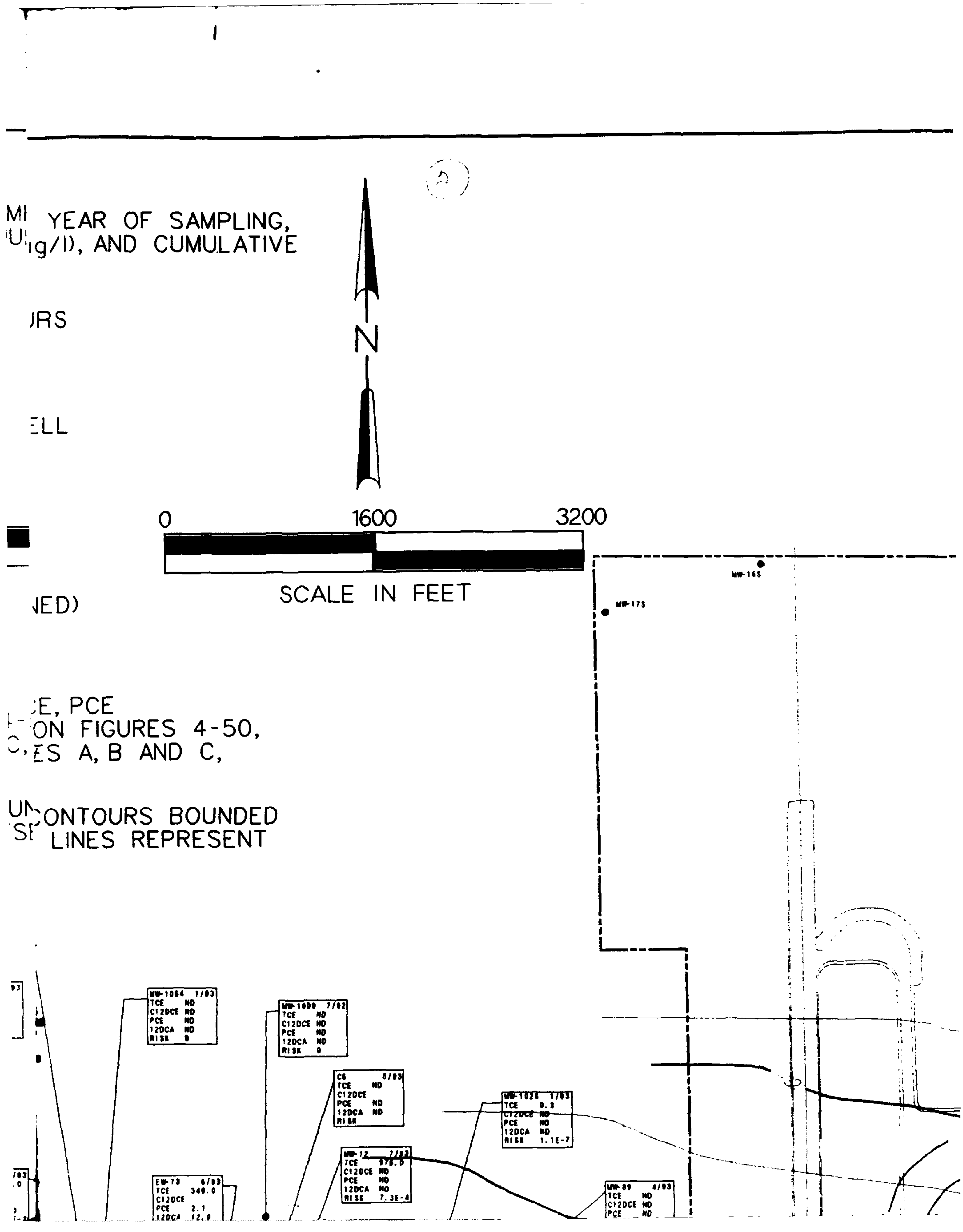
SOURCE AREAS (SCREENED)

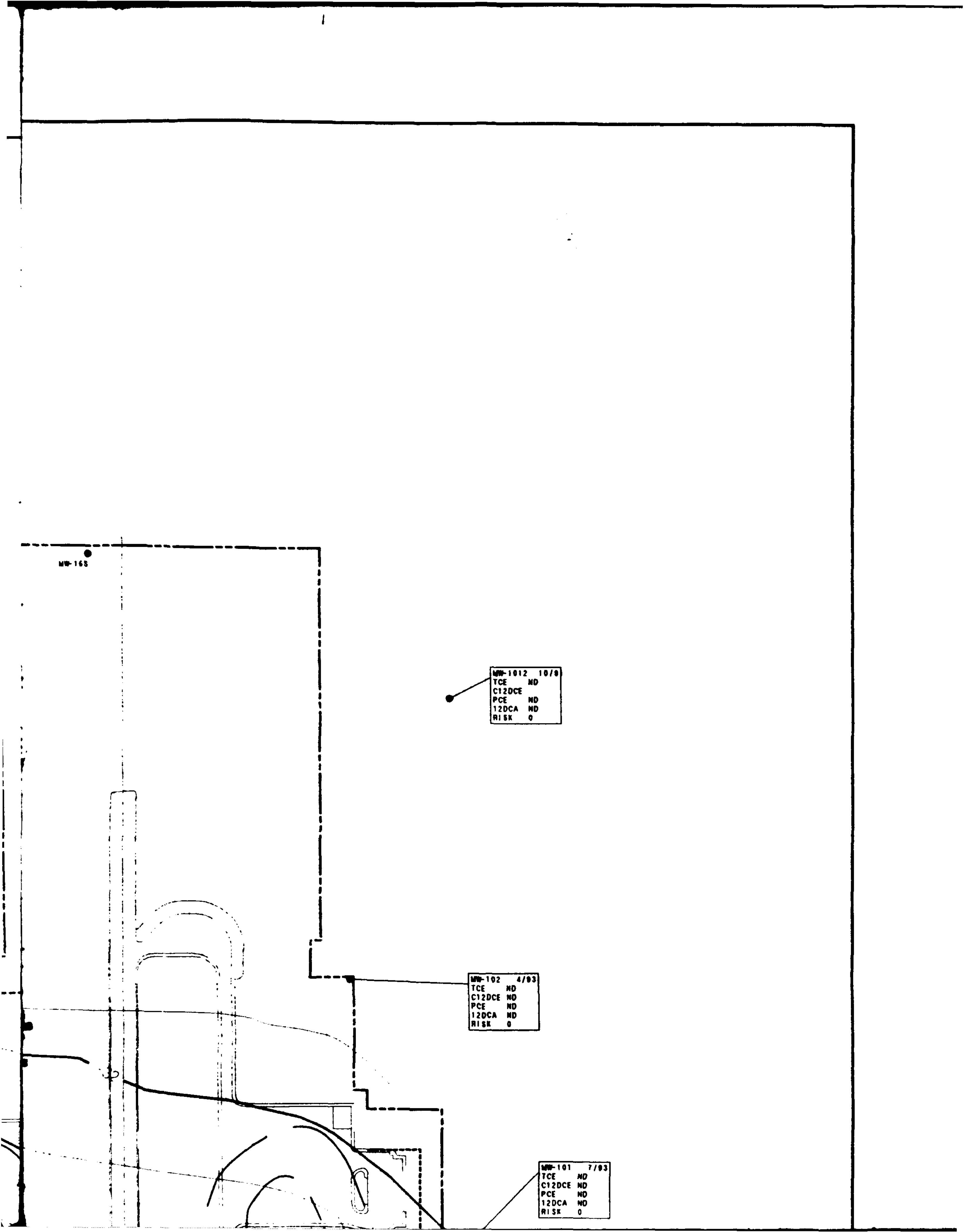
0

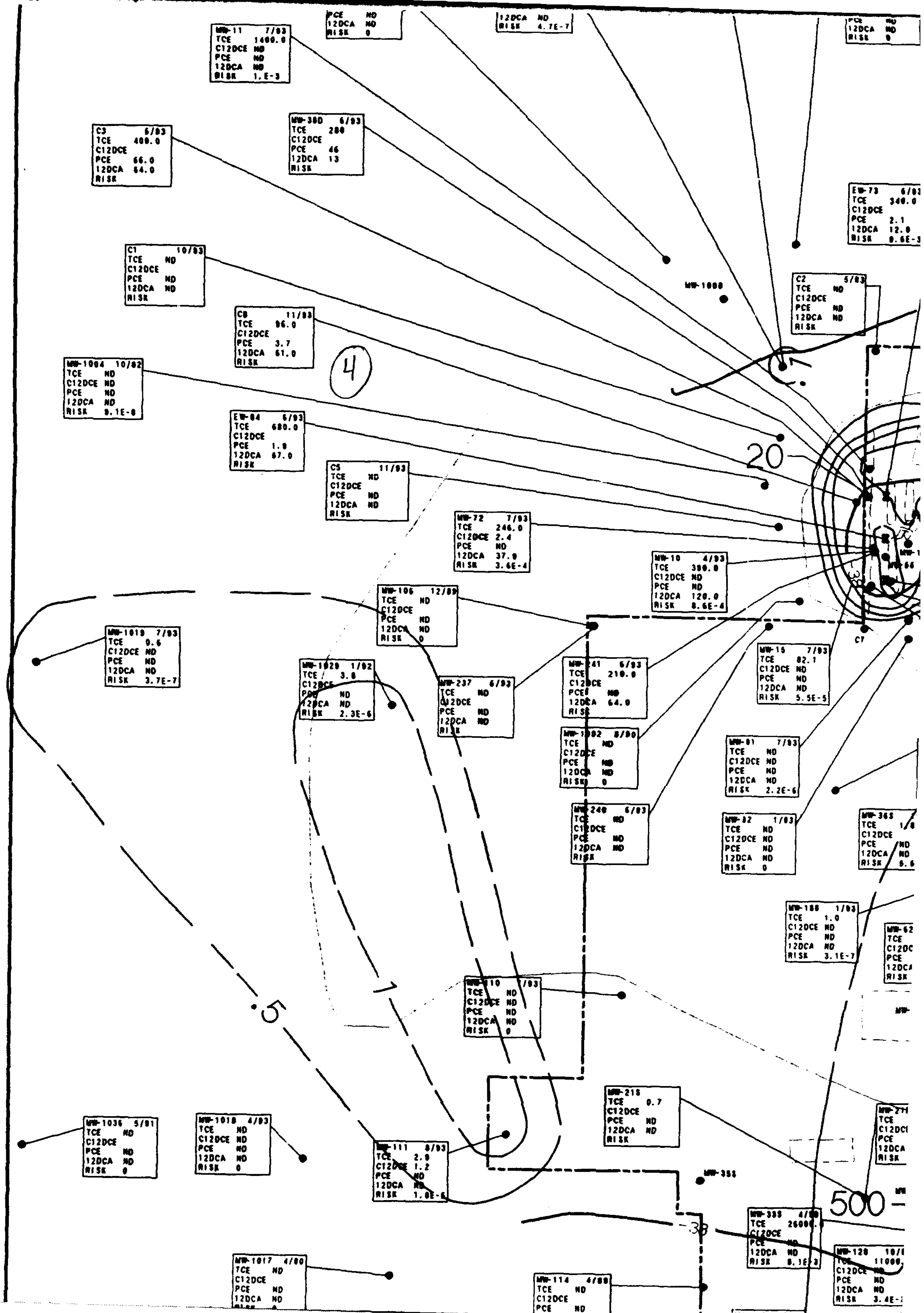
NOTES: 1. CONTOURS FOR CIS-1,2-DCE, PCE AND 1,2-DCA ARE SHOWN ON FIGURES 4-52, AND 4-54 FOR ZONES A, B AND RESPECTIVELY.

2. SOLID LINES REPRESENT CONTOURS BY DATA POINTS, DASHED LINES REP UNBOUND CONTOUR LINES.

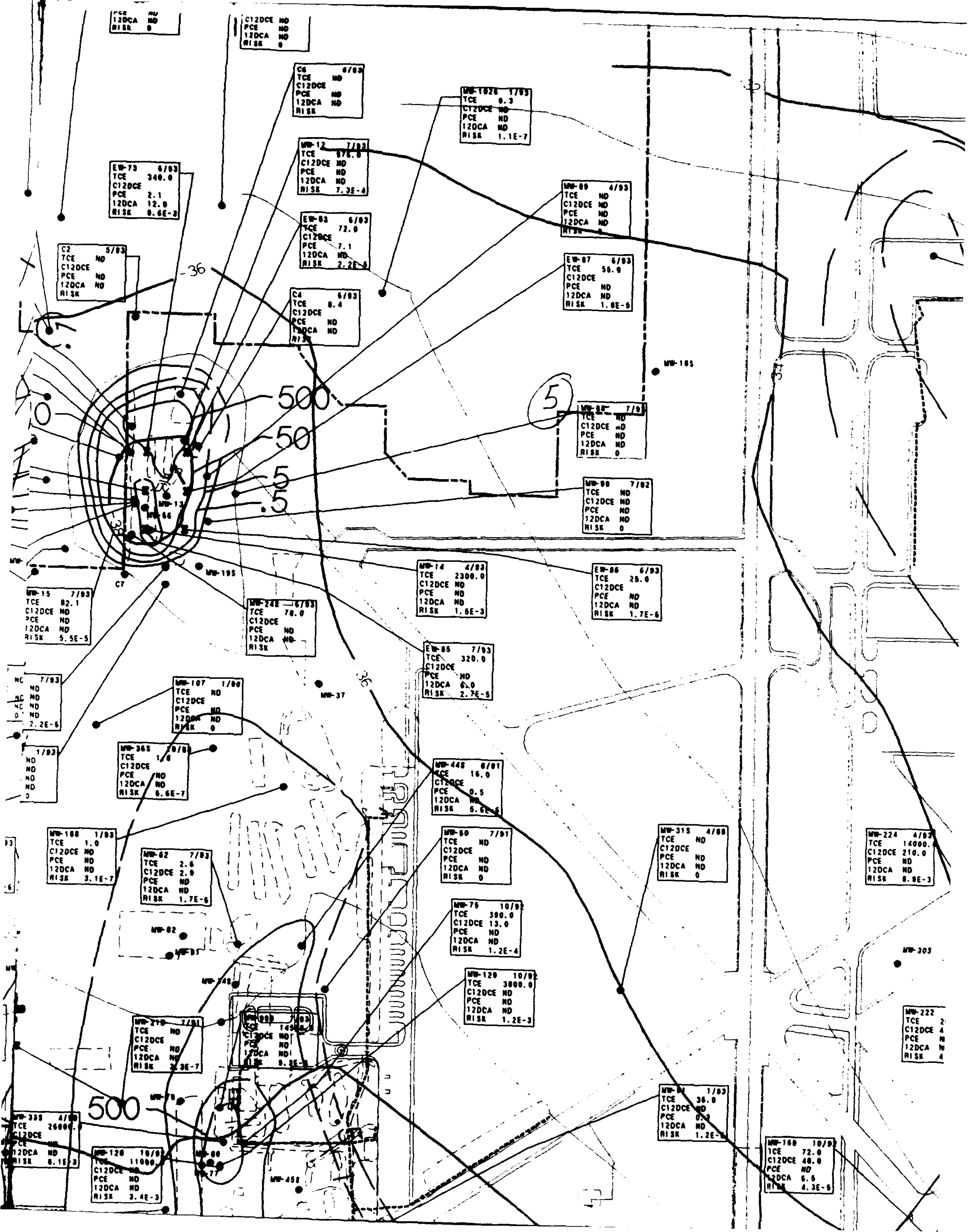



MI YEAR OF SAMPLING,
U ig/l), AND CUMULATIVE
JRS
ELL
NED)
CE, PCE
ON FIGURES 4-50,
ES A, B AND C,
CONTOURS BOUNDED
LINES REPRESENT
N
0
1600
3200
SCALE IN FEET
MW-16S
MW-17S
MW-1064 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1000 7/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
C6 6/93
TCE ND
C12DCE
PCE ND
12DCA ND
RISK
MW-1026 1/93
TCE 0.3
C12DCE ND
PCE ND
12DCA ND
RISK 1.1E-7
MW-12 7/93
TCE
C12DCE ND
PCE ND
12DCA ND
RISK 7.3E-4
EW-73 6/93
TCE 340.0
C12DCE
PCE 2.1
12DCA 12.0
MW-89 4/93
TCE ND
C12DCE ND
PCE ND

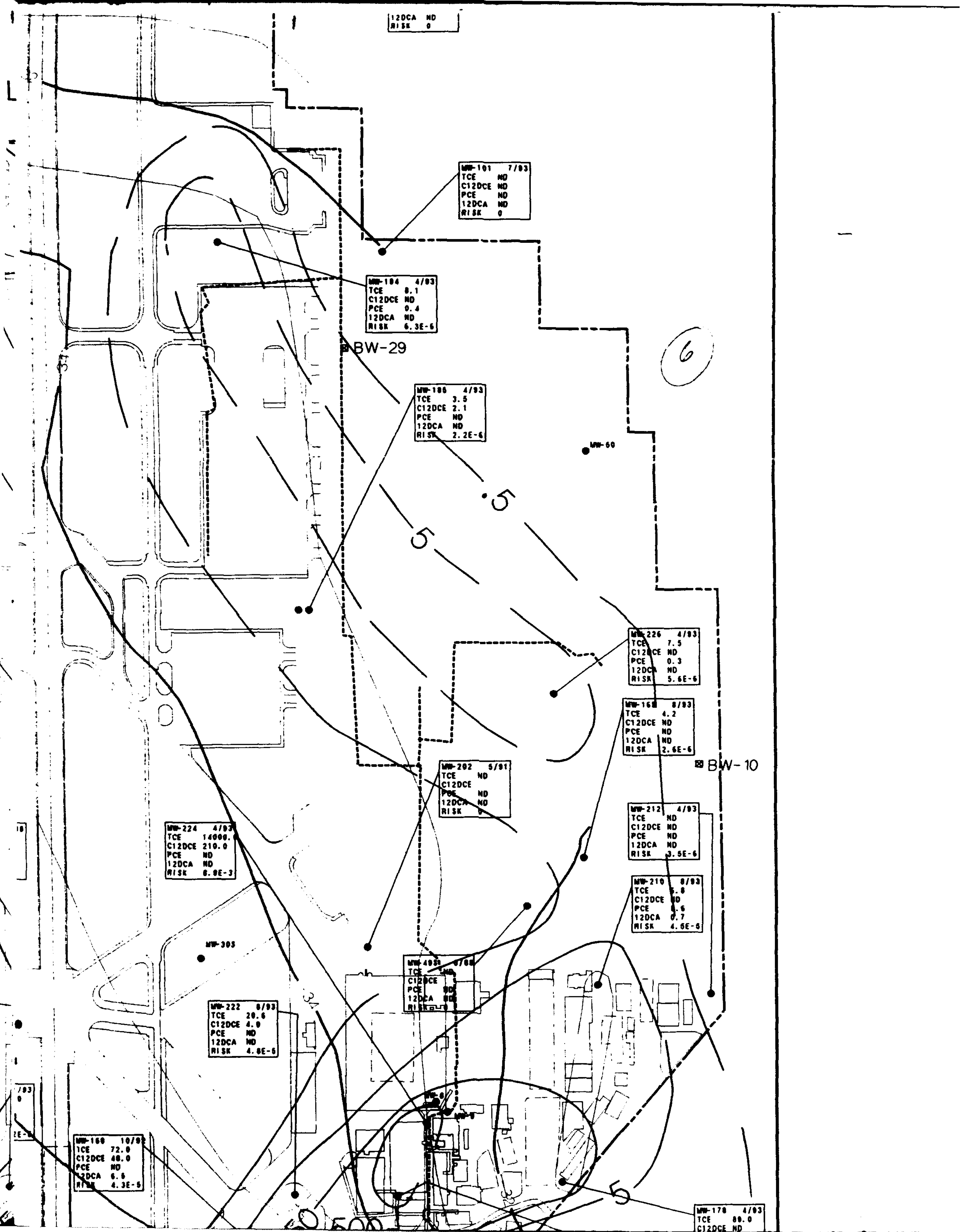

MW-16S
MW-1012 10/9
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-102 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-101 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0



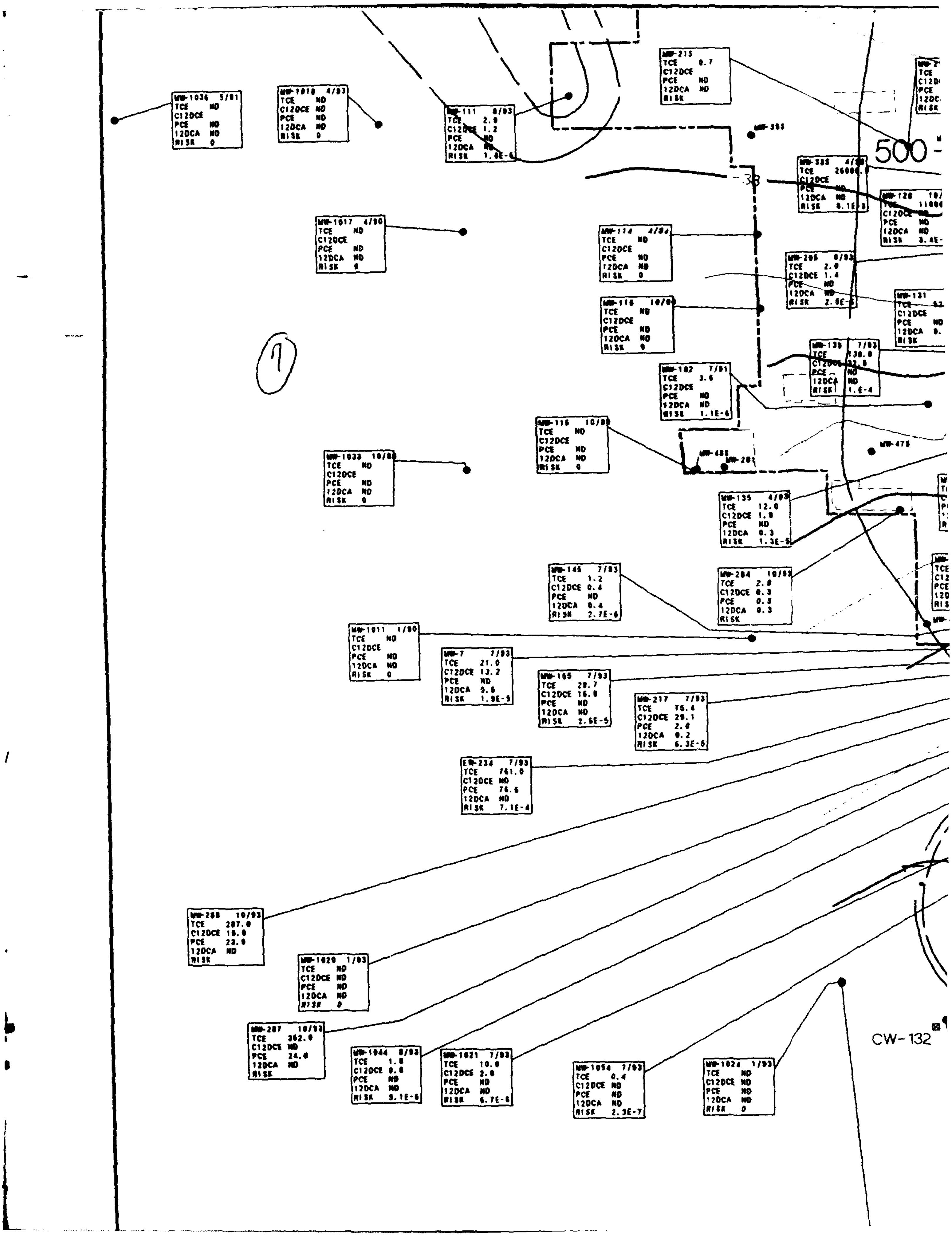
PCE ND
12DCA ND
RISK 0
12DCA ND
RISK 4.7E-7
12DCA ND
RISK 0
MW-11 7/93
TCE 1400.0
C12DCE ND
PCE ND
12DCA ND
RISK 1.E-3
MW-38D 6/93
TCE 280
C12DCE
PCE 46
12DCA 13
RISK
C3 6/93
TCE 400.0
C12DCE
PCE 66.0
12DCA 64.0
RISK
EW-73 6/93
TCE 340.0
C12DCE
PCE 2.1
12DCA 12.0
RISK
C1 10/93
TCE ND
C12DCE
PCE ND
12DCA ND
RISK
MW-1000
C2 5/93
TCE ND
C12DCE
PCE ND
12DCA ND
RISK
C8 11/93
TCE 96.0
C12DCE
PCE 3.7
12DCA 61.0
RISK
4
MW-1004 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 9.1E-8
EW-84 6/93
TCE 680.0
C12DCE
PCE 1.9
12DCA 67.0
RISK
20
C5 11/93
TCE ND
C12DCE
PCE ND
12DCA ND
RISK
MW-72 7/93
TCE 246.0
C12DCE 2.4
PCE ND
12DCA 37.0
RISK 3.6E-4
MW-10 4/93
TCE 390.0
C12DCE ND
PCE ND
12DCA 120.0
RISK 8.6E-4
MW-106 12/89
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
C7
MW-1019 7/93
TCE 0.6
C12DCE ND
PCE ND
12DCA ND
RISK 3.7E-7
MW-1029 1/92
TCE 3.6
C12DCE
PCE ND
12DCA ND
RISK 2.3E-6
MW-237 6/93
TCE ND
C12DCE
PCE ND
12DCA ND
RISK
MW-241 6/93
TCE 210.0
C12DCE
PCE ND
12DCA 64.0
RISK
MW-15 7/93
TCE 82.1
C12DCE ND
PCE ND
12DCA ND
RISK 5.5E-5
MW-1002 8/90
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-81 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 2.2E-6
MW-240 6/93
TCE ND
C12DCE
PCE ND
12DCA ND
RISK
MW-32 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-36S
TCE
C12DCE
PCE ND
12DCA ND
RISK
MW-188 1/93
TCE 1.0
C12DCE ND
PCE ND
12DCA ND
RISK 3.1E-7
MW-62
TCE
C12DC
PCE
12DC
RISK
MW-110 /93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
7
5
MW-21S
TCE 0.7
C12DCE
PCE ND
12DCA ND
RISK
MW-1036 5/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-1018 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-111 8/93
TCE 2.9
C12DCE 1.2
PCE ND
12DCA ND
RISK
MW-35S
500
MW-33S 4/90
TCE 26000
C12DCE
PCE ND
12DCA ND
RISK
MW-120 10/
TCE 11000
C12DCE ND
PCE ND
12DCA ND
RISK 3.4E-
MW-1017 4/80
TCE ND
C12DCE
PCE ND
12DCA ND
MW-114 4/88
TCE ND
C12DCE
PCE ND



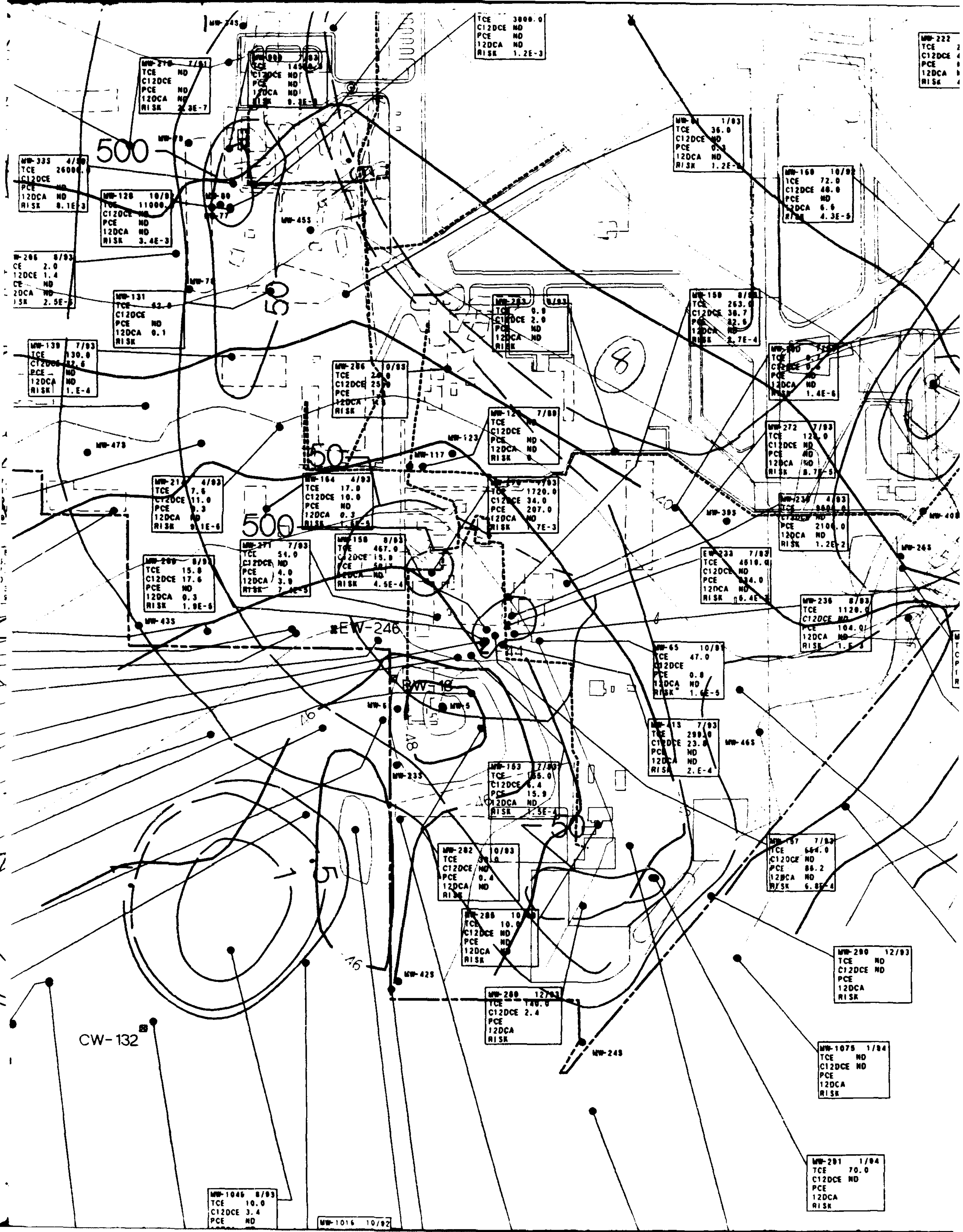
C6 6/93
TCE ND
C12DCE
PCE ND
12DCA ND
RISK
MW-102B 1/93
TCE 0.3
C12DCE ND
PCE ND
12DCA ND
RISK 1.1E-7
MW-12 7/93
C12DCE ND
PCE ND
12DCA ND
RISK 7.3E-4
EW-73 6/93
TCE 340.0
C12DCE
PCE 2.1
12DCA 12.0
RISK 8.6E-3
EW-83 6/93
TCE 72.0
PCE 7.1
12DCA ND
RISK 2.2E-5
C2 5/93
TCE ND
C12DCE
PCE ND
12DCA ND
RISK
C4 6/93
TCE 8.4
C12DCE
PCE ND
12DCA ND
MW-89 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
EW-87 6/93
TCE 56.0
C12DCE
PCE ND
12DCA ND
RISK 1.8E-5
MW-18S
500
50
5
MW-90 7/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-13
MW-19S
C7
MW-14 4/93
TCE 2300.0
C12DCE ND
PCE ND
12DCA ND
RISK 1.5E-3
EW-86 6/93
TCE 25.0
C12DCE
PCE ND
12DCA ND
RISK 1.7E-5
MW-15 7/93
TCE 82.1
C12DCE ND
PCE ND
12DCA ND
RISK 5.5E-5
MW-242 6/93
TCE 78.0
C12DCE
PCE ND
12DCA ND
RISK
EW-85 7/93
TCE 320.0
C12DCE
PCE ND
12DCA 6.0
RISK 2.7E-5
36
MW-37
MW-107 1/90
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-36S 10/90
C12DCE
PCE ND
12DCA ND
RISK 5.6E-7
MW-44S 6/91
TCE 16.0
C12DCE
PCE 0.5
12DCA ND
MW-188 1/93
TCE 1.0
C12DCE ND
PCE ND
12DCA ND
RISK 3.1E-7
MW-62 7/93
TCE 2.6
C12DCE 2.0
PCE ND
12DCA ND
RISK 1.7E-6
MW-60 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-31S 4/88
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-224 4/93
C12DCE 210.0
PCE ND
12DCA ND
RISK 8.9E-3
MW-75 10/92
TCE 390.0
C12DCE 13.0
PCE ND
12DCA ND
RISK 1.2E-4
MW-82
MW-303
MW-129 10/92
TCE 3800.0
C12DCE ND
PCE ND
12DCA ND
RISK 1.2E-3
MW-222
MW-21D 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
500
MW-79
MW-33S 4/90
C12DCE
12DCA ND
RISK 8.1E-3
MW-128 10/92
TCE 11000.
C12DCE ND
PCE ND
12DCA ND
RISK 3.4E-3
MW-91 1/93
TCE 36.0
C12DCE ND
12DCA ND
MW-168 10/92
TCE 72.0
C12DCE 48.0
PCE ND
12DCA 6.5
RISK 4.3E-5
MW-45S
MW-77



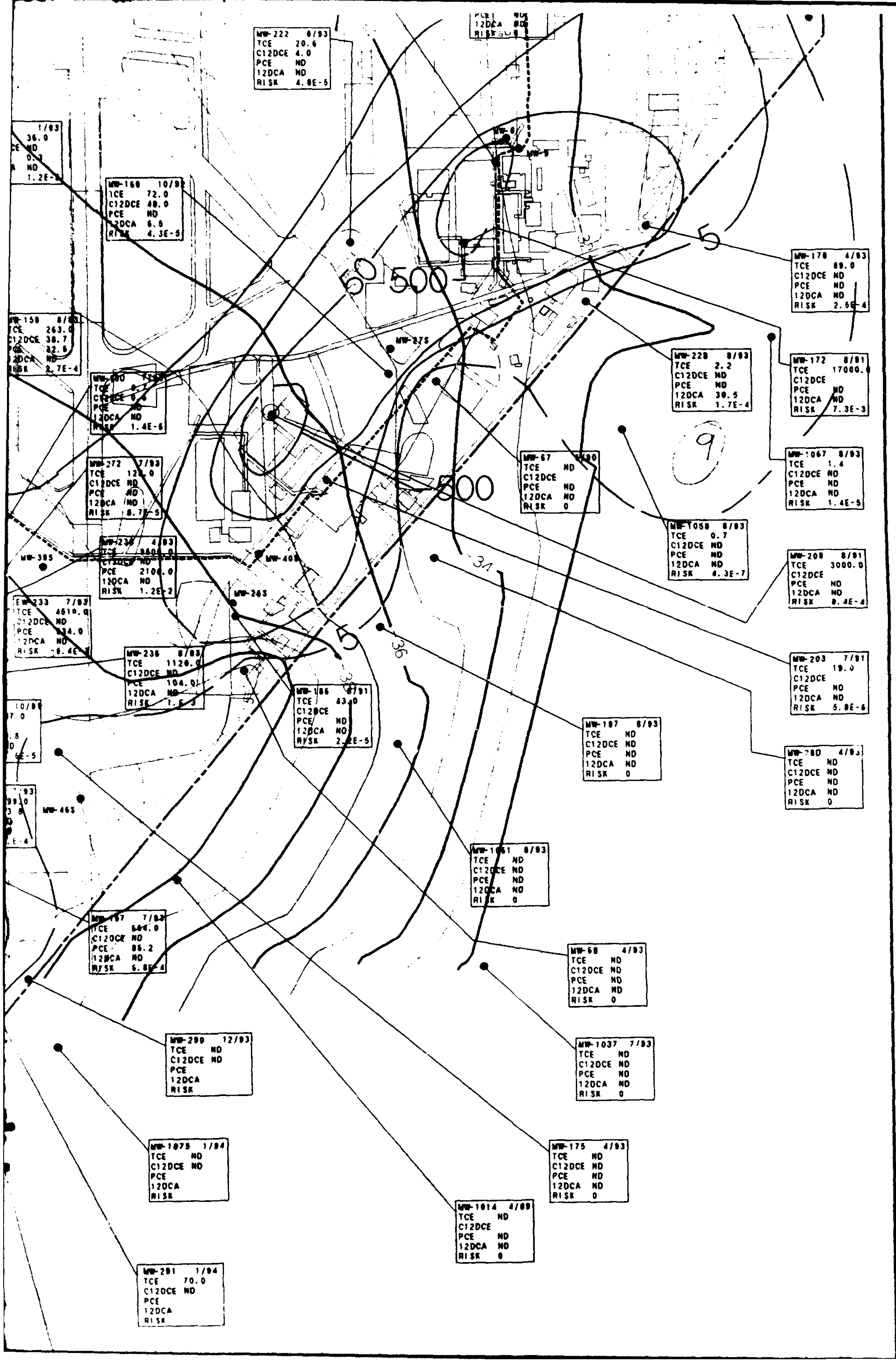
12DCA ND
RISK 0
MW-101 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-104 4/93
TCE 8.1
C12DCE ND
PCE 0.4
12DCA ND
RISK 6.3E-6
BW-29
MW-186 4/93
TCE 3.5
C12DCE 2.1
PCE ND
12DCA ND
RISK 2.2E-6
MW-60
5
5
6
MW-226 4/93
TCE 7.5
C12DCE ND
PCE 0.3
12DCA ND
RISK 5.6E-6
TCE 4.2
C12DCE ND
PCE ND
12DCA ND
RISK 2.6E-6
BW-10
MW-292 5/91
TCE ND
C12DCE
PCE ND
12DCA ND
MW-212 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 3.5E-6
MW-210 8/93
RISK 4.6E-6
MW-224 4/93
TCE 14000.
C12DCE 210.0
PCE ND
12DCA ND
RISK 6.8E-3
MW-303
MW-222 8/93
TCE 20.6
C12DCE 4.0
PCE ND
12DCA ND
RISK 4.8E-6
MW-160 10/92
TCE 72.0
C12DCE 48.0
PCE ND
RISK 4.3E-5
5
MW-178 4/93
TCE 80.0
C12DCE ND



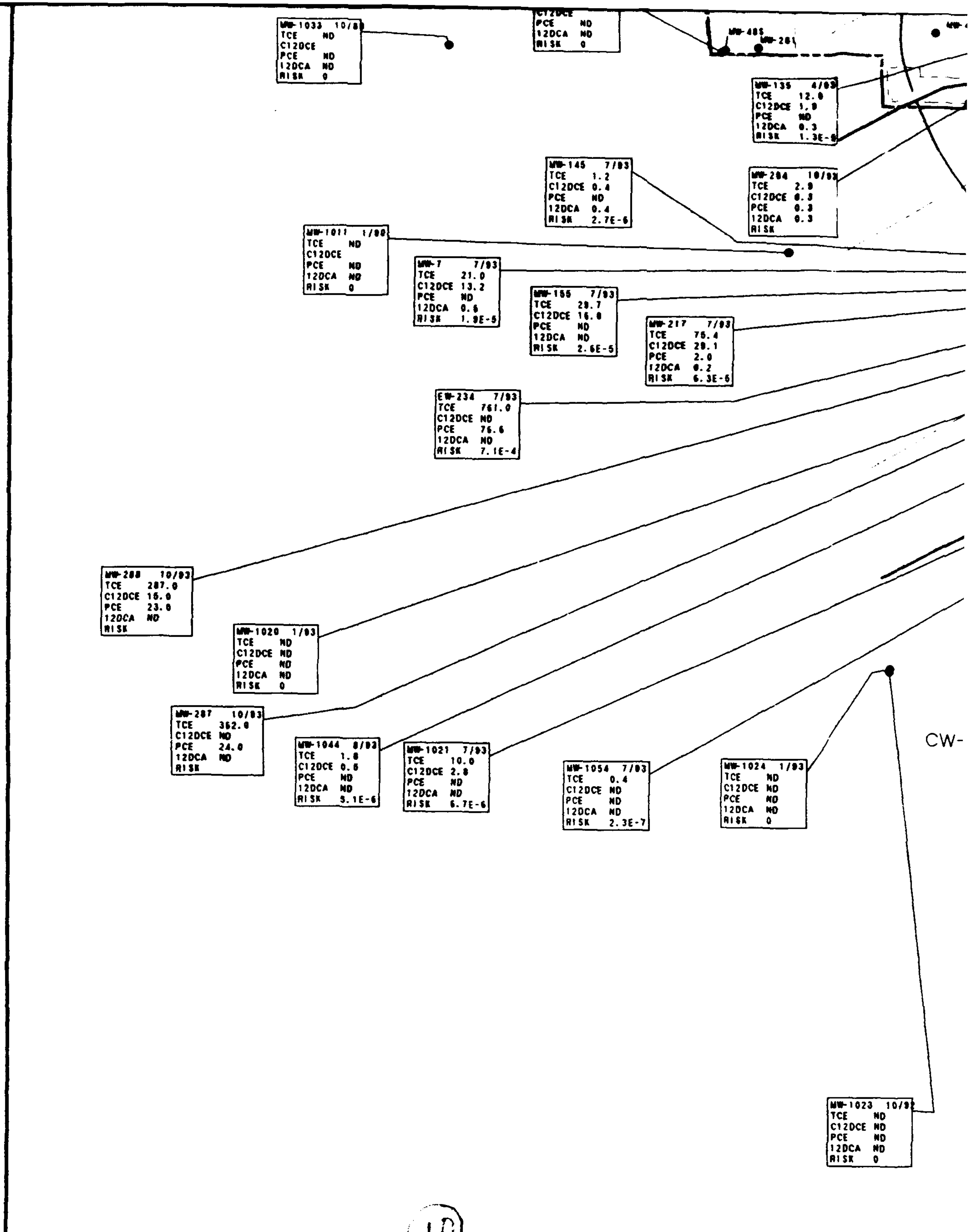
MW-1036 5/81 TCE ND C12DCE PCE ND 12DCA ND RISK 0
MW-1018 4/93 TCE ND C12DCE ND PCE ND 12DCA ND RISK 0
MW-111 8/93 TCE 2.9 C12DCE 1.2 PCE ND 12DCA ND RISK 1.8E-6
MW-215 TCE 0.7 C12DCE PCE ND 12DCA ND RISK
MW-355
500
38
MW-335 4/93 TCE 26000 C12DCE PCE ND 12DCA ND RISK 8.1E-3
MW-126 TCE 11000 C12DCE ND PCE ND 12DCA ND RISK 3.4E-
MW-1017 4/90 TCE ND C12DCE PCE ND 12DCA ND RISK 0
MW-114 4/94 TCE ND C12DCE PCE ND 12DCA ND RISK 0
MW-205 8/93 TCE 2.0 C12DCE 1.4 PCE ND 12DCA ND RISK 2.5E-5
MW-131 TCE C12DCE PCE ND 12DCA
MW-116 10/90 TCE ND C12DCE PCE ND 12DCA ND RISK 0
MW-139 7/93 TCE 130.0 PCE ND 12DCA ND RISK 1.E-4
MW-182 7/91 TCE 3.6 C12DCE PCE ND 12DCA ND RISK 1.1E-6
MW-115 10/89 TCE ND C12DCE PCE ND 12DCA ND RISK 0
MW-485
MW-281
MW-475
MW-1033 10/88 TCE ND C12DCE PCE ND 12DCA ND RISK 0
MW-135 4/93 TCE 12.0 C12DCE 1.9 PCE ND 12DCA 0.3 RISK 1.3E-5
MW-145 7/93 TCE 1.2 C12DCE 0.4 PCE ND 12DCA 0.4 RISK 2.7E-6
MW-284 10/93 TCE 2.8 C12DCE 0.3 PCE 0.3 12DCA 0.3 RISK
MW-1011 1/90 TCE ND C12DCE PCE ND 12DCA ND RISK 0
MW-7 7/93 TCE 21.0 C12DCE 13.2 PCE ND 12DCA 9.6 RISK 1.9E-5
MW-155 7/93 TCE 28.7 C12DCE 16.8 PCE ND 12DCA ND RISK 2.5E-5
MW-217 7/93 TCE 75.4 C12DCE 29.1 PCE 2.0 12DCA 0.2 RISK 6.3E-5
EW-234 7/93 TCE 761.0 C12DCE ND PCE 76.6 12DCA ND RISK 7.1E-4
MW-288 10/93 TCE 287.0 C12DCE 16.0 PCE 23.0 12DCA ND RISK
MW-1020 1/93 TCE ND C12DCE ND PCE ND 12DCA ND RISK 0
MW-287 10/93 TCE 352.0 C12DCE ND PCE 24.0 12DCA ND RISK
MW-1044 8/93 TCE 1.8 C12DCE 0.8 PCE ND 12DCA ND RISK 5.1E-6
MW-1021 7/93 TCE 10.0 C12DCE 2.8 PCE ND 12DCA ND RISK 6.7E-6
MW-1054 7/93 TCE 0.4 C12DCE ND PCE ND 12DCA ND RISK 2.3E-7
MW-1024 1/93 TCE ND C12DCE ND PCE ND 12DCA ND RISK 0
CW-132



TCE 3800.0
C12DCE ND
PCE ND
12DCA ND
RISK 1.2E-3
MW-222
MW-218 7/93
TCE ND
C12DCE
PCE ND
12DCA ND
500
MW-79
MW-333 4/93
TCE 26000.0
C12DCE
PCE ND
12DCA ND
RISK 8.1E-3
MW-128 10/93
TCE 11000.0
C12DCE ND
PCE ND
12DCA ND
RISK 3.4E-3
MW-80
MW-77
MW-453
MW-81 1/93
TCE 36.0
C12DCE ND
12DCA ND
MW-160 10/93
TCE 72.0
C12DCE 40.0
PCE ND
12DCA 6.6
RISK 4.3E-5
MW-286 8/93
TCE 2.0
C12DCE 1.4
PCE ND
12DCA ND
RISK 2.5E-5
MW-131
TCE 52.0
C12DCE
PCE ND
12DCA 0.1
RISK
MW-78
MW-283 8/93
TCE 0.9
C12DCE 2.0
PCE ND
12DCA ND
RISK
MW-159 8/93
TCE 263.0
C12DCE 38.7
PCE 82.6
12DCA ND
RISK 2.7E-4
MW-139 7/93
TCE 130.0
PCE ND
12DCA ND
RISK 1.E-4
MW-286 10/93
8
MW-473
MW-123
MW-117
50
MW-272 7/93
TCE 120.0
C12DCE ND
PCE ND
12DCA ND
RISK 8.7E-5
MW-164 4/93
TCE 17.0
C12DCE 10.0
PCE ND
12DCA 0.3
MW-270 7/93
TCE 1720.0
C12DCE 34.0
PCE 207.0
12DCA ND
500
MW-393
MW-403
MW-239 4/93
PCE 2100.0
12DCA ND
RISK 1.2E-2
MW-271 7/93
TCE 51.0
C12DCE ND
PCE 4.0
12DCA 3.9
MW-158 8/93
TCE 467.0
C12DCE 15.0
12DCA ND
RISK 4.5E-4
MW-209 8/93
TCE 15.0
C12DCE 17.6
PCE ND
12DCA 0.3
RISK 1.0E-5
EW-233 7/93
TCE 4610.0
12DCA ND
MW-265
MW-236 8/93
TCE 1120.0
PCE 104.0
12DCA ND
MW-433
EW-246
MW-65 10/93
TCE 47.0
PCE 0.8
12DCA ND
RISK 1.6E-5
EW-18
MW-5
MW-413 7/93
C12DCE 23.0
PCE ND
12DCA ND
RISK 2.E-4
MW-463
48
46
MW-233
MW-153 12/93
PCE 15.9
12DCA ND
RISK 1.5E-4
7
5
MW-282 10/93
TCE
PCE 0.4
12DCA ND
MW-157 7/93
TCE 664.0
C12DCE ND
PCE 86.2
12DCA ND
RISK 6.8E-4
MW-288 10/93
TCE 10.0
C12DCE ND
PCE ND
12DCA ND
RISK
46
MW-423
MW-290 12/93
TCE ND
C12DCE ND
PCE
12DCA
RISK
MW-289 12/93
C12DCE 2.4
PCE
12DCA
RISK
CW-132
MW-243
MW-1075 1/94
TCE ND
C12DCE ND
PCE
12DCA
RISK
MW-291 1/94
TCE 70.0
C12DCE ND
PCE
12DCA
RISK
MW-1046 8/93
TCE 10.0
C12DCE 3.4
PCE ND
MW-1016 10/92



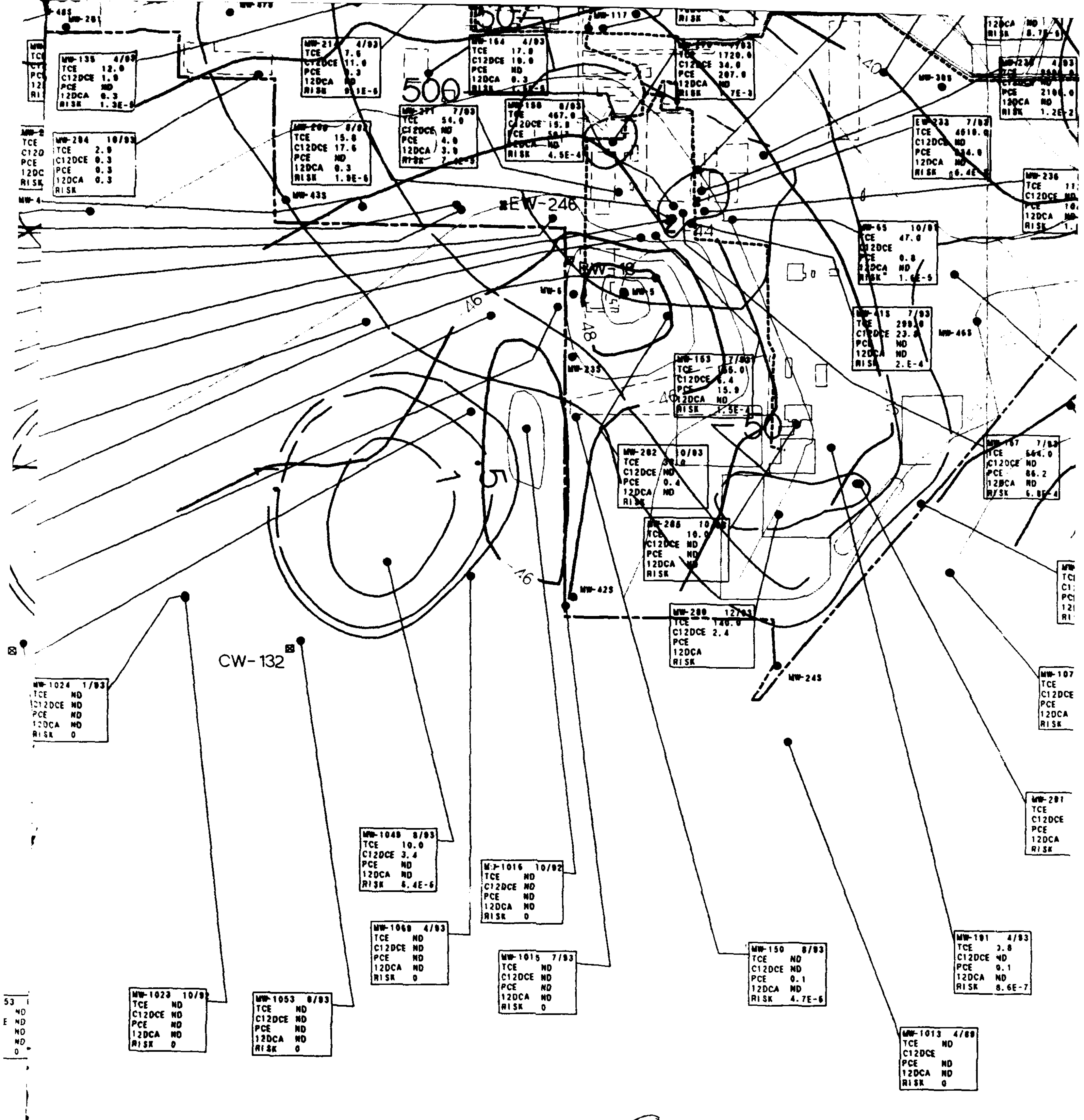
MW-222 8/93
TCE 20.6
C12DCE 4.0
PCE ND
12DCA ND
RISK 4.8E-5
MW-160 10/92
TCE 72.0
C12DCE 40.0
PCE ND
12DCA 6.5
RISK 4.3E-5
MW-170 4/93
TCE 89.0
C12DCE ND
PCE ND
12DCA ND
MW-228 8/93
TCE 2.2
C12DCE ND
PCE ND
12DCA 30.5
RISK 1.7E-4
MW-172 8/91
TCE 17000.0
C12DCE
PCE ND
12DCA ND
RISK 7.3E-3
MW-1067 8/93
TCE 1.4
C12DCE ND
PCE ND
12DCA ND
RISK 1.4E-5
MW-67
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-1058 8/93
TCE 0.7
C12DCE ND
PCE ND
12DCA ND
RISK 4.3E-7
MW-208 8/91
TCE 3000.0
C12DCE
PCE ND
12DCA ND
MW-203 7/91
TCE 19.0
C12DCE
PCE ND
12DCA ND
RISK 5.8E-6
MW-272 7/93
MW-236 8/93
TCE 1120.0
C12DCE ND
PCE 104.0
12DCA ND
MW-186 8/91
TCE 43.0
C12DCE
PCE ND
12DCA ND
RISK 2.2E-5
MW-197 8/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-280 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1061 8/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-68 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1037 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-299 12/93
TCE ND
C12DCE ND
PCE
12DCA
RISK
MW-1079 1/94
TCE ND
C12DCE ND
PCE
12DCA
RISK
MW-175 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1014 4/89
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-291 1/94
TCE 70.0
C12DCE ND
PCE
12DCA
RISK
MW-27S
MW-39S
MW-40S
MW-26S
MW-46S
50
500
500
5
5
9



RDD 1454 May, 1994

10

MEY94/4-51.DGN


EW-246
CW-132
MW-1024 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1049 8/93
TCE 10.0
C12DCE 3.4
PCE ND
12DCA ND
RISK 6.4E-6
MW-1016 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1060 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1015 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-150 8/93
TCE ND
C12DCE ND
PCE 0.1
12DCA ND
RISK 4.7E-6
MW-191 4/93
TCE 3.8
C12DCE ND
PCE 0.1
12DCA ND
RISK 8.6E-7
MW-1023 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1053 8/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1013 4/89
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-280 12/93
TCE 180.0
C12DCE 2.4
PCE
12DCA
RISK
MW-245
MW-42S
MW-23S
MW-153 7/93
MW-202 10/93
MW-286
MW-65 10/93
MW-41S 7/93
MW-46S
MW-167 7/93
MW-107
MW-201
MW-135 4/93
TCE 12.0
C12DCE 1.9
PCE ND
12DCA 0.3
RISK 1.3E-6
MW-204 10/93
TCE 2.9
C12DCE 0.3
PCE 0.3
12DCA 0.3
MW-200 8/93
TCE 15.8
C12DCE 17.6
PCE ND
12DCA 0.3
RISK 1.9E-6
MW-43S
MW-164 4/93
TCE 17.0
C12DCE 19.0
PCE ND
12DCA 0.3
MW-271 7/93
MW-188 8/93
EW-233 7/93
TCE 4610.0
MW-236
MW-117
MW-38S
500
46
48
44
40
5

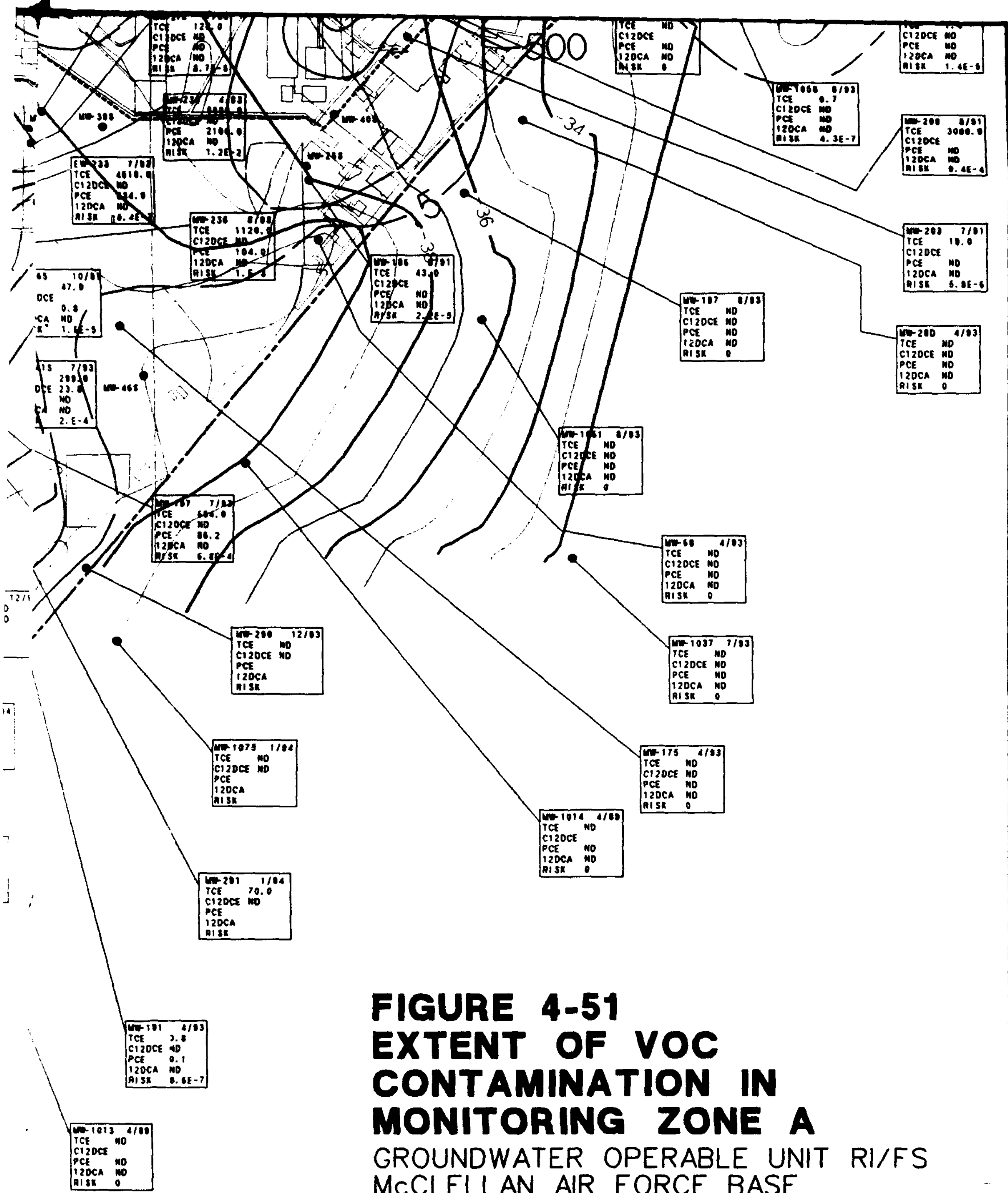
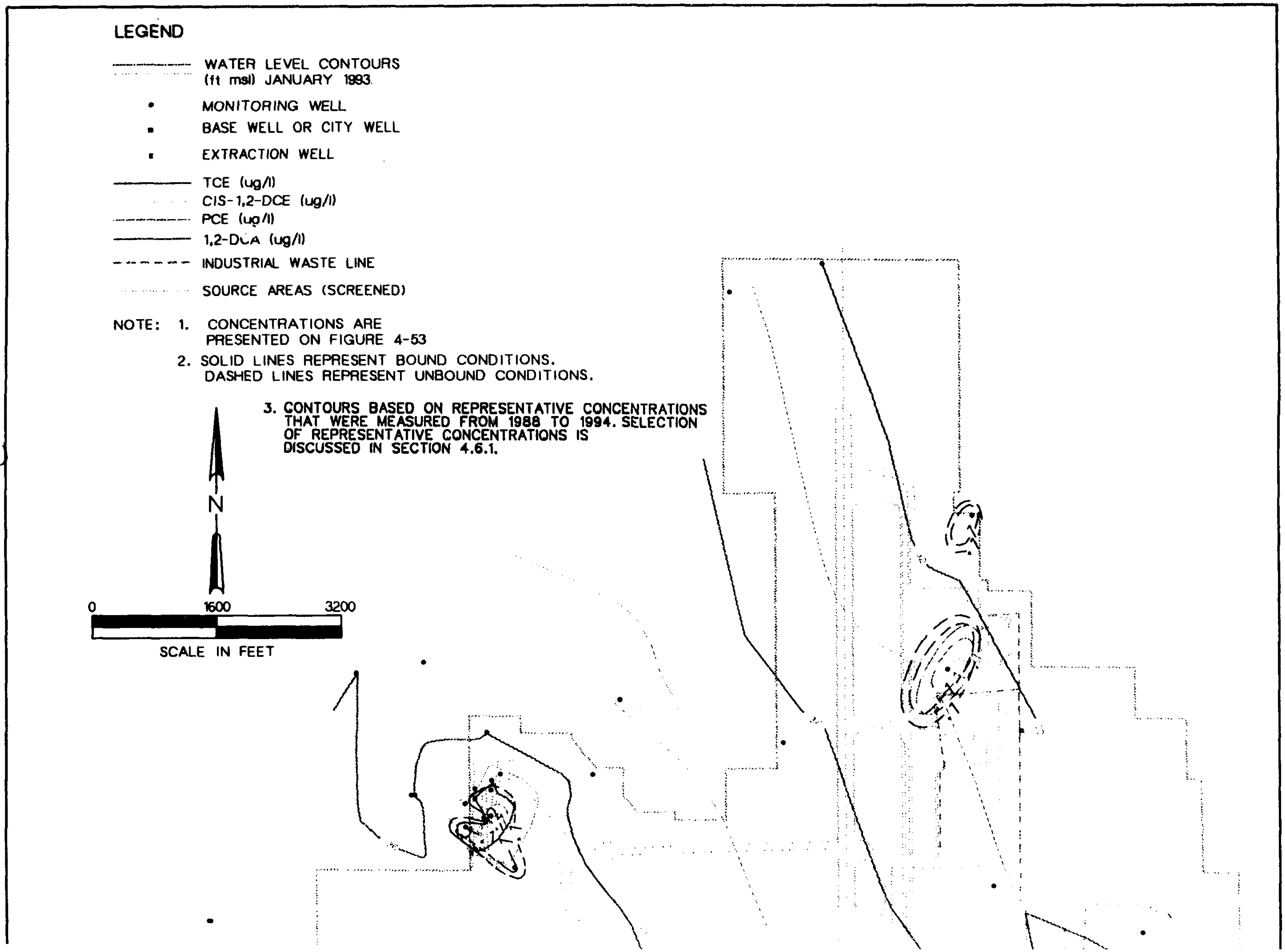
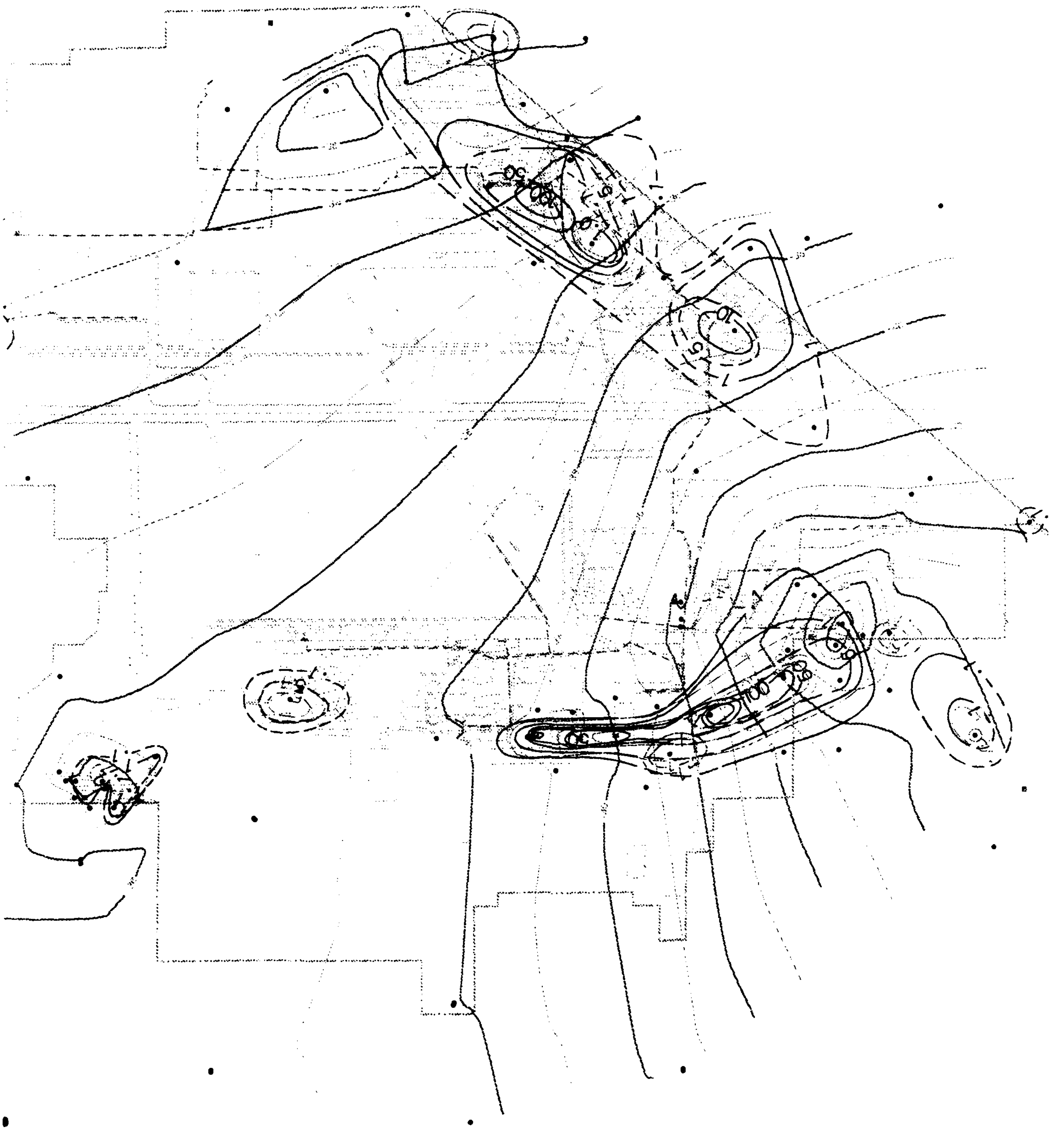


FIGURE 4-51
EXTENT OF VOC CONTAMINATION IN MONITORING ZONE A

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


LEGEND
WATER LEVEL CONTOURS (ft msl) JANUARY 1993
MONITORING WELL
BASE WELL OR CITY WELL
EXTRACTION WELL
TCE (ug/l)
CIS-1,2-DCE (ug/l)
PCE (ug/l)
1,2-DCA (ug/l)
INDUSTRIAL WASTE LINE
SOURCE AREAS (SCREENED)
NOTE: 1. CONCENTRATIONS ARE PRESENTED ON FIGURE 4-53
2. SOLID LINES REPRESENT BOUND CONDITIONS. DASHED LINES REPRESENT UNBOUND CONDITIONS.
3. CONTOURS BASED ON REPRESENTATIVE CONCENTRATIONS THAT WERE MEASURED FROM 1988 TO 1994. SELECTION OF REPRESENTATIVE CONCENTRATIONS IS DISCUSSED IN SECTION 4.6.1.
N
0
1600
3200
SCALE IN FEET



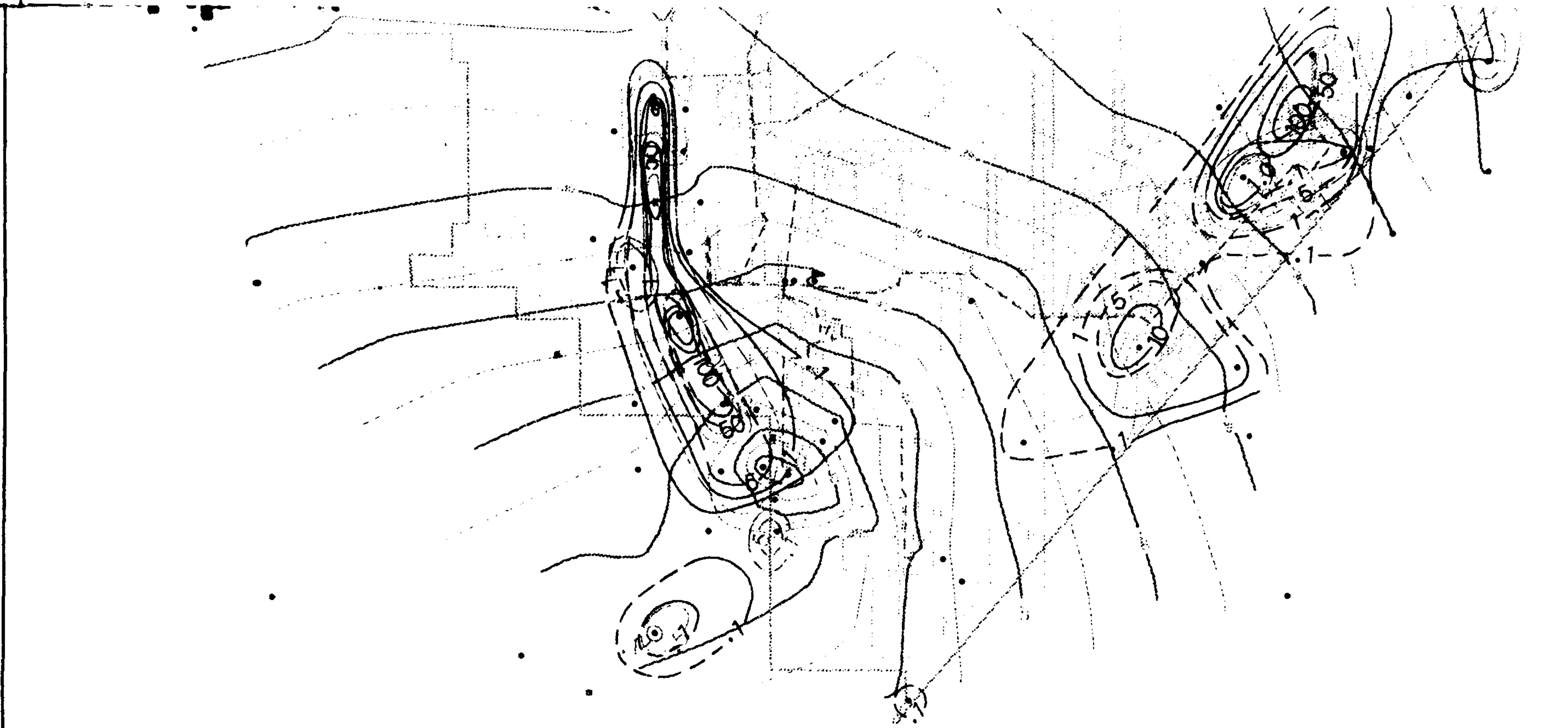


FIGURE 4-52
EXTENT OF VOC CONTAMINATION IN MONITORING ZONE B
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD 1454
MEY94/4-52.DGN

LEGEND

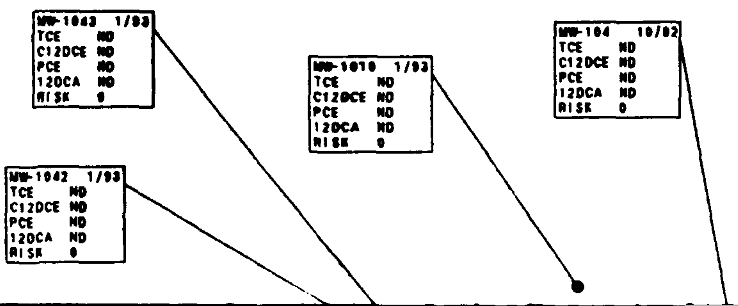
MW-1043 1/93 TCE ND C12DCE ND PCE ND 12DCA ND RISK 0	WELL NAME, MONTH AND YEAR OF SAMPLING, VOC CONCENTRATION (ug/l), CUMALATIVE RISK VALUE
——— / – – –	WATER LEVEL CONTOURS (ft msl) JANUARY 1993
•	MONITORING WELL
⊠	BASE WELL OR CITY WELL
x	EXTRACTION WELL
-----------	INDUSTRIAL WASTE LINE
———	SOURCE AREAS (SCREENED)

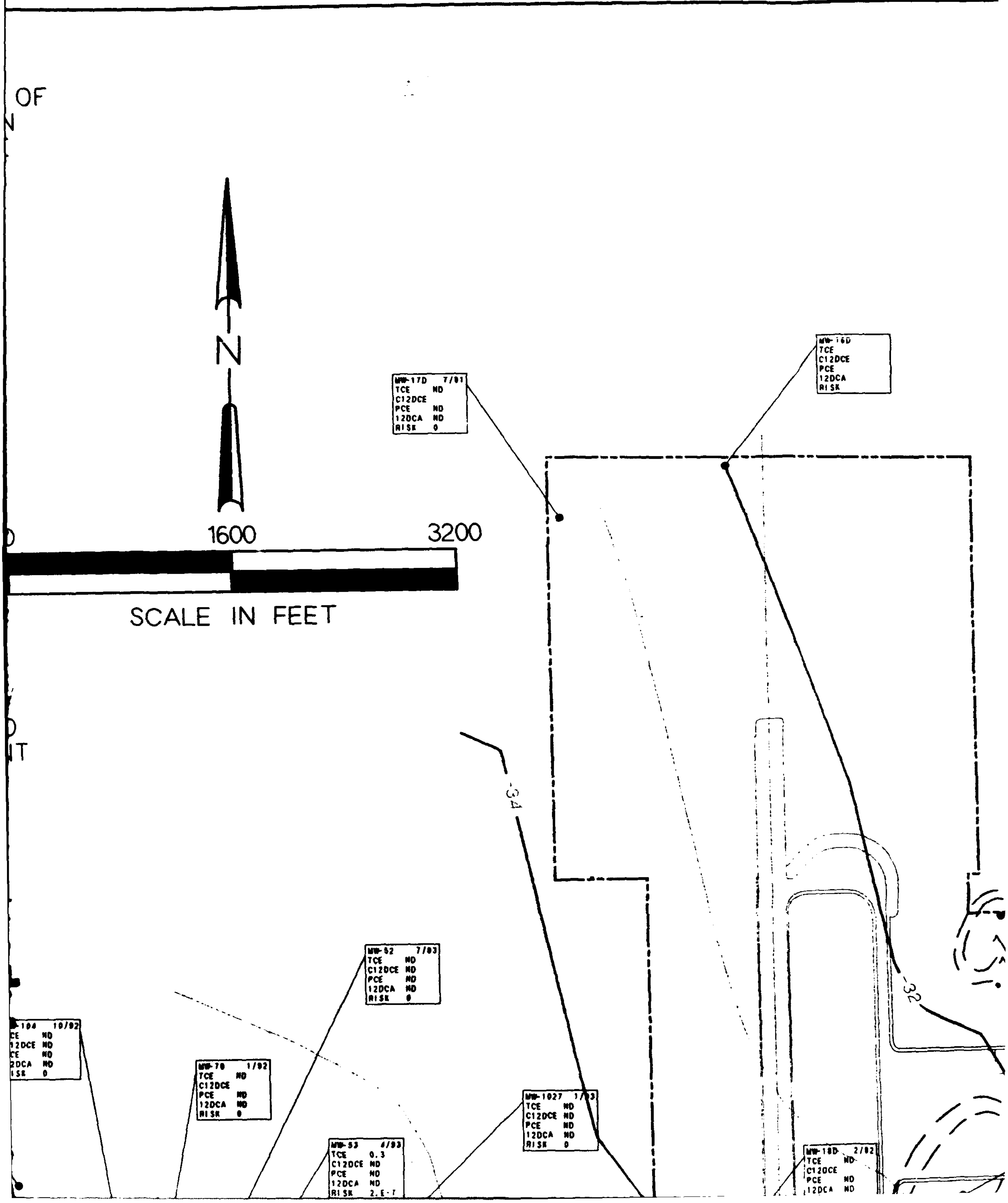
0

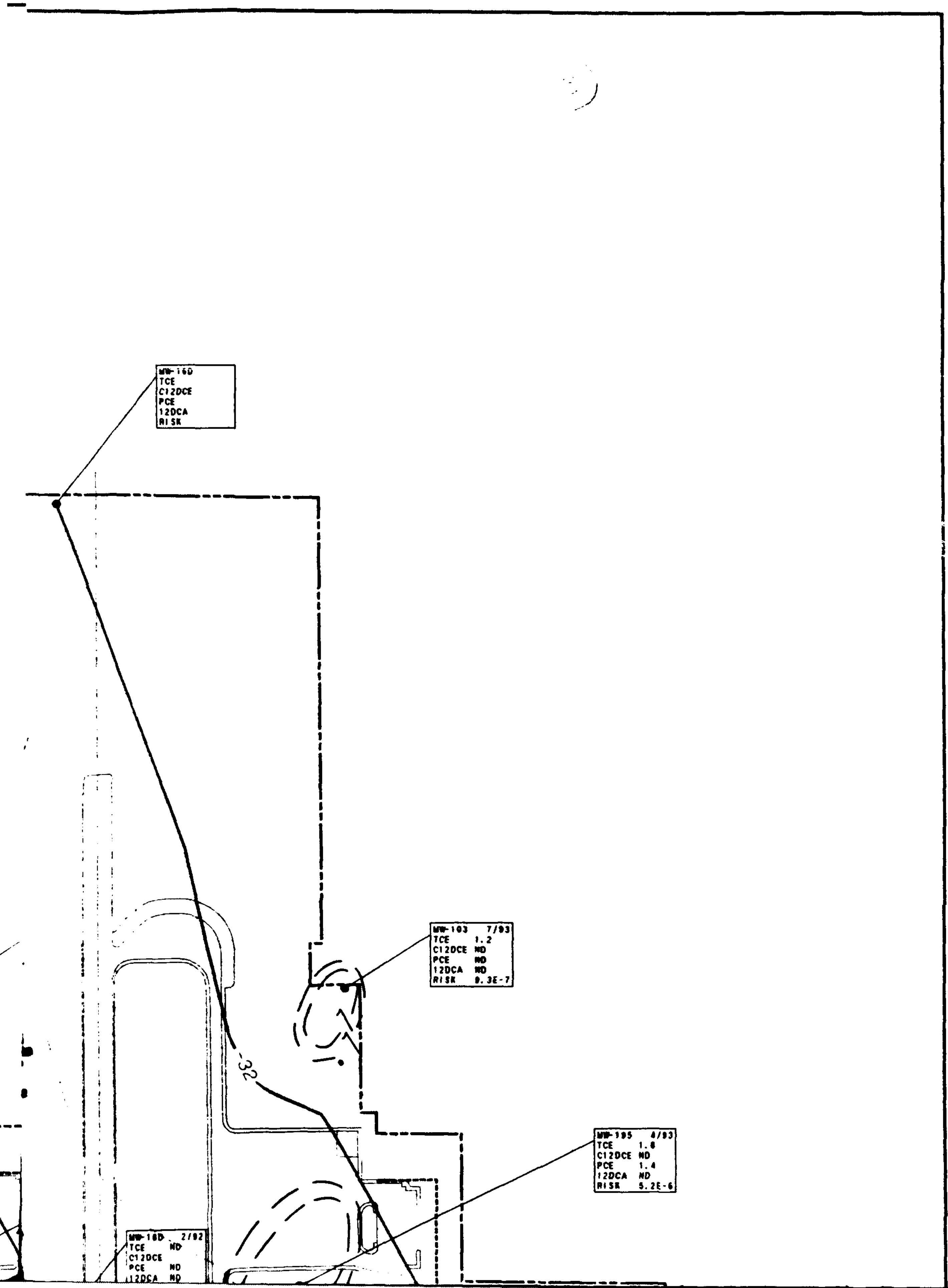
SCA

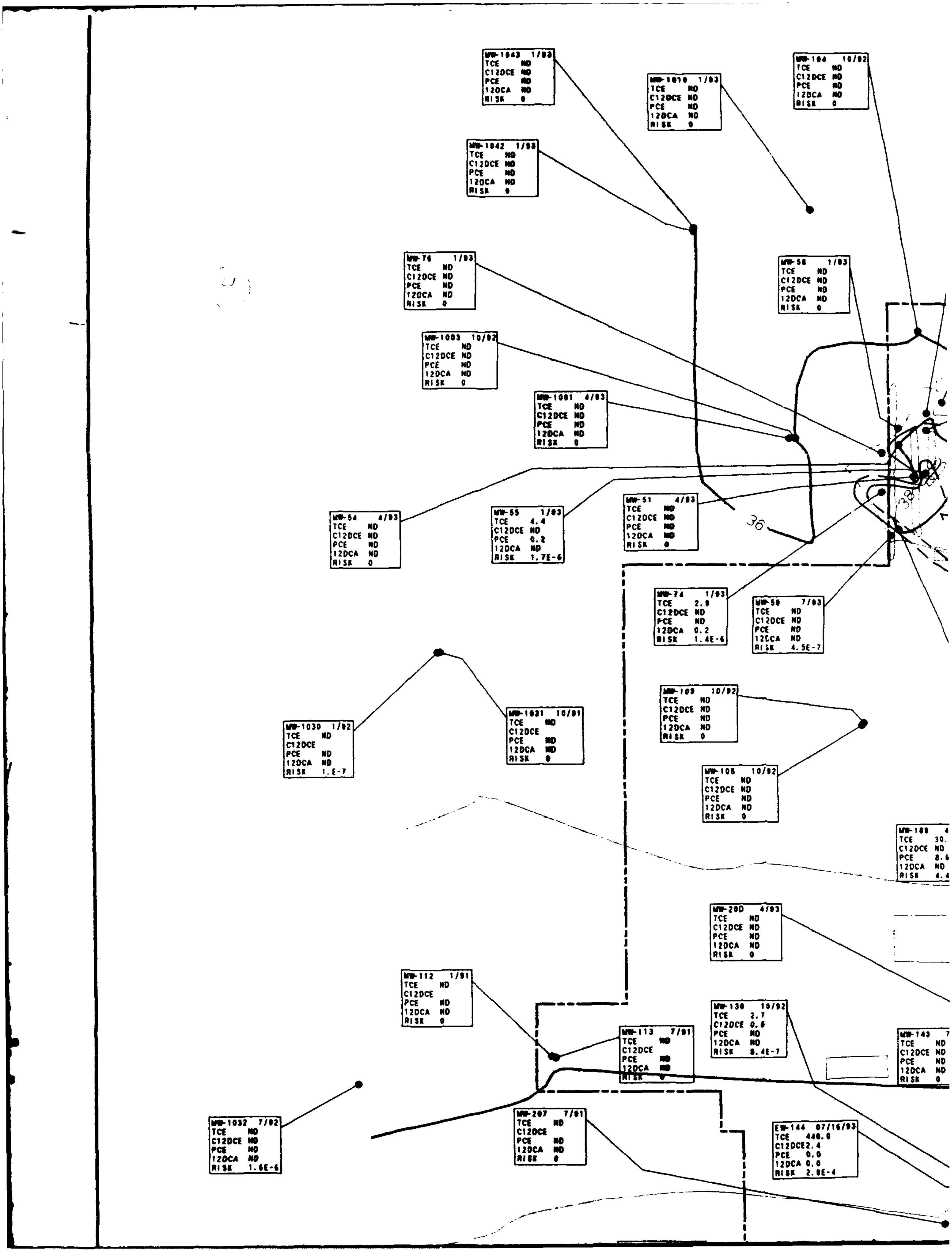
NOTES: 1. CONTOURS FOR CIS-1,2-DCE, PCE AND 1,2-DCA ARE SHOWN ON FIGURES 4-50, 4-52, AND 4-54 FOR ZONES A, B AND C, RESPECTIVELY.

2. SOLID LINES REPRESENT CONTOURS BOUND BY DATA POINTS, DASHED LINES REPRESENT UNBOUNED CONTOUR LINES.

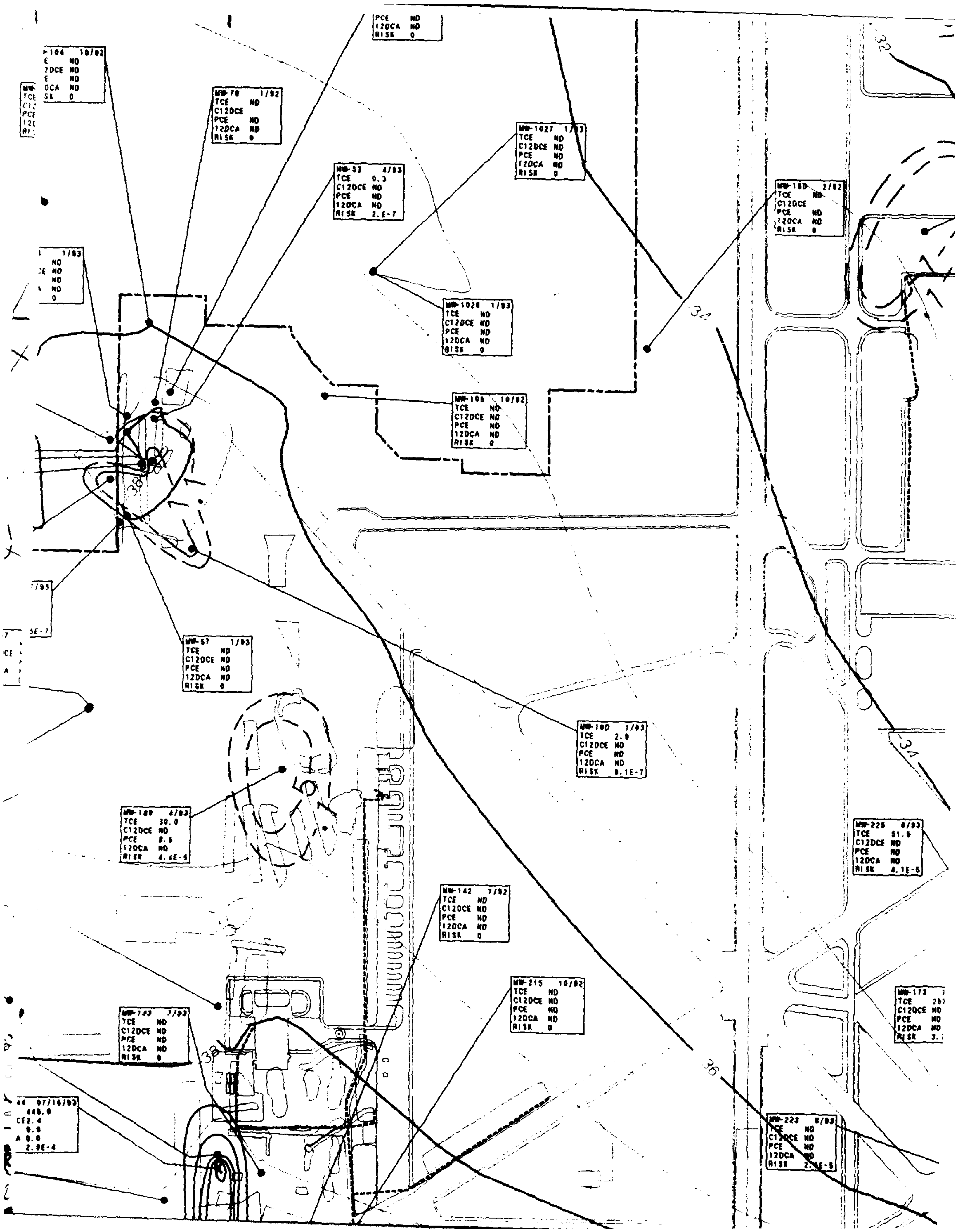



OF
N
1600
3200
SCALE IN FEET
MW-17D 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-16D
TCE
C12DCE
PCE
12DCA
RISK
-34
-32
MW-52 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
-104 10/92
CE ND
12DCE ND
CE ND
2DCA ND
ISK 0
MW-70 1/92
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-1027 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-53 4/93
TCE 0.3
C12DCE ND
PCE ND
12DCA ND
RISK 2.E-7
MW-18D 2/92
TCE ND
C12DCE
PCE ND
12DCA ND
IT

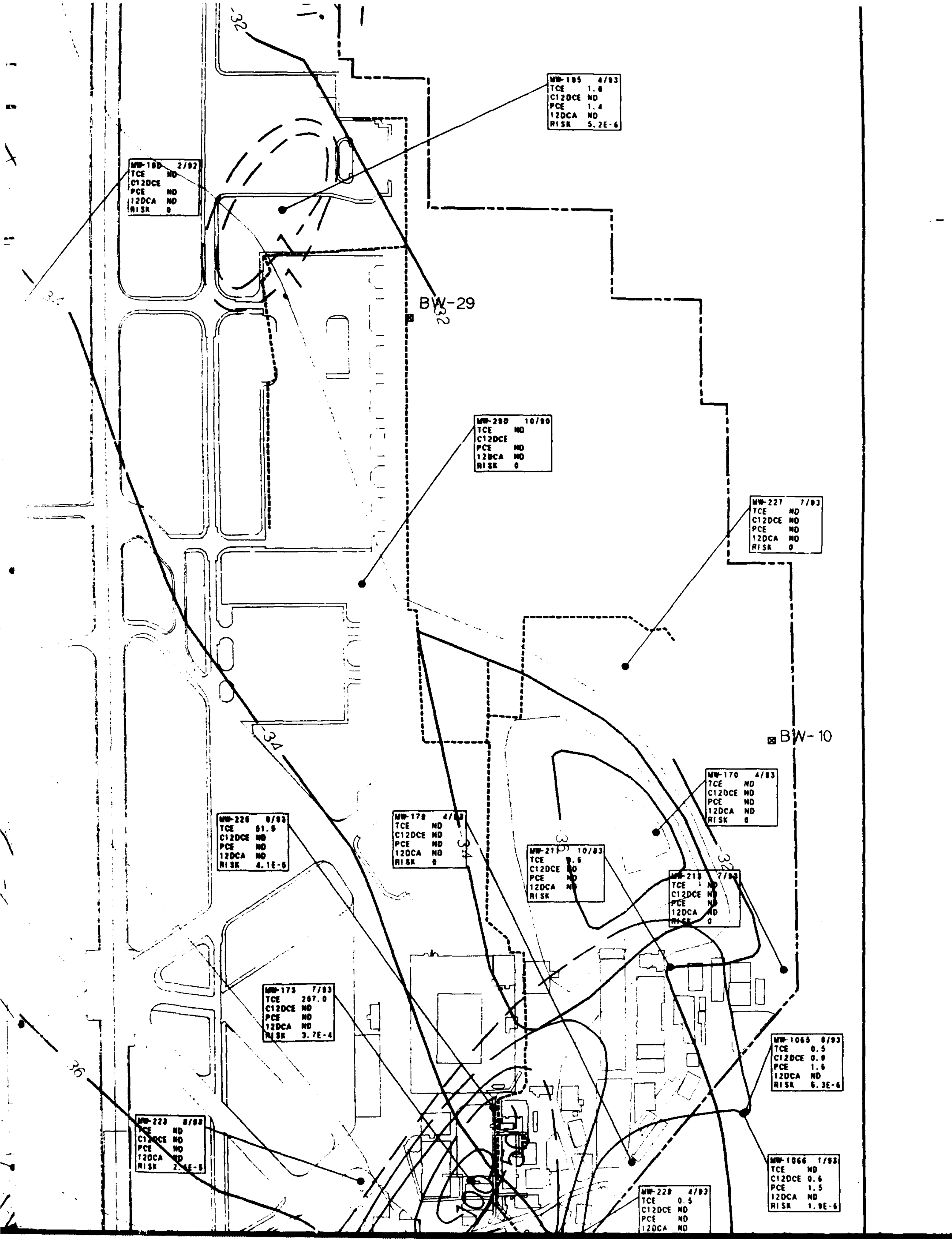

MW-16D
TCE
C12DCE
PCE
12DCA
RISK
MW-103 7/93
TCE 1.2
C12DCE ND
PCE ND
12DCA ND
RISK 9.3E-7
32
MW-195 4/93
TCE 1.8
C12DCE ND
PCE 1.4
12DCA ND
RISK 5.2E-6
MW-18D 2/92
TCE ND
C12DCE
PCE ND
12DCA ND



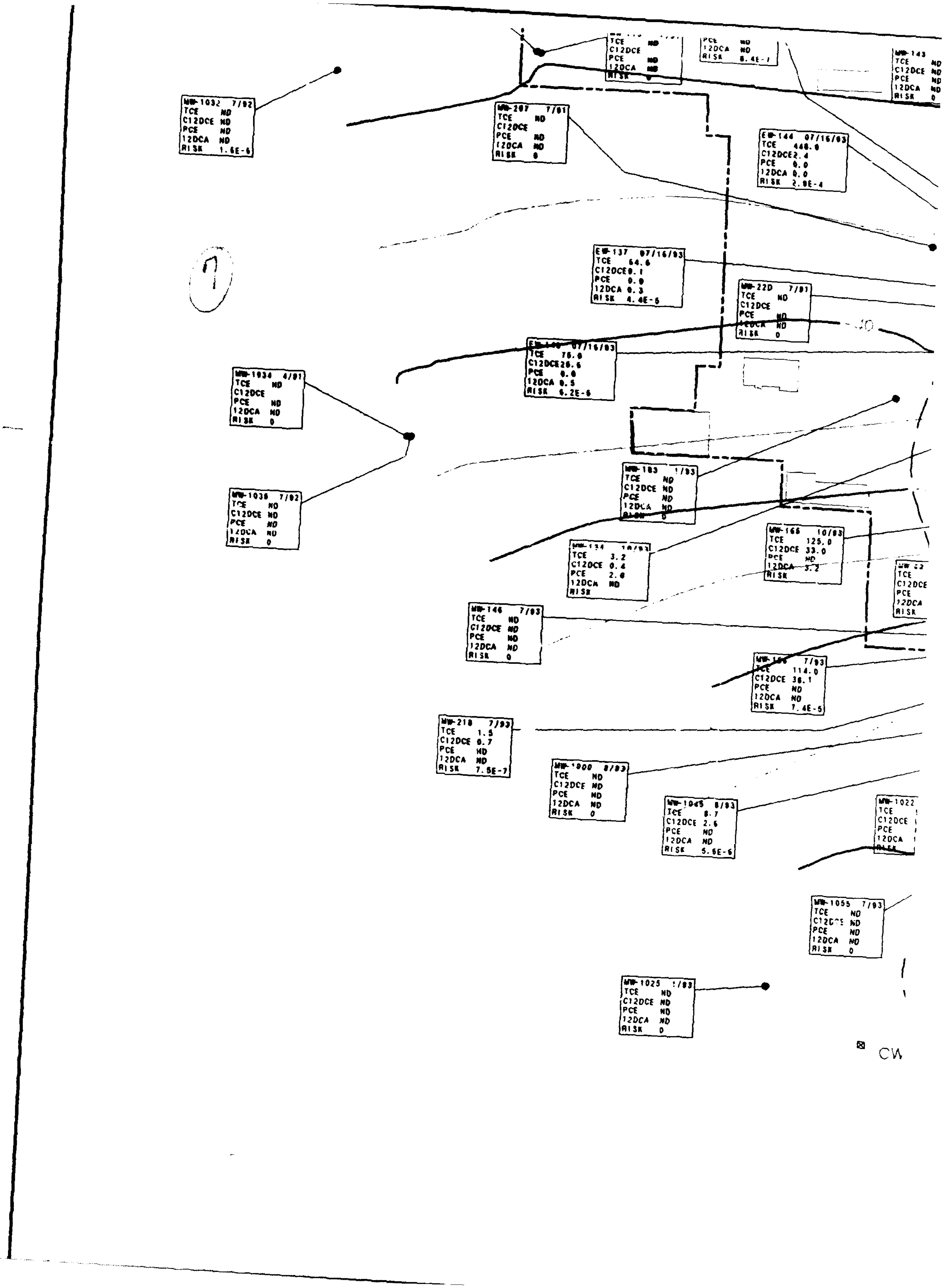
MW-1043 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1010 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-104 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1042 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-76 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-58 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1003 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1001 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-54 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-55 1/93
TCE 4.4
C12DCE ND
PCE 0.2
12DCA ND
RISK 1.7E-6
MW-51 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
36
38
MW-74 1/93
TCE 2.9
C12DCE ND
PCE ND
12DCA 0.2
RISK 1.4E-6
MW-59 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 4.5E-7
MW-109 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1030 1/92
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 1.E-7
MW-1031 10/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-108 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-189 4
TCE 30.
C12DCE ND
PCE 8.6
12DCA ND
RISK 4.4
MW-20D 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-112 1/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-130 10/92
TCE 2.7
C12DCE 0.6
PCE ND
12DCA ND
RISK 8.4E-7
MW-113 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-143 7
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1032 7/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 1.6E-6
MW-207 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
EW-144 07/16/93
TCE 440.0
C12DCE 2.4
PCE 0.0
12DCA 0.0
RISK 2.9E-4

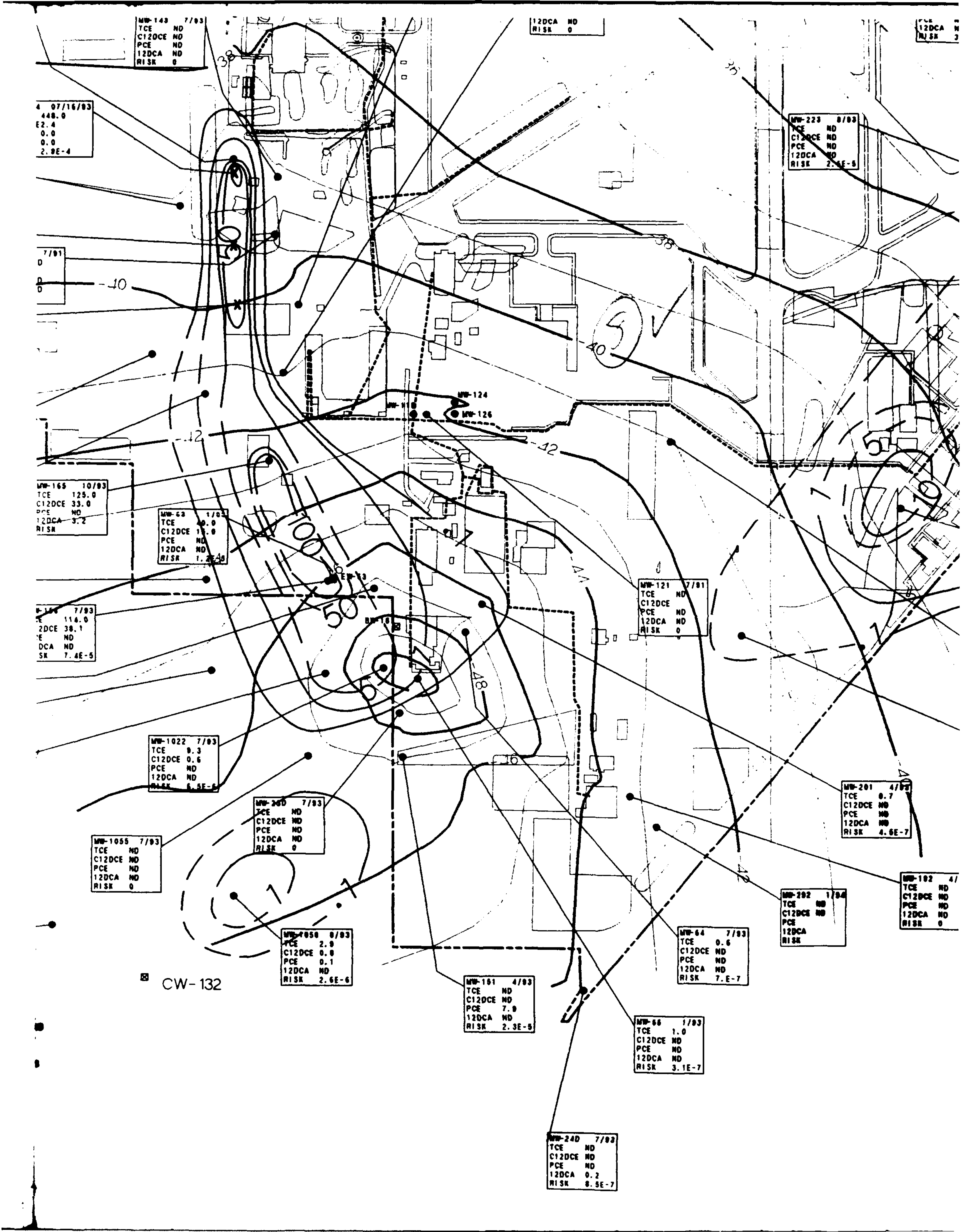


MW-70 1/92
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-53 4/93
TCE 0.3
C12DCE ND
PCE ND
12DCA ND
RISK 2.E-7
MW-1027 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1028 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-105 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-57 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-18D 1/93
TCE 2.9
C12DCE ND
PCE ND
12DCA ND
MW-189 4/93
TCE 30.0
C12DCE ND
PCE 8.6
12DCA ND
RISK 4.4E-5
MW-225 8/93
TCE 51.5
C12DCE ND
PCE ND
12DCA ND
RISK 4.1E-5
MW-142 7/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-215 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-143 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-223 8/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
32
34
34
36
38

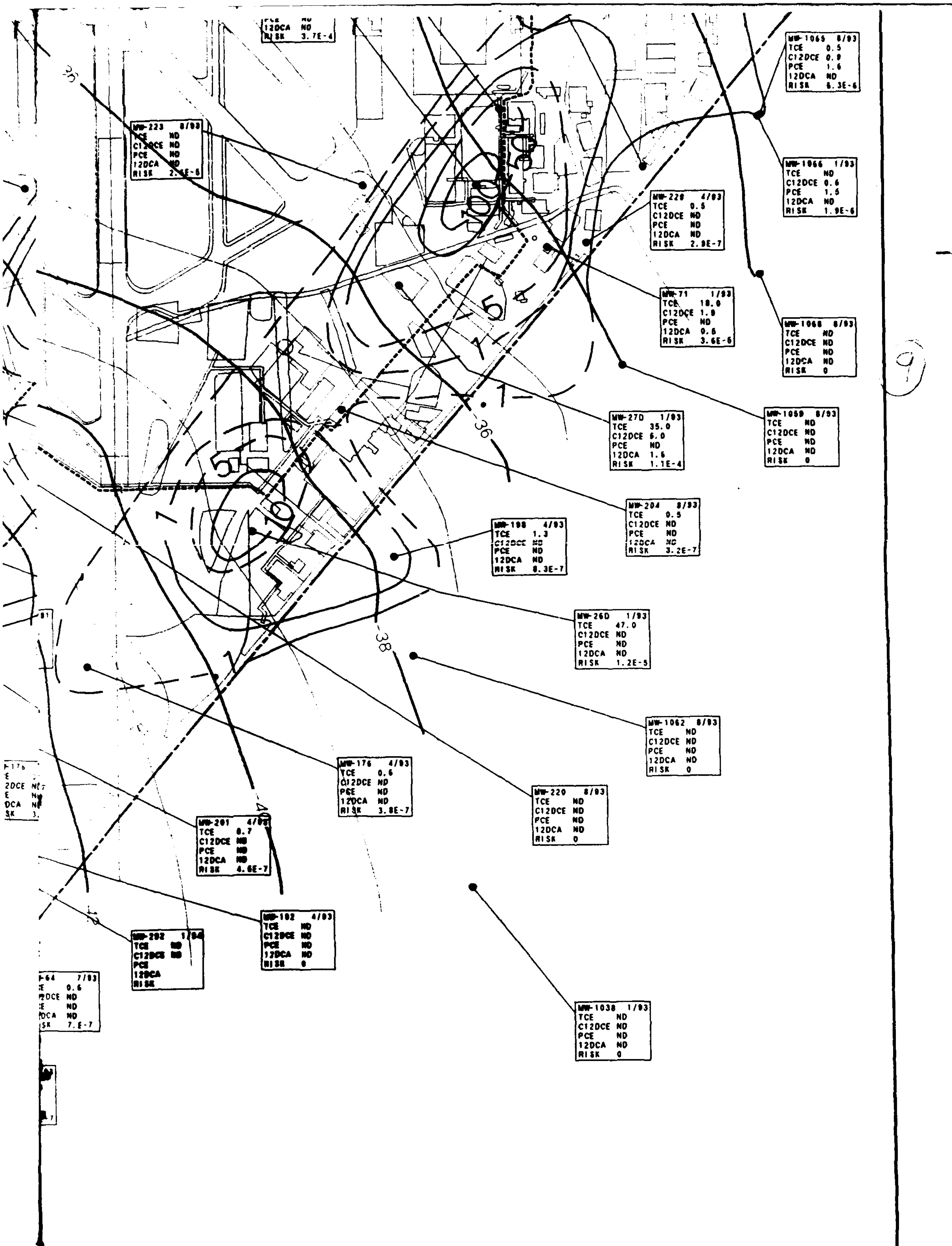


MW-195 4/93
TCE 1.8
C12DCE ND
PCE 1.4
12DCA ND
RISK 5.2E-6
MW-19D 2/92
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
BW-29
MW-29D 10/90
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-227 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
BW-10
MW-170 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-226 8/93
TCE 61.5
C12DCE ND
PCE ND
12DCA ND
RISK 4.1E-6
MW-179 4/
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-21 10/93
TCE
C12DCE
PCE
12DCA
RISK
MW-213 7/93
TCE
C12DCE
PCE
12DCA ND
RISK 0
MW-173 7/93
TCE 287.0
C12DCE ND
PCE ND
12DCA ND
RISK 3.7E-4
MW-1065 8/93
TCE 0.5
C12DCE 0.9
PCE 1.6
12DCA ND
RISK 6.3E-6
MW-223 8/93
C12DCE ND
PCE ND
12DCA
RISK
MW-1066 1/93
TCE ND
C12DCE 0.6
PCE 1.5
12DCA ND
RISK 1.9E-6
MW-228 4/93
TCE 0.5
C12DCE ND
PCE ND
12DCA ND
-32
-34
36


MW-1032 7/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 1.6E-6
MW-207 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
EW-144 07/16/93
TCE 448.0
C12DCE 2.4
PCE 0.0
12DCA 0.0
RISK 2.8E-4
EW-137 07/16/93
TCE 64.6
C12DCE 0.1
PCE 0.0
12DCA 0.3
RISK 4.4E-5
MW-220 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
TCE 75.0
C12DCE 26.5
PCE 0.0
12DCA 0.5
RISK 6.2E-5
MW-1034 4/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-1035 7/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-183 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
MW-165 10/93
TCE 125.0
C12DCE 33.0
PCE ND
12DCA 3.2
RISK
TCE 3.2
C12DCE 0.4
PCE 2.0
12DCA ND
RISK
MW-146 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
TCE 114.0
C12DCE 36.1
PCE ND
12DCA ND
RISK 7.4E-5
MW-218 7/93
TCE 1.5
C12DCE 0.7
PCE ND
12DCA ND
RISK 7.5E-7
MW-1900 8/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1045 8/93
TCE 8.7
C12DCE 2.6
PCE ND
12DCA ND
RISK 5.5E-6
MW-1055 7/93
TCE ND
PCE ND
12DCA ND
RISK 0
MW-1025 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
CW

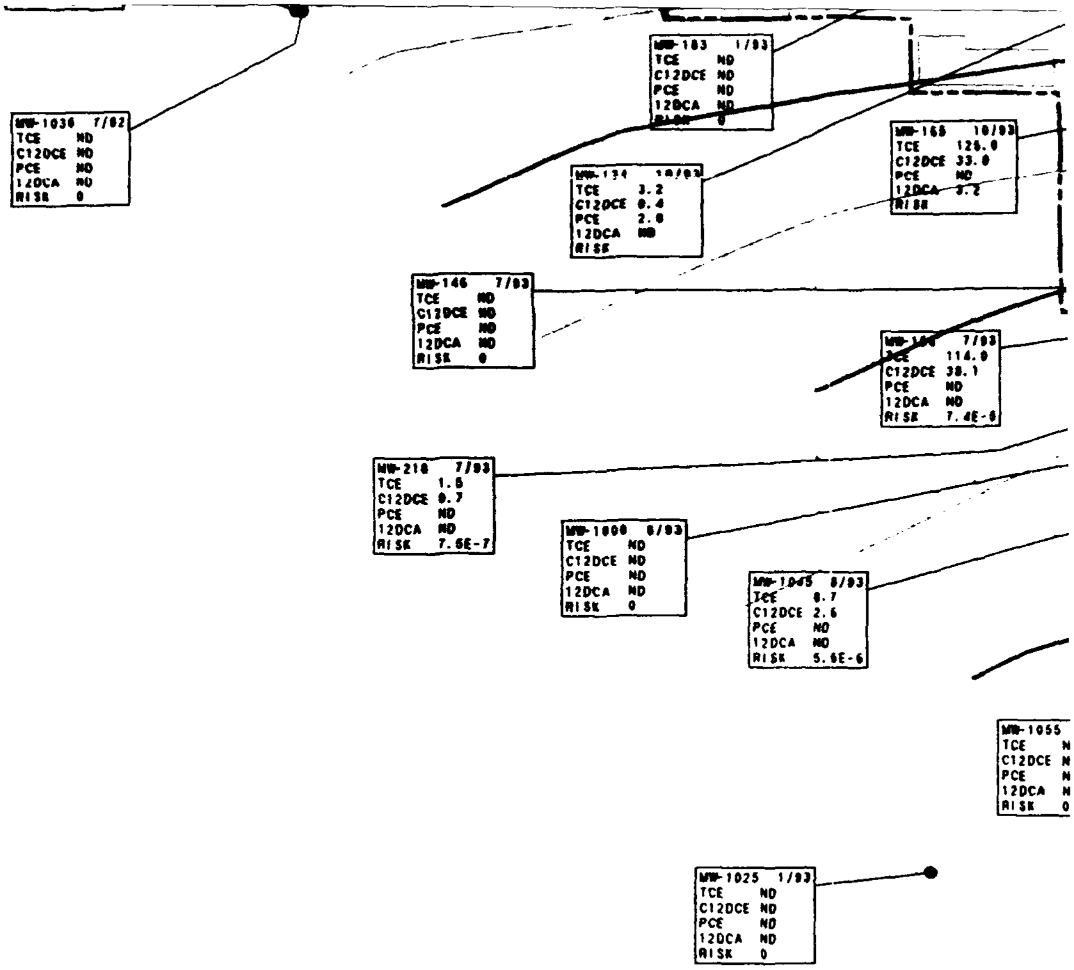


MW-143 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
12DCA ND
RISK 0
MW-223 8/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
MW-165 10/93
TCE 125.0
C12DCE 33.0
PCE ND
12DCA 3.2
MW-124
MW-126
MW-121 7/93
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-1022 7/93
TCE 9.3
C12DCE 0.6
PCE ND
12DCA ND
MW-26D 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1055 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1050 8/93
TCE 2.9
C12DCE 0.0
PCE 0.1
12DCA ND
RISK 2.6E-6
CW-132
MW-161 4/93
TCE ND
C12DCE ND
PCE 7.9
12DCA ND
RISK 2.3E-5
MW-64 7/93
TCE 0.6
C12DCE ND
PCE ND
12DCA ND
RISK 7.E-7
MW-55 1/93
TCE 1.0
C12DCE ND
PCE ND
12DCA ND
RISK 3.1E-7
MW-24D 7/93
TCE ND
C12DCE ND
PCE ND
12DCA 0.2
RISK 8.5E-7
MW-201 4/93
TCE 0.7
C12DCE ND
PCE ND
12DCA ND
RISK 4.6E-7
MW-202 1/94
TCE ND
C12DCE ND
PCE
12DCA
RISK
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
38
40
42
44
48
100
50
10
5
1



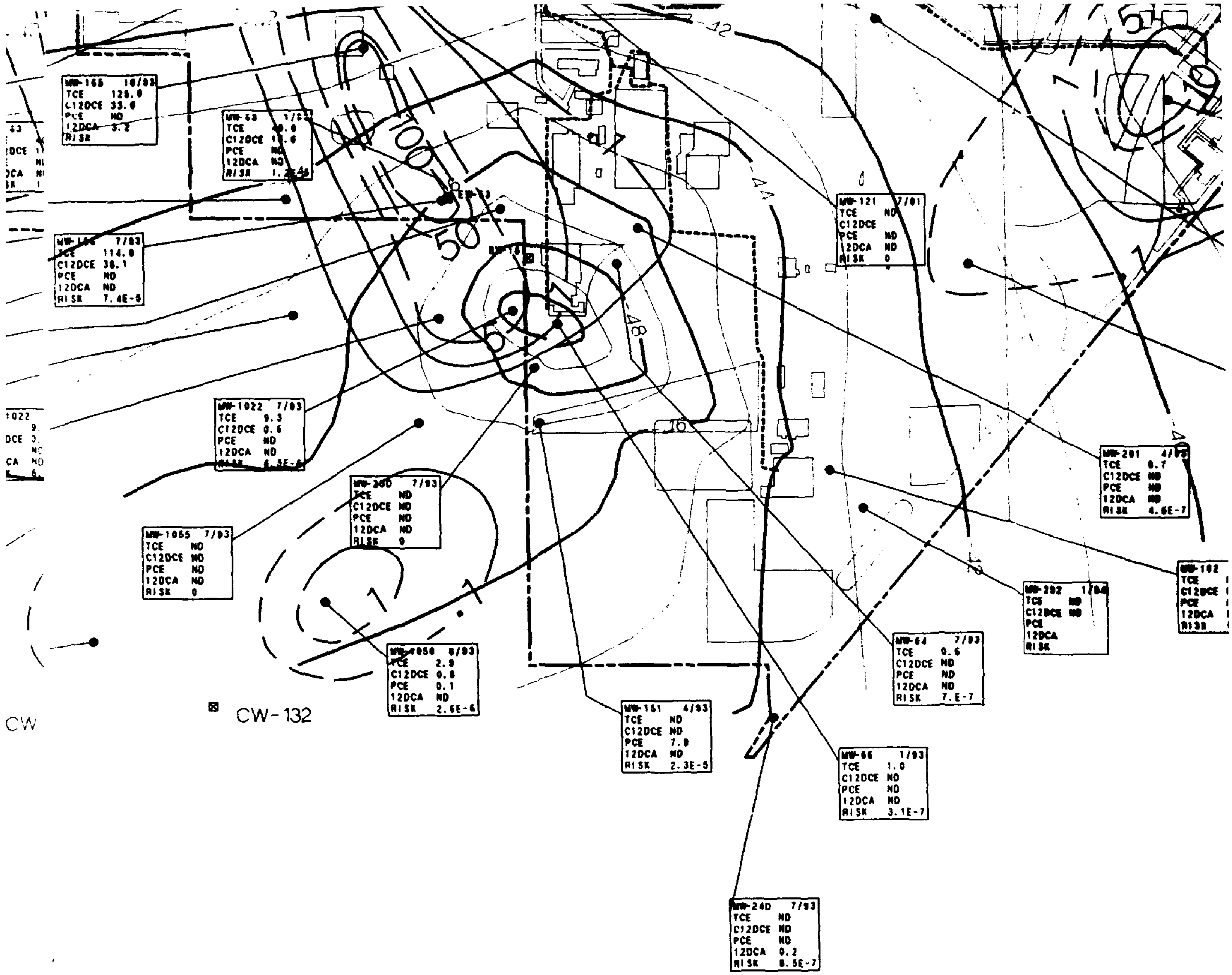
IG

FIGURE 4-53



(10)

RDD1454 MAY, 1994
MEY94/4-53.DGN



MW-165 10/93
TCE 128.0
C12DCE 33.0
PCE ND
12DCA 3.2
RISK
MW-63
TCE
C12DCE
PCE ND
12DCA ND
RISK
7/93
TCE 114.0
C12DCE 38.1
PCE ND
12DCA ND
RISK 7.4E-5
100
50
MW-121 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-1022 7/93
TCE 9.3
C12DCE 0.6
PCE ND
12DCA ND
7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1055 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
TCE 2.9
C12DCE 0.8
PCE 0.1
12DCA ND
RISK 2.6E-6
CW-132
CW
MW-151 4/93
TCE ND
C12DCE ND
PCE 7.8
12DCA ND
RISK 2.3E-5
MW-201
TCE 0.7
C12DCE ND
PCE ND
12DCA ND
RISK 4.6E-7
MW-202
TCE ND
C12DCE ND
PCE
12DCA
RISK
MW-102
TCE
C12DCE
PCE
12DCA
RISK
MW-64 7/93
TCE 0.6
C12DCE ND
PCE ND
12DCA ND
RISK 7.E-7
MW-66 1/93
TCE 1.0
C12DCE ND
PCE ND
12DCA ND
RISK 3.1E-7
MW-24D 7/93
TCE ND
C12DCE ND
PCE ND
12DCA 0.2
RISK 8.5E-7

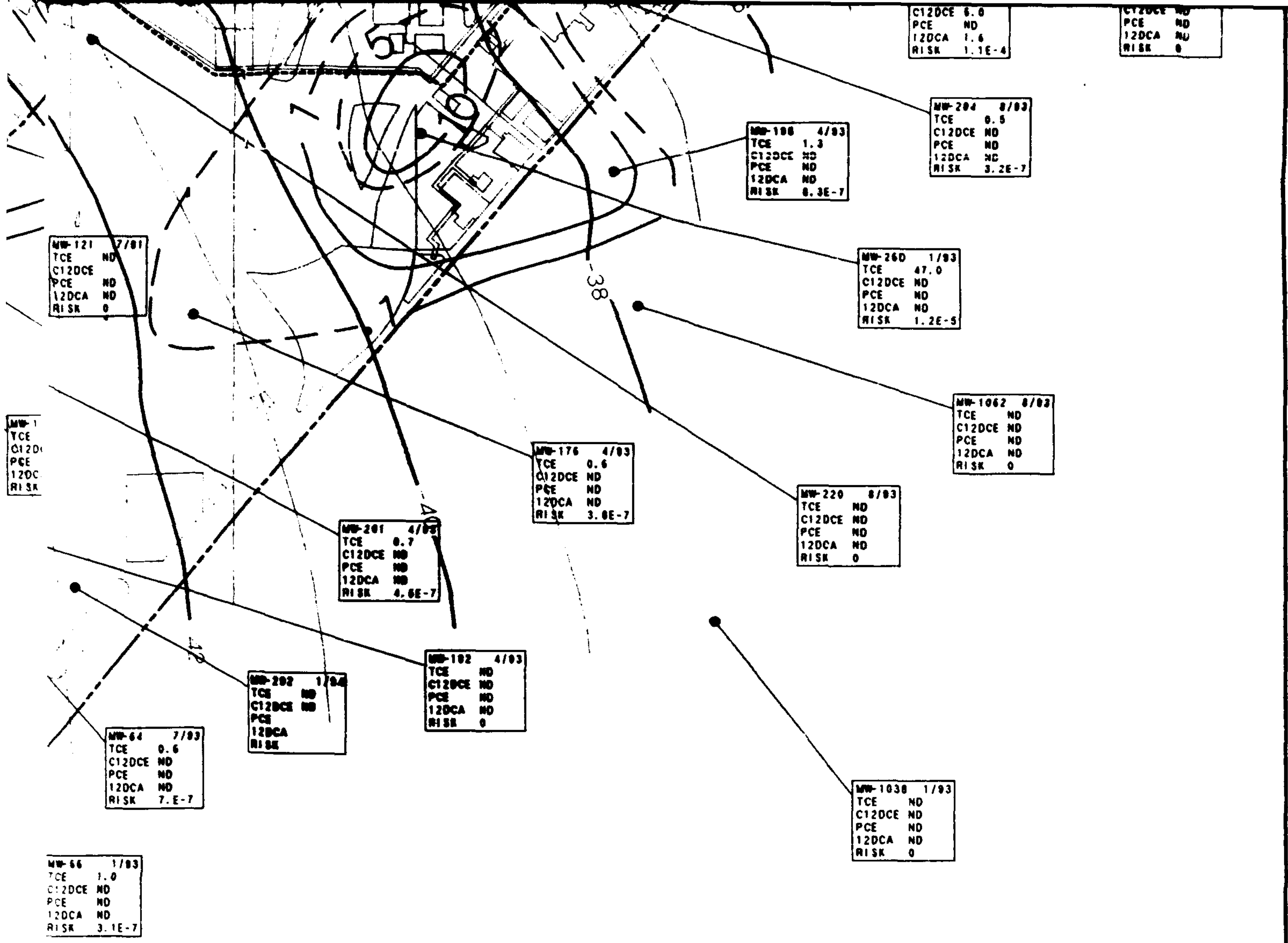
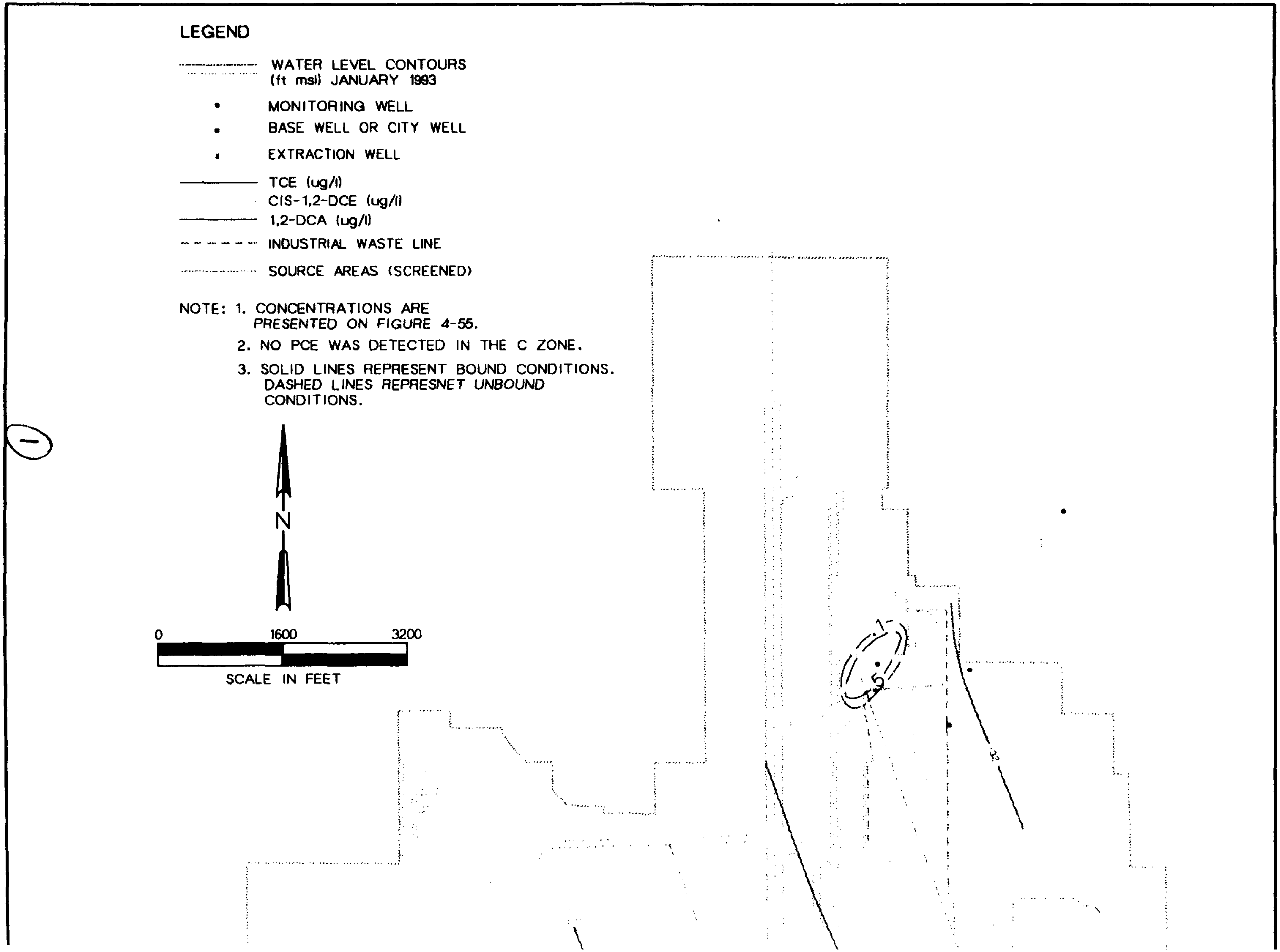


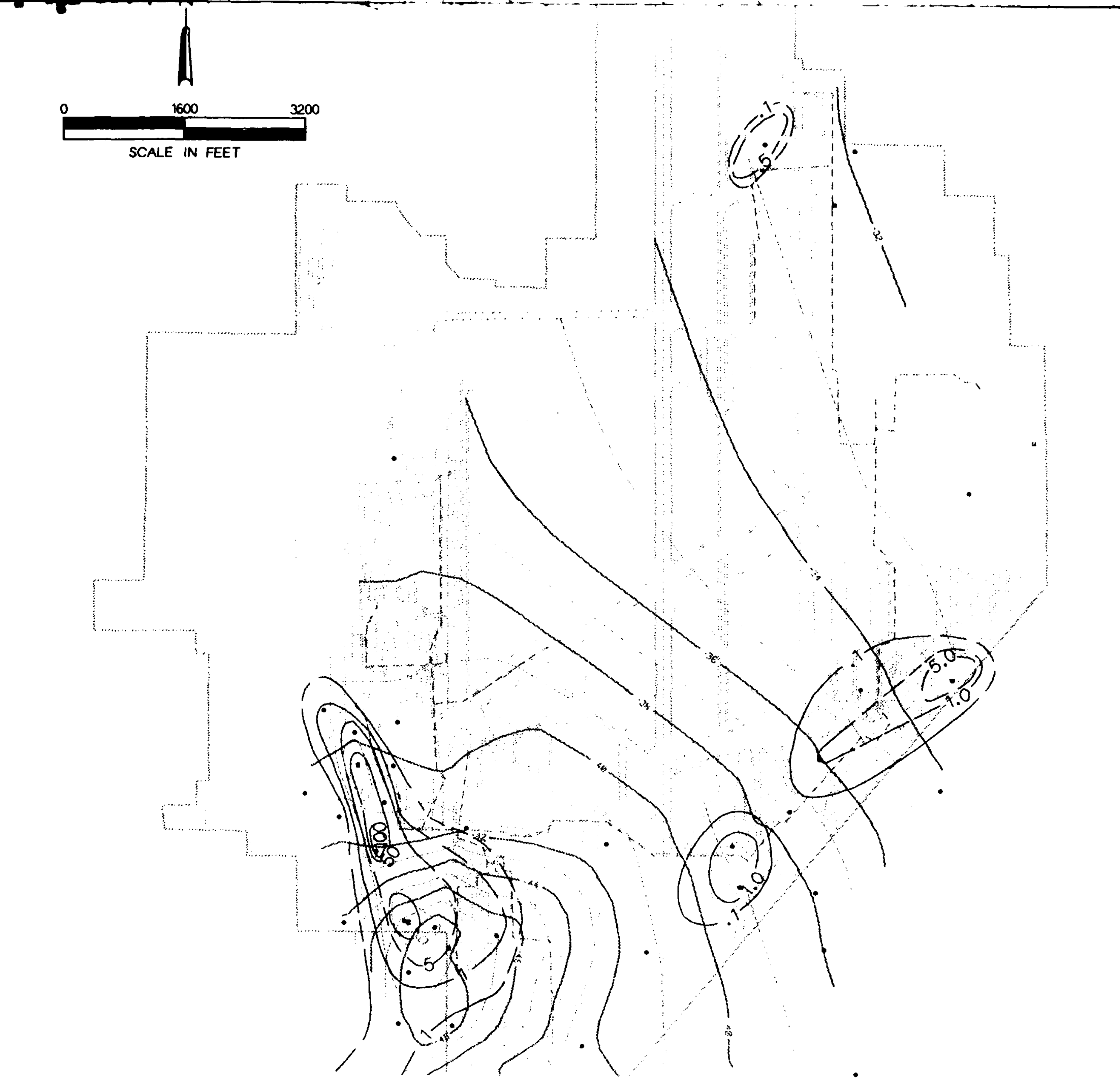
FIGURE 4-53
EXTENT OF VOC CONTAMINATION IN MONITORING ZONE B

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

12


LEGEND
WATER LEVEL CONTOURS (ft msl) JANUARY 1993
MONITORING WELL
BASE WELL OR CITY WELL
EXTRACTION WELL
TCE (ug/l)
CIS-1,2-DCE (ug/l)
1,2-DCA (ug/l)
INDUSTRIAL WASTE LINE
SOURCE AREAS (SCREENED)
NOTE: 1. CONCENTRATIONS ARE PRESENTED ON FIGURE 4-55.
2. NO PCE WAS DETECTED IN THE C ZONE.
3. SOLID LINES REPRESENT BOUND CONDITIONS. DASHED LINES REPRESNET UNBOUND CONDITIONS.
N
0
1600
3200
SCALE IN FEET
1
5
32



(2)

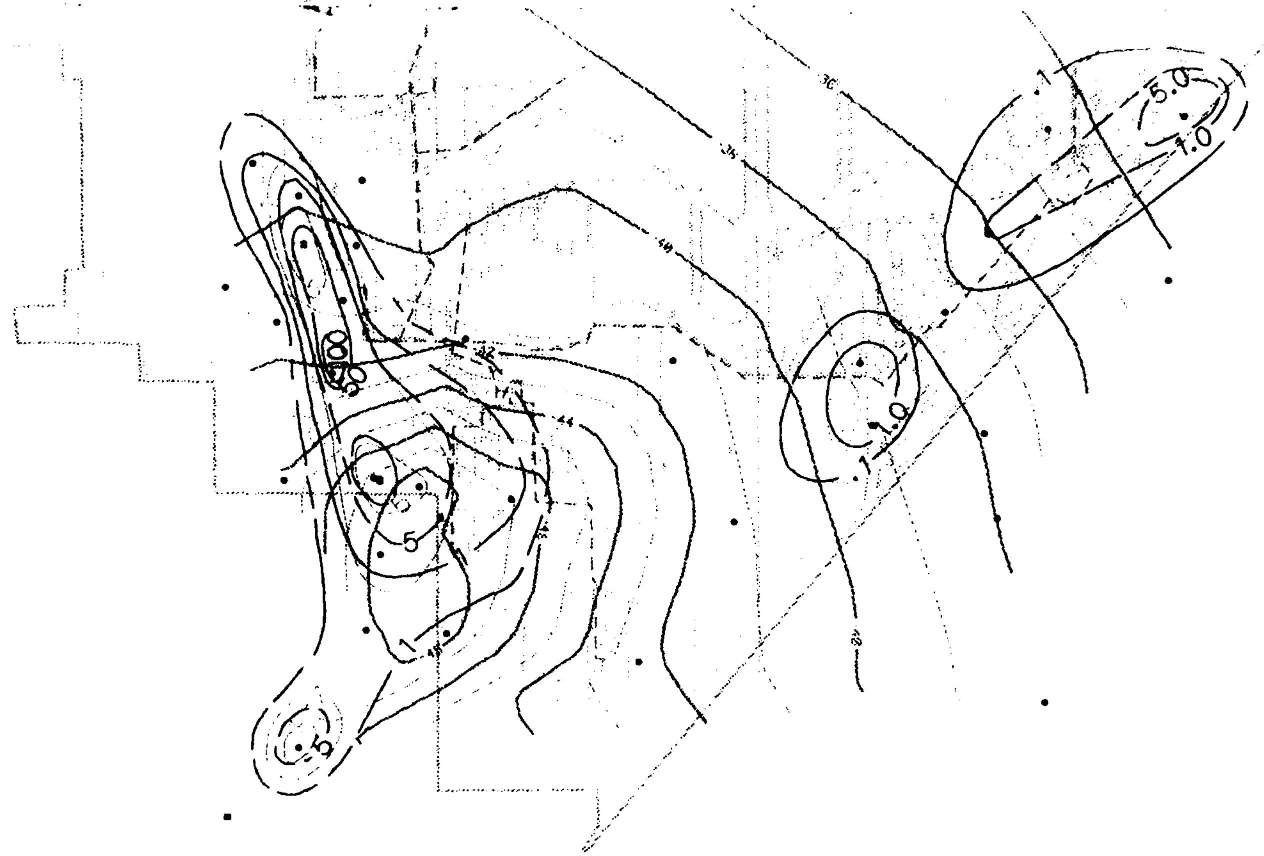


FIGURE 4-54
EXTENT OF VOC
CONTAMINATION IN
MONITORING ZONE C
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454 Mar 28, 1994
MEY94/4-54.DGN

LEGEND

(sample well label box)	WELL NAME, MONTH AND YEAR OF SAM VOC CONCENTRATION (ug/l), AND CUMU RISK VALUE
——— / — — —	WATER LEVEL CONTOURS (ft msl) JANUARY 1993
•	MONITORING WELL
⊠	BASE WELL OR CITY WELL
x	EXTRACTION WELL
———	TCE (ug/l)
-------	INDUSTRIAL WASTE LINE
- - - -	SOURCE AREAS (SCREENED)

NOTES: 1. CONTOURS FOR CIS-1,2-DCE, PCE AND 1,2-DCA ARE SHOWN ON FIGURES 4-50, 4-52, AND 4-54 FOR ZONES A, B AND C, RESPECTIVELY.

2. SOLID LINES REPRESENT CONTOURS BOUND B DATA POINTS, DASHED LINES PREPRESENT UNE CONTOUR LINES.

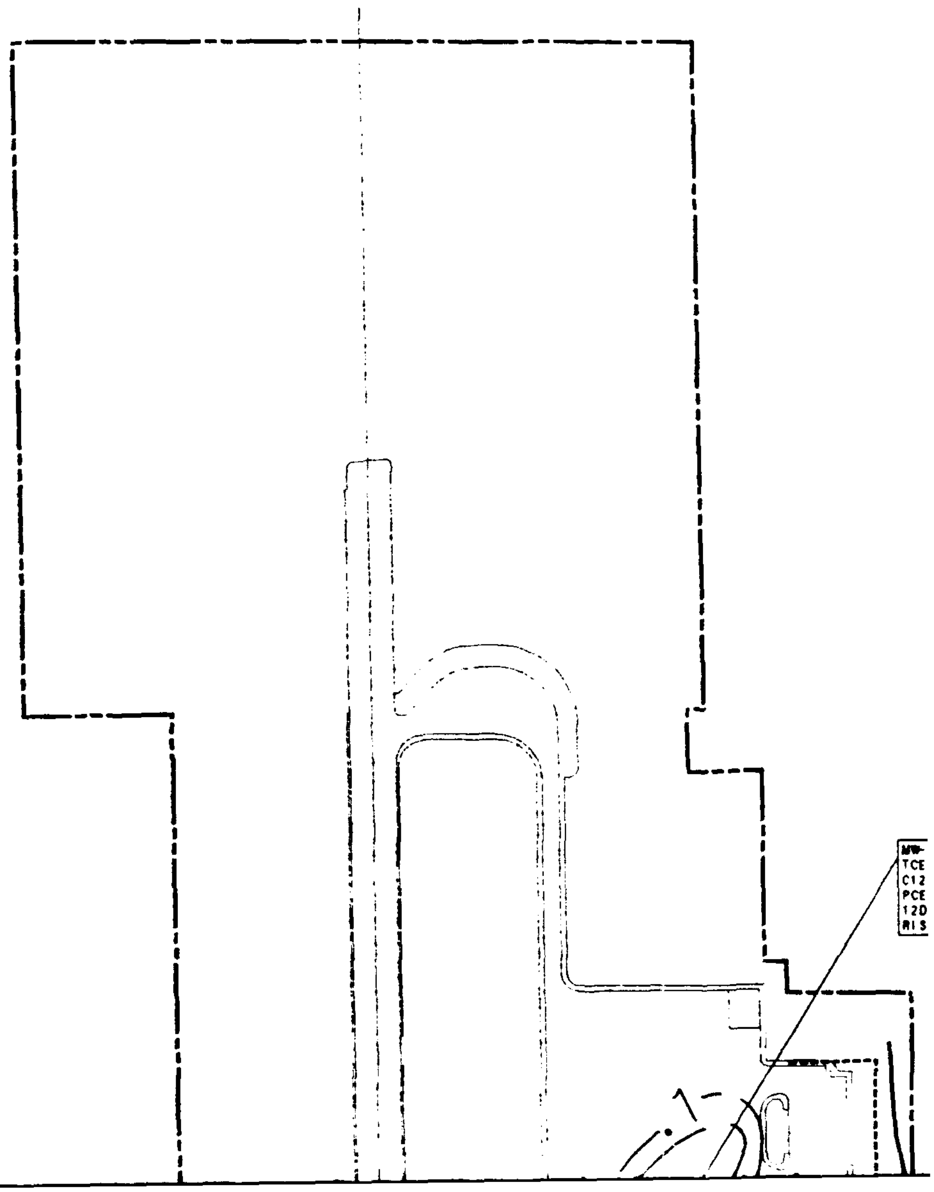
0 1600 3200

.INEAR OF SAMPLING,
\TI), AND CUMULATIVE

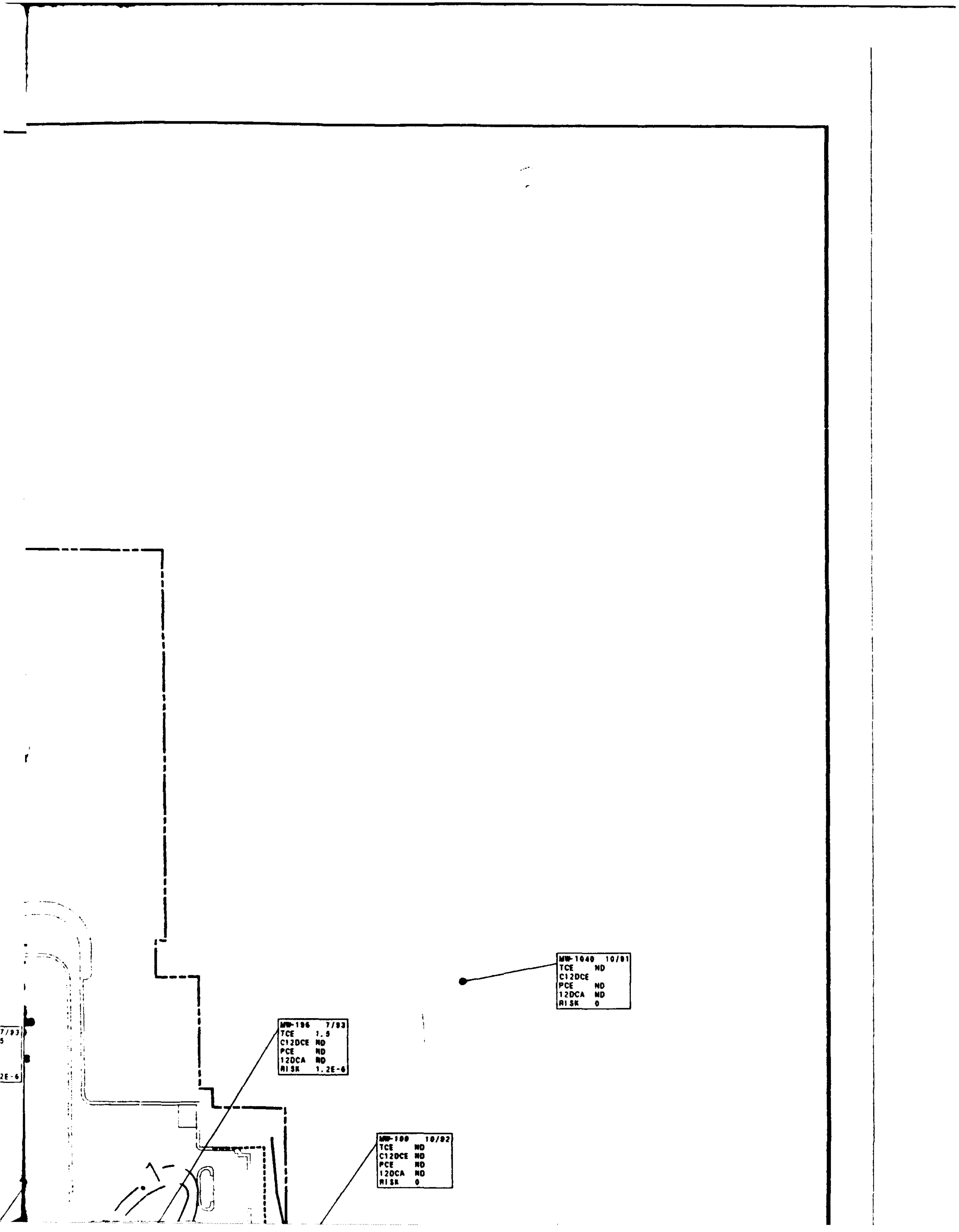
)

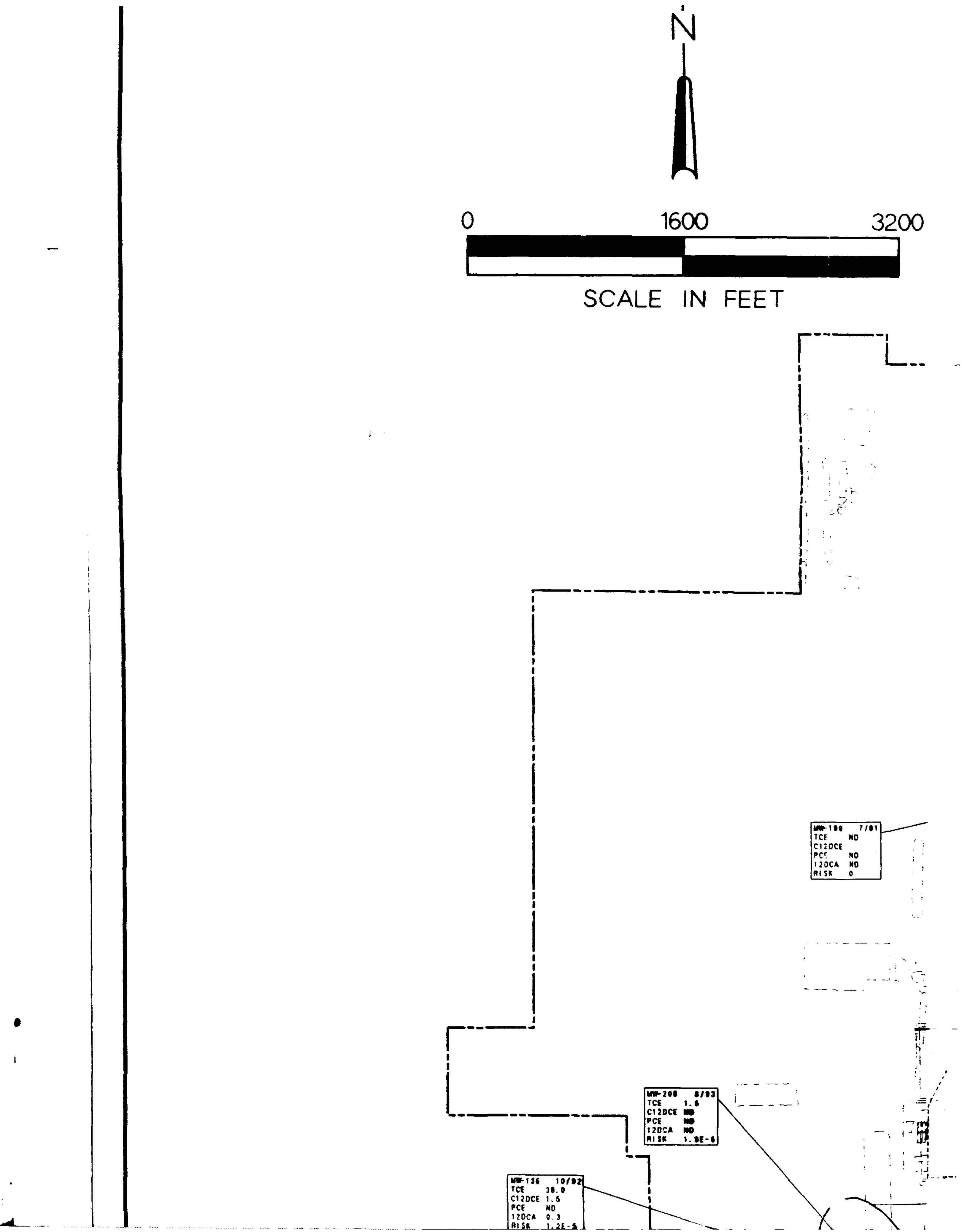
RES 4-50,
AND C,

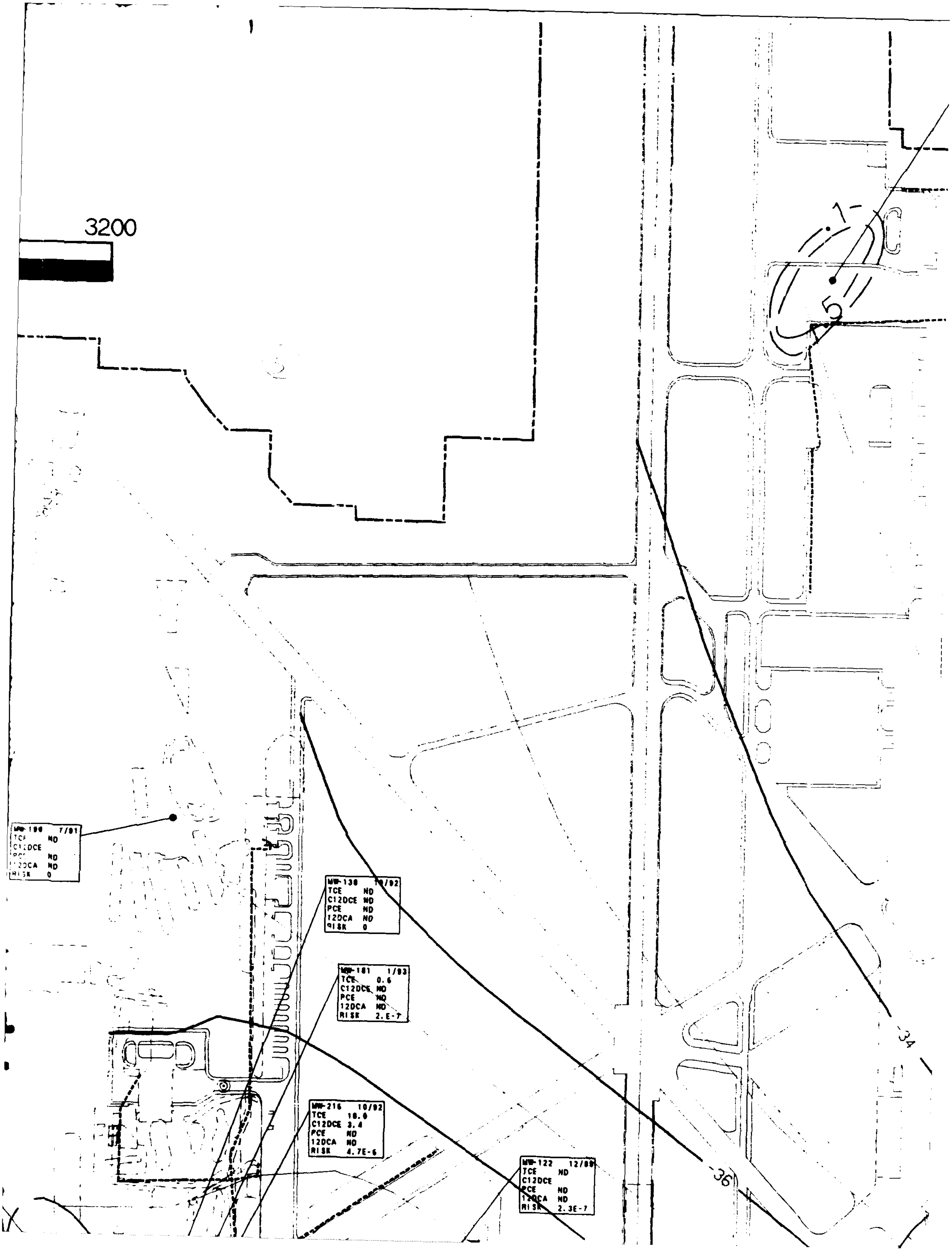
S BOUND BY
JN RESENT UNBOUND



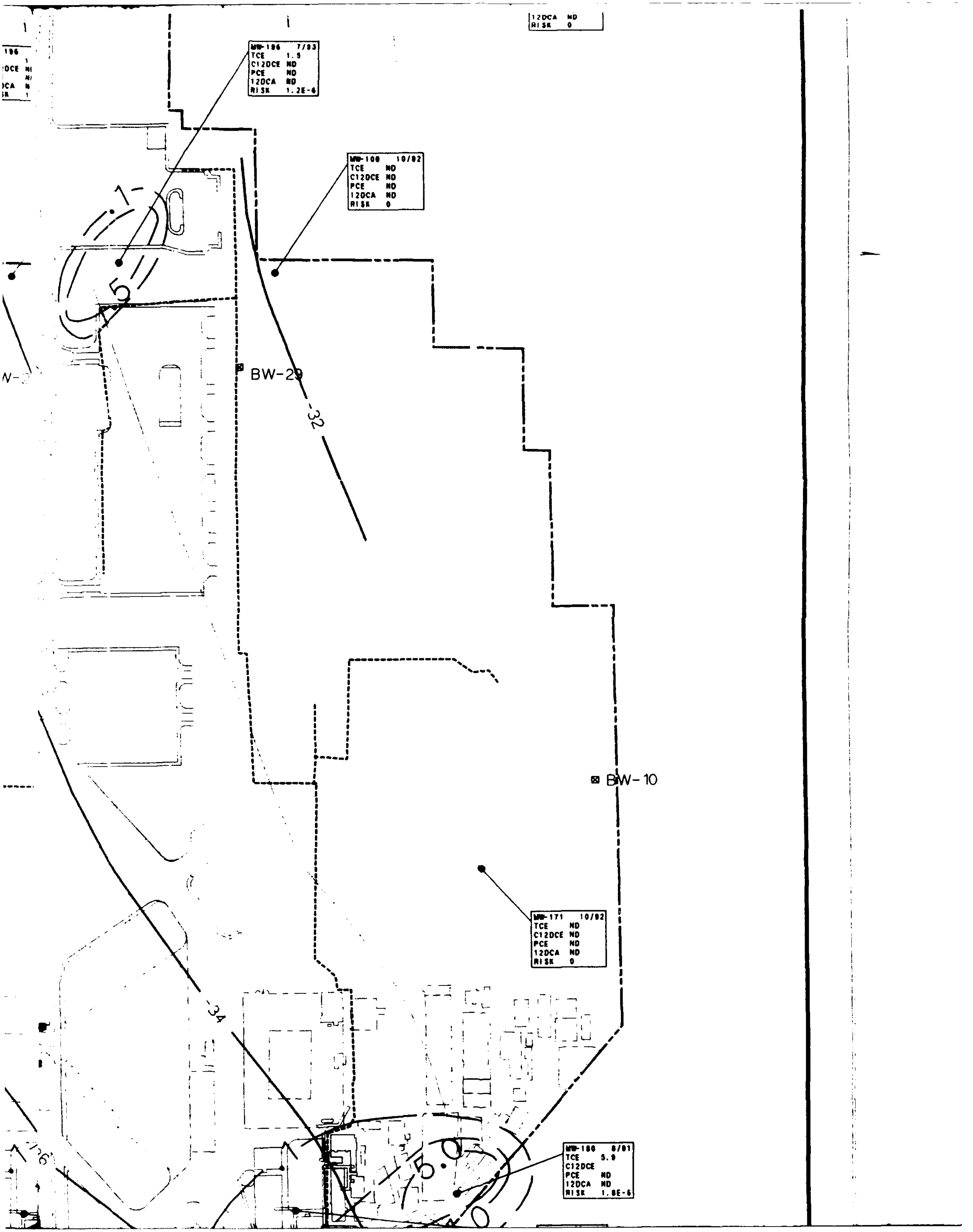
3200

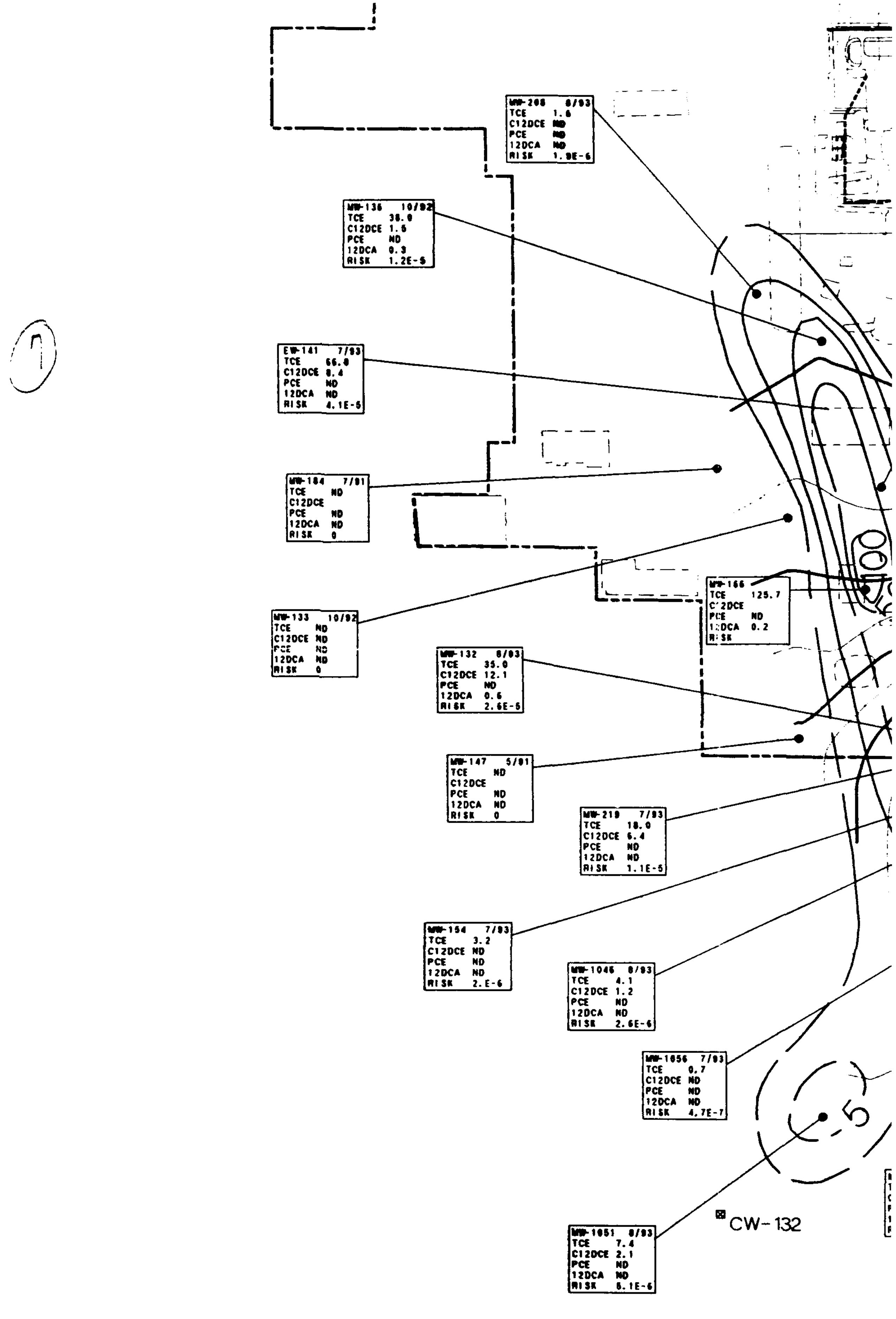

MW-1040 10/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-196 7/93
TCE 1.5
C12DCE ND
PCE ND
12DCA ND
RISK 1.2E-6
MW-100 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0

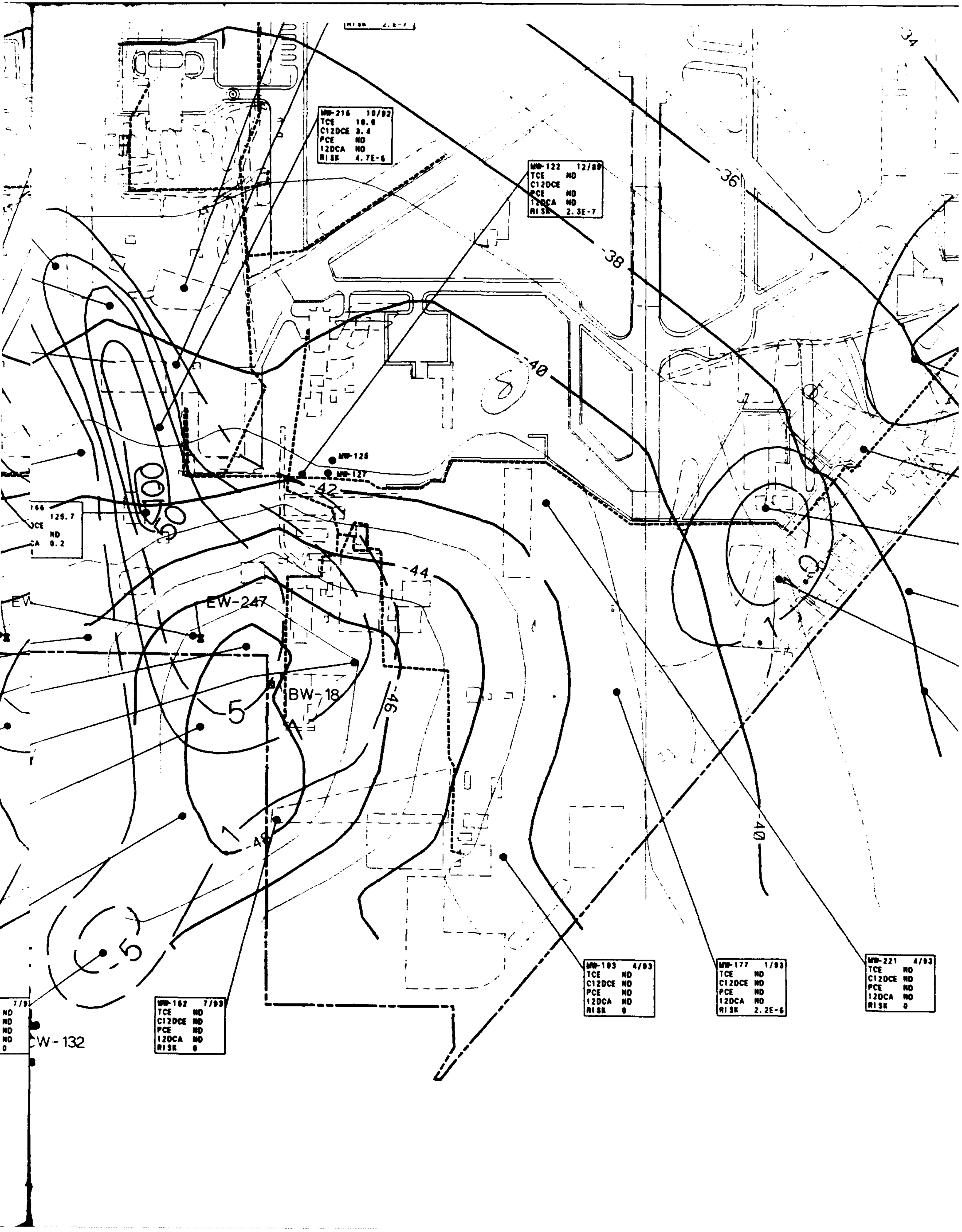

N
0
1600
3200
SCALE IN FEET
MW-190 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-208 8/93
TCE 1.6
C12DCE ND
PCE ND
12DCA ND
RISK 1.9E-6
MW-136 10/92
TCE 38.0
C12DCE 1.5
PCE ND
12DCA 0.3
RISK 1.2E-5

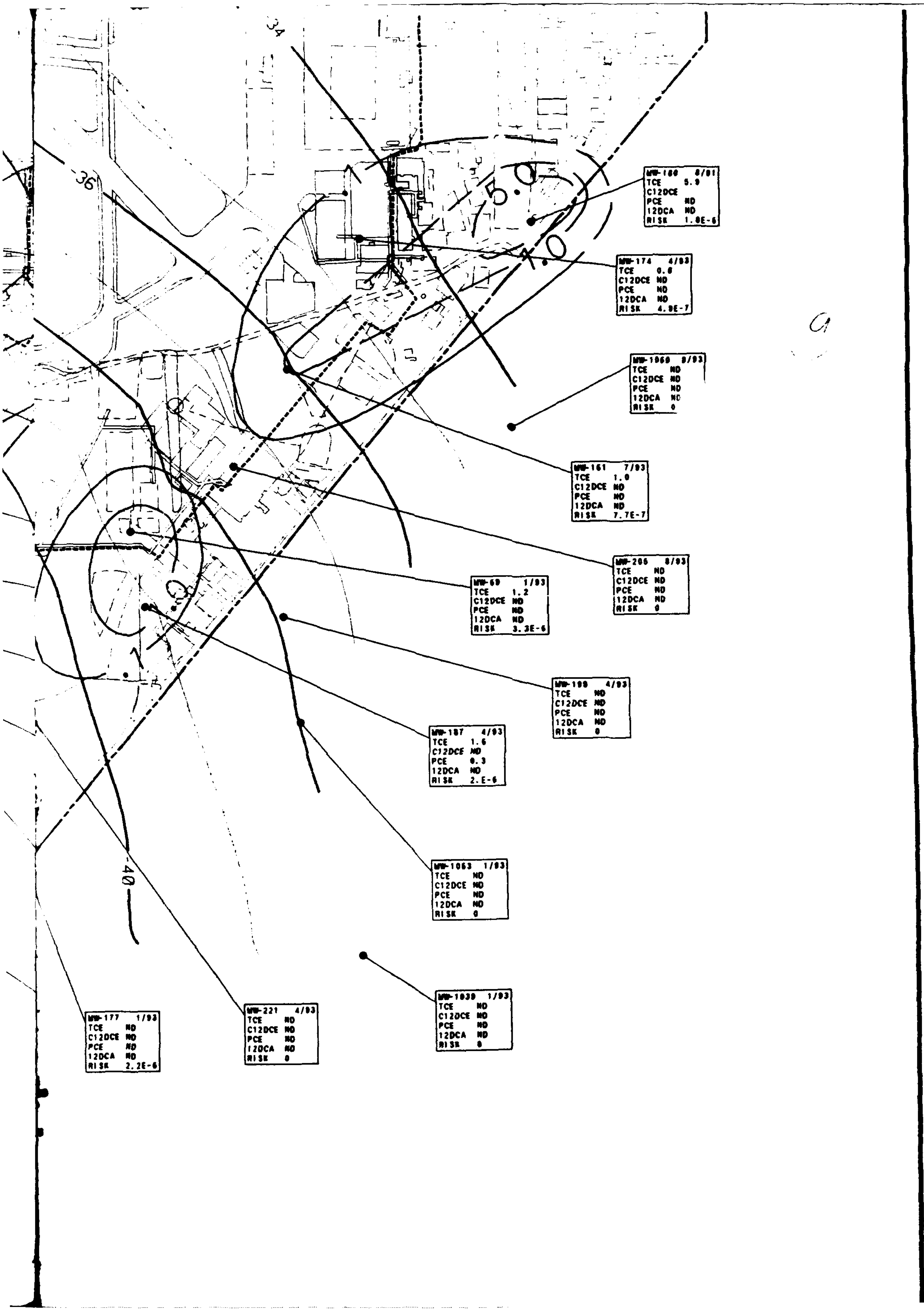


3200
1
5
34
36
MW-130 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-181 1/93
TCE 0.6
C12DCE ND
PCE ND
12DCA ND
RISK 2.E-7
MW-216 10/92
TCE 18.0
C12DCE 3.4
PCE ND
12DCA ND
RISK 4.7E-6
MW-122
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 2.3E-7


12DCA ND
RISK 0
MW-186 7/83
TCE 1.5
C12DCE ND
PCE ND
12DCA ND
RISK 1.2E-6
MW-100 10/82
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
BW-29
32
5
BW-10
MW-171 10/82
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
34
MW-180 8/81
TCE 5.9
C12DCE
PCE ND
12DCA ND
RISK 1.8E-6

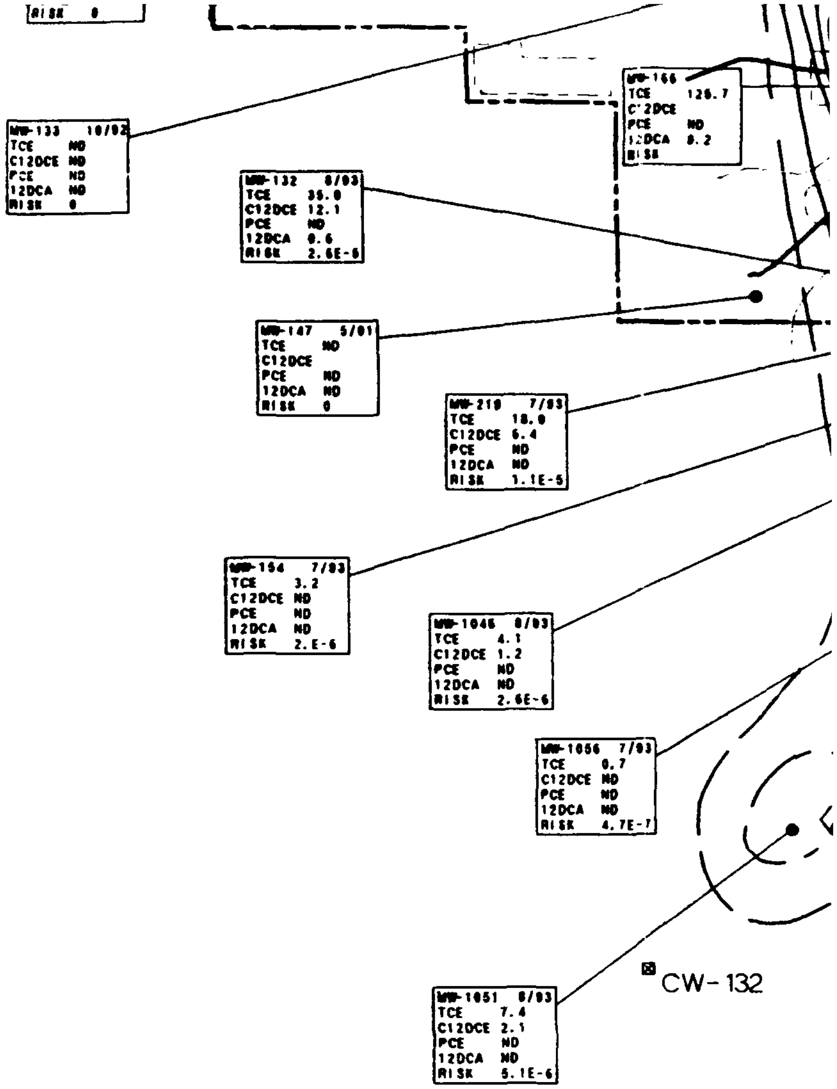

MW-208 8/93
TCE 1.6
C12DCE ND
PCE ND
12DCA ND
RISK 1.9E-6
MW-136 10/92
TCE 38.0
C12DCE 1.6
PCE ND
12DCA 0.3
RISK 1.2E-5
EW-141 7/93
TCE 66.0
C12DCE 8.4
PCE ND
12DCA ND
RISK 4.1E-5
MW-184 7/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-133 10/92
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-166
TCE 125.7
C12DCE
PCE ND
12DCA 0.2
RISK
MW-132 8/93
TCE 35.0
C12DCE 12.1
PCE ND
12DCA 0.6
RISK 2.6E-5
MW-147 5/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-219 7/93
TCE 18.0
C12DCE 6.4
PCE ND
12DCA ND
RISK 1.1E-5
MW-154 7/93
TCE 3.2
C12DCE ND
PCE ND
12DCA ND
RISK 2.E-6
MW-1046 8/93
TCE 4.1
C12DCE 1.2
PCE ND
12DCA ND
RISK 2.6E-6
MW-1056 7/93
TCE 0.7
C12DCE ND
PCE ND
12DCA ND
RISK 4.7E-7
MW-1051 8/93
TCE 7.4
C12DCE 2.1
PCE ND
12DCA ND
RISK 5.1E-6
CW-132


MW-216 10/92
TCE 16.0
C12DCE 3.4
PCE ND
12DCA ND
RISK 4.7E-6
MW-122 12/89
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 2.3E-7
-36
-38
-40
-42
-44
-46
-48
MW-126
MW-127
EW-247
BW-18
5
-5
CW-132
MW-162 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-193 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-177 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 2.2E-6
MW-221 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0



34
36
40
5.0
1.0
MW-180 8/91
TCE 5.9
C12DCE
PCE ND
12DCA ND
RISK 1.8E-6
MW-174 4/93
TCE 0.6
C12DCE ND
PCE ND
12DCA ND
RISK 4.9E-7
MW-1069 8/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-161 7/93
TCE 1.0
C12DCE ND
PCE ND
12DCA ND
RISK 7.7E-7
MW-205 8/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-69 1/93
TCE 1.2
C12DCE ND
PCE ND
12DCA ND
RISK 3.3E-6
MW-199 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-187 4/93
TCE 1.6
C12DCE ND
PCE 0.3
12DCA ND
RISK 2.E-6
MW-1063 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-1039 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-177 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 2.2E-6
MW-221 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0

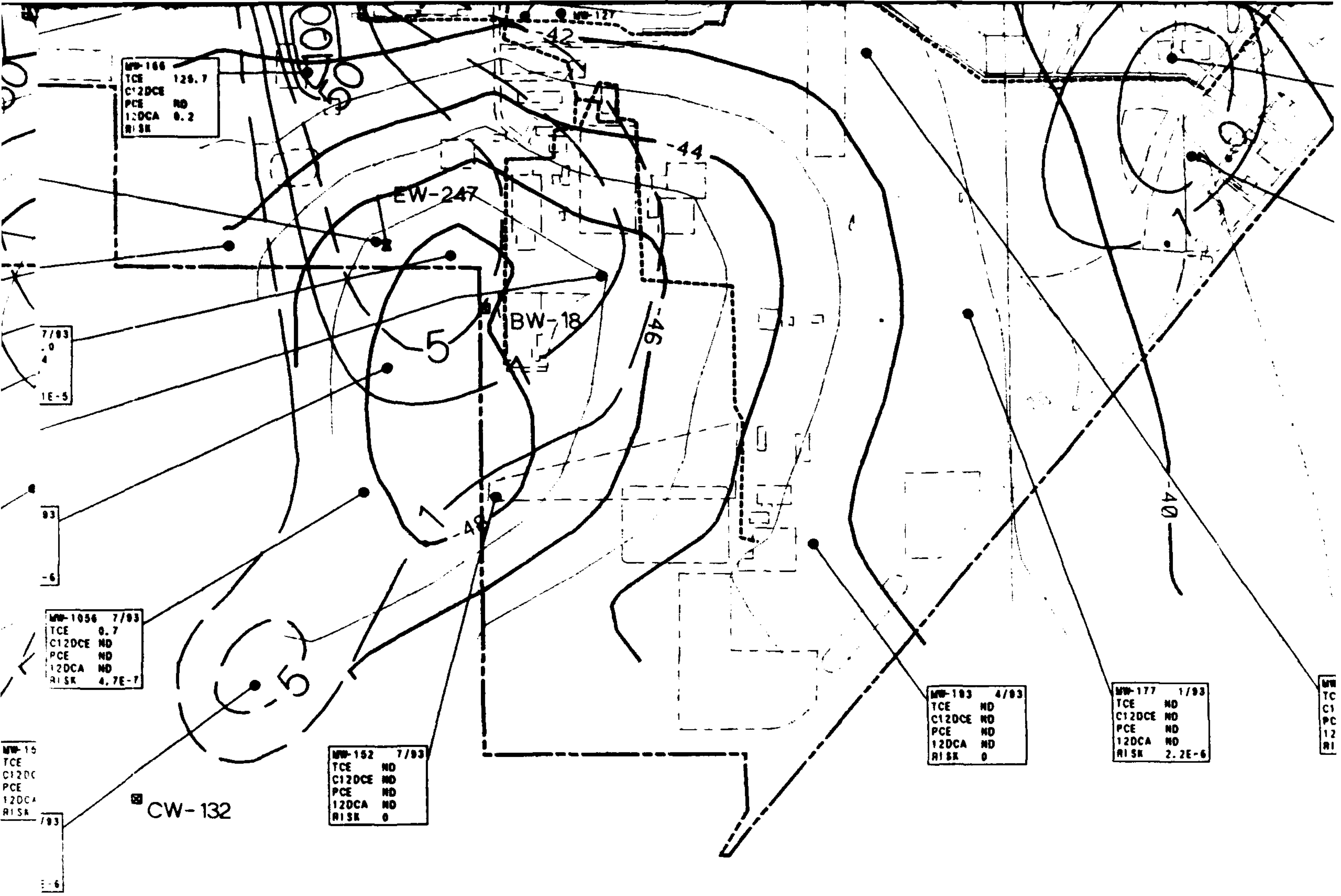
9



(10)

RDD 1454 May, 1994

MEY94/4-55.DGN


MW-166
TCE 125.7
C12DCE
PCE ND
12DCA 0.2
RISK
-42
-44
EW-247
BW-18
-46
-5
1
-48
-40
-5
MW-1056 7/93
TCE 0.7
C12DCE ND
PCE ND
12DCA ND
RISK 4.7E-7
CW-132
MW-152 7/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-183 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-177 1/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 2.2E-6

11

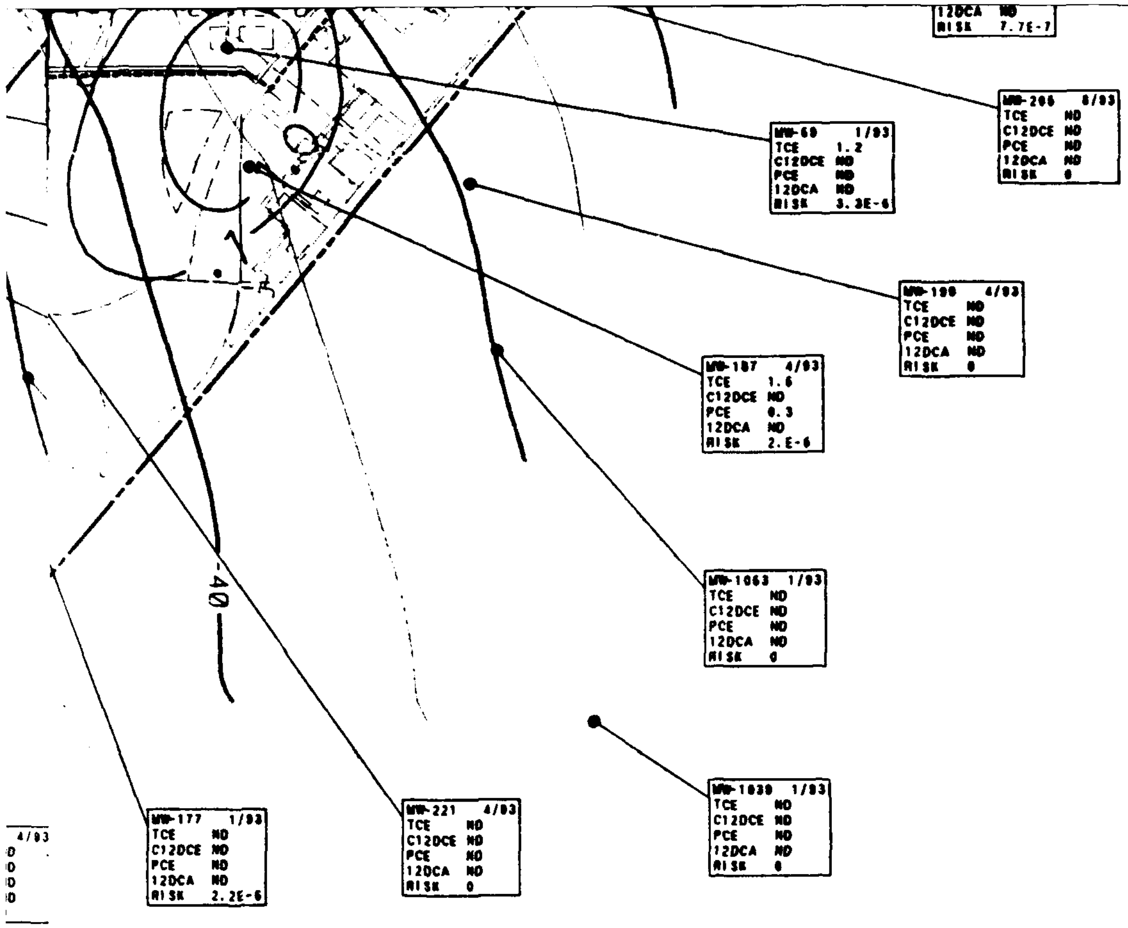
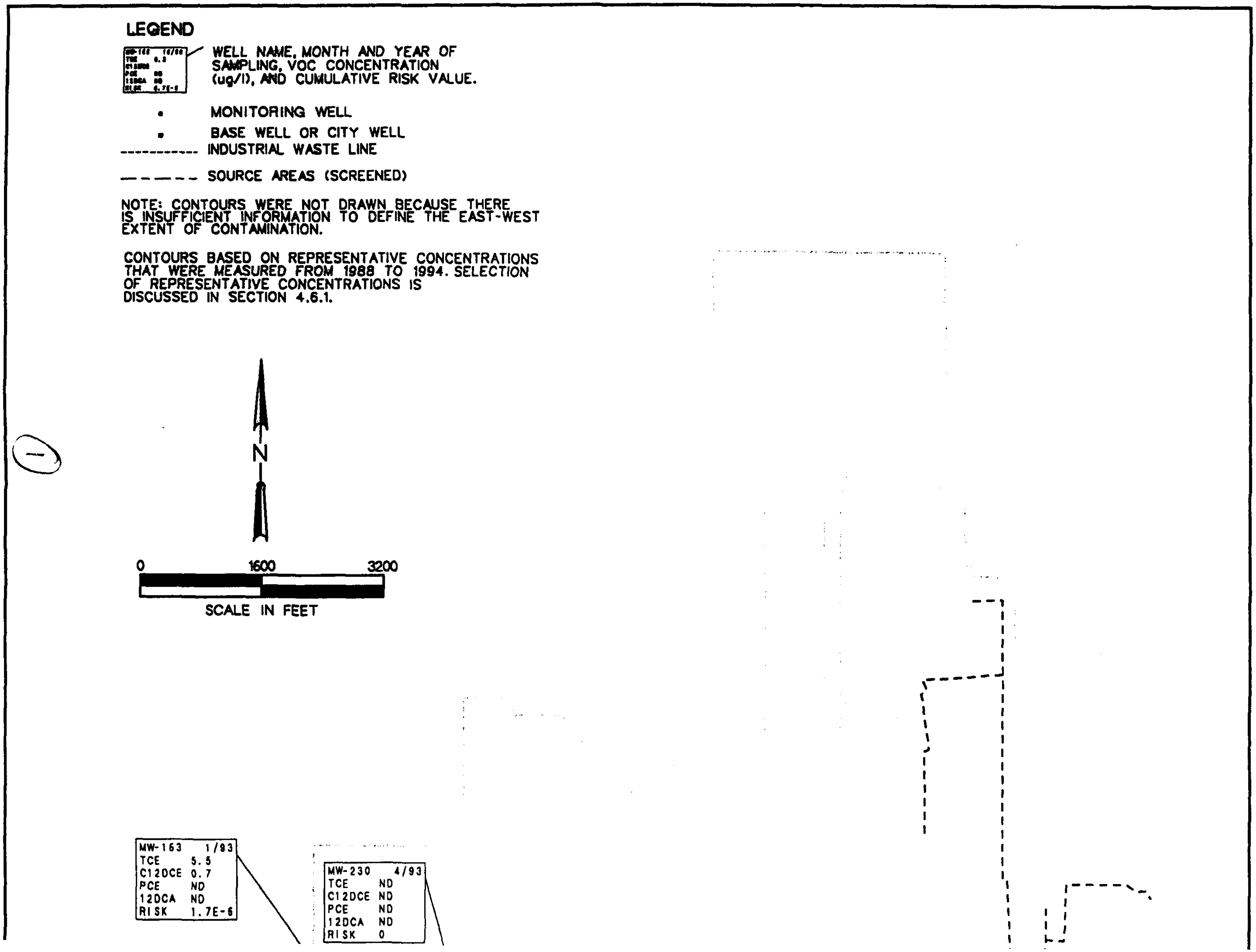


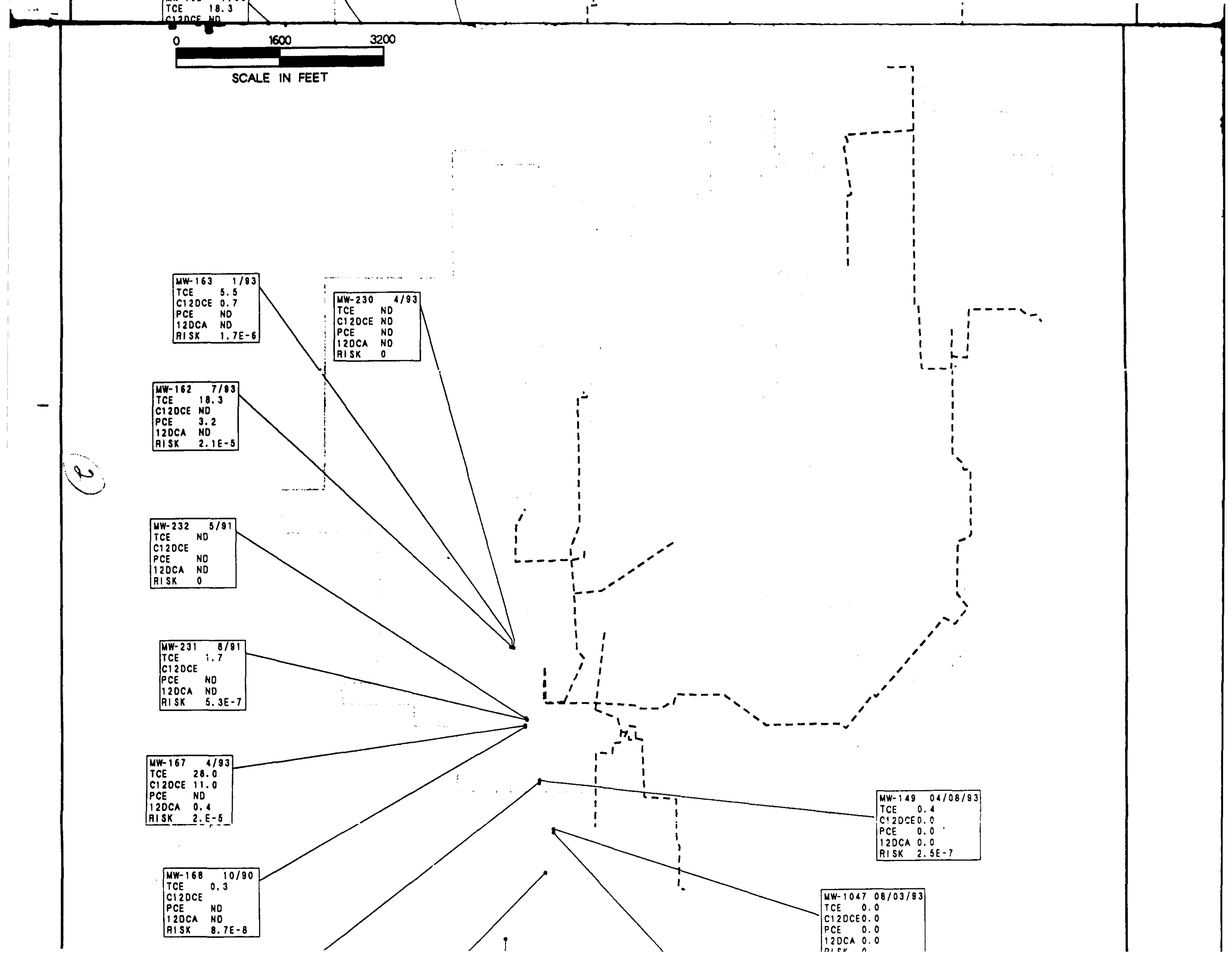
FIGURE 4-55
EXTENT OF VOC CONTAMINATION IN MONITORING ZONE C

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

12

CH2M HILL


LEGEND
WELL NAME, MONTH AND YEAR OF SAMPLING, VOC CONCENTRATION (ug/l), AND CUMULATIVE RISK VALUE.
MONITORING WELL
BASE WELL OR CITY WELL
INDUSTRIAL WASTE LINE
SOURCE AREAS (SCREENED)
NOTE: CONTOURS WERE NOT DRAWN BECAUSE THERE IS INSUFFICIENT INFORMATION TO DEFINE THE EAST-WEST EXTENT OF CONTAMINATION.
CONTOURS BASED ON REPRESENTATIVE CONCENTRATIONS THAT WERE MEASURED FROM 1988 TO 1994. SELECTION OF REPRESENTATIVE CONCENTRATIONS IS DISCUSSED IN SECTION 4.6.1.
N
0
1600
3200
SCALE IN FEET
MW-163 1/93
TCE 5.5
C12DCE 0.7
PCE ND
12DCA ND
RISK 1.7E-6
MW-230 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0



0 1600 3200
SCALE IN FEET
MW-163 1/93
TCE 5.5
C12DCE 0.7
PCE ND
12DCA ND
RISK 1.7E-6
MW-230 4/93
TCE ND
C12DCE ND
PCE ND
12DCA ND
RISK 0
MW-162 7/93
TCE 18.3
C12DCE ND
PCE 3.2
12DCA ND
RISK 2.1E-5
MW-232 5/91
TCE ND
C12DCE
PCE ND
12DCA ND
RISK 0
MW-231 8/91
TCE 1.7
C12DCE
PCE ND
12DCA ND
RISK 5.3E-7
MW-167 4/93
TCE 28.0
C12DCE 11.0
PCE ND
12DCA 0.4
RISK 2.E-5
MW-168 10/90
TCE 0.3
C12DCE
PCE ND
12DCA ND
RISK 8.7E-8
MW-149 04/08/93
TCE 0.4
C12DCE 0.0
PCE 0.0
12DCA 0.0
RISK 2.5E-7
MW-1047 08/03/93
TCE 0.0
C12DCE 0.0
PCE 0.0
12DCA 0.0
TCE 18.3
C12DCE ND

2

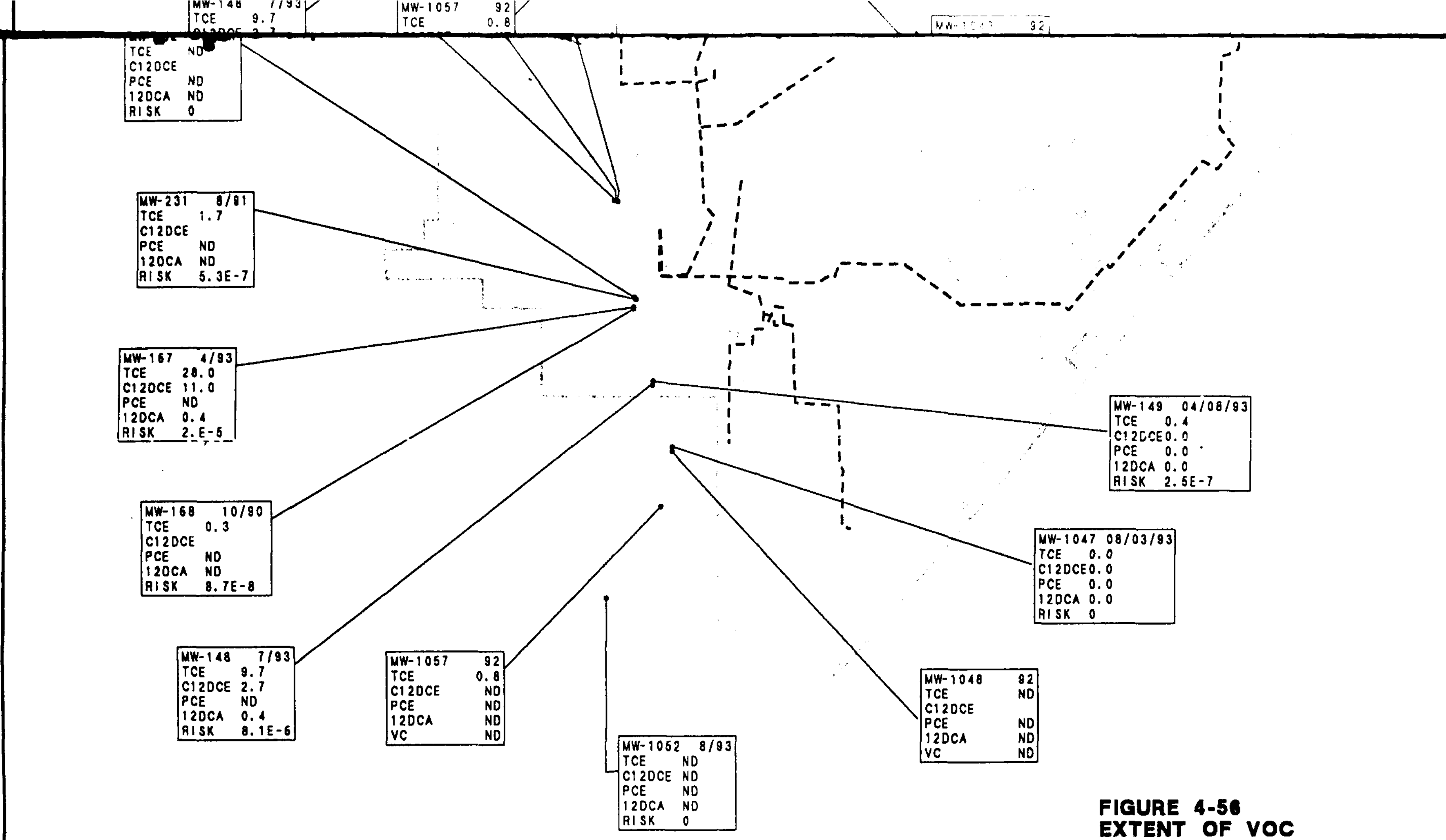
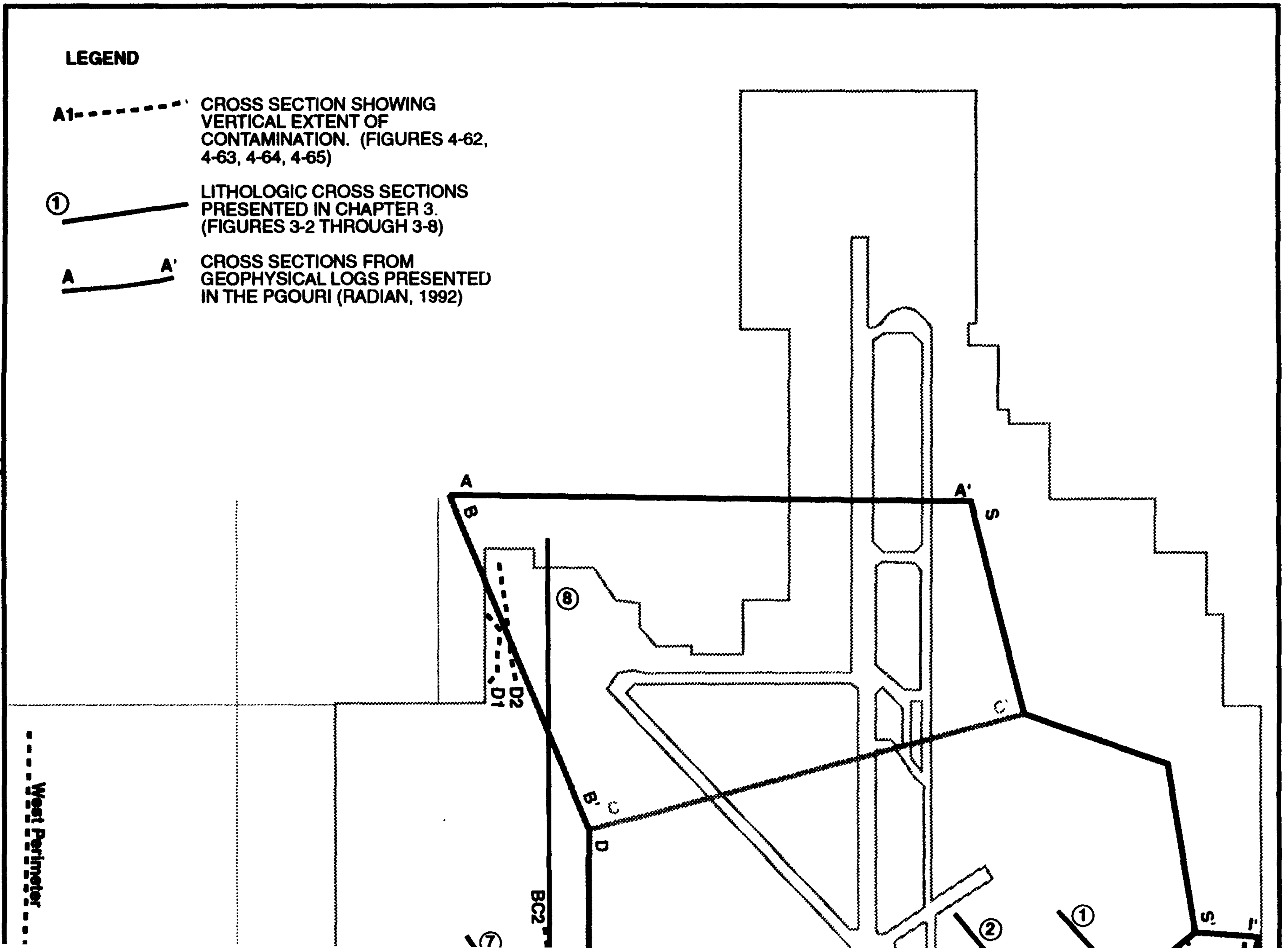
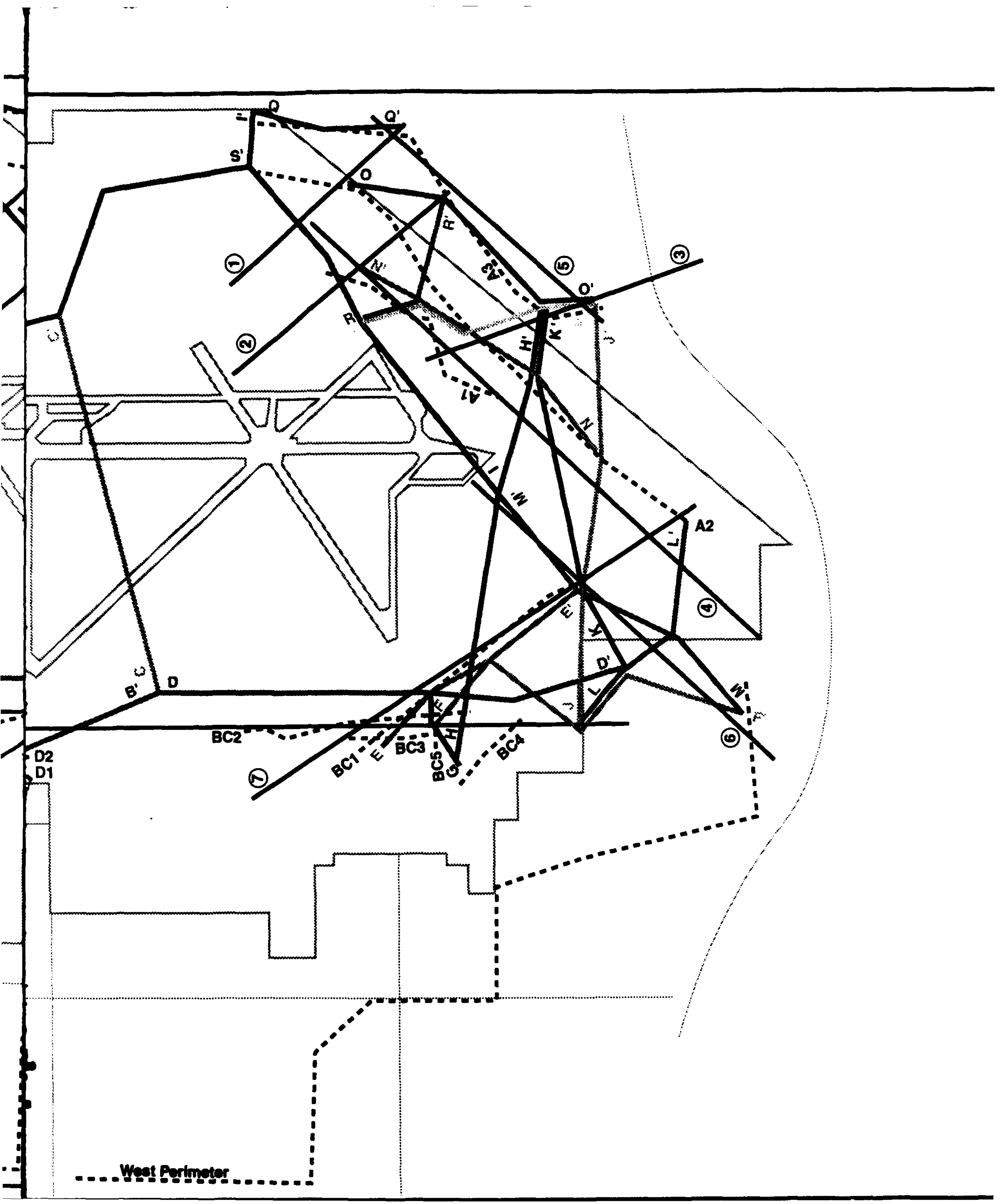


FIGURE 4-56
EXTENT OF VOC CONTAMINATION IN MONITORING ZONE D AND E
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454
MEY94/4-56.DGN


LEGEND
A1 CROSS SECTION SHOWING VERTICAL EXTENT OF CONTAMINATION. (FIGURES 4-62, 4-63, 4-64, 4-65)
① LITHOLOGIC CROSS SECTIONS PRESENTED IN CHAPTER 3. (FIGURES 3-2 THROUGH 3-8)
A A' CROSS SECTIONS FROM GEOPHYSICAL LOGS PRESENTED IN THE PGOURI (RADIAN, 1992)
A
A'
B
B'
C
C'
D
D1
D2
S
S'
BC2
①
②
⑦
⑧
West Perimeter



Q
Q'
S'
O
R'
N'
R
O'
K'
H'
J'
A1
A2
A3
L'
N
M'
E'
K
D'
C'
B'
D
F
H
BC2
BC1
E
BC3
BC5
G
BC4
J
L
M
D2
D1
1
2
3
4
5
6
7
West Perimeter

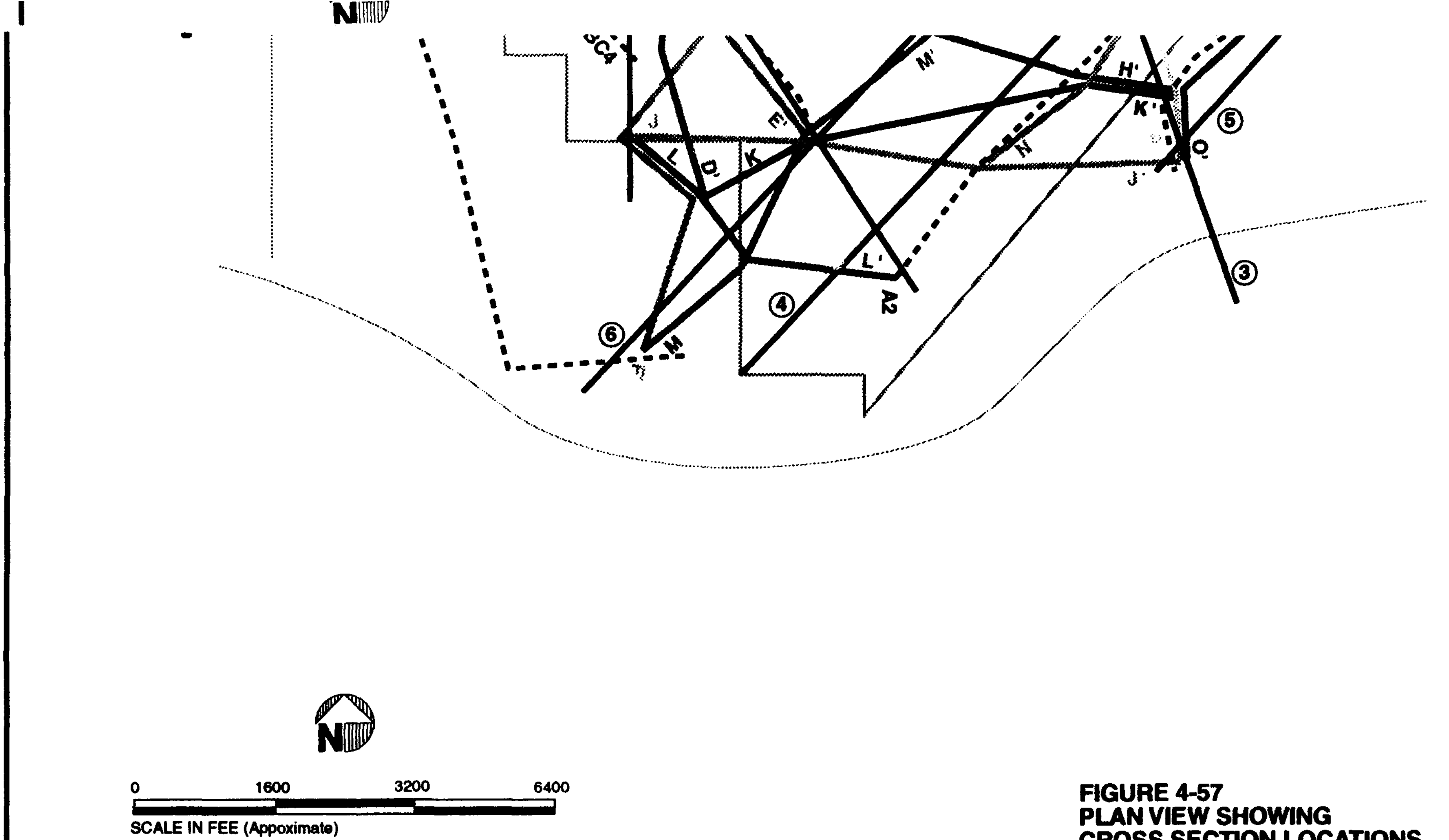
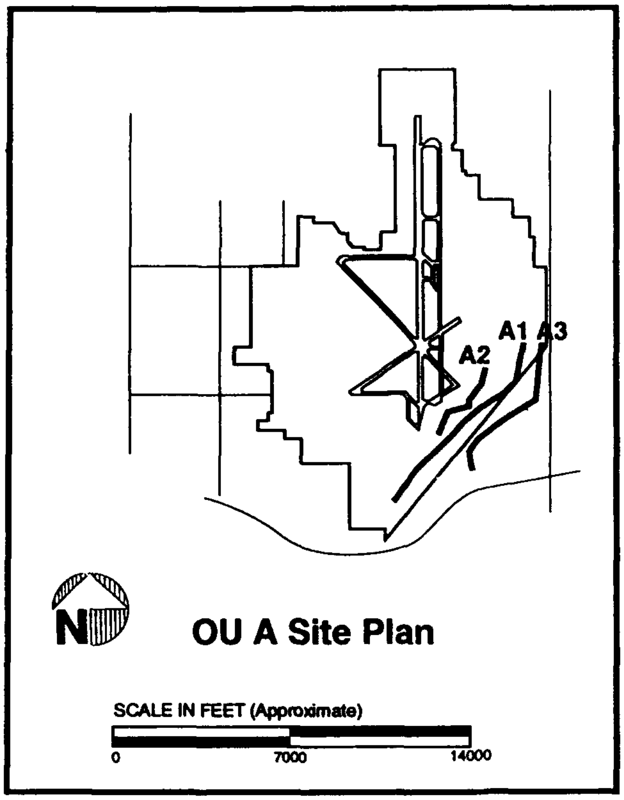
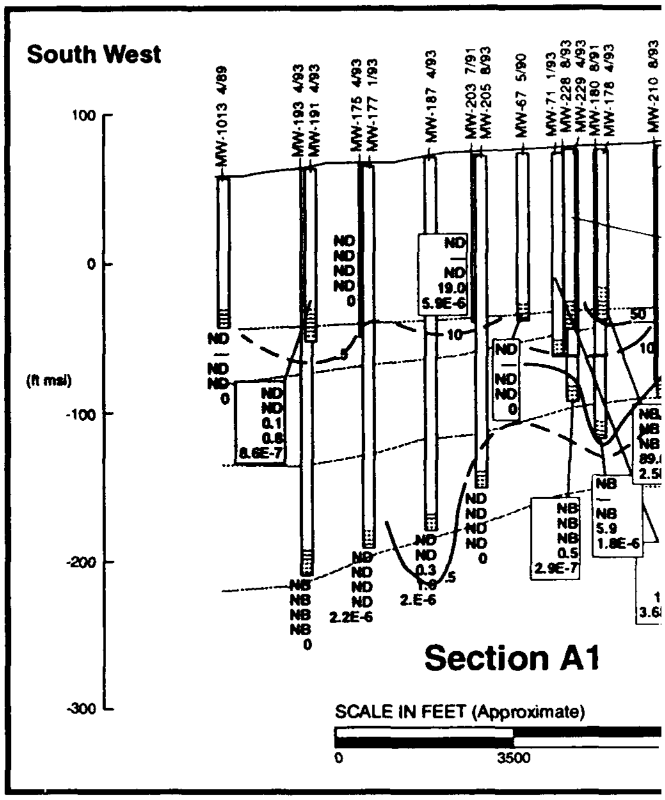


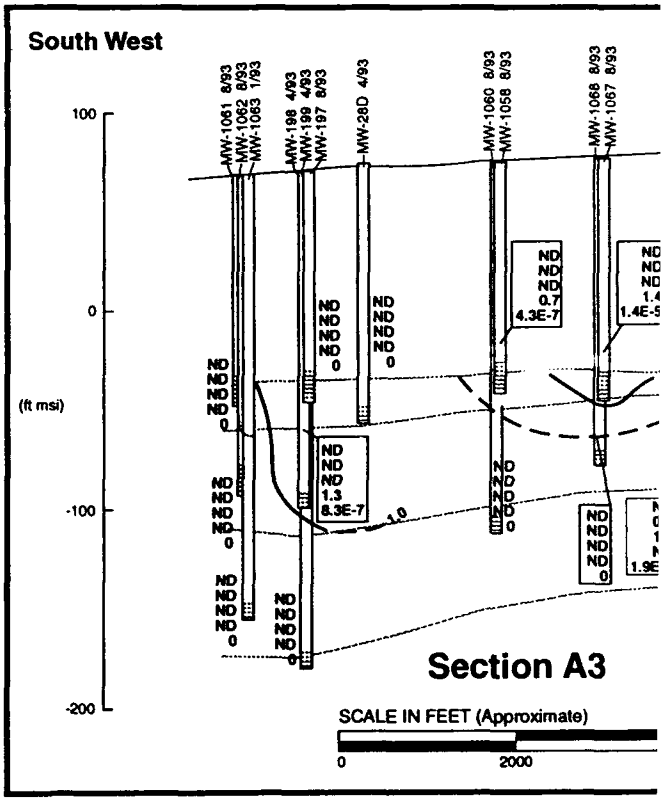
FIGURE 4-57
PLAN VIEW SHOWING CROSS SECTION LOCATIONS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454_184







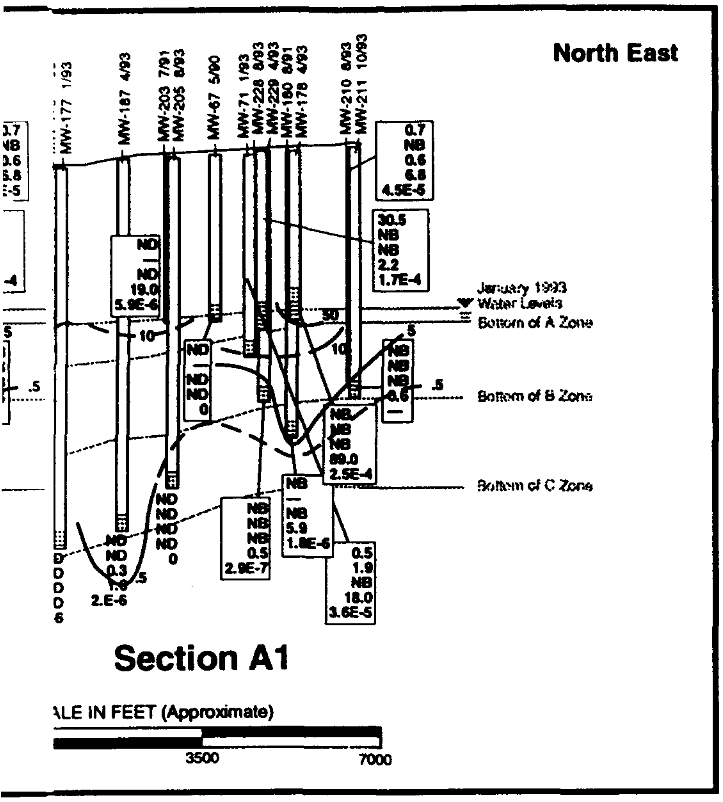
LEGEND

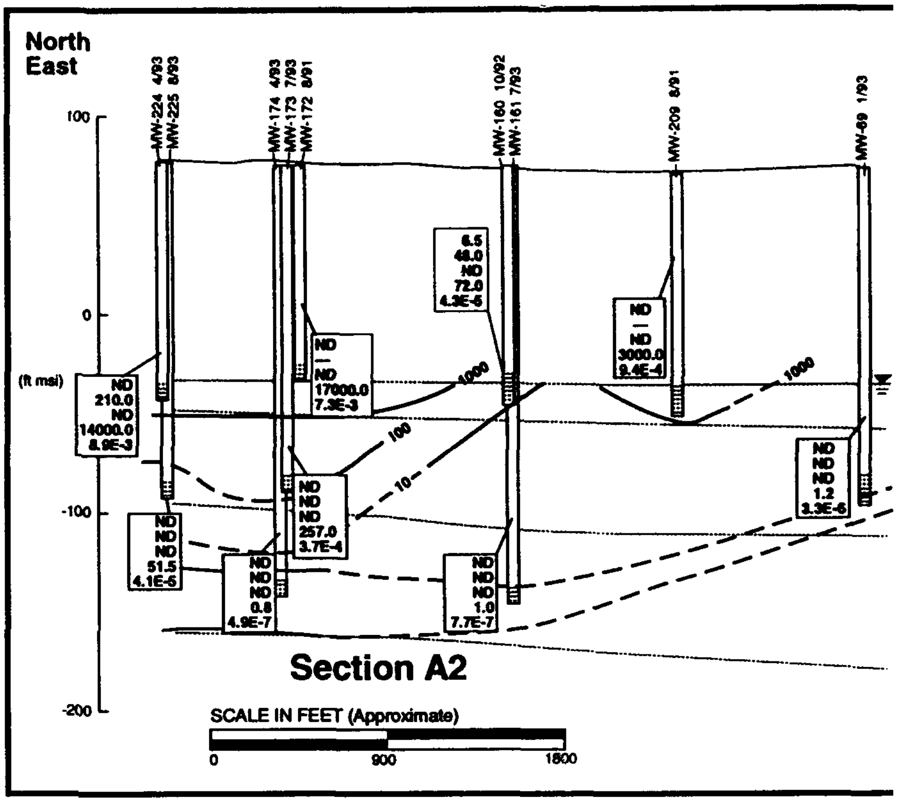
Contaminant	Contamination µg/l
1,2-DCA	2400
cis-1,2-DCE	2
PCE	3
TCE	5
Risk	6.4 E-6

– Contaminant not analyzed on this date.
Dashed lines represent unbound condition
Solid lines represent bound conditions
— TCE Contours
ND: Non Detect

RDD1454_162

1





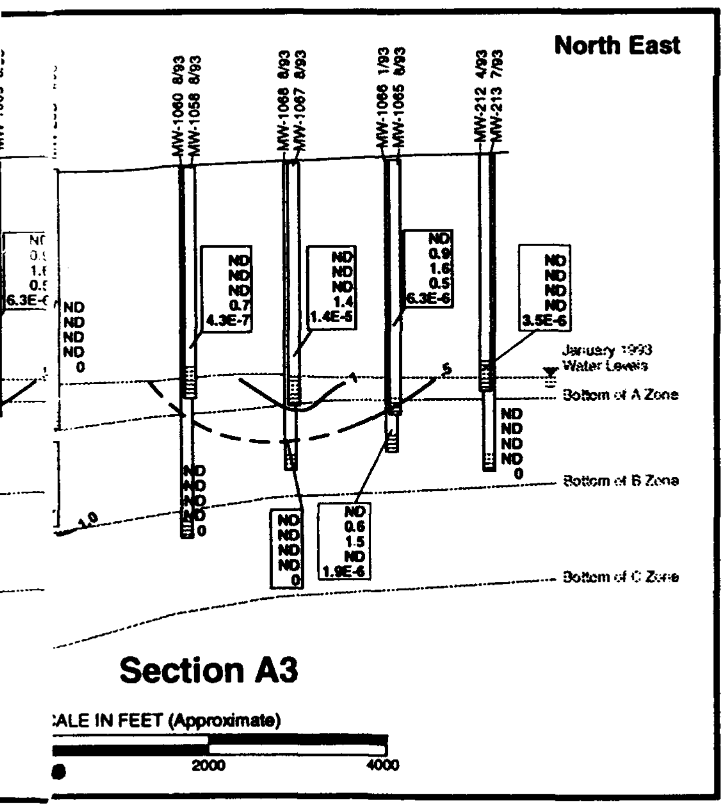


FIGURE 4-58
VERTICAL EXTE
CONTAMINATION
GROUNDWATER OPERAB
McCLELLAN AIR FORCE B
SACRAMENTO, CALIFOR

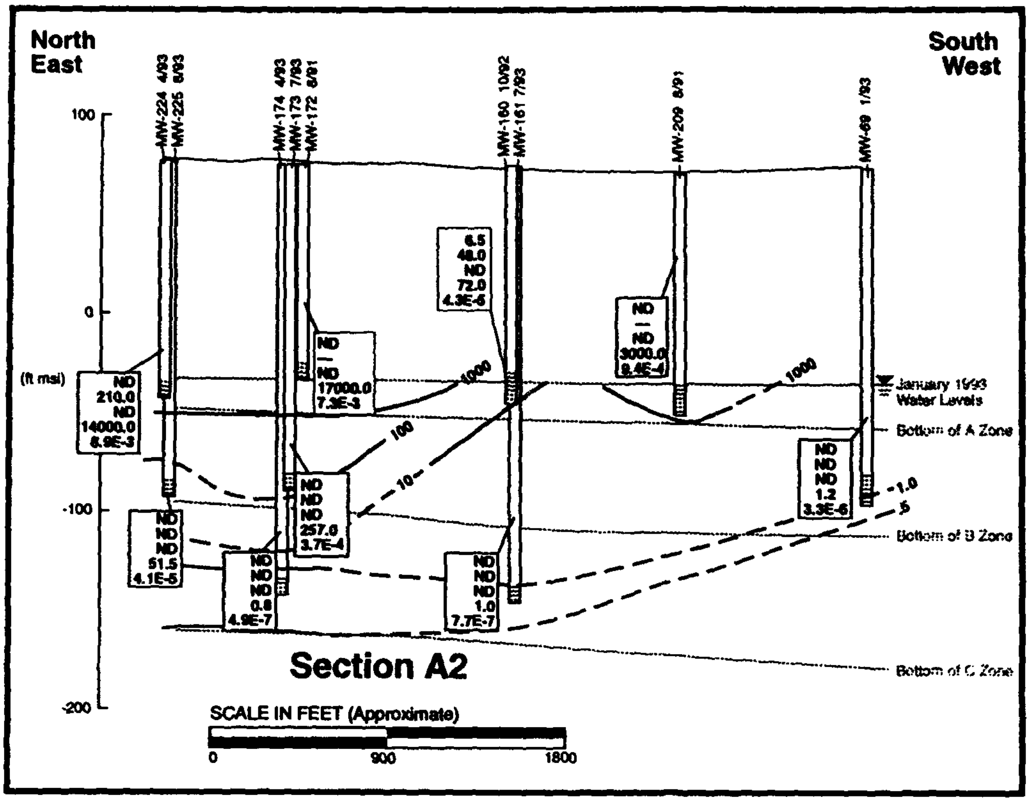
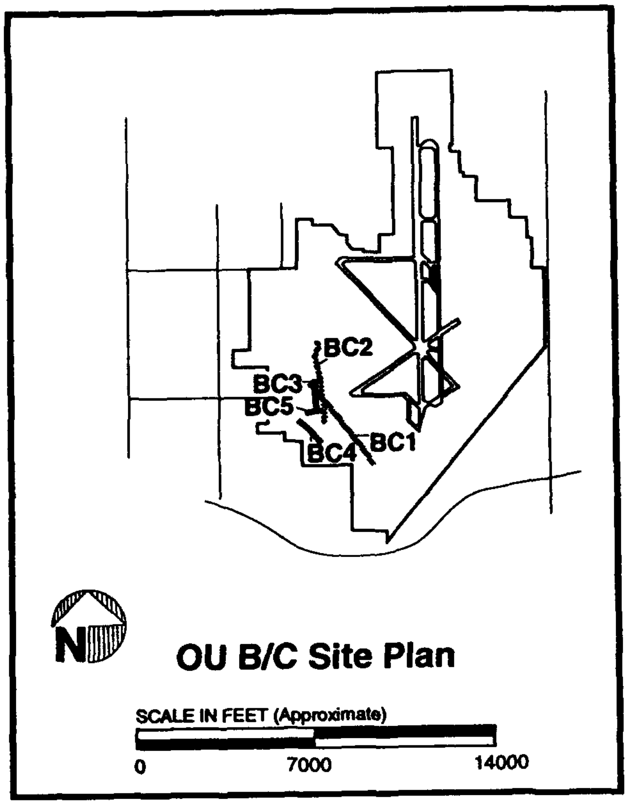
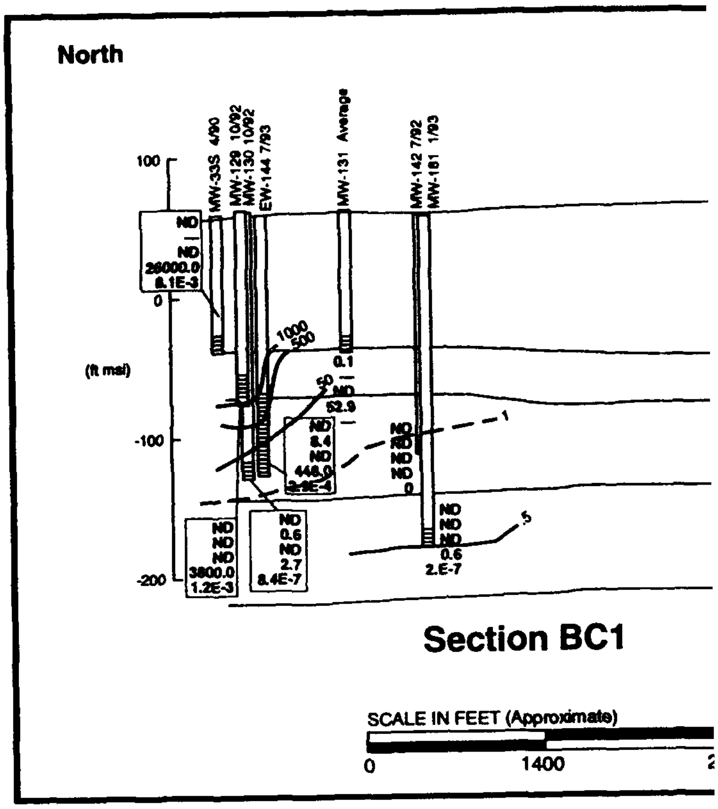
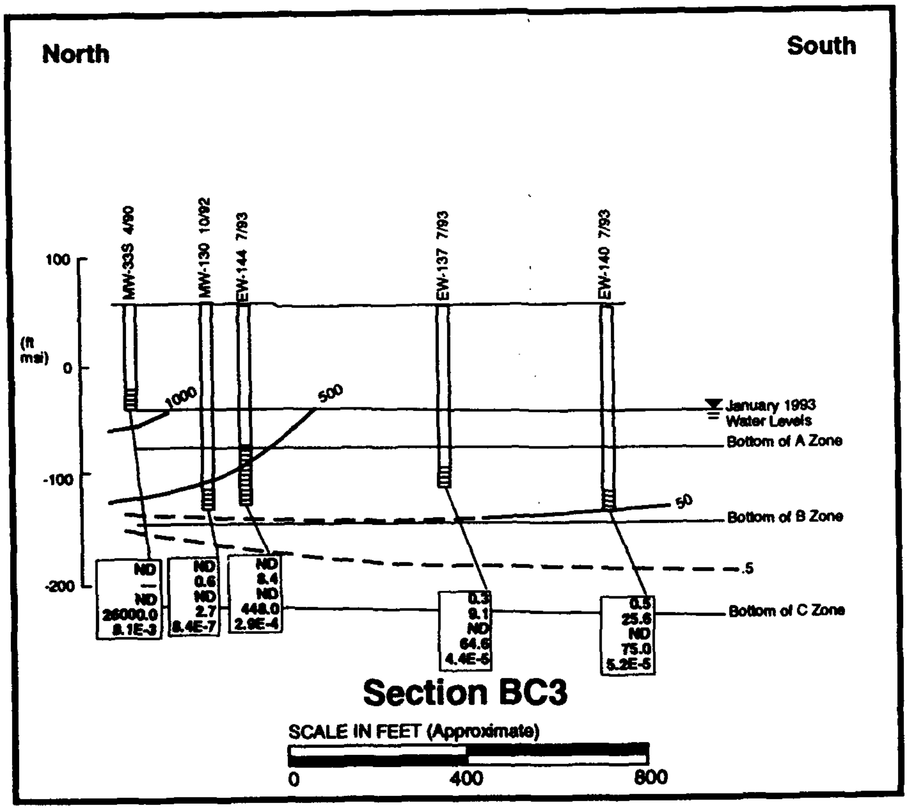


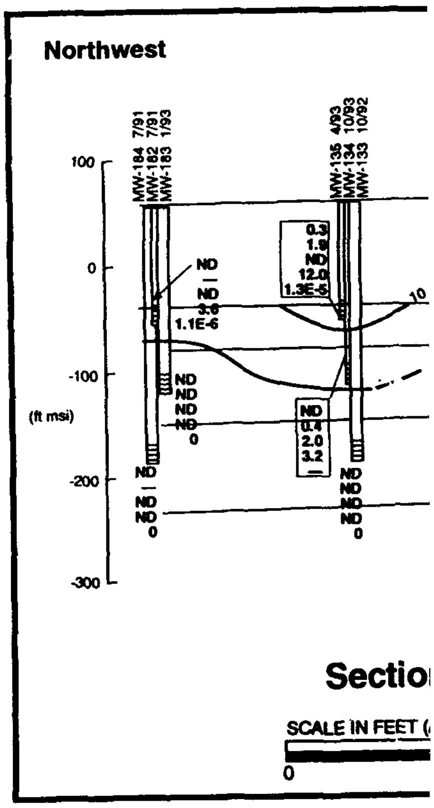
FIGURE 4-58
VERTICAL EXTENT OF CONTAMINATION IN OU A
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL









LEGEND

Contaminant	Contamination µg/l
1,2-DCA	2400
cis-1,2-DCE	2
PCE	3
TCE	5
Risk	6.4 E-6

Average: concentrations had fluctuated; average was calculated and used in the data set.
– Contaminant not analyzed on this date.
Dashed lines represent unbound condition
Solid lines represent bound conditions
— TCE Contours
ND Non Detect

RDD1454_163

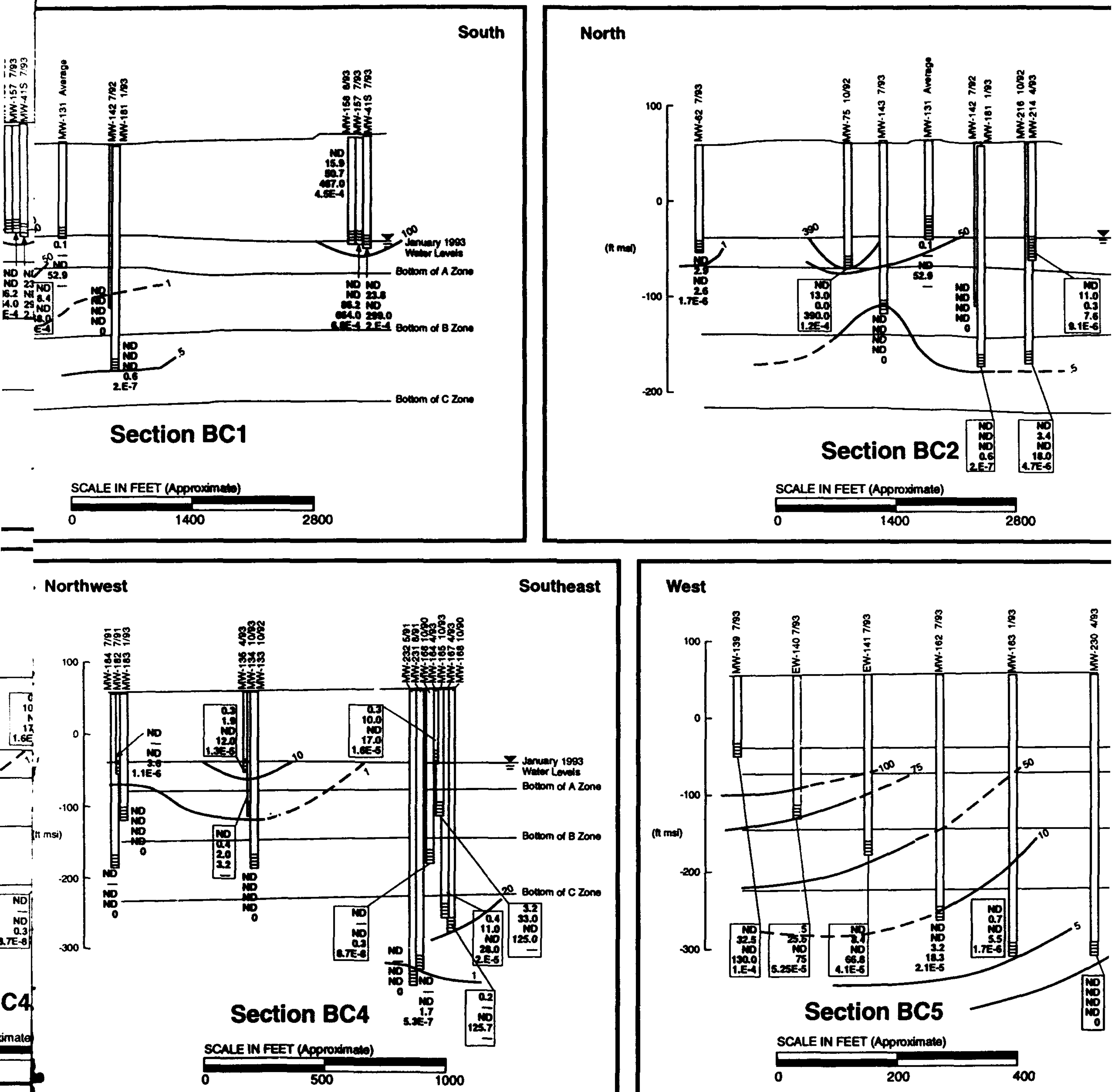


FIGURE 4-59
VERTICAL EXTENT C
CONTAMINATION IN
GROUNDWATER OPERABLE UN
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

2

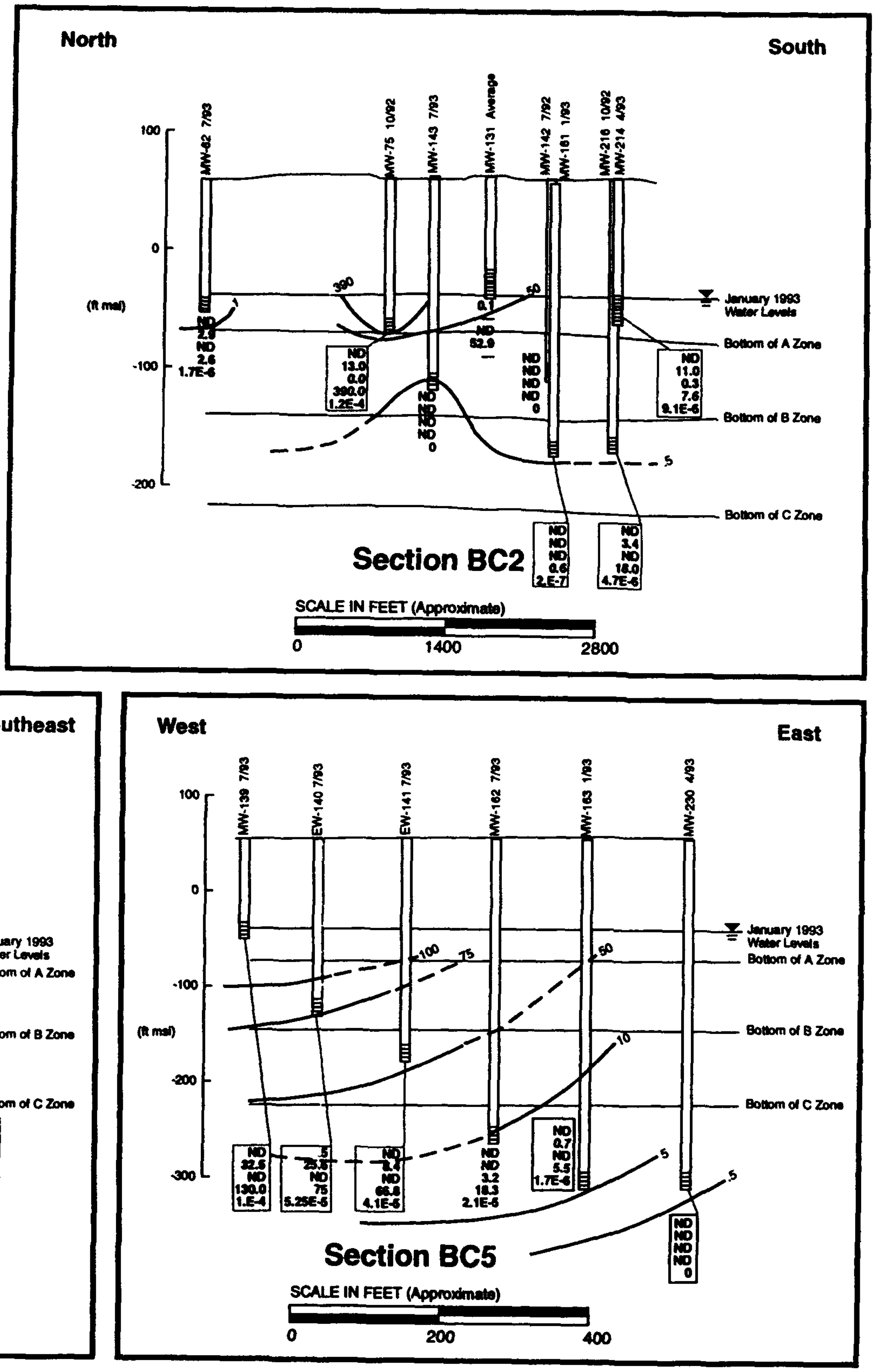
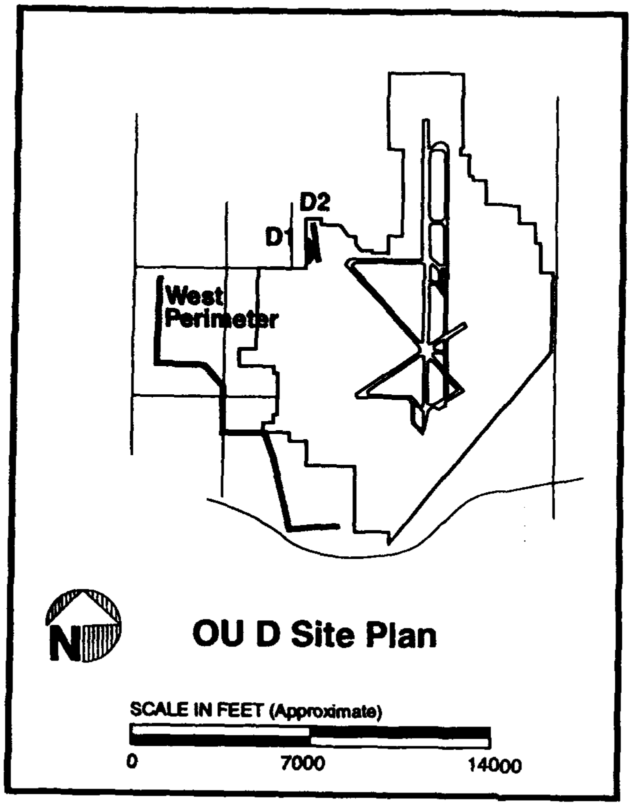
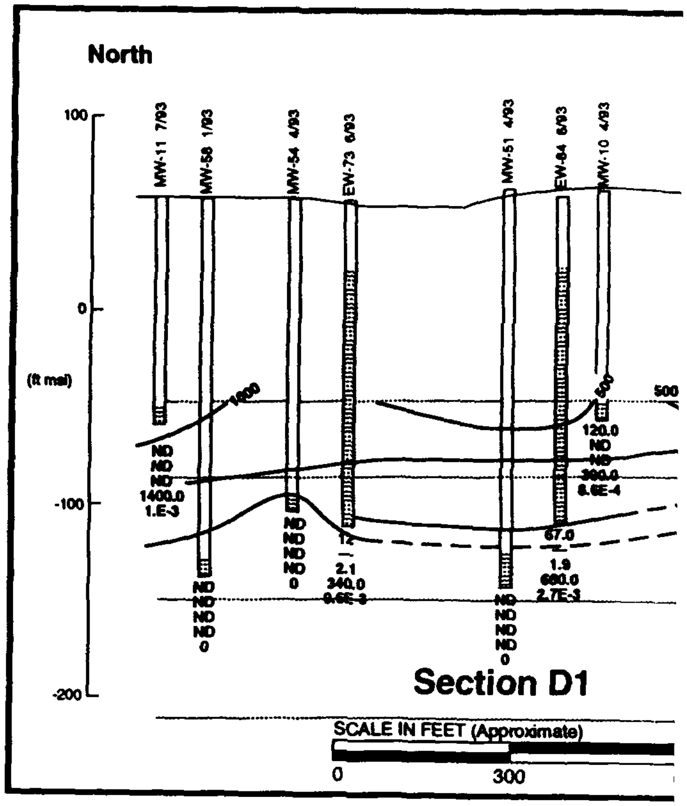
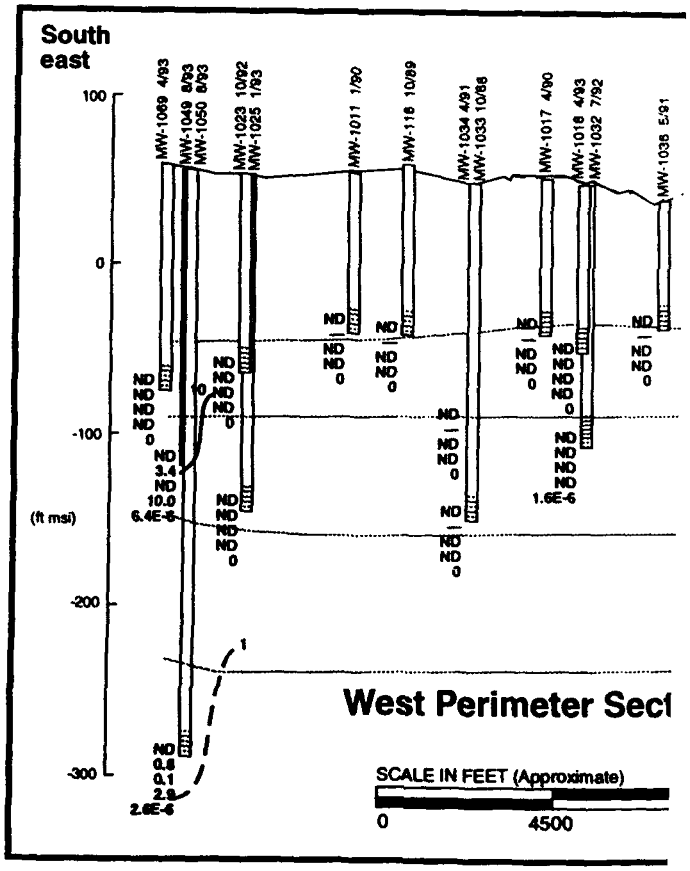


FIGURE 4-59
VERTICAL EXTENT OF CONTAMINATION IN OU B/C
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2MHILL





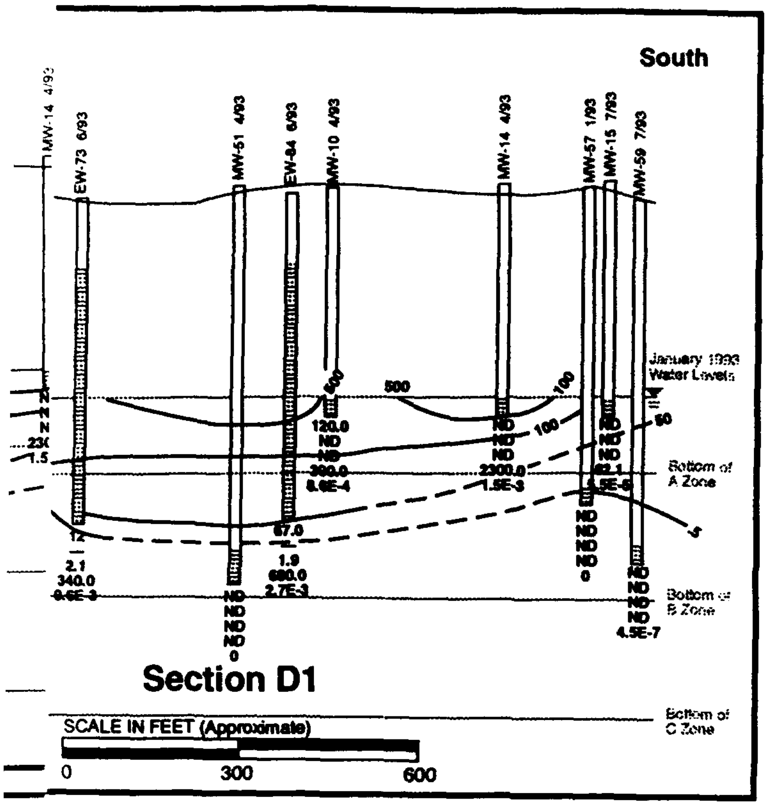


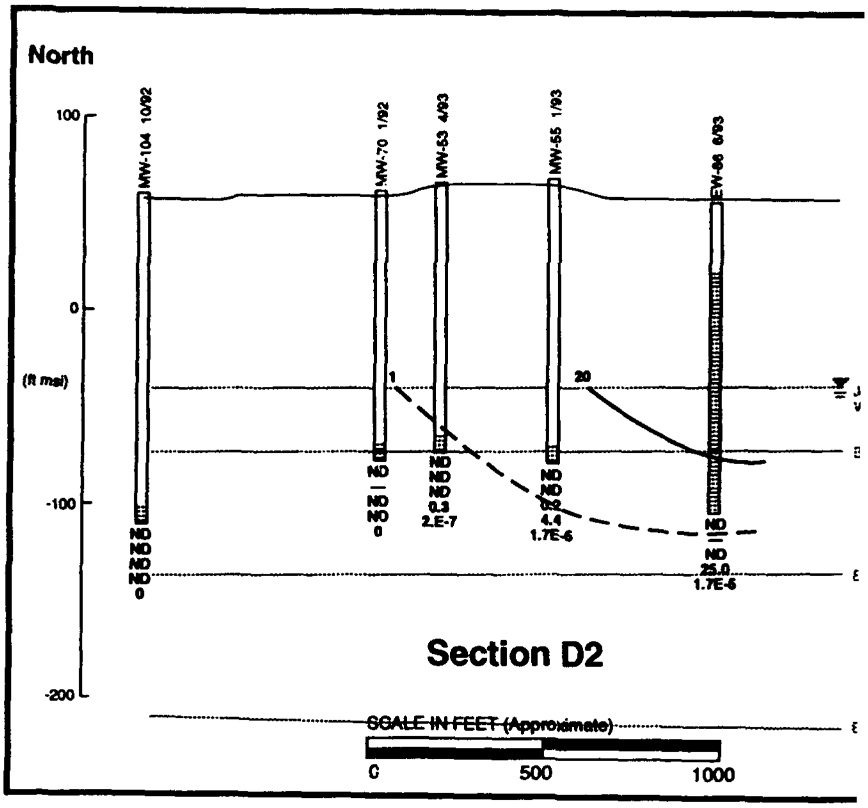
LEGEND

Contaminant	Contamination µg/l
1,2-DCA	2400
cis-1,2-DCE	2
PCE	3
TCE	5
Risk	6.4 E-6

– Contaminant not analyzed on this date.
Dashed lines represent unbound condition
Solid lines represent bound conditions
— TCE Contours
ND: Non Detect

RDD1454_164





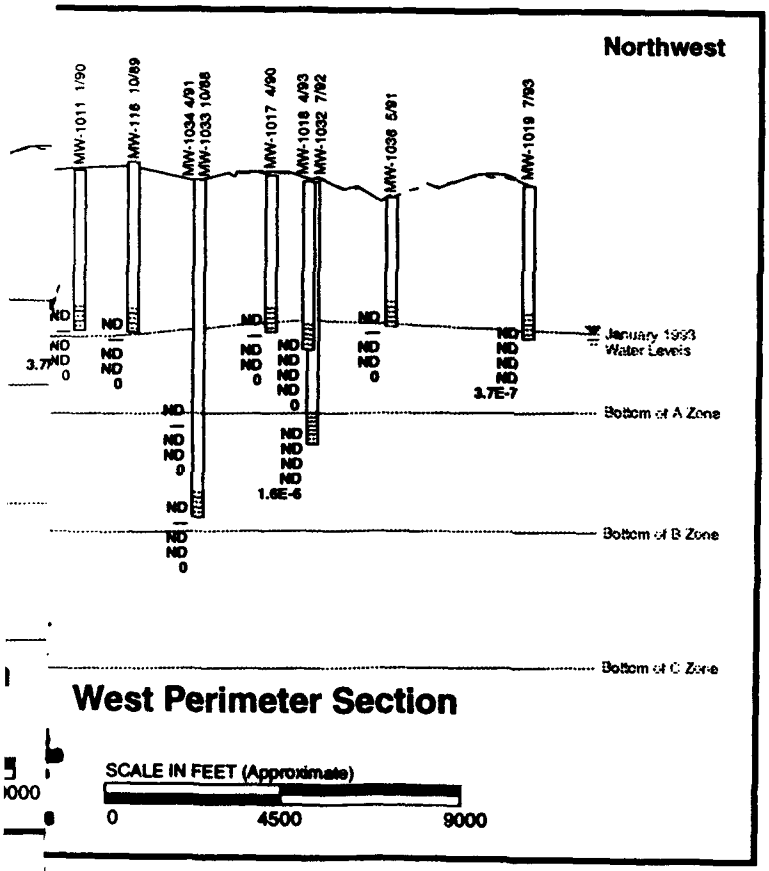


FIGURE 4-60
VERTICAL EXTENT OF
CONTAMINATION IN O
AND WEST PERIMETE
GROUNDWATER OPERABLE UNIT
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

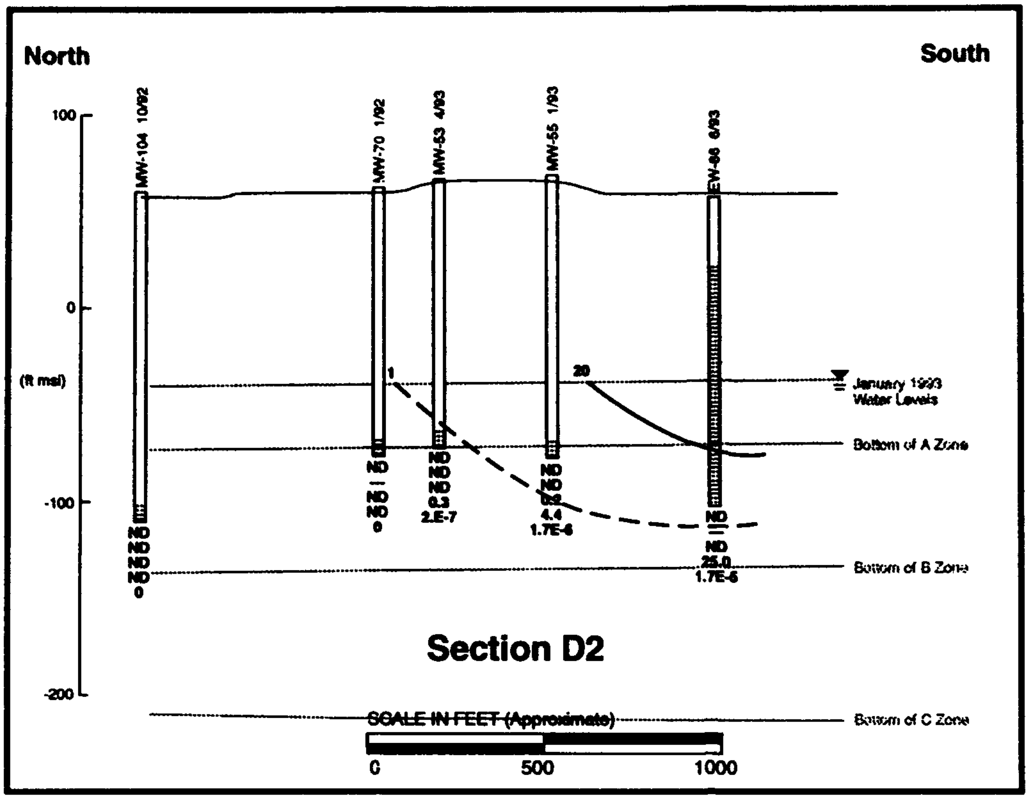
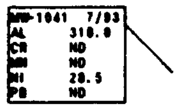


FIGURE 4-60
VERTICAL EXTENT OF CONTAMINATION IN OU D AND WEST PERIMETER
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

LEGEND



WELL NAME, MONTH AND YEAR OF SAM
AND METALS CONCENTRATIONS (ug/l)

WATER LEVEL CONTOURS (ft msl) JANUARY 1993

MONITORING WELL

BASE WELL OR CITY WELL

EXTRACTION WELL

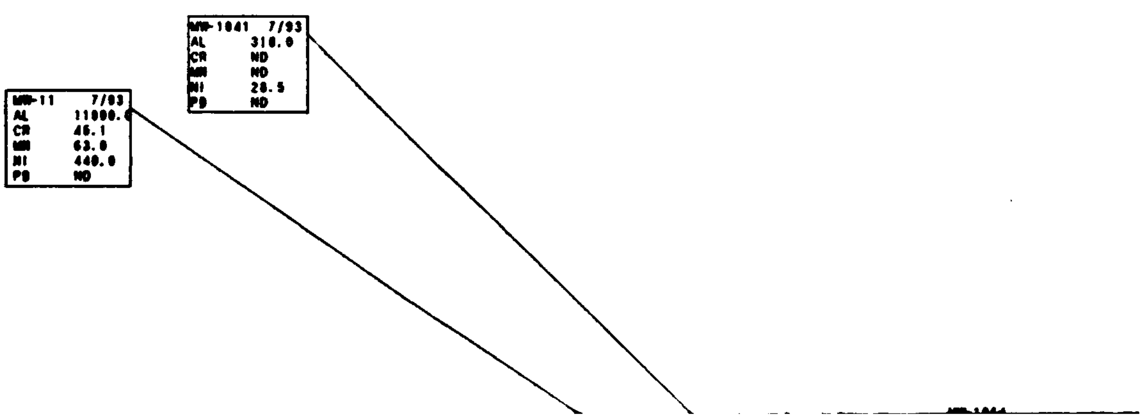
INDUSTRIAL WASTE LINE

SOURCE AREAS (SCREENED)

0

NOTES: 1. MOST RECENT SECOND AND THIRD QUARTER 1993
IS PRESENTED.

2. WELLS WITHOUT LABELS WERE NOT SAMPLED DURING SECOND AND THIRD QUARTER 1993.



YEAR OF SAMPLING,
IONS (ug/l)

S

N

L

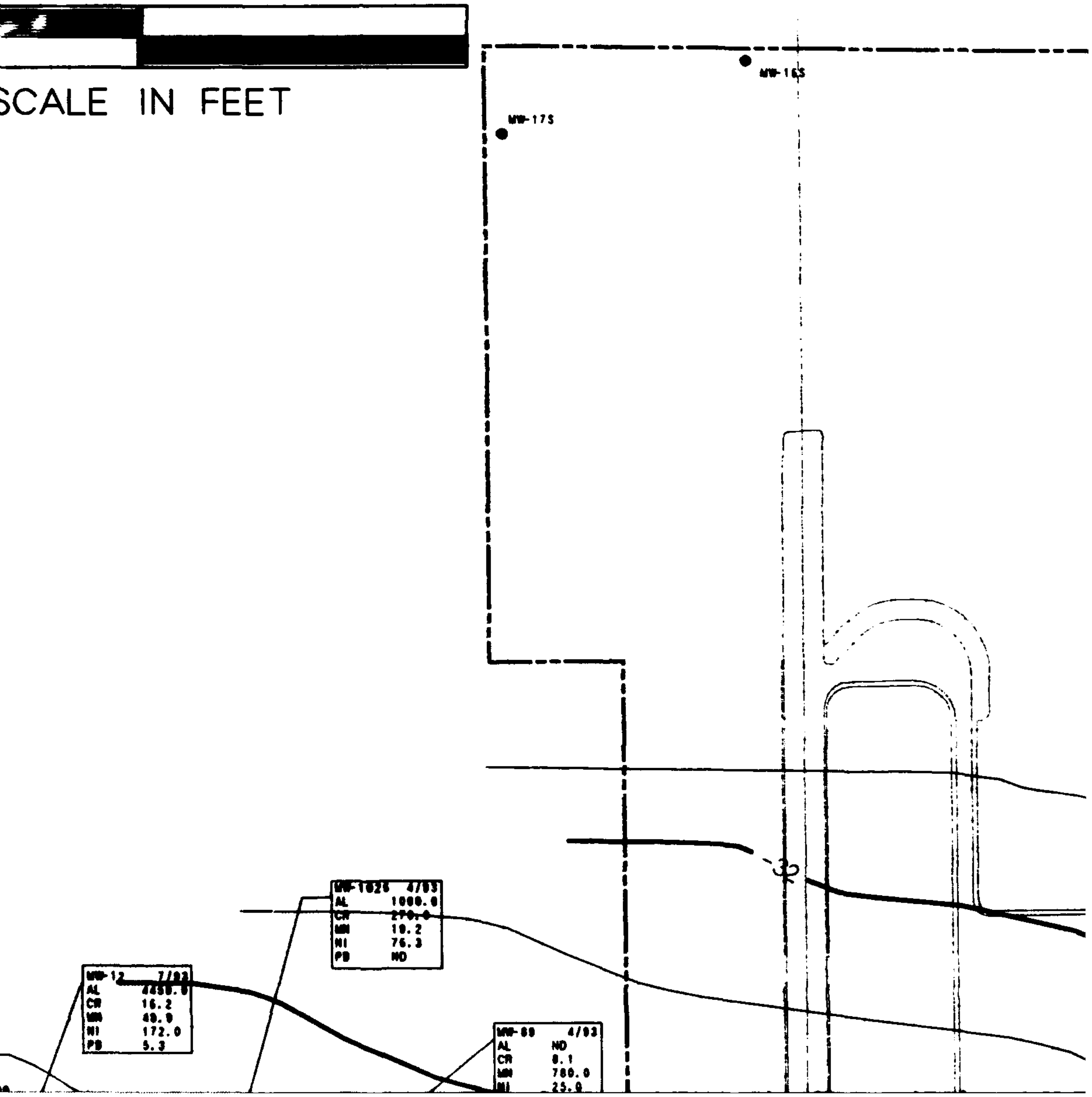
D)

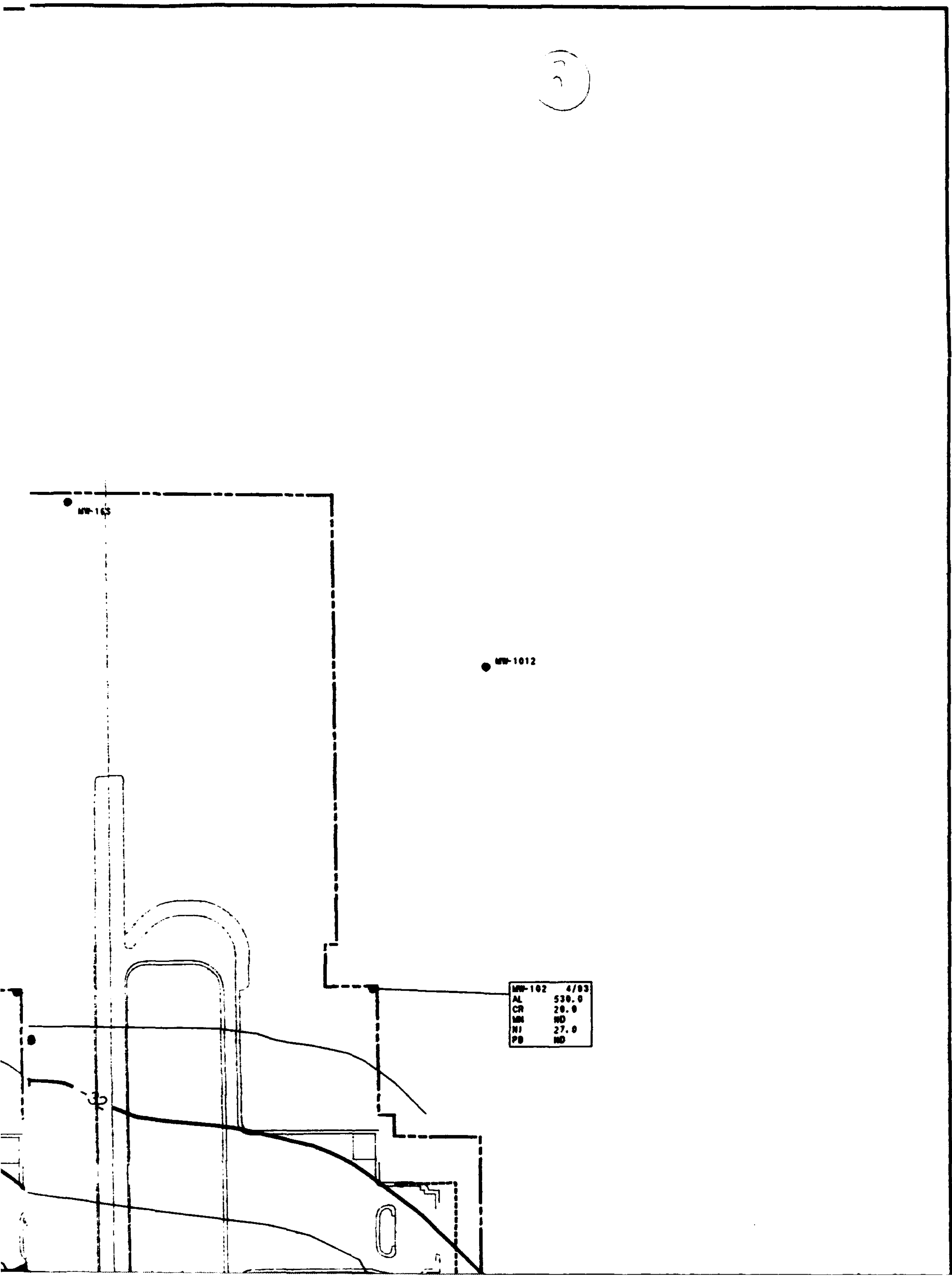
0 1600 3200

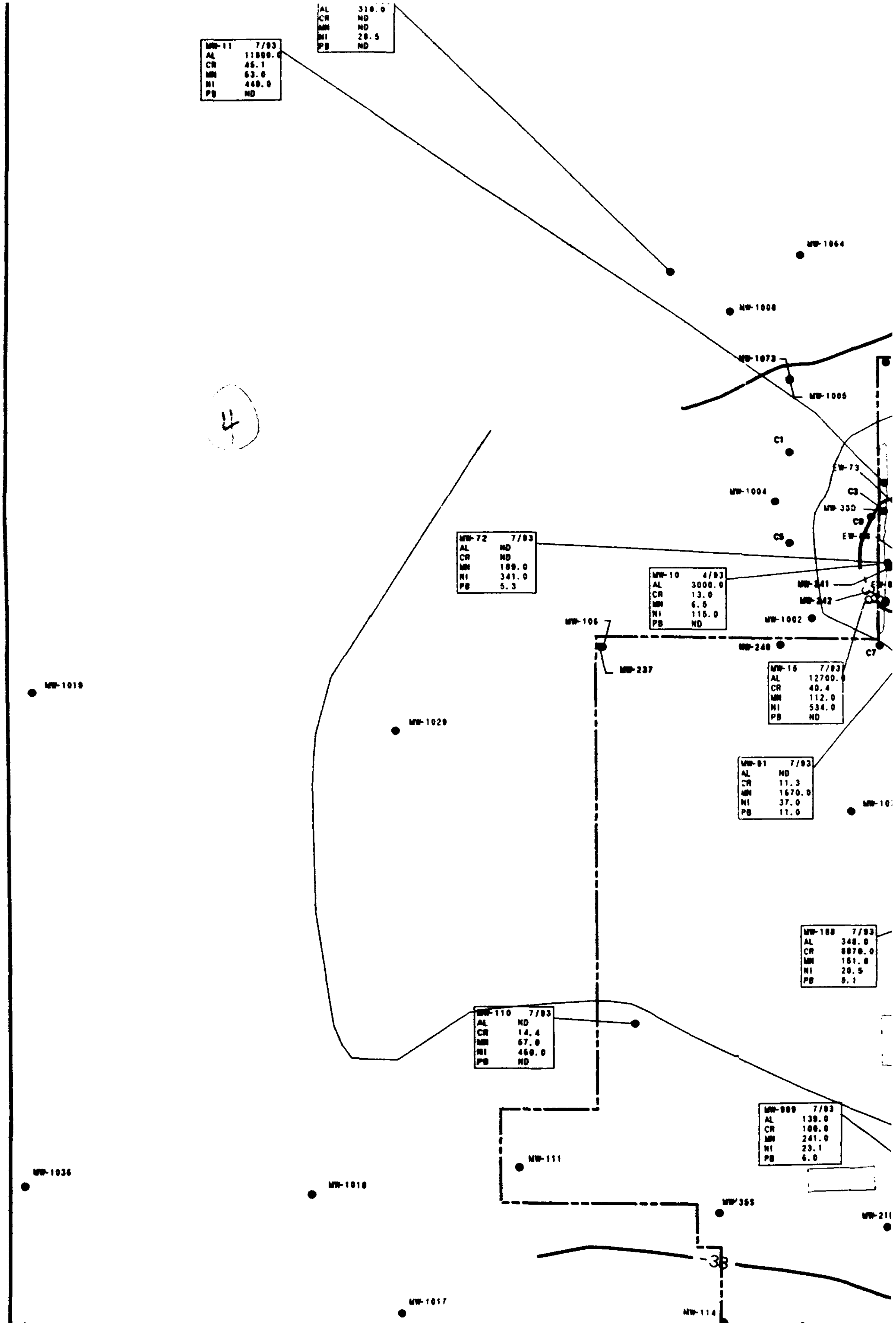
SCALE IN FEET

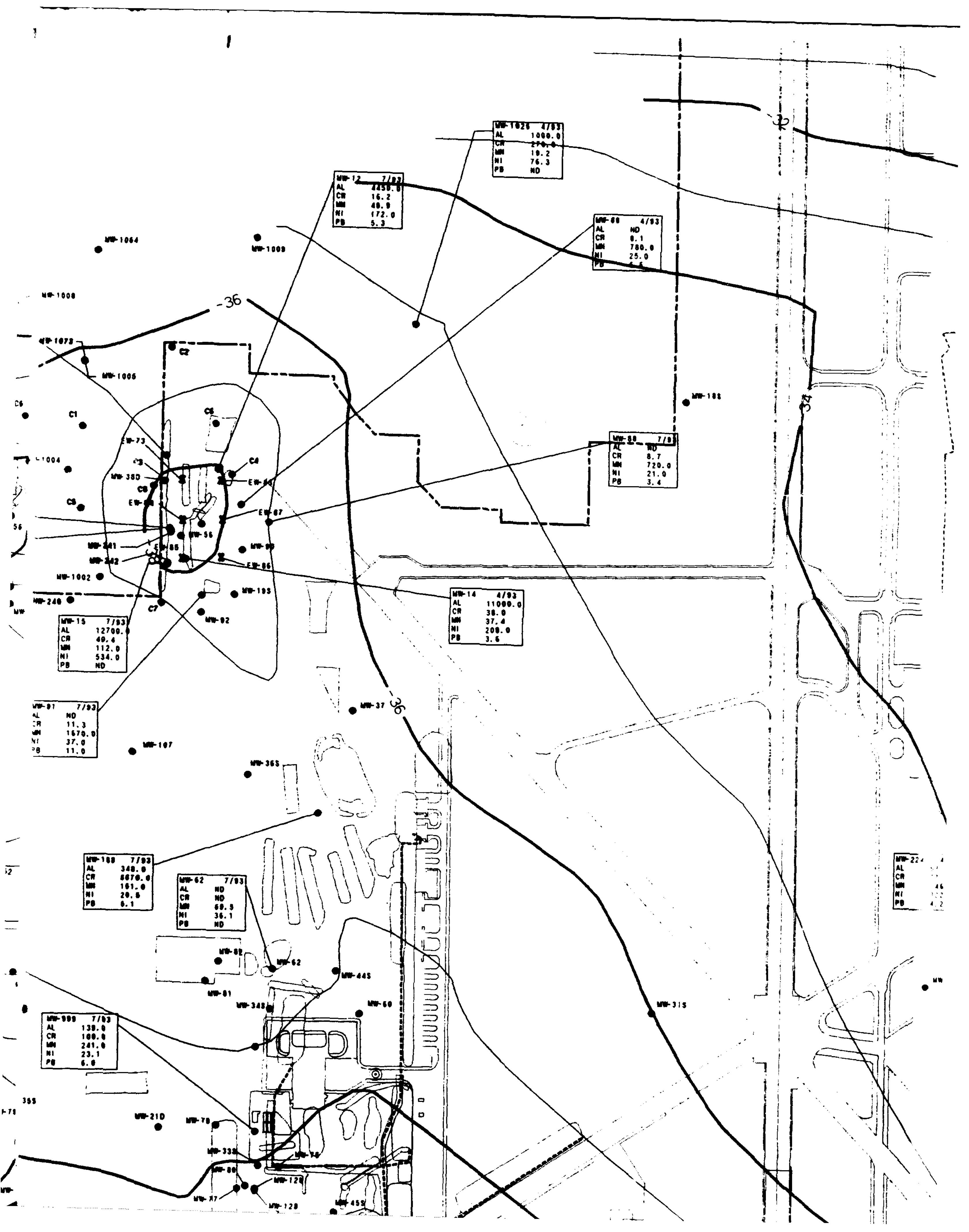
JARTER 1993 DATA

SAMPLED
1993.

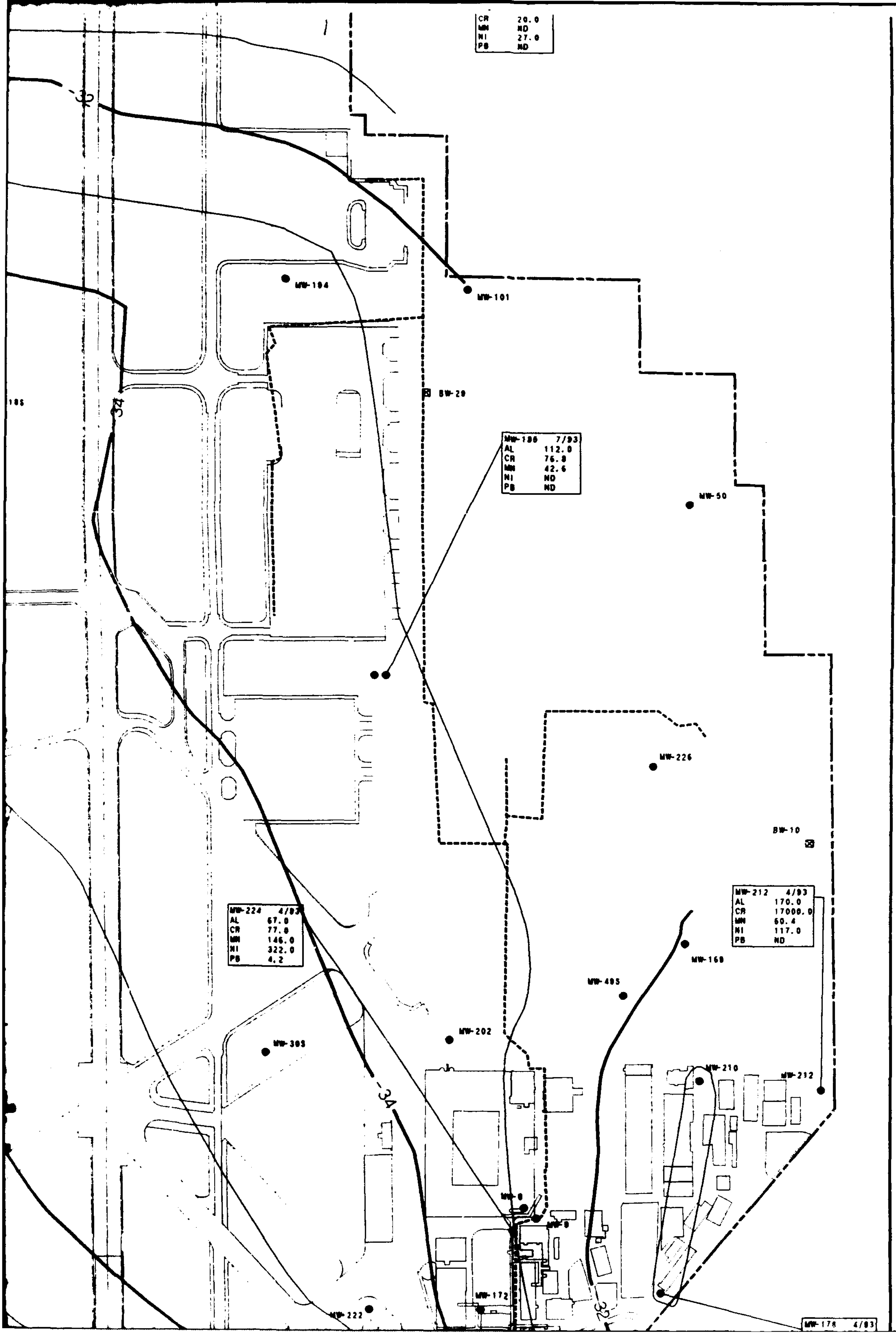


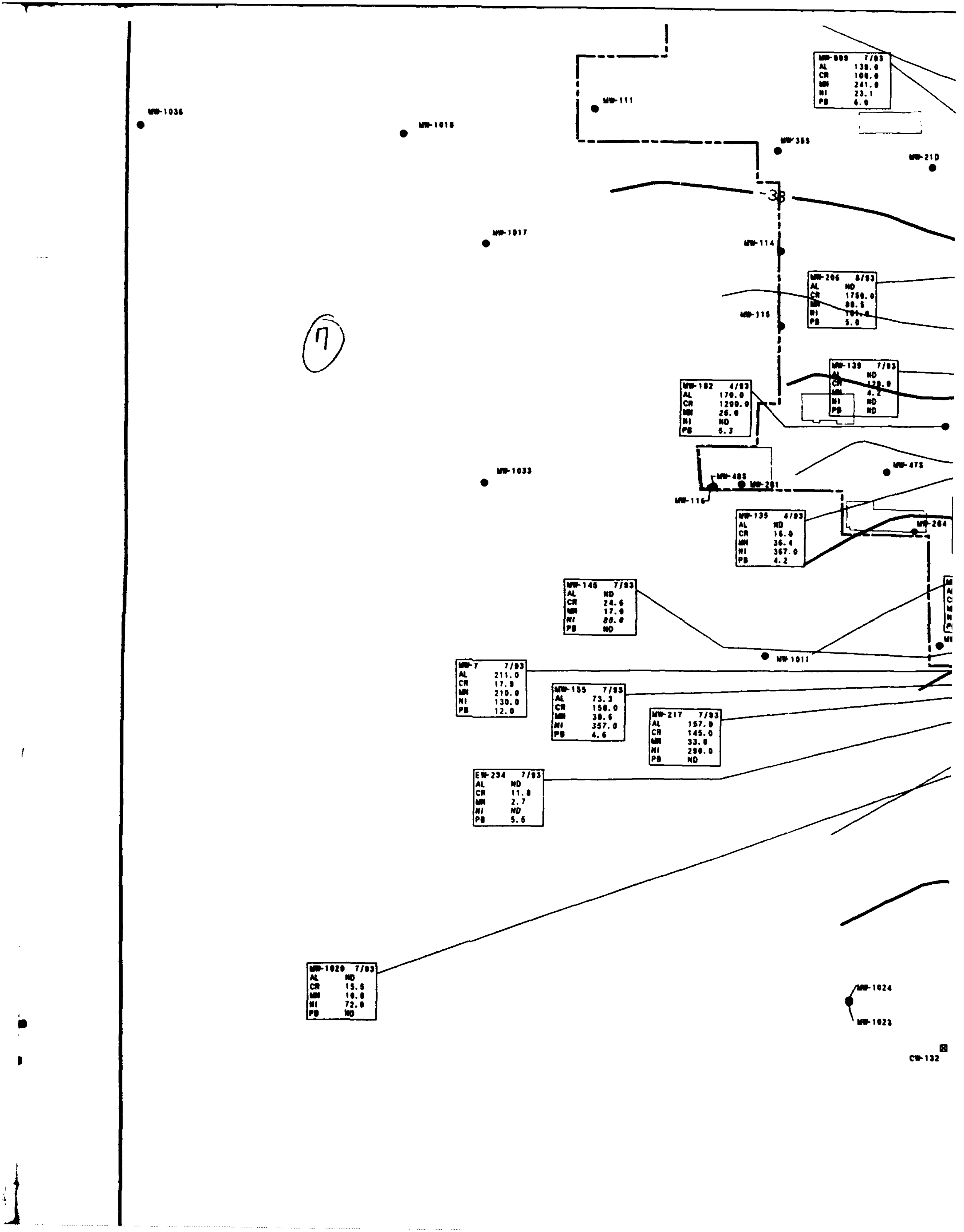

MW-1012
MW-102 4/93
AL 530.0
CR 20.0
MN ND
NI 27.0
PB ND


AL 310.0
CR ND
MN ND
NI 28.5
PB ND
MW-11 7/93
AL 11800.0
CR 45.1
MN 63.0
NI 440.0
PB ND
MW-1064
MW-1008
MW-1073
MW-1005
C1
EW-73
C3
MW-1004
MW-33D
C8
C5
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-241
MW-242
MW-1002
MW-106
MW-237
MW-240
C7
MW-15 7/93
AL 12700.0
CR 40.4
MN 112.0
NI 534.0
PB ND
MW-1019
MW-1029
MW-91 7/93
AL ND
CR 11.3
MN 1670.0
NI 37.0
PB 11.0
MW-188 7/93
AL 348.0
CR 8870.0
MN 161.0
NI 20.5
PB 5.1
MW-110 7/93
AL ND
CR 14.4
MN 57.0
NI 460.0
PB ND
MW-899 7/93
AL 139.0
CR 100.0
MN 241.0
NI 23.1
PB 6.0
MW-1036
MW-111
MW-1018
MW 36S
MW-211
MW-1017
MW-114

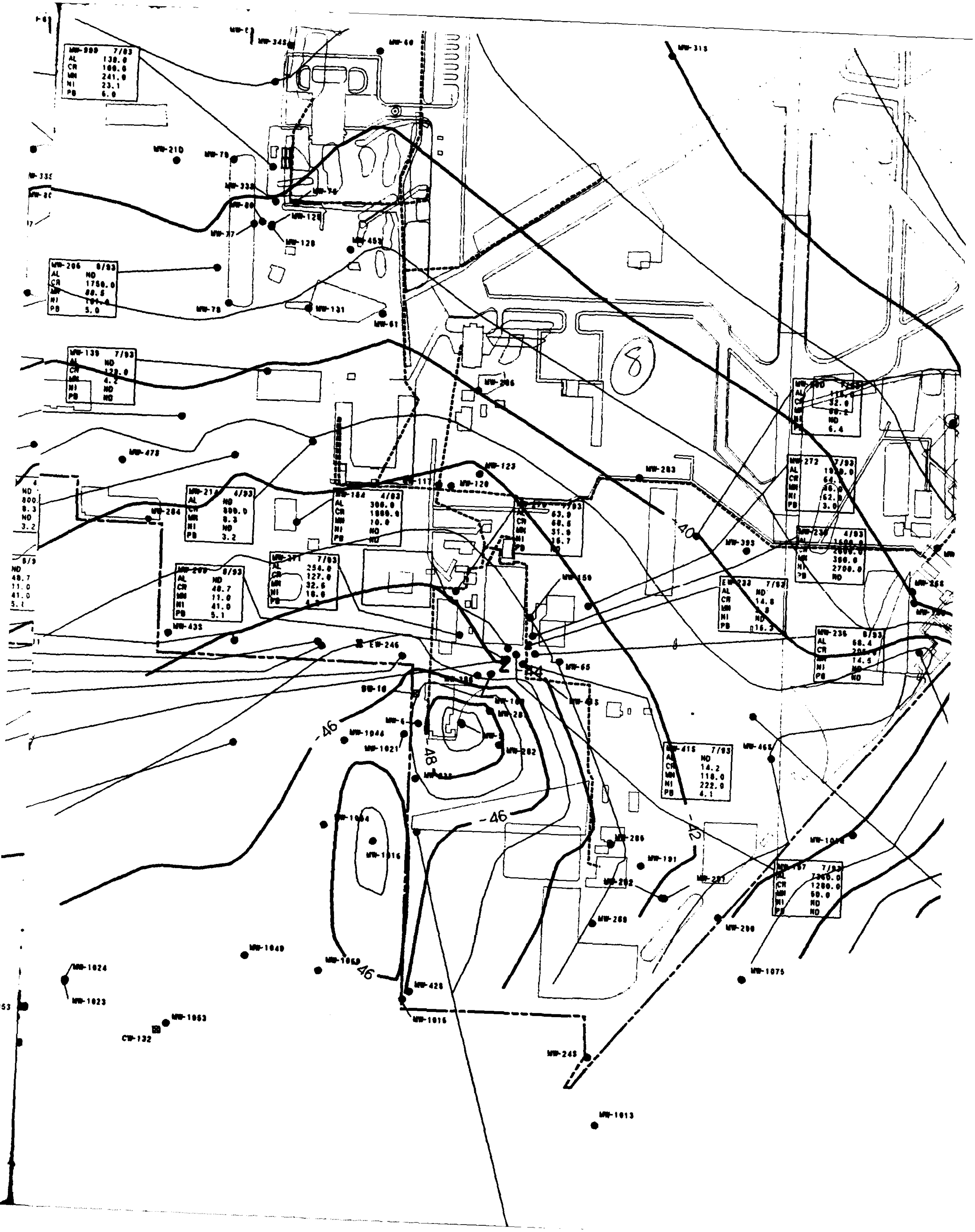


MW-1026 4/93
AL 1090.0
MN 19.2
NI 76.3
PB ND
MW-12 7/93
CR 16.2
MN 48.9
NI 172.0
PB 5.3
MW-88 4/93
AL ND
CR 8.1
MN 780.0
NI 25.0
MW-1064
MW-1009
MW-1008
36
MW-1073
MW-1005
C2
C6
C1
C5
C4
C3
C8
C7
EW-73
MW-38D
EW-87
EW-86
EW-85
MW-55
MW-241
MW-242
MW-1002
MW-240
MW-19S
MW-92
MW-18S
34
MW-88 7/93
AL ND
CR 8.7
MN 720.0
NI 21.0
PB 3.4
MW-14 4/93
AL 11000.0
CR 38.0
MN 37.4
NI 208.0
PB 3.6
MW-15 7/93
AL 12700.0
CR 40.4
MN 112.0
NI 534.0
PB ND
AL ND
CR 11.3
MN 1670.0
PB 11.0
MW-37
36
MW-107
MW-36S
MW-62 7/93
AL ND
CR ND
MN 69.5
NI 36.1
PB ND
MW-62
MW-44S
MW-60
MW-34S
MW-31S
MW-999 7/93
AL 139.0
CR 100.0
MN 241.0
NI 23.1
PB 6.0
MW-21D
MW-79
MW-33S
MW-128
MW-45S

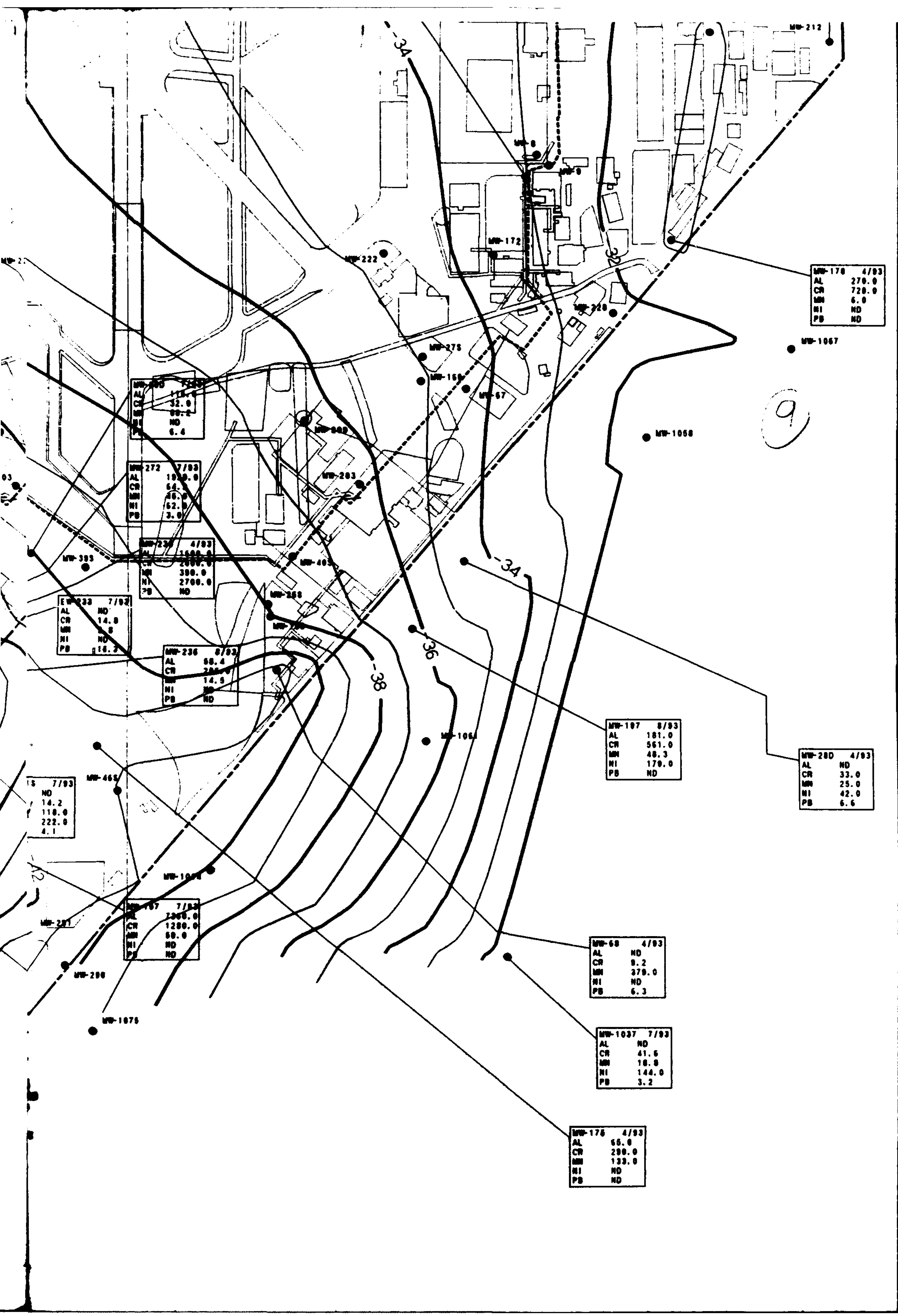

CR 20.0
MN ND
NI 27.0
PB ND
MW-194
MW-101
185
BW-29
MW-186 7/93
AL 112.0
CR 76.8
MN 42.6
NI ND
PB ND
MW-50
34
32
MW-226
BW-10
MW-212 4/93
AL 170.0
CR 17000.0
MN 60.4
NI 117.0
PB ND
MW-224 4/93
AL 67.0
CR 77.0
MN 146.0
NI 322.0
PB 4.2
MW-169
MW-485
MW-202
MW-303
MW-210
MW-212
MW-8
MW-9
MW-172
MW-222
MW-178 4/93



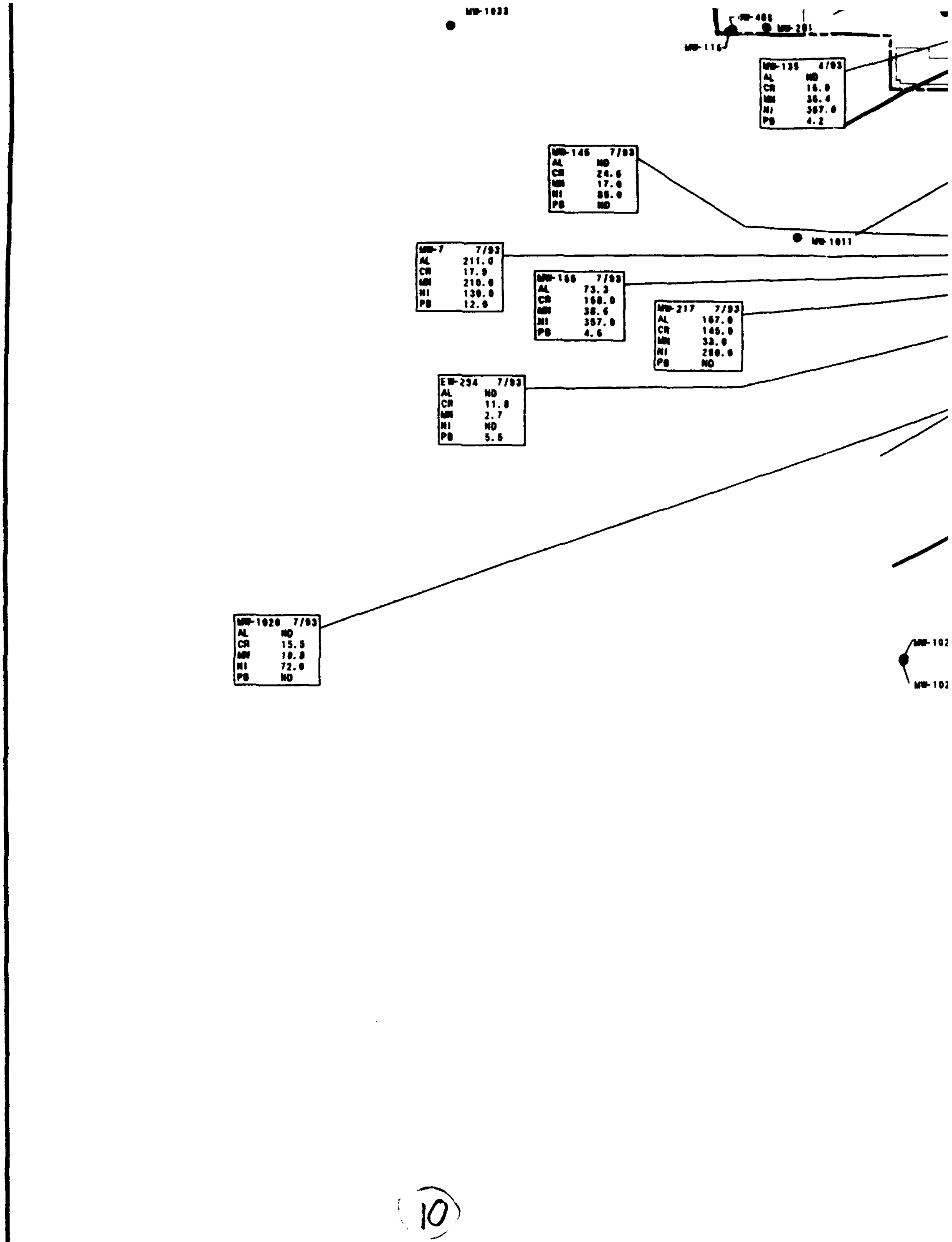
MW-1036
MW-1018
MW-111
MW-899 7/93
AL 138.0
CR 100.0
MN 241.0
NI 23.1
PB 6.0
MW-35S
MW-21D
38
MW-1017
MW-114
MW-206 8/93
AL ND
CR 1750.0
MN 88.5
NI 101.0
PB 5.0
MW-115
7
MW-139 7/93
AL ND
CR 120.0
MN 4.2
NI ND
PB ND
MW-182 4/93
AL 170.0
CR 1200.0
MN 26.0
NI ND
PB 5.3
MW-1033
MW-47S
MW-48S
MW-201
MW-116
MW-135 4/93
AL ND
CR 16.0
MN 36.4
NI 367.0
PB 4.2
MW-204
MW-145 7/93
AL ND
CR 24.6
MN 17.0
NI 85.0
PB ND
MW-1011
MW-7 7/93
AL 211.0
CR 17.9
MN 210.0
NI 130.0
PB 12.0
MW-155 7/93
AL 73.3
CR 150.0
MN 38.6
NI 357.0
PB 4.6
MW-217 7/93
AL 157.0
CR 145.0
MN 33.0
NI 290.0
PB ND
EW-234 7/93
AL ND
CR 11.8
MN 2.7
NI ND
PB 5.6
MW-1020 7/93
AL ND
CR 15.5
MN 10.0
NI 72.0
PB ND
MW-1024
MW-1023
CW-132



MW-315
MW-210
MW-79
MW-131
MW-61
MW-206
MW-478
MW-123
MW-283
MW-117
MW-264
MW-393
MW-159
MW-433
EW-246
MW-65
MW-1044
MW-1021
MW-282
MW-1016
MW-286
MW-191
MW-269
MW-281
MW-290
MW-468
MW-1075
MW-1049
MW-1059
MW-1024
MW-1023
MW-1053
CW-132
MW-428
MW-1015
MW-245
MW-1013
MW-415 7/93
AL ND
CR 14.2
MN 118.0
NI 222.0
PB 4.1
MW-164 4/93
AL 300.0
CR 1800.0
MN 10.0
NI ND
PB ND
MW-235 8/93
AL 68.4
MN 14.5
NI ND
PB ND
40
42
46
48
8

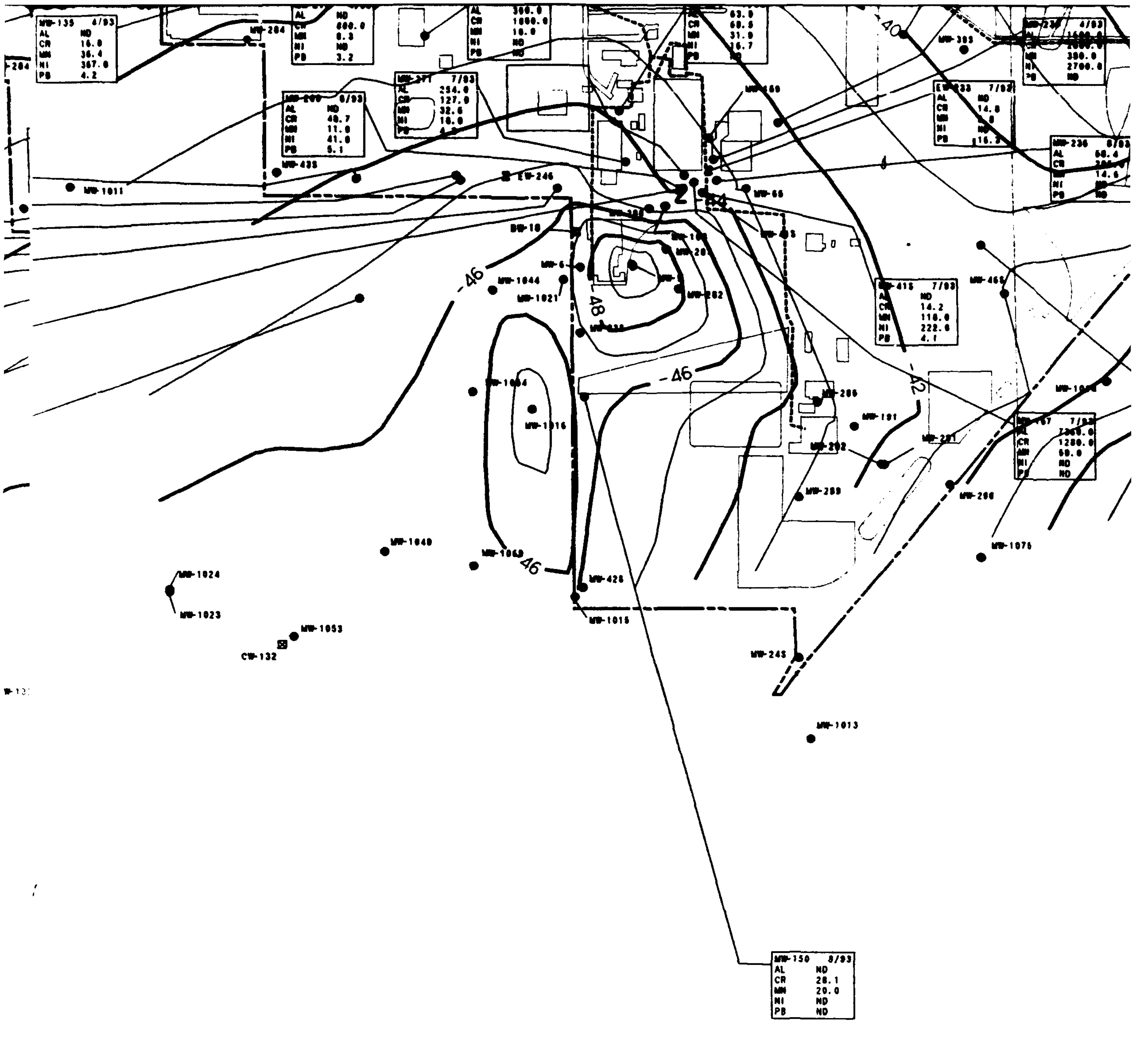


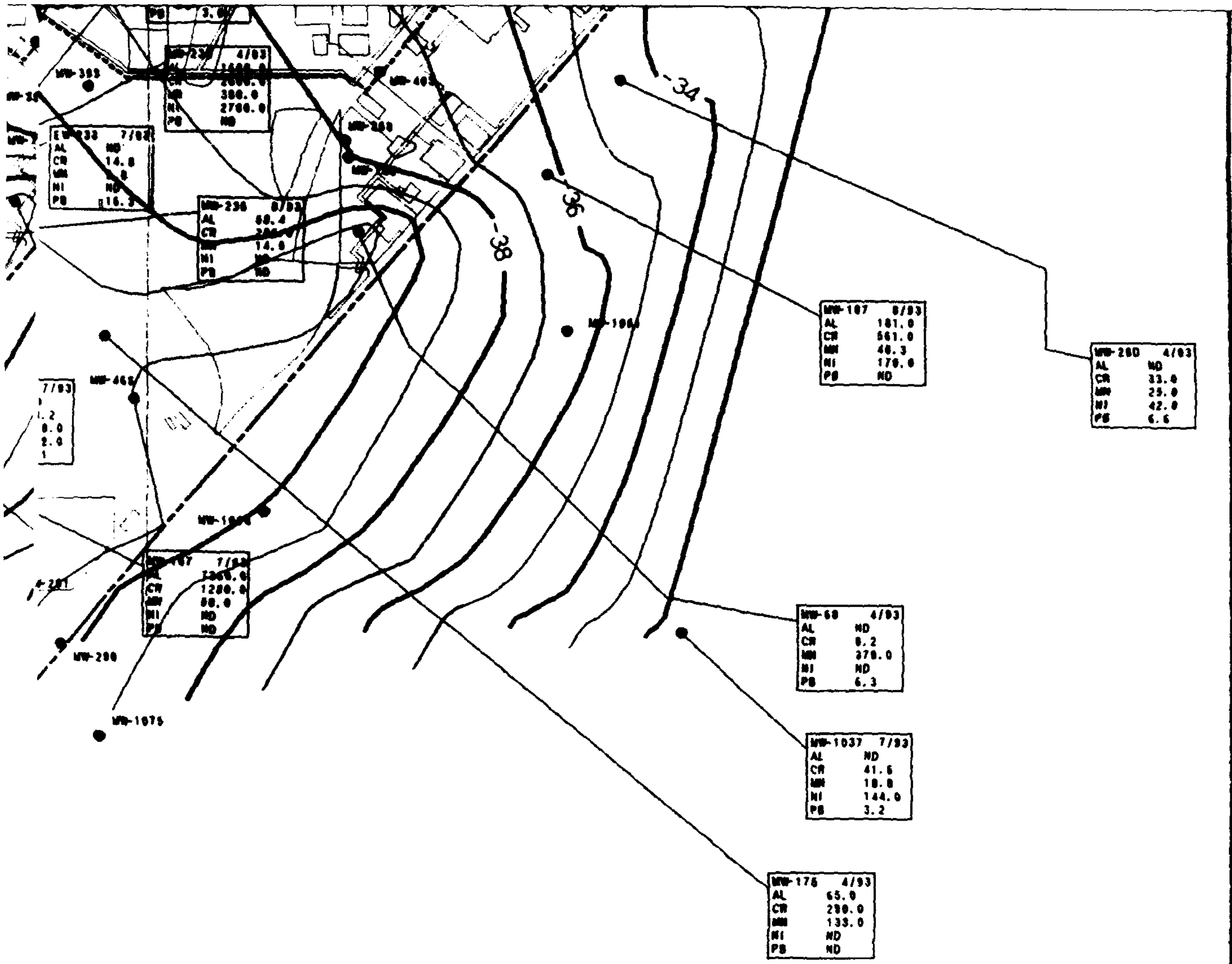
MW-212
MW-222
MW-172
MW-275
MW-1067
MW-1058
MW-283
MW-1061
MW-1075
MW-290
MW-178 4/93
AL 270.0
CR 720.0
MN 6.0
NI ND
PB ND
MW-28D 4/93
AL ND
CR 33.0
MN 25.0
NI 42.0
PB 6.6
MW-107 8/93
AL 181.0
CR 561.0
MN 48.3
NI 179.0
PB ND
MW-68 4/93
AL ND
CR 9.2
MN 379.0
NI ND
PB 6.3
MW-1037 7/93
AL ND
CR 41.6
MN 18.8
NI 144.0
PB 3.2
MW-175 4/93
AL 65.0
CR 298.0
MN 133.0
NI ND
PB ND
MW-272 7/93
MW-236 8/93
AL 68.4
MN 14.5
PB ND
-34
-36
-38
9



RDD 1454 MAY, 1994

MEY94/4-62.DGN


MW-135 4/93
AL ND
CR 16.0
MN 36.4
NI 367.0
PB 4.2
MW-284
MW-1011
MW-43S
EW-246
MW-65
MW-1044
MW-1021
MW-6
MW-202
MW-1016
MW-1049
MW-1063
MW-1024
MW-1023
MW-1053
CW-132
MW-42S
MW-1015
MW-24S
MW-1013
MW-191
MW-289
MW-1075
MW-393
MW-41S 7/93
AL ND
CR 14.2
MN 116.0
NI 222.0
PB 4.1
MW-150 8/93
AL ND
CR 28.1
MN 20.0
NI ND
PB ND
46
48
42
40



12

FIGURE 4-62
METALS CONCENTRATIONS IN MONITORING ZONE A

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

LEGEND

MW-54	4/93
AL	ND
CR	ND
MN	220.0
NI	370.0
PB	24.0

WELL NAME, MONTH AND YEAR OF S
AND METALS CONCENTRATIONS (ug/l

WATER LEVEL CONTOURS
(ft msl) JANUARY 1993

• MONITORING WELL

⊠ BASE WELL OR CITY WELL

x EXTRACTION WELL

INDUSTRIAL WASTE LINE

SOURCE AREAS (SCREENED)

0

NOTES: 1. MOST RECENT SECOND AND THIRD QUARTER 199
IS PRESENTED.

2. WELLS WITHOUT LABELS WERE NOT SAMPLED DURING SECOND AND THIRD QUARTER 1993.

MW-1043	4/93
AL	ND
CR	ND
MN	ND
NI	ND
PB	ND

MW-1010

YEAR OF SAMPLING,
ATIONS (ug/l)

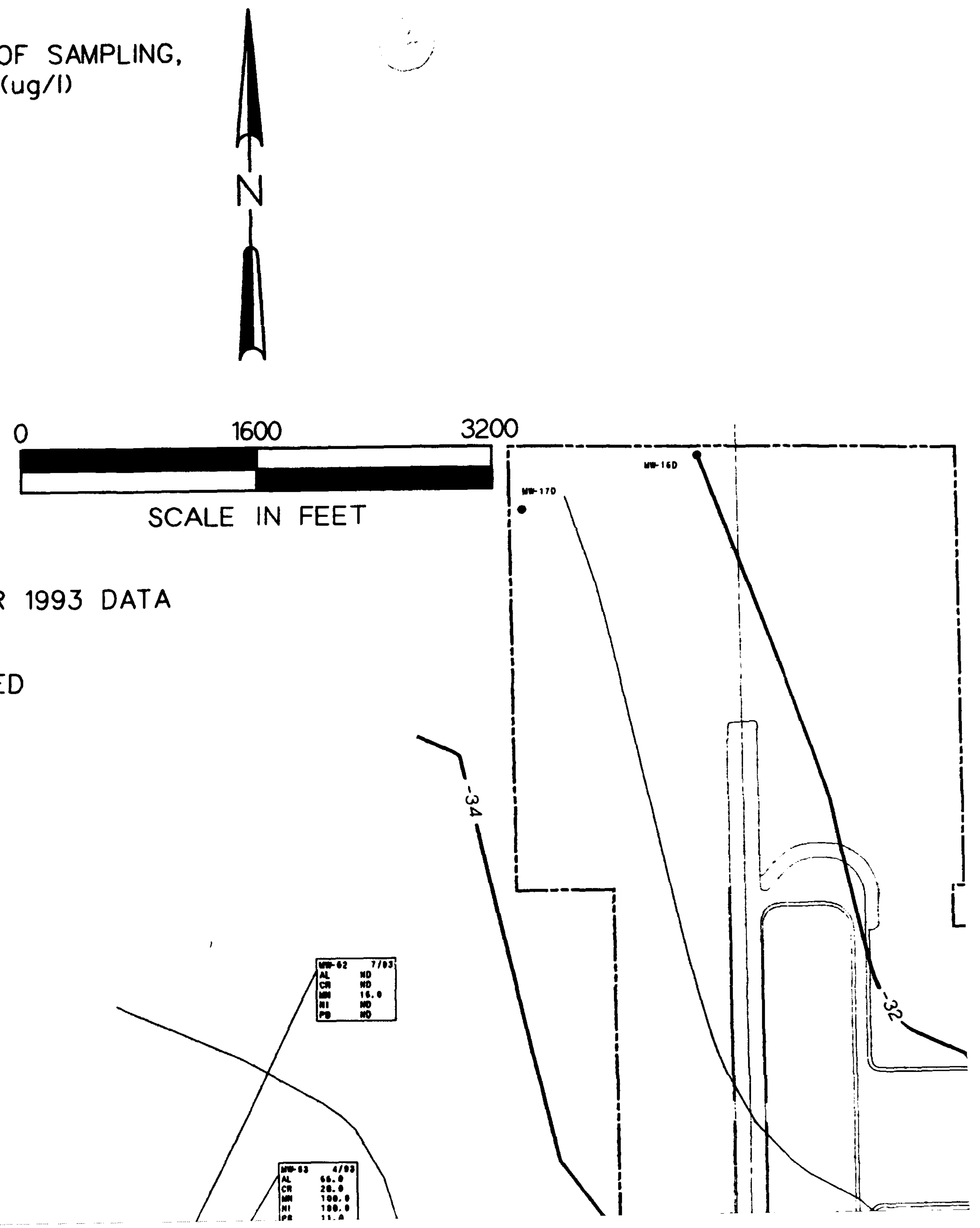
RS

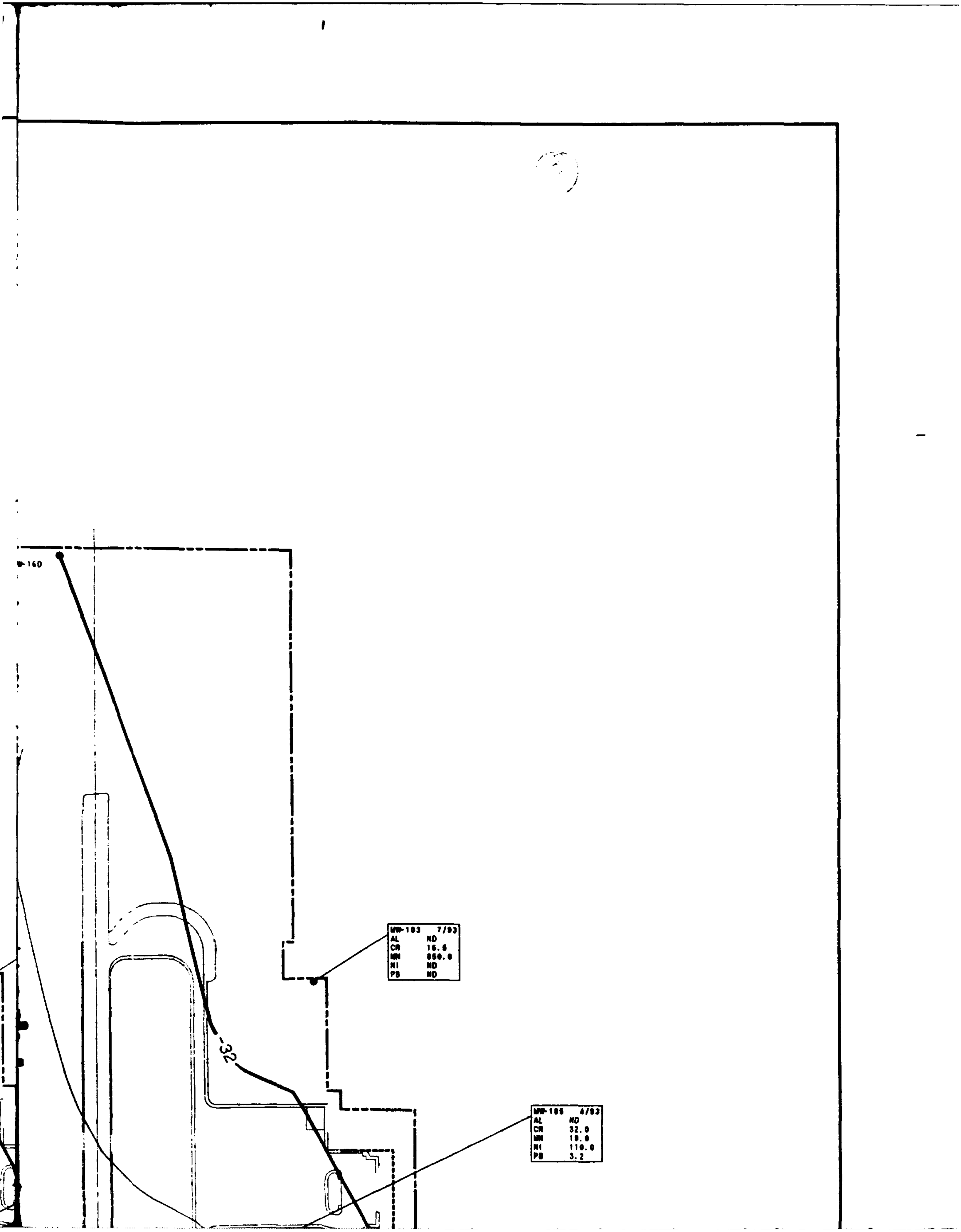
LL

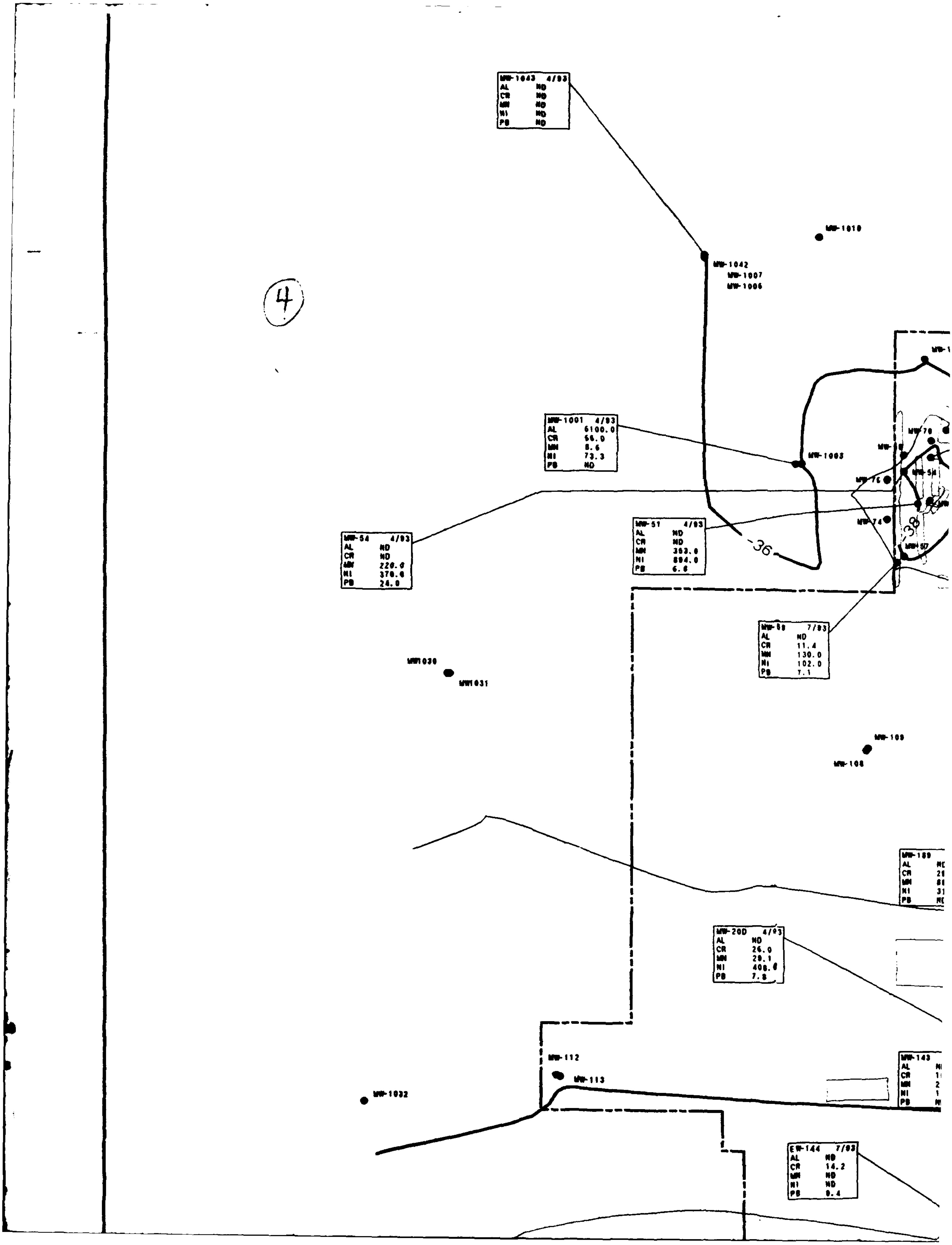
ED)

UARTER 1993 DATA

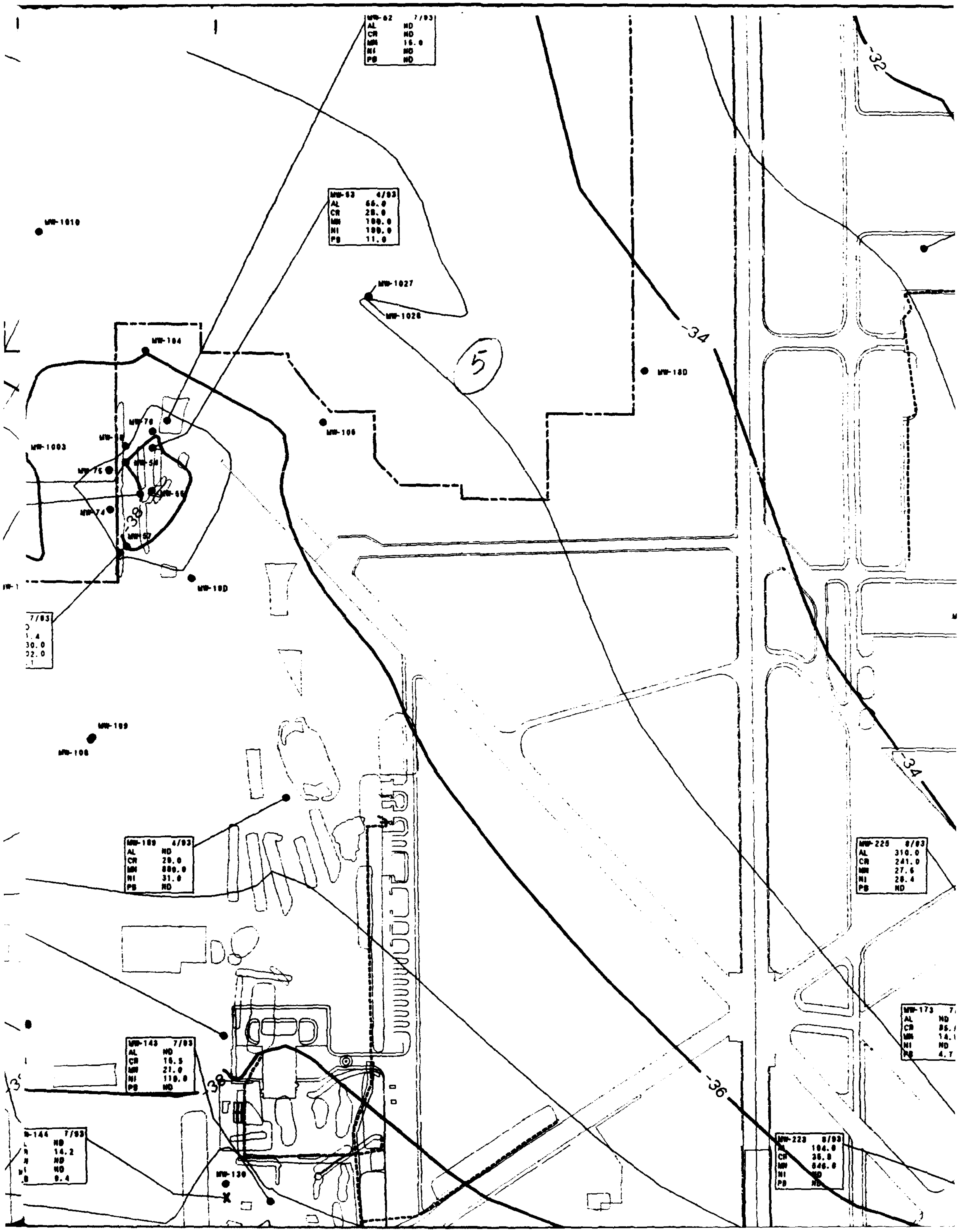
SAMPLED
1993.



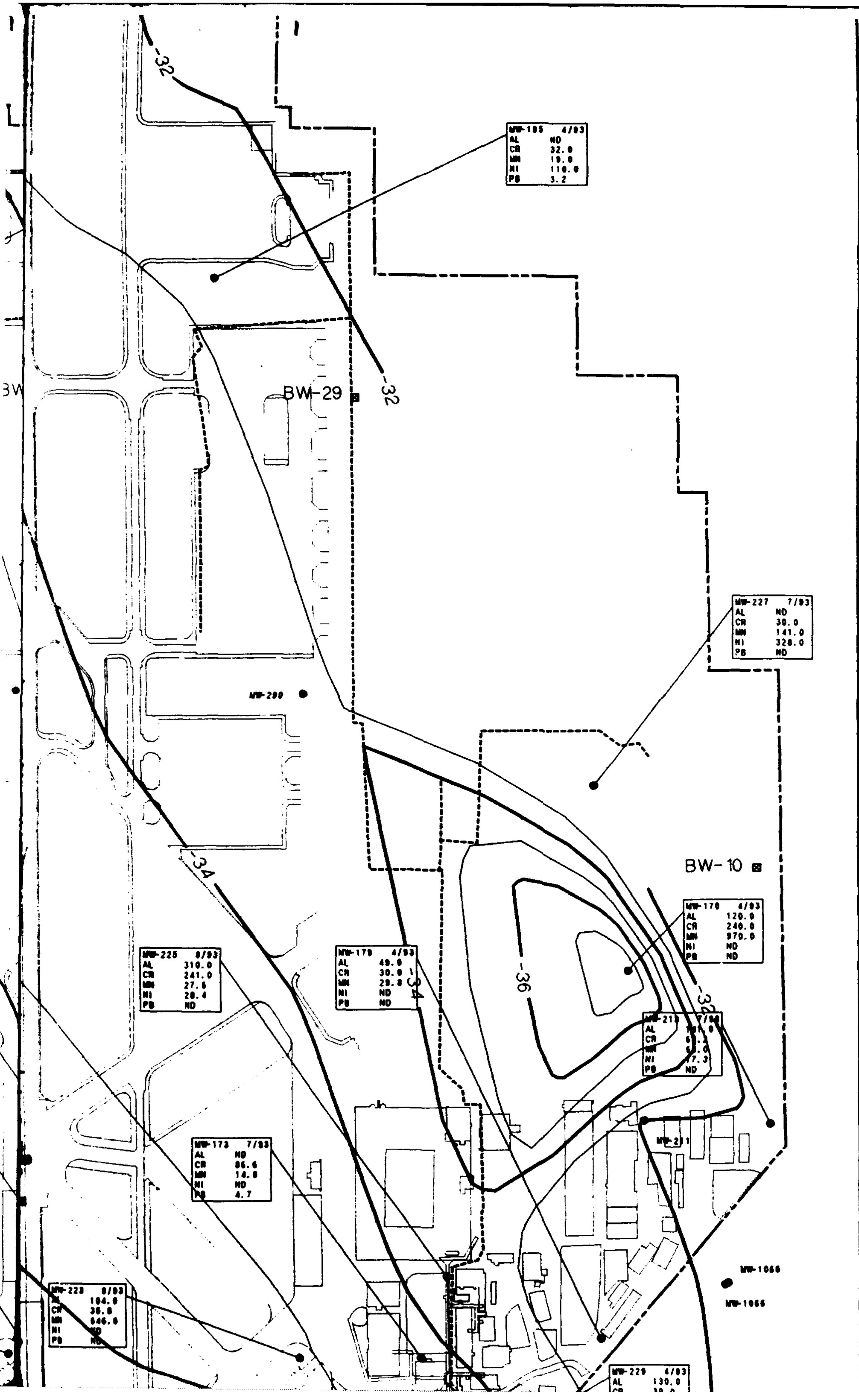

W-16D
MW-103 7/93
AL ND
CR 16.6
MN 850.0
NI ND
PB ND
32
MW-105 4/93
AL ND
CR 32.0
MN 19.0
NI 110.0
PB 3.2



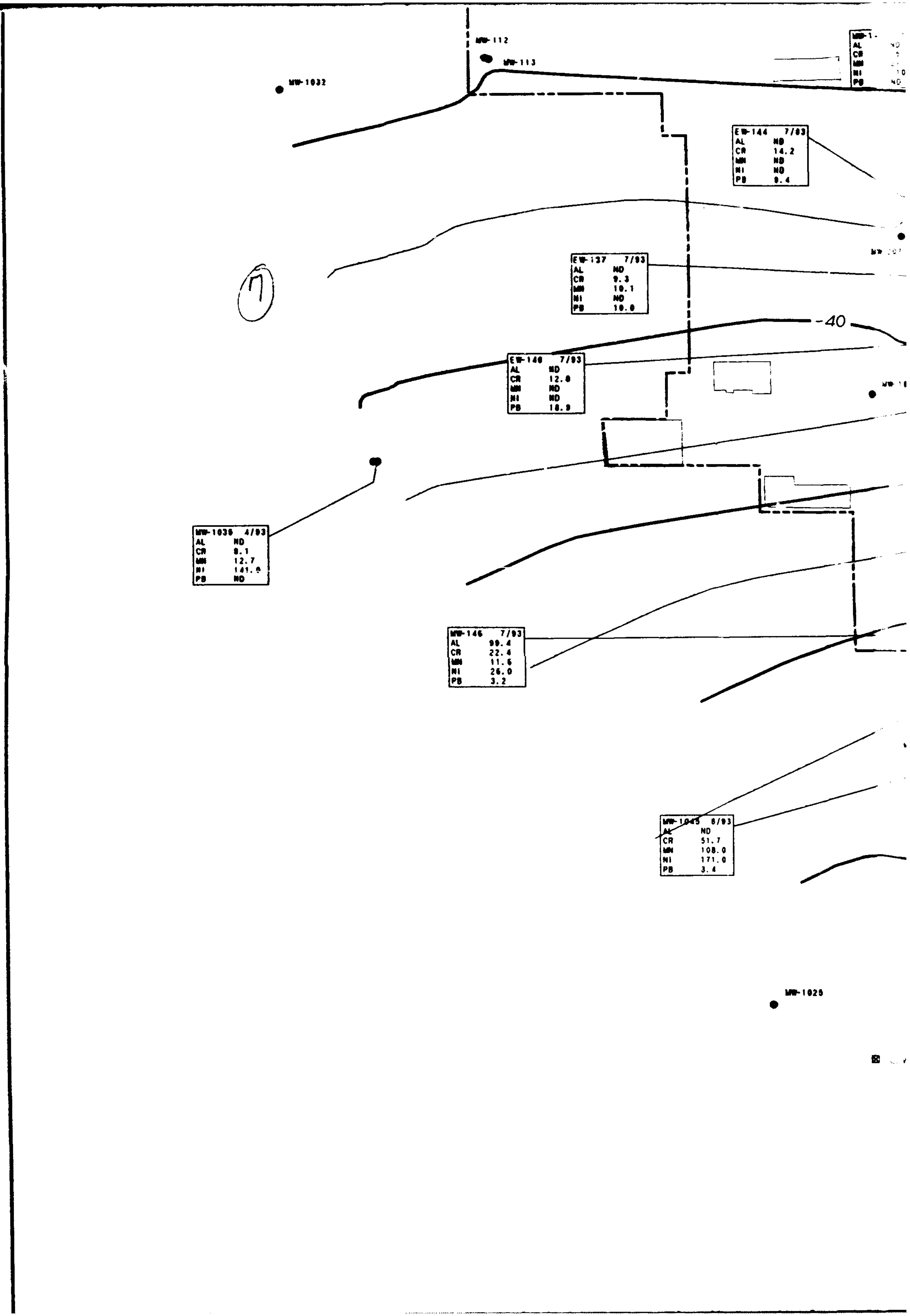
MW-1043 4/93
AL ND
CR ND
MN ND
NI ND
PB ND
MW-1019
MW-1042
MW-1007
MW-1006
4
MW-1001 4/93
AL 6100.0
CR 56.0
MN 8.6
NI 73.3
PB ND
MW-1003
MW-78
MW-76
MW-74
MW-54 4/93
AL ND
CR ND
MN 220.0
NI 370.0
PB 24.0
MW-51 4/93
AL ND
CR ND
MN 353.0
NI 894.0
PB 6.6
36
38
7/93
AL ND
CR 11.4
MN 130.0
NI 102.0
PB 7.1
MW1030
MW1031
MW-109
MW-108
MW-200 4/93
AL ND
CR 26.0
MN 29.1
NI 408.0
PB 7.8
MW-112
MW-113
MW-1032
EW-144 7/93
AL ND
CR 14.2
MN ND
NI ND
PB 9.4

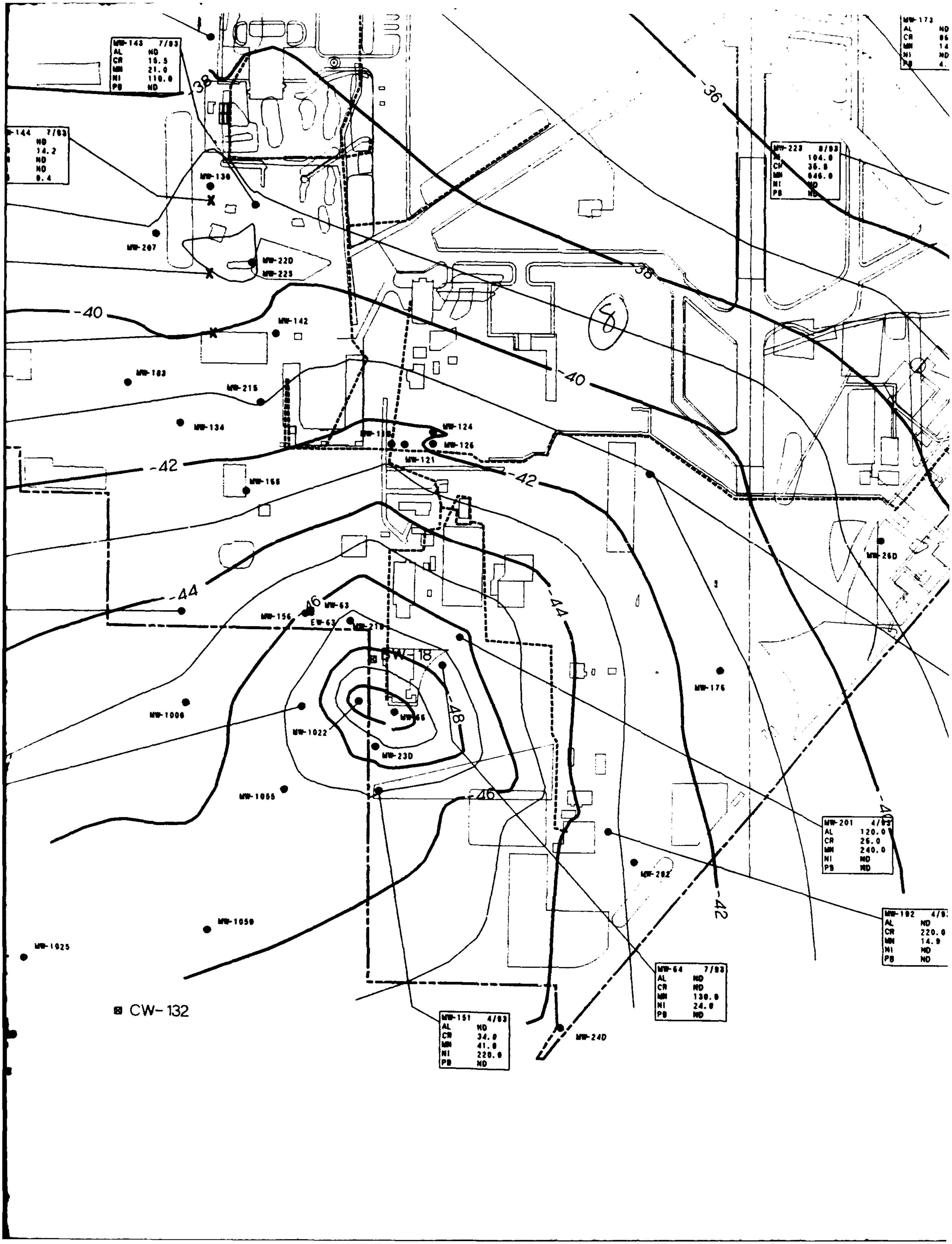


MW-62 7/93
AL ND
CR ND
MN 16.0
NI ND
PB ND
MW-63 4/93
AL 66.0
CR 28.0
MN 100.0
NI 100.0
PB 11.0
MW-1027
MW-1026
MW-184
MW-106
MW-1003
MW-75
MW-74
MW-109
MW-143 7/93
AL ND
CR 15.5
MN 21.0
NI 110.0
PB ND
MW-144 7/93
MW-130
MW-225 8/93
AL 310.0
CR 241.0
MN 27.6
NI 28.4
PB ND
MW-173
AL ND
NI ND
MW-223 8/93
CR 35.8
PB ND
-32
-34
-34
-36
-38
5

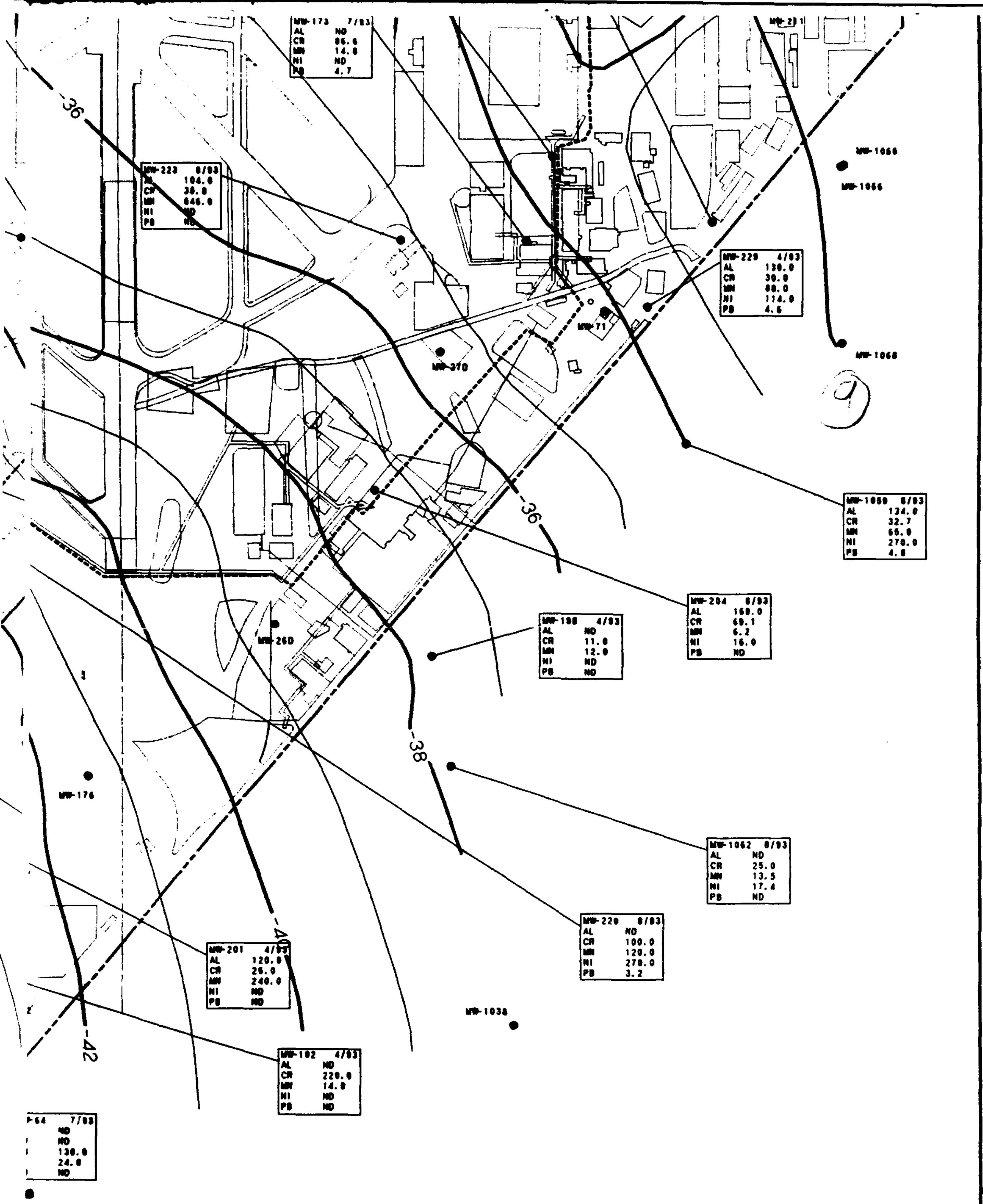


MW-195 4/93
AL ND
CR 32.0
MN 19.0
NI 110.0
PB 3.2
BW-29
-32
-32
MW-227 7/93
AL ND
CR 30.0
MN 141.0
NI 328.0
PB ND
MW-290
BW-10
MW-170 4/93
AL 120.0
CR 240.0
MN 970.0
NI ND
PB ND
-36
-34
34
MW-225 8/93
AL 310.0
CR 241.0
MN 27.6
NI 28.4
PB ND
MW-179 4/93
AL 49.0
CR 30.0
MN 29.8
NI ND
PB ND
MW-173 7/93
AL ND
CR 86.6
MN 14.8
NI ND
PB 4.7
MW-223 8/93
MW-1066
MW-1066
MW-229 4/93
AL 130.0

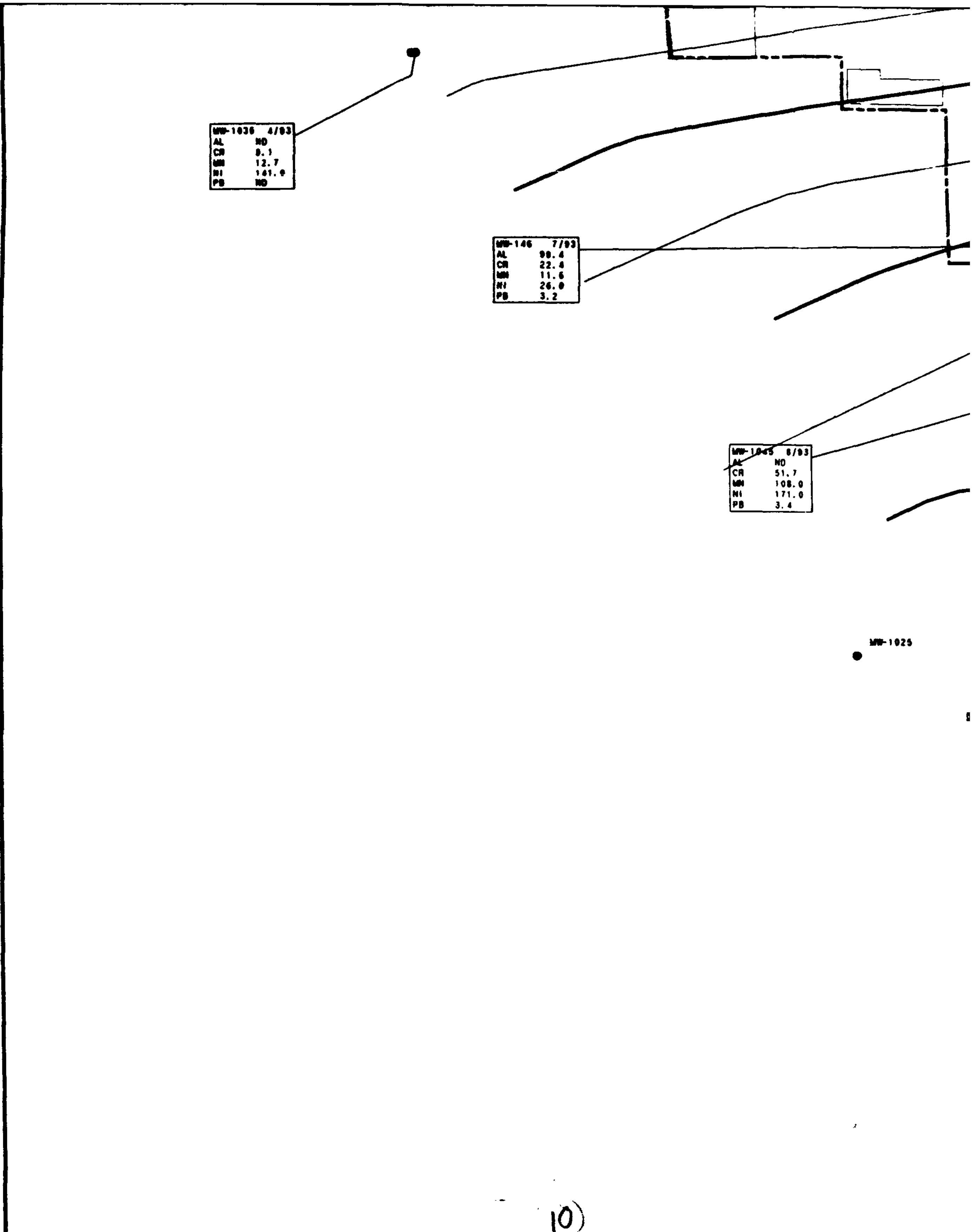

MW-112
MW-113
MW-1032
EW-144 7/93
AL ND
CR 14.2
MN ND
NI ND
PB 9.4
EW-137 7/93
AL ND
CR 9.3
MN 10.1
NI ND
PB 10.0
-40
EW-140 7/93
AL ND
CR 12.0
MN ND
NI ND
PB 18.9
MW-1036 4/93
AL ND
CR 9.1
MN 12.7
NI 141.0
PB ND
MW-146 7/93
AL 90.4
CR 22.4
MN 11.6
NI 26.0
PB 3.2
MW-1045 8/93
AL ND
CR 51.7
MN 108.0
NI 171.0
PB 3.4
MW-1025
7



MW-143 7/93
AL ND
CR 16.5
MN 21.0
NI 110.0
PB ND
MW-144 7/93
14.2
ND
ND
8.4
MW-173
MW-223 8/93
104.0
36.8
646.0
ND
ND
MW-136
MW-207
MW-22D
MW-223
MW-142
MW-183
MW-215
MW-134
MW-124
MW-126
MW-121
MW-165
MW-26D
MW-63
MW-156
EW-63
MW-219
CW-18
MW-1006
MW-1022
MW-66
MW-23D
MW-1055
MW-176
MW-201 4/93
AL 120.0
CR 26.0
MN 240.0
NI ND
PB ND
MW-202
MW-192 4/93
AL ND
CR 220.0
MN 14.9
NI ND
PB ND
MW-64 7/93
AL ND
CR ND
MN 130.0
NI 24.0
PB ND
MW-1059
MW-1025
CW-132
MW-151 4/93
AL ND
CR 34.0
MN 41.0
NI 220.0
PB ND
MW-24D
36
38
40
42
44
46
48

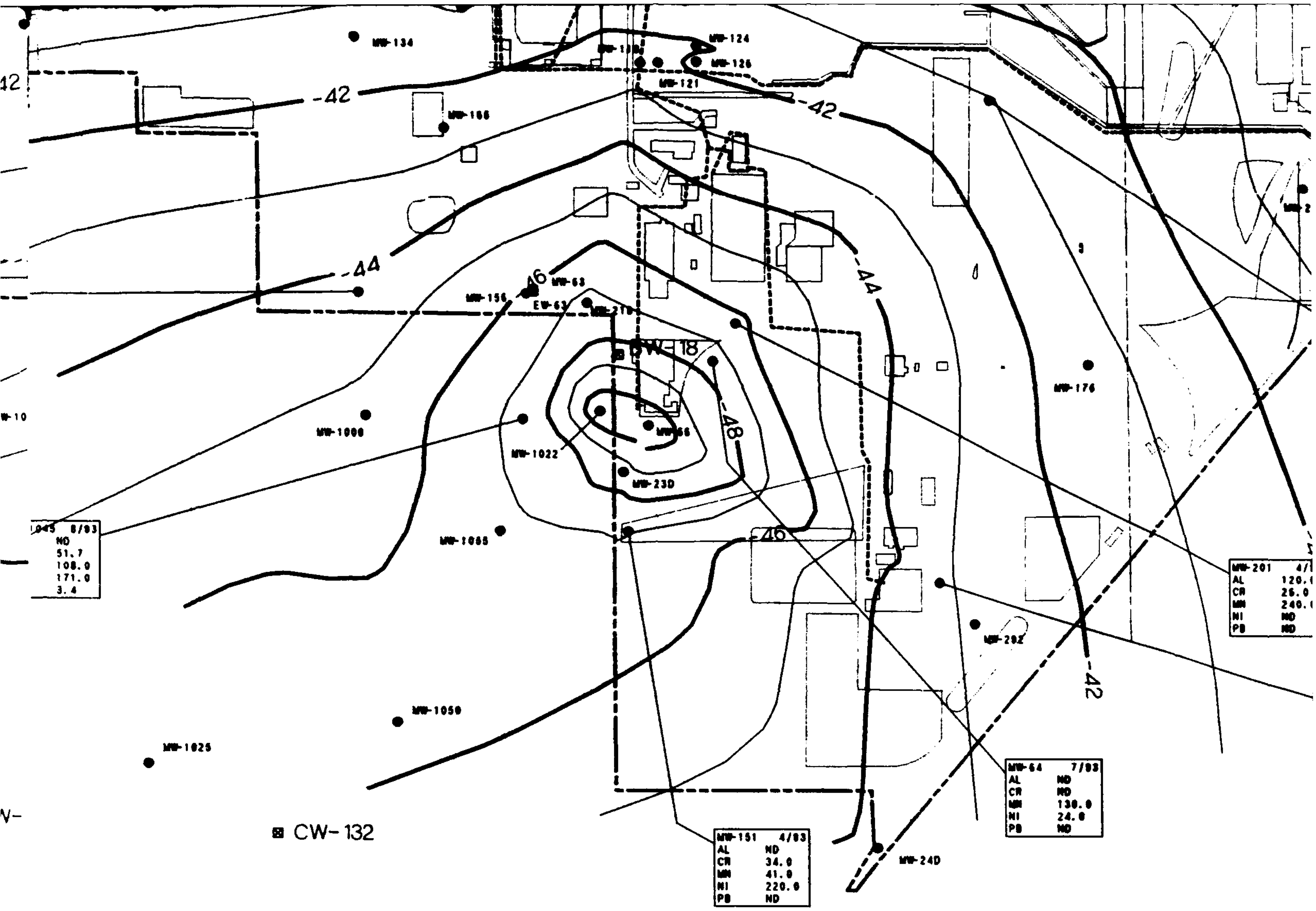


MW-173 7/93
AL ND
CR 86.6
MN 14.8
NI ND
PB 4.7
MW-223 8/93
AL 104.0
CR 38.8
MN 846.0
NI ND
PB ND
MW-229 4/93
AL 130.0
CR 30.0
MN 88.0
NI 114.0
PB 4.6
MW-1066
MW-1068
MW-71
MW-37D
MW-1059 8/93
AL 134.0
CR 32.7
MN 65.0
NI 270.0
PB 4.8
MW-204 8/93
AL 160.0
CR 69.1
MN 5.2
NI 16.0
PB ND
MW-198 4/93
AL ND
CR 11.0
MN 12.0
NI ND
PB ND
MW-26D
MW-176
MW-1062 8/93
AL ND
CR 25.0
MN 13.5
NI 17.4
PB ND
MW-220 8/93
AL ND
CR 100.0
MN 120.0
NI 270.0
PB 3.2
MW-201 4/93
AL 120.0
CR 26.0
MN 240.0
NI ND
PB ND
MW-1038
MW-192 4/93
AL ND
CR 220.0
MN 14.0
NI ND
PB ND
7/93
ND
ND
130.0
24.0
ND
-36
-36
-38
-40
-42



10)

RDD 1454 MAY, 1994
mey94/4-63.DGN



MW-134
MW-124
MW-126
MW-121
MW-166
42
44
46
48
MW-63
MW-156
EW-63
CW-18
MW-176
MW-1000
MW-1022
MW-66
MW-23D
MW-1065
MW-202
MW-1059
MW-1025
CW-132
MW-24D
MW-151 4/93
AL ND
CR 34.0
MN 41.0
NI 220.0
PB ND
MW-64 7/93
AL ND
CR ND
MN 130.0
NI 24.0
PB ND
AL 120.
CR 26.0
MN 240.
NI ND
PB ND
ND
51.7
108.0
171.0
3.4

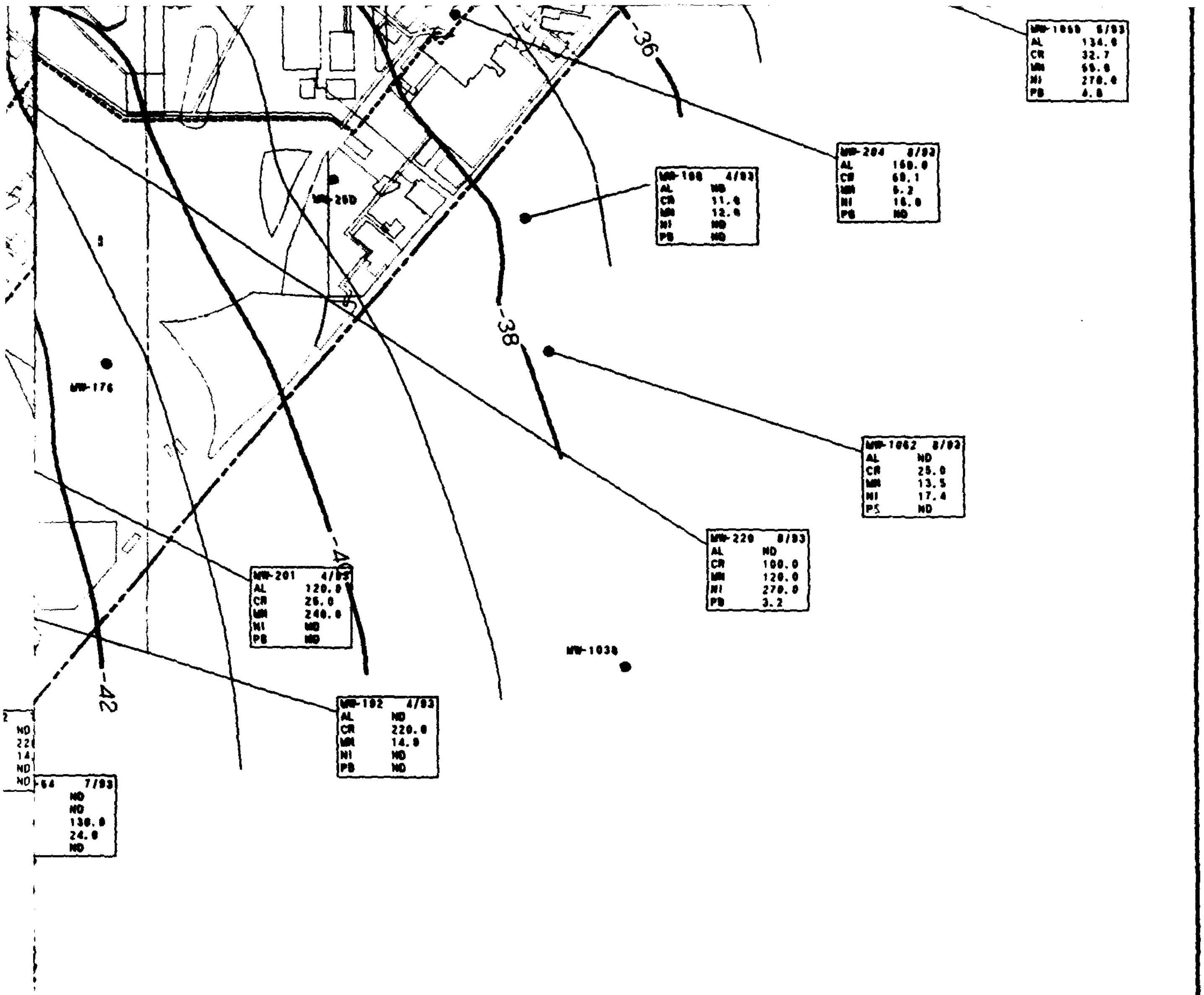


FIGURE 4-63
METALS CONCENTRATIONS IN MONITORING ZONE B

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

LEGEND

EW-141	7/93
AL	ND
CR	15.0
MN	ND
NI	ND
PB	8.7

WELL NAME, MONTH AND YEAR SAMPLING, METALS CONCENTRATION (ug/l)

WATER LEVEL CONTOURS (ft msl) JANUARY 1993

MONITORING WELL

BASE WELL OR CITY WELL

EXTRACTION WELL

INDUSTRIAL WASTE LINE

SOURCE AREAS (SCREENED)

0

SCA

NOTES: 1. MOST RECENT SECOND AND THIRD QUARTER 1993 DA IS PRESENTED.

2. WELLS WITHOUT LABELS WERE NOT SAMPLED DURING SECOND AND THIRD QUARTER 1993.

ION (ug/l)

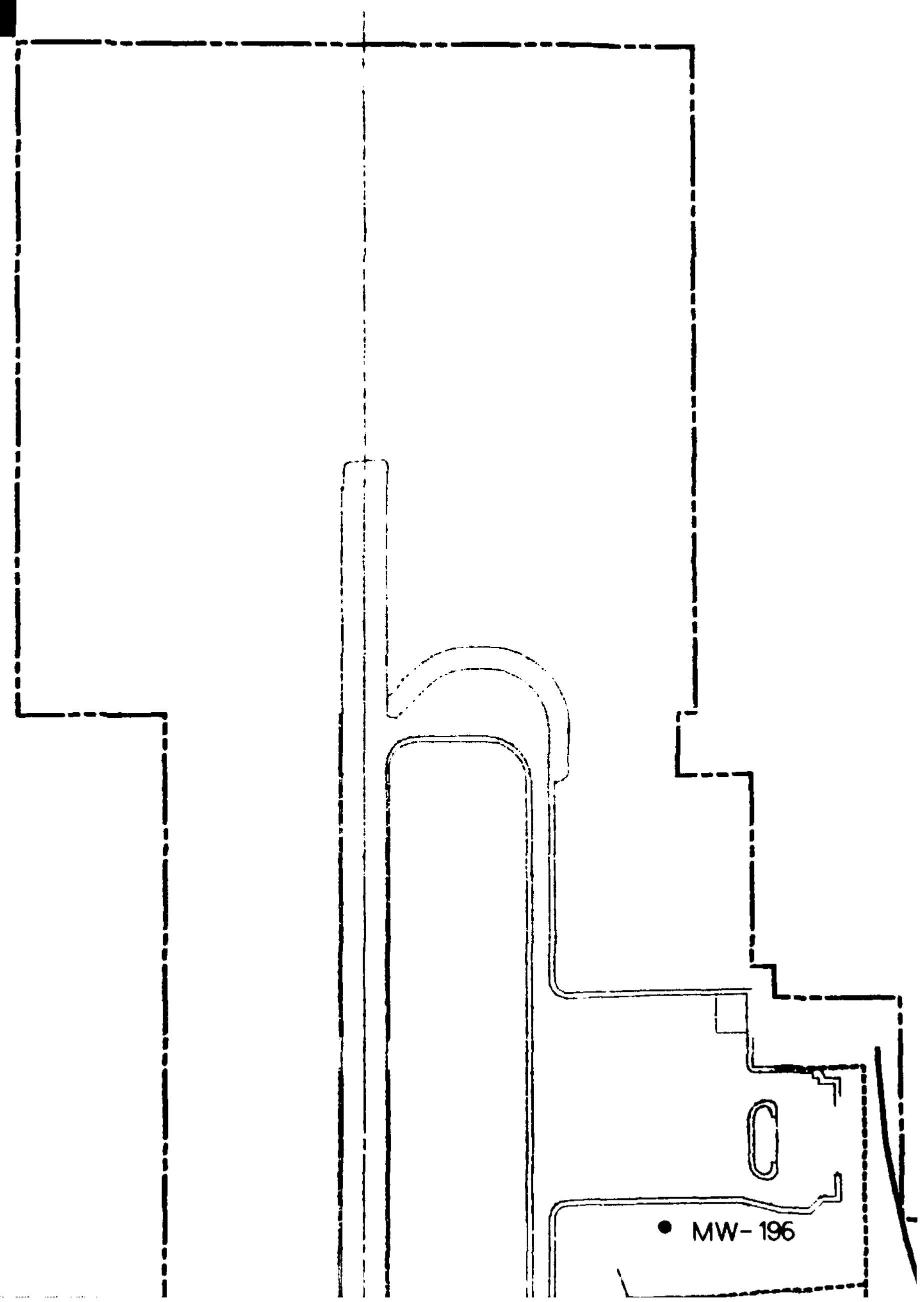
N

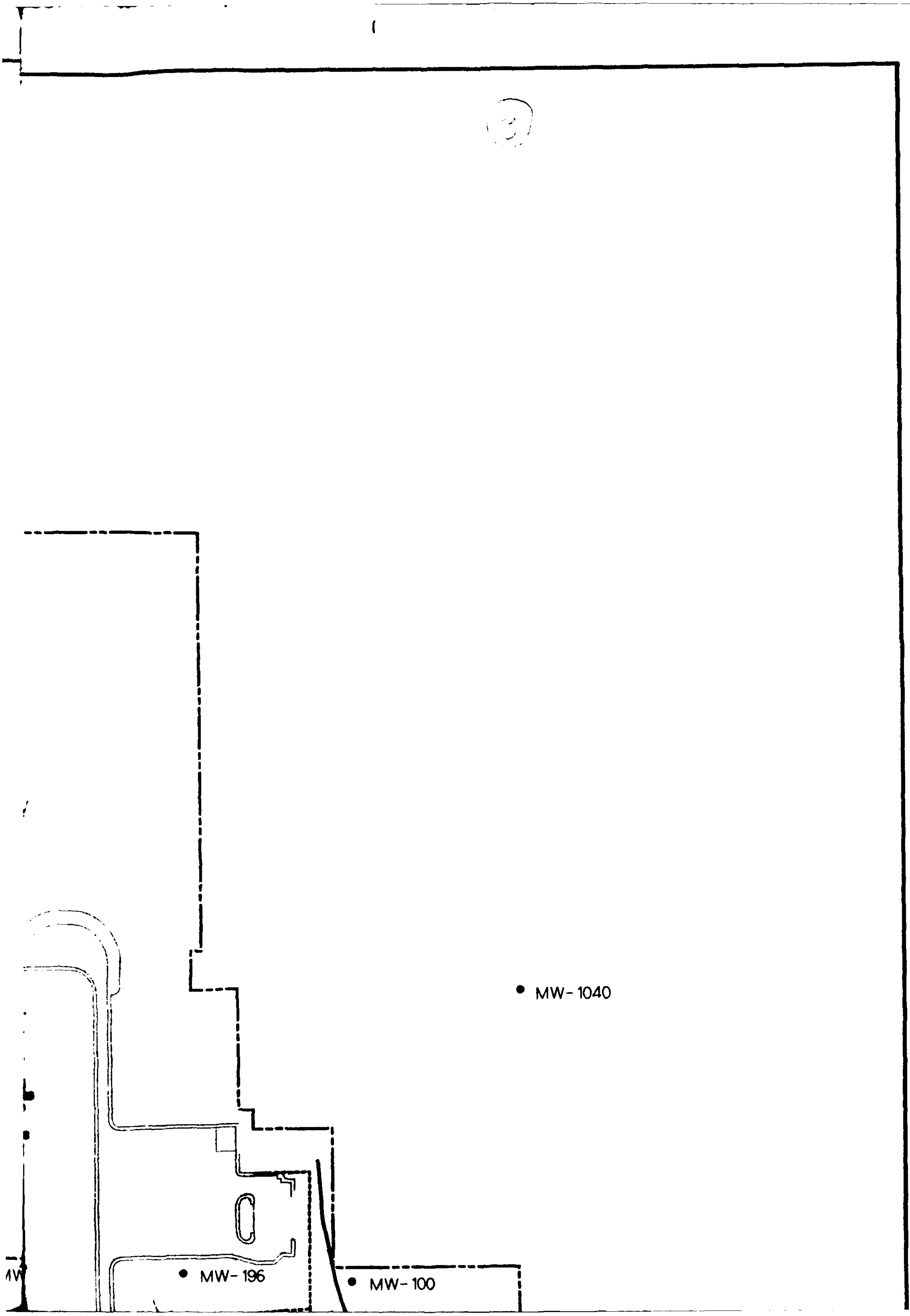
16 1600 3200

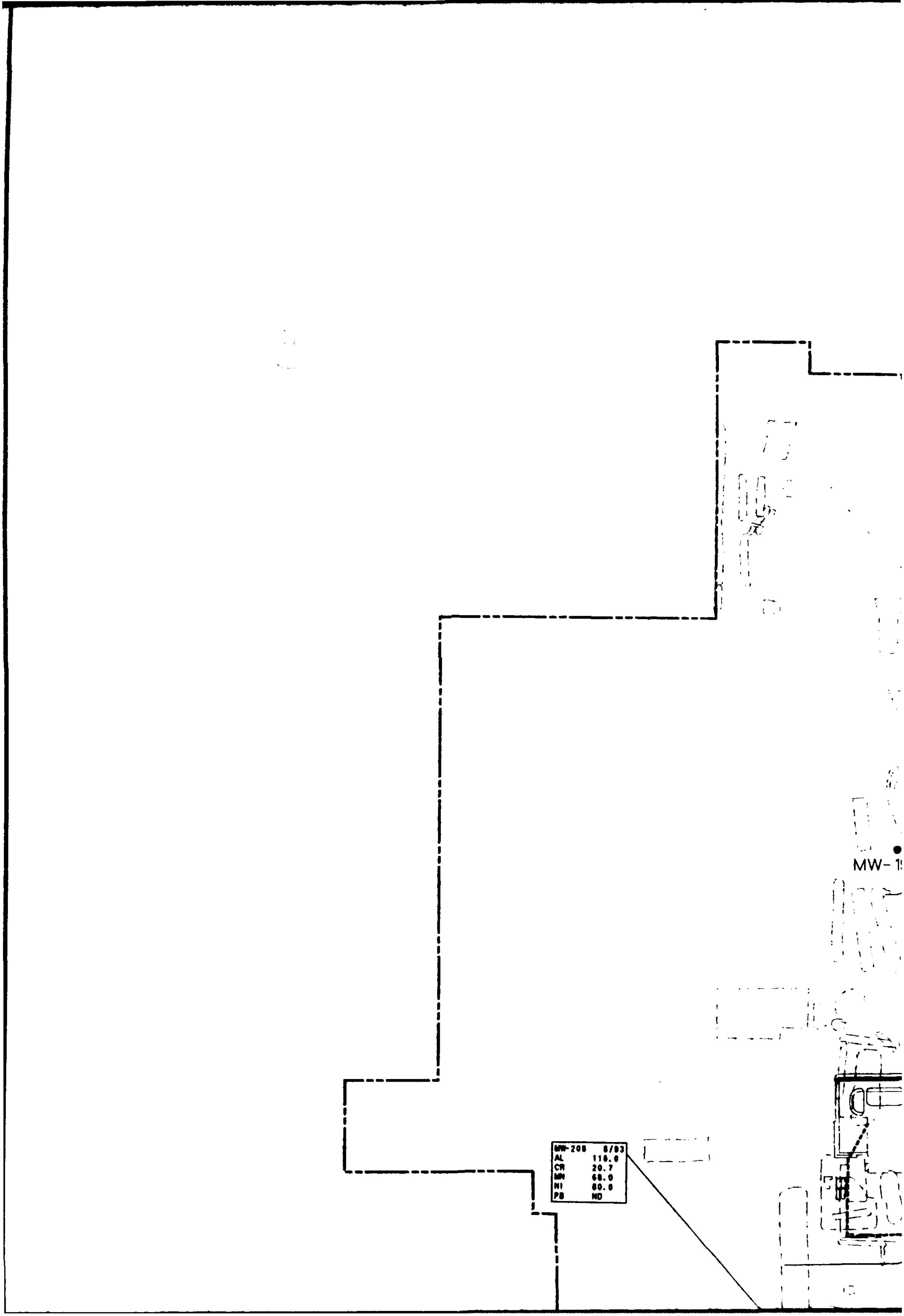
SCALE IN FEET

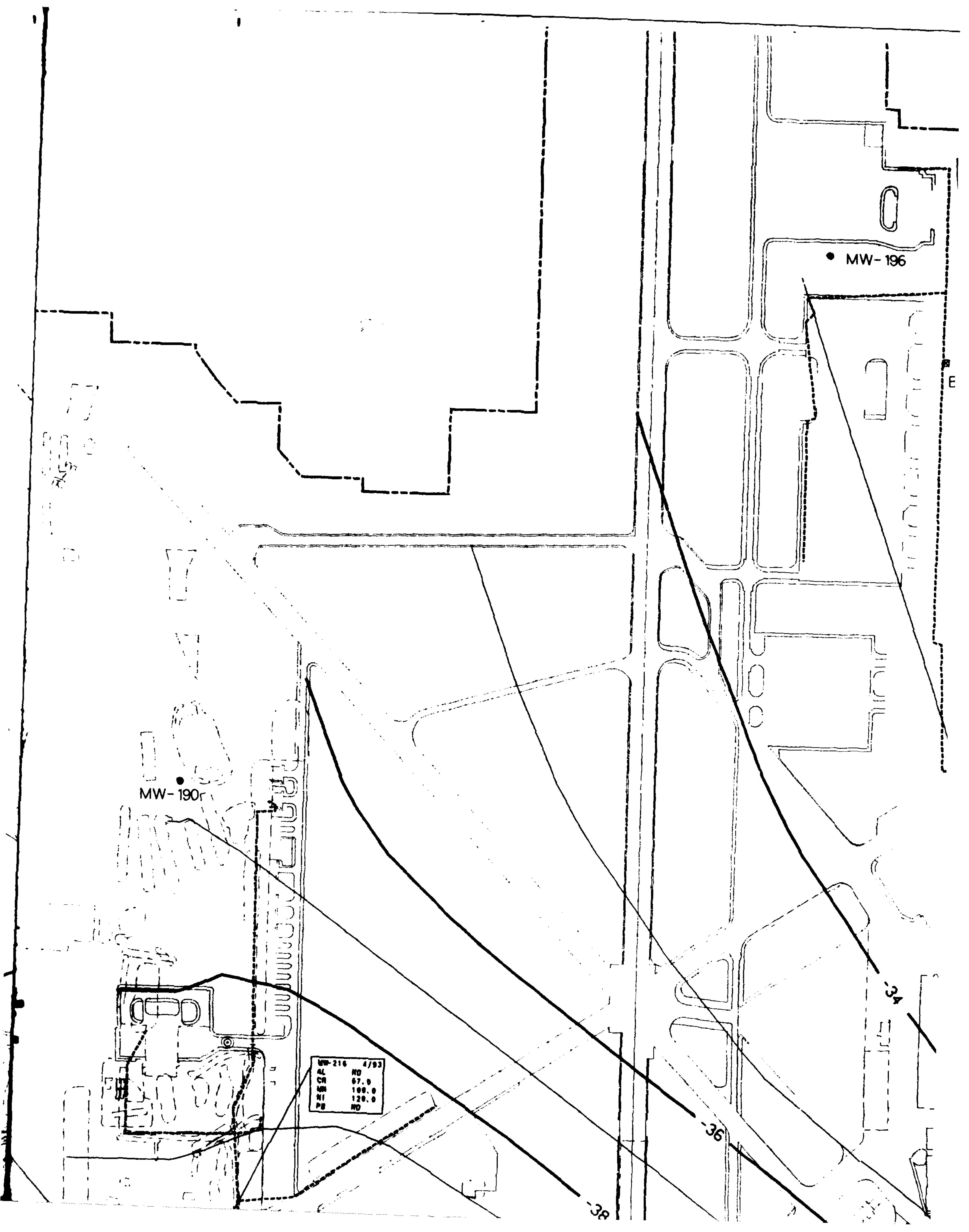
ER 1993 DATA

LED DURING

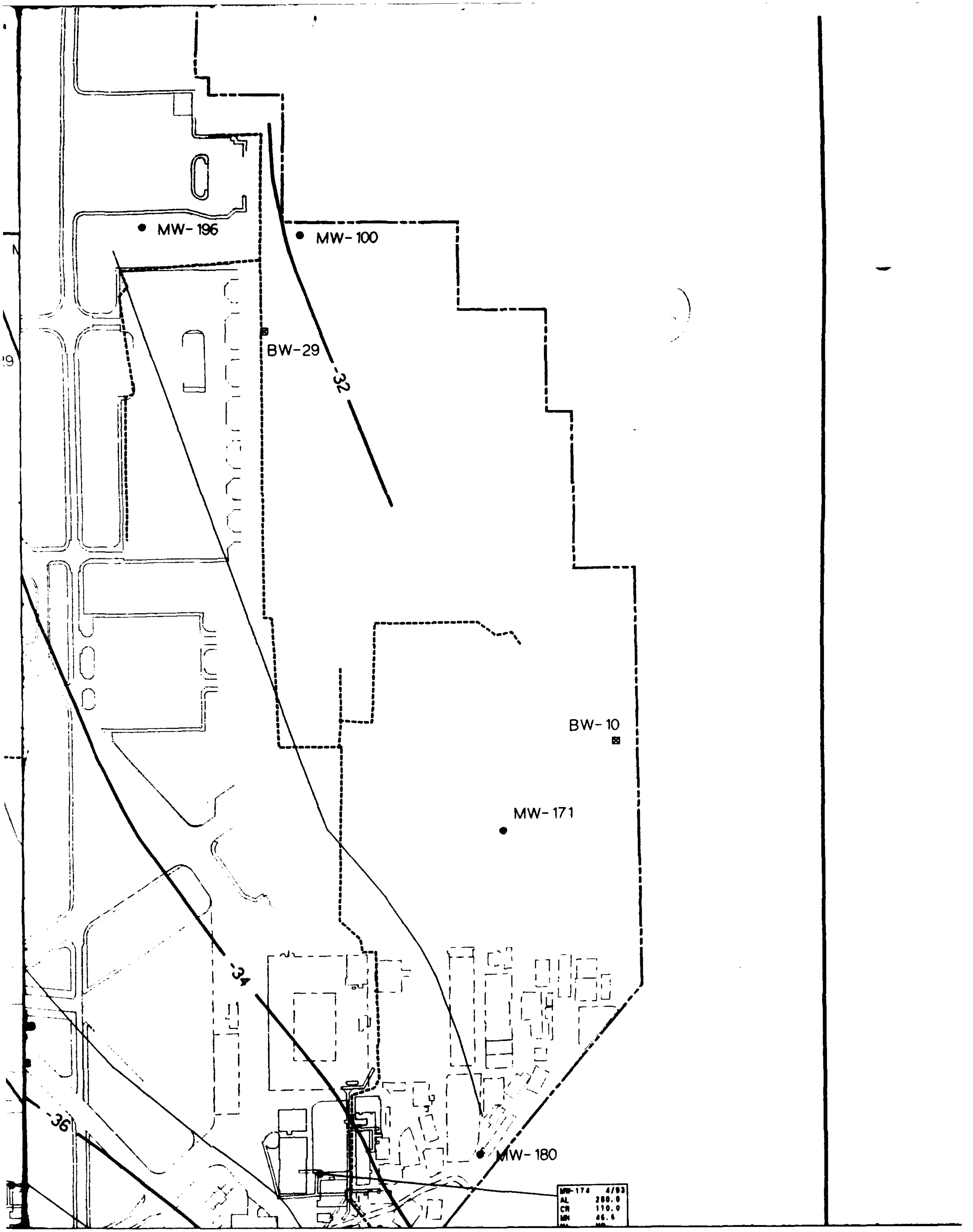


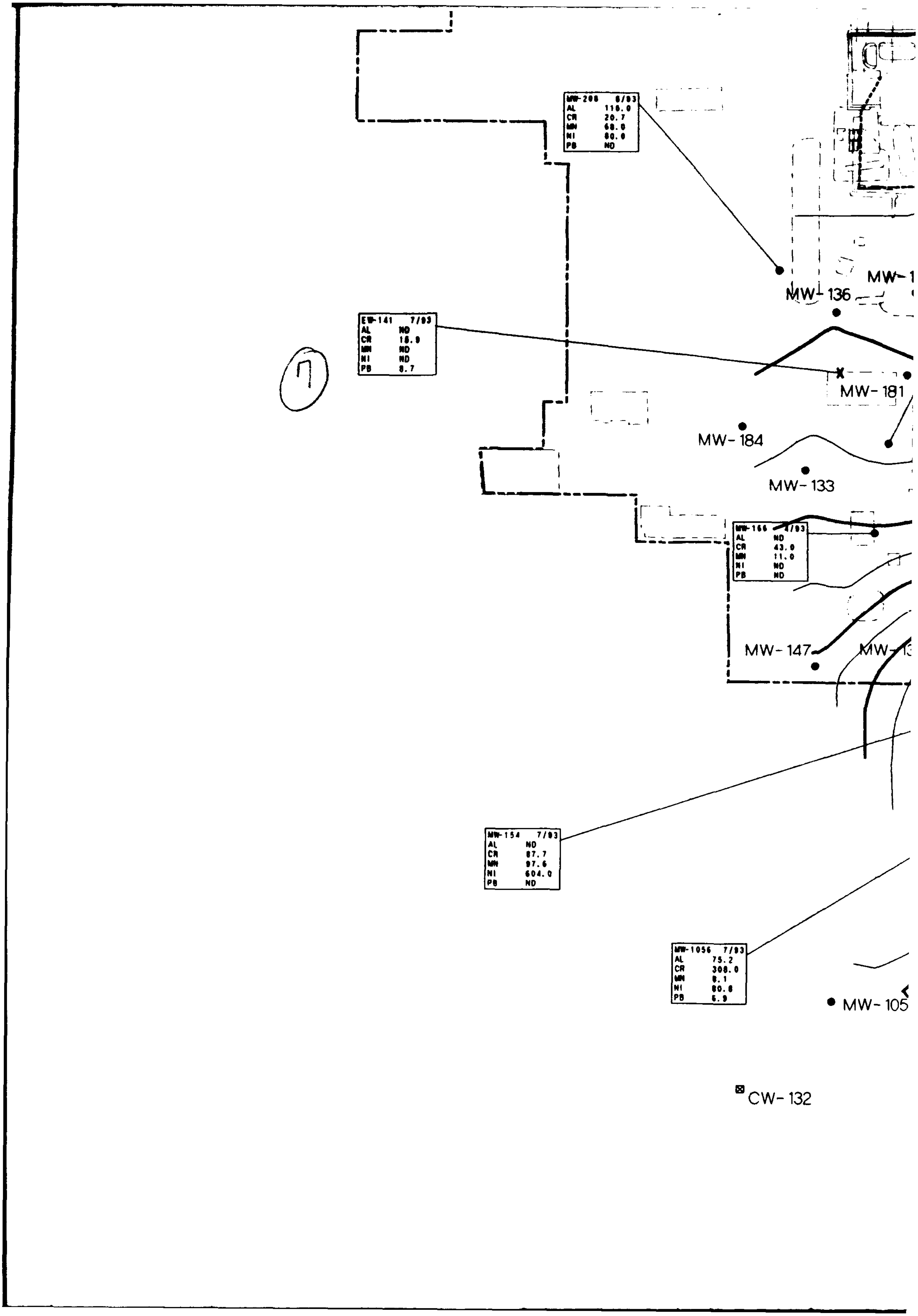

MW-1040
MW-196
MW-100


MW-1
MW-20S 8/93
AL 118.0
CR 20.7
MN 68.0
NI 60.0
PB ND

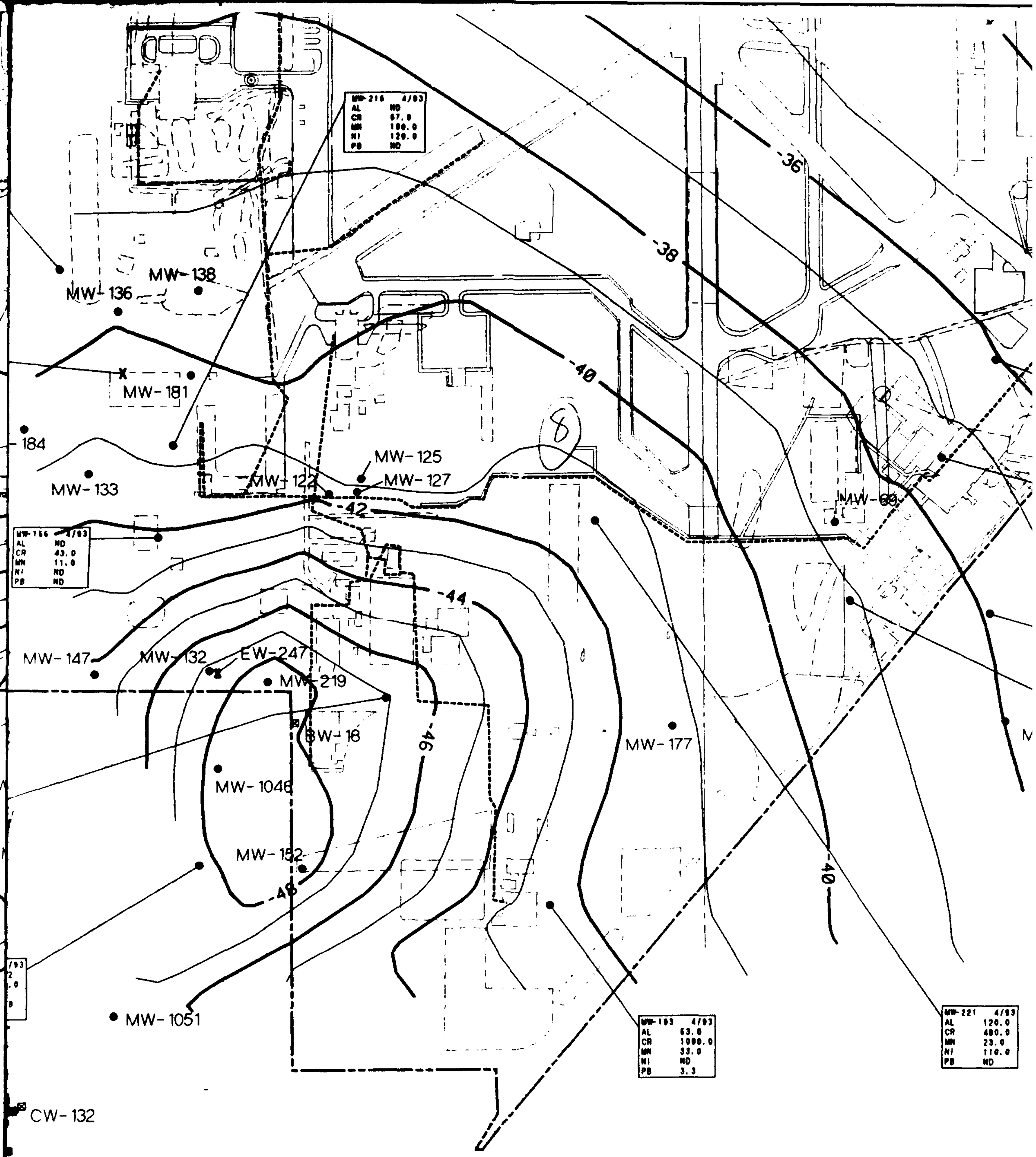


MW-196
E
MW-190
MW-216 4/93
AL ND
CR 67.0
MN 100.0
NI 120.0
PB ND
-34
-36
-38

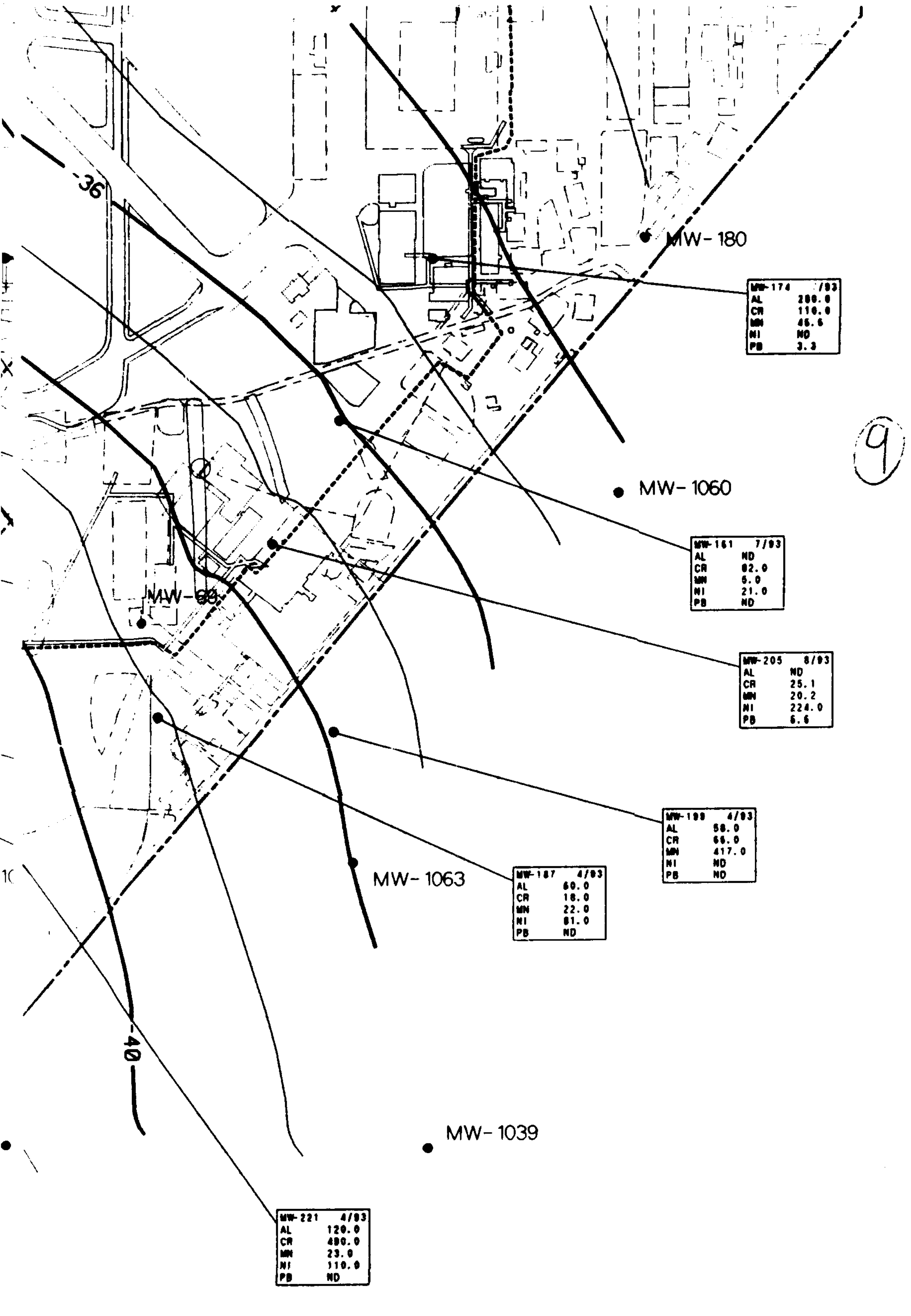

MW-196
MW-100
BW-29
32
BW-10
MW-171
34
36
MW-180
MW-174 4/93
AL 280.0
CR 110.0
MN 46.6

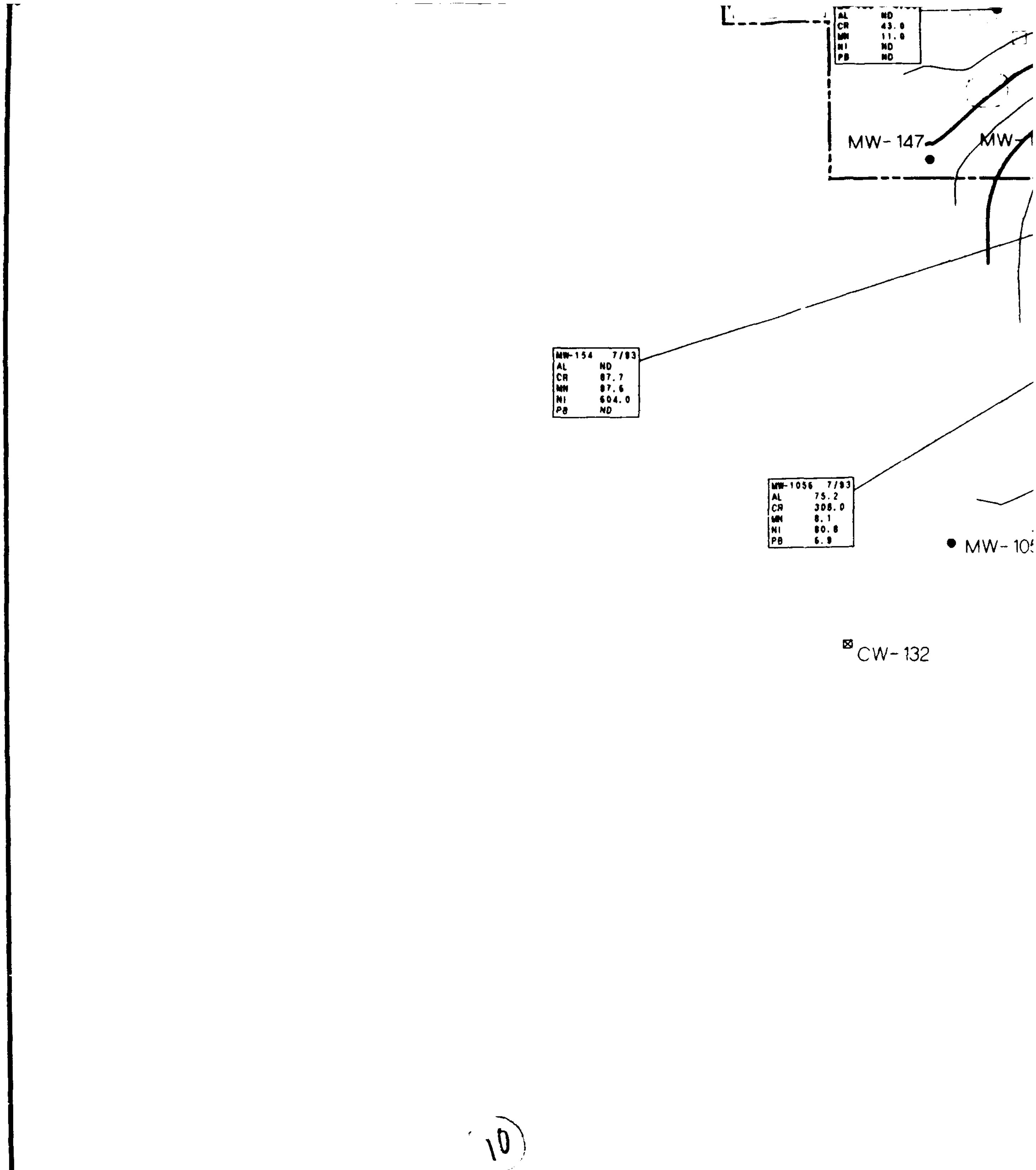


MW-208 6/93
AL 116.0
CR 20.7
MN 68.0
NI 80.0
PB ND
EW-141 7/93
AL ND
CR 16.9
MN ND
NI ND
PB 8.7
MW-136
MW-181
MW-184
MW-133
MW-166 4/93
AL ND
CR 43.0
MN 11.0
NI ND
PB ND
MW-147
MW-154 7/93
AL ND
CR 87.7
MN 97.6
NI 604.0
PB ND
MW-1056 7/93
AL 75.2
CR 308.0
MN 8.1
NI 80.6
PB 6.9
MW-105
CW-132



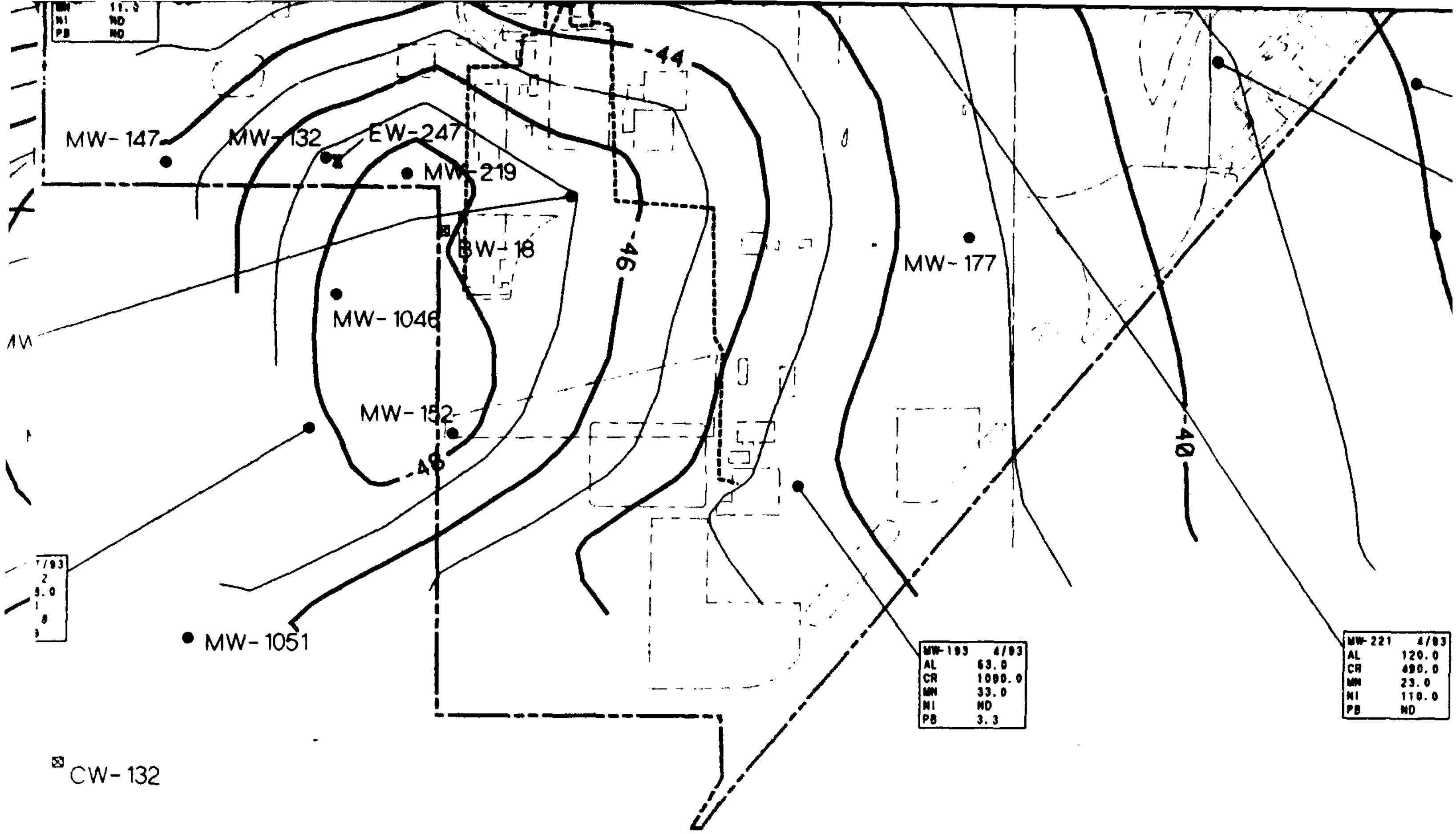
MW-216 4/93
AL ND
CR 67.0
MN 100.0
NI 120.0
PB ND
-36
-38
MW-138
MW-136
MW-181
-40
184
MW-125
MW-127
MW-122
MW-133
MW-99
-42
MW-166 4/93
AL ND
CR 43.0
MN 11.0
NI ND
PB ND
-44
MW-147
MW-132
EW-247
MW-219
BW-18
46
MW-177
MW-1046
MW-152
48
40
MW-1051
MW-193 4/93
AL 63.0
CR 1000.0
MN 33.0
NI ND
PB 3.3
MW-221 4/93
AL 120.0
CR 400.0
MN 23.0
NI 110.0
PB ND
CW-132


36
40
MW-180
MW-1060
MW-99
MW-1063
MW-1039
9
MW-174 /93
AL 280.0
CR 110.0
MN 46.6
NI ND
PB 3.3
MW-161 7/93
AL ND
CR 82.0
MN 5.0
NI 21.0
PB ND
MW-205 8/93
AL ND
CR 25.1
MN 20.2
NI 224.0
PB 6.6
MW-199 4/93
AL 58.0
CR 66.0
MN 417.0
NI ND
PB ND
MW-187 4/93
AL 60.0
CR 18.0
MN 22.0
NI 81.0
PB ND
MW-221 4/93
AL 120.0
CR 490.0
MN 23.0
NI 110.0
PB ND



RDD 1454 May, 1994

MEY94/4-64.DGN


MN 11.3
NI ND
PB ND
MW-147
MW-132
EW-247
MW-219
44
46
BW-18
MW-1046
MW-152
48
MW-177
40
MW-1051
MW-193 4/93
AL 63.0
CR 1000.0
MN 33.0
NI ND
PB 3.3
MW-221 4/93
AL 120.0
CR 490.0
MN 23.0
NI 110.0
PB ND
CW-132

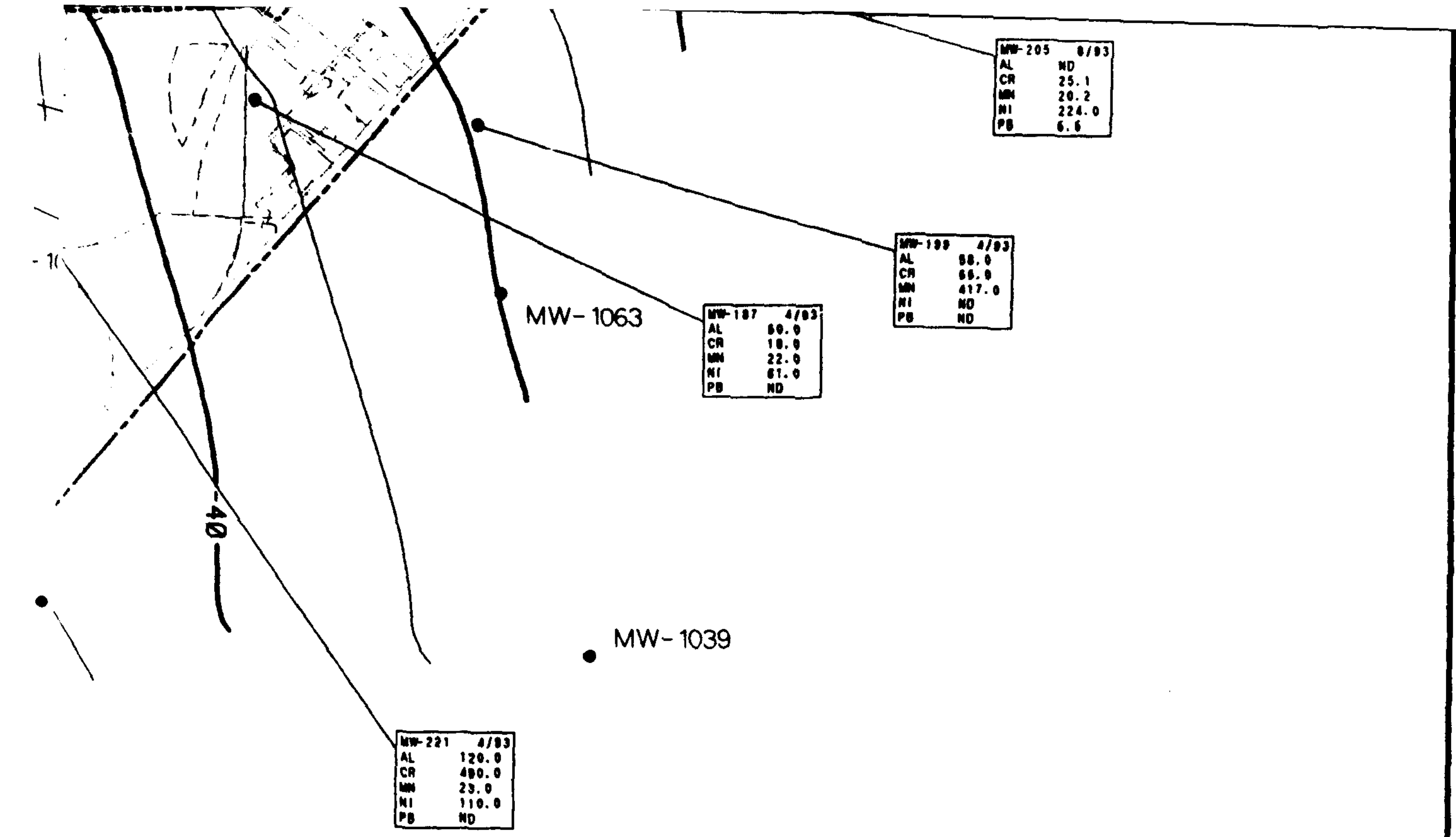
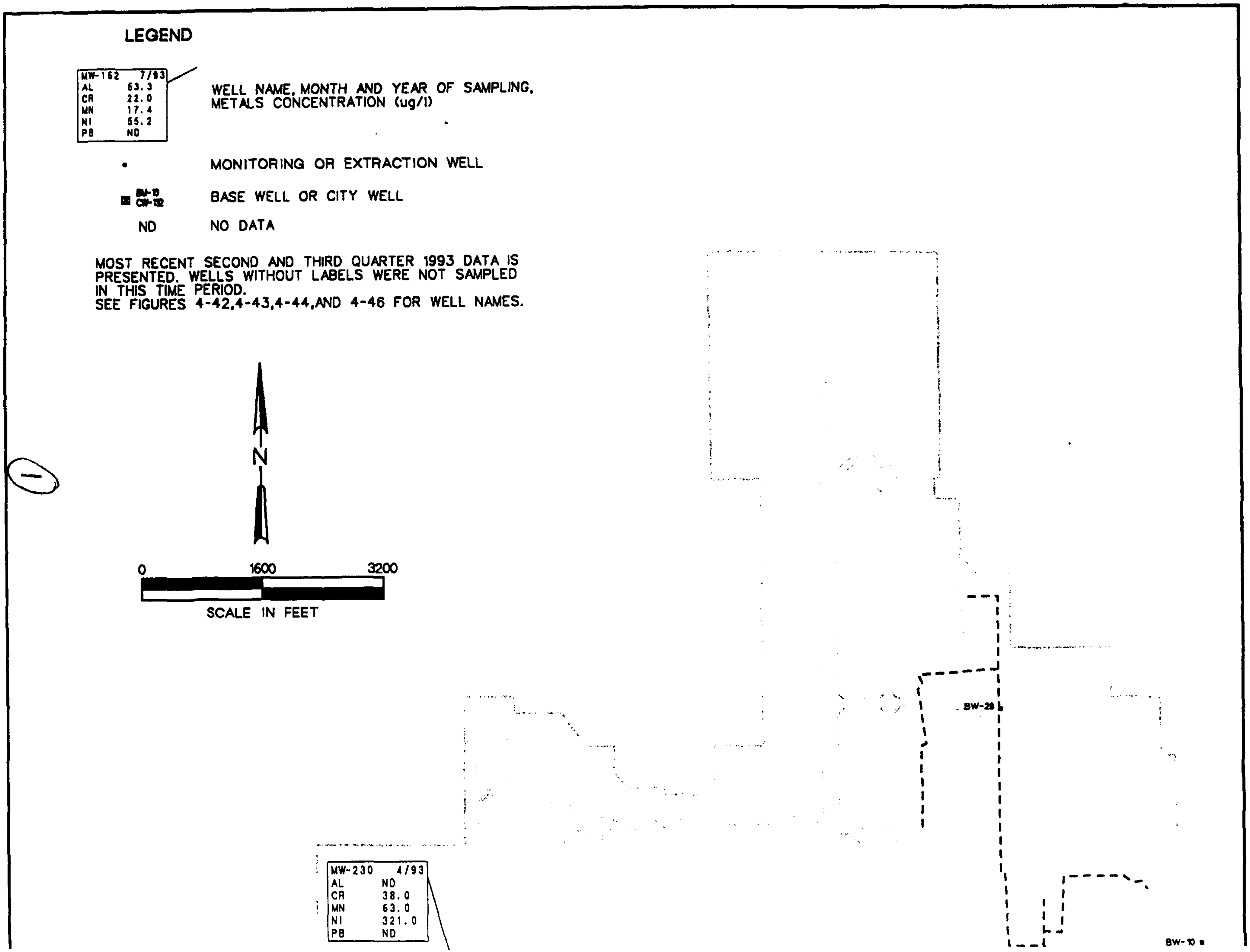


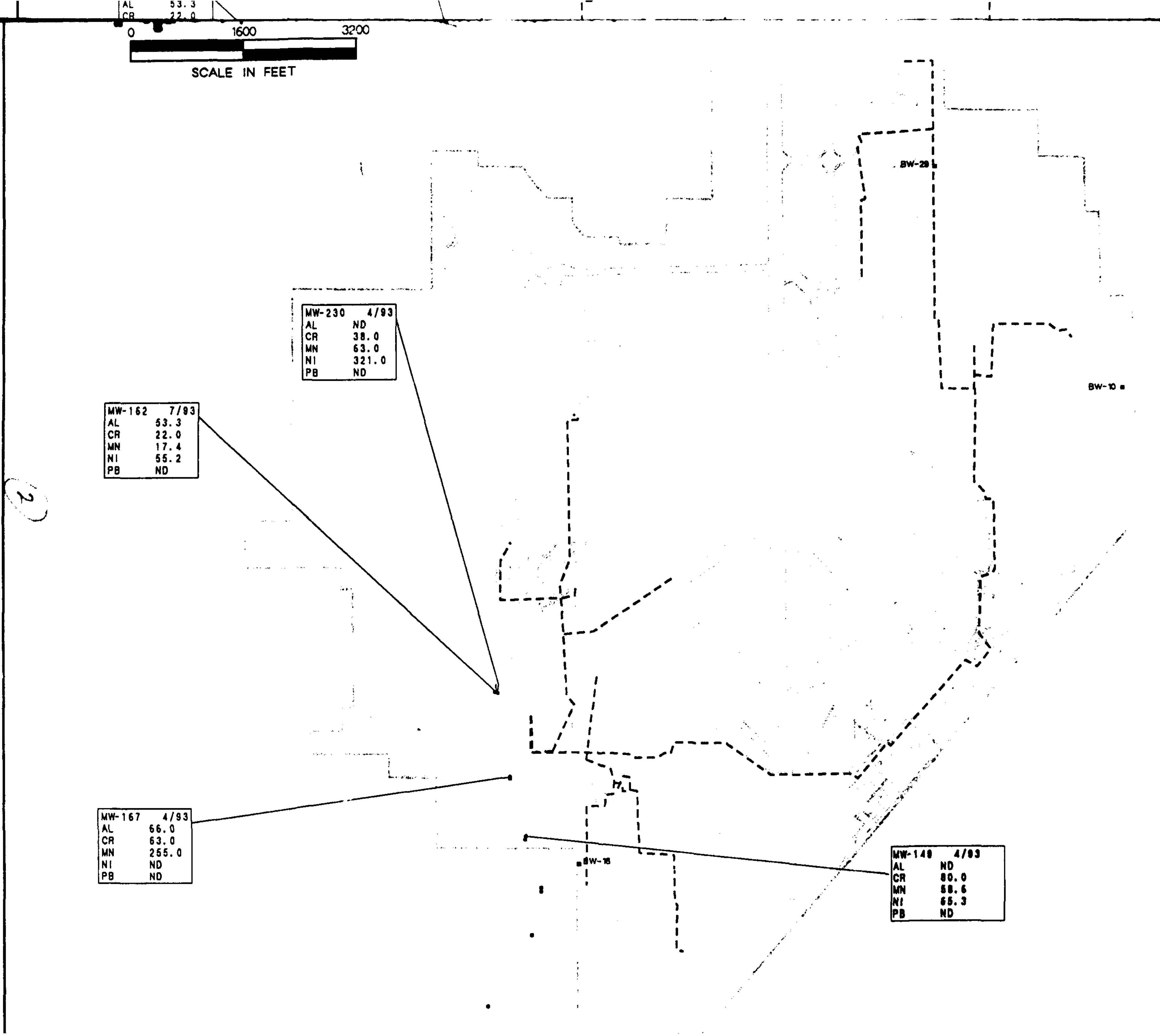
FIGURE 4-64
METALS CONCENTRATIONS IN MONITORING ZONE C

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

12


LEGEND
MW-162 7/93
AL 53.3
CR 22.0
MN 17.4
NI 55.2
PB ND
WELL NAME, MONTH AND YEAR OF SAMPLING, METALS CONCENTRATION (ug/l)
MONITORING OR EXTRACTION WELL
BW-19
CW-132
BASE WELL OR CITY WELL
ND
NO DATA
MOST RECENT SECOND AND THIRD QUARTER 1993 DATA IS PRESENTED. WELLS WITHOUT LABELS WERE NOT SAMPLED IN THIS TIME PERIOD.
SEE FIGURES 4-42,4-43,4-44,AND 4-46 FOR WELL NAMES.
N
0
1600
3200
SCALE IN FEET
BW-29
MW-230 4/93
AL ND
CR 38.0
MN 63.0
NI 321.0
PB ND
BW-10



AL 53.3
CR 22.0
0
1600
3200
SCALE IN FEET
MW-230 4/93
AL ND
CR 38.0
MN 63.0
NI 321.0
PB ND
MW-162 7/93
AL 53.3
CR 22.0
MN 17.4
NI 55.2
PB ND
MW-167 4/93
AL 66.0
CR 63.0
MN 255.0
NI ND
PB ND
MW-149 4/93
AL ND
CR 80.0
MN 58.6
NI 65.3
PB ND
BW-29
BW-10
BW-16
2

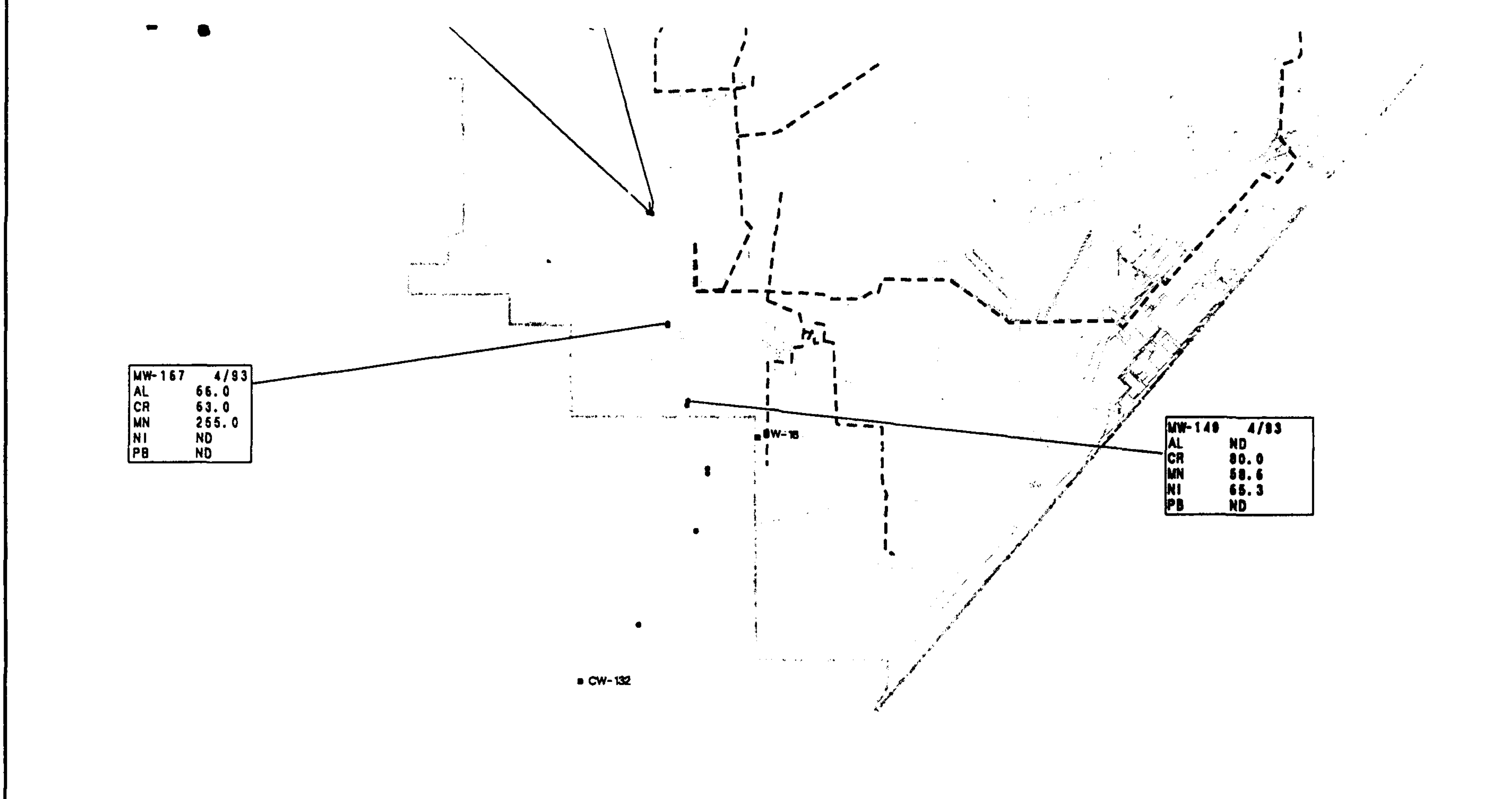
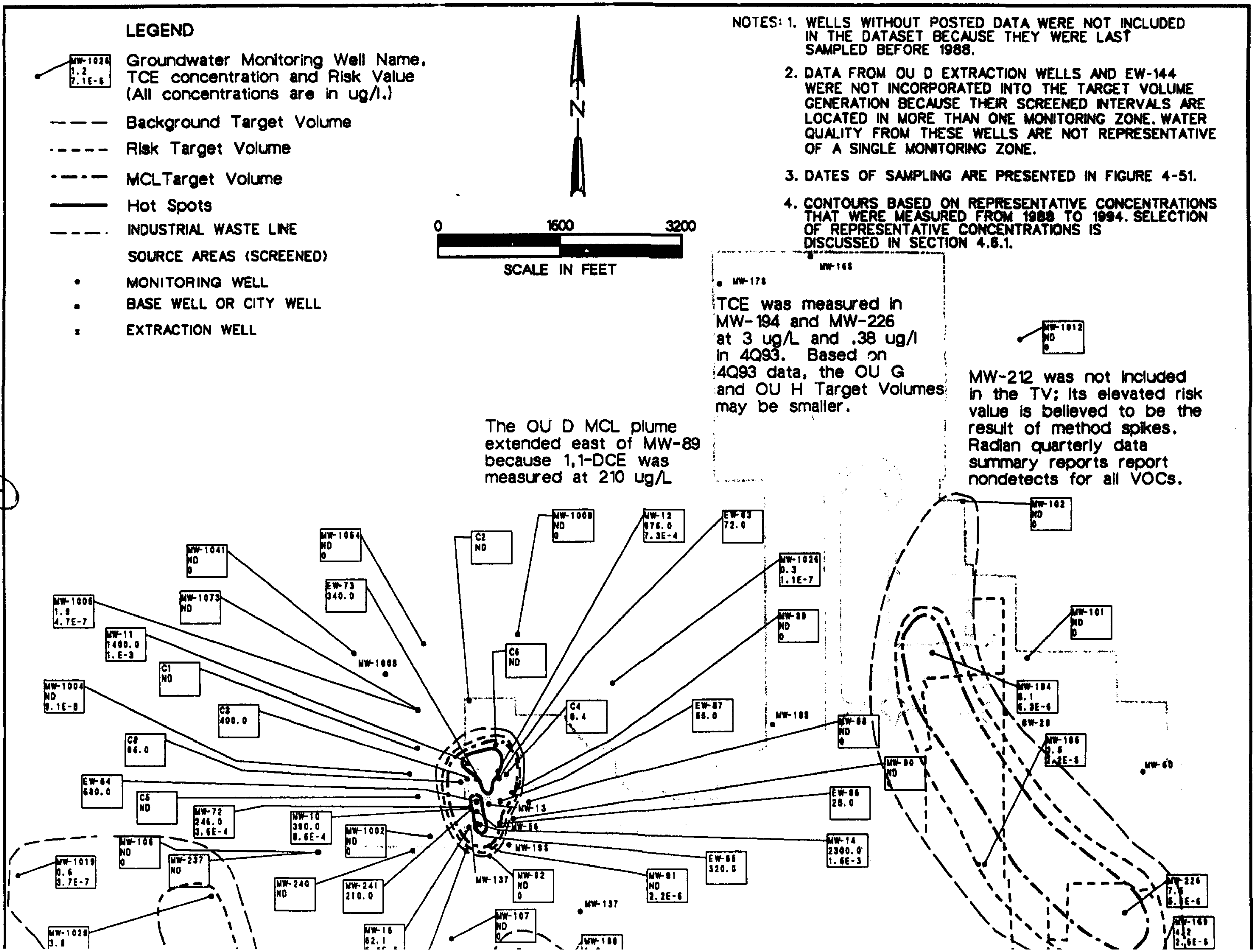


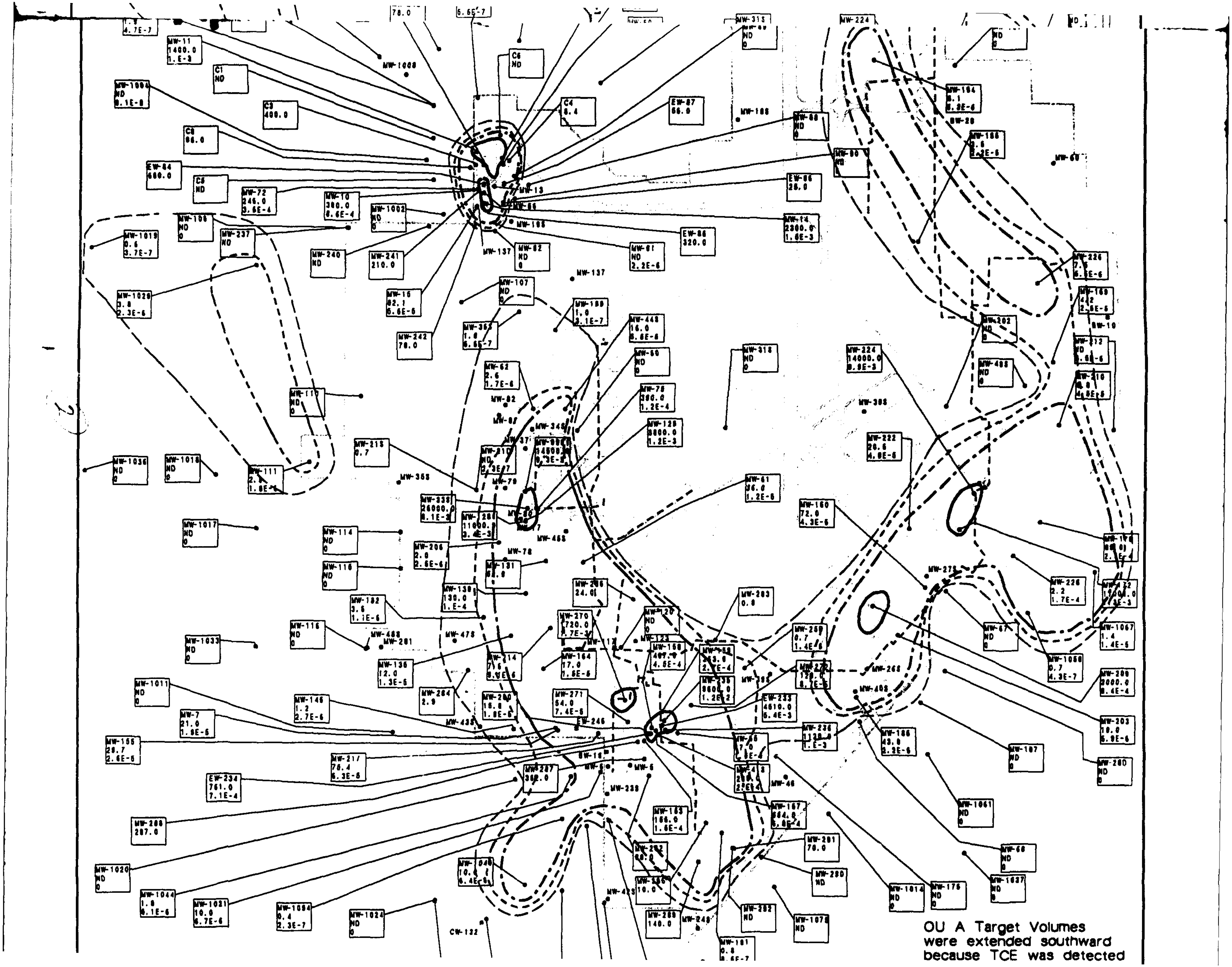
FIGURE 4-65
METALS CONCENTRATIONS
IN MONITORING ZONE D AND E
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

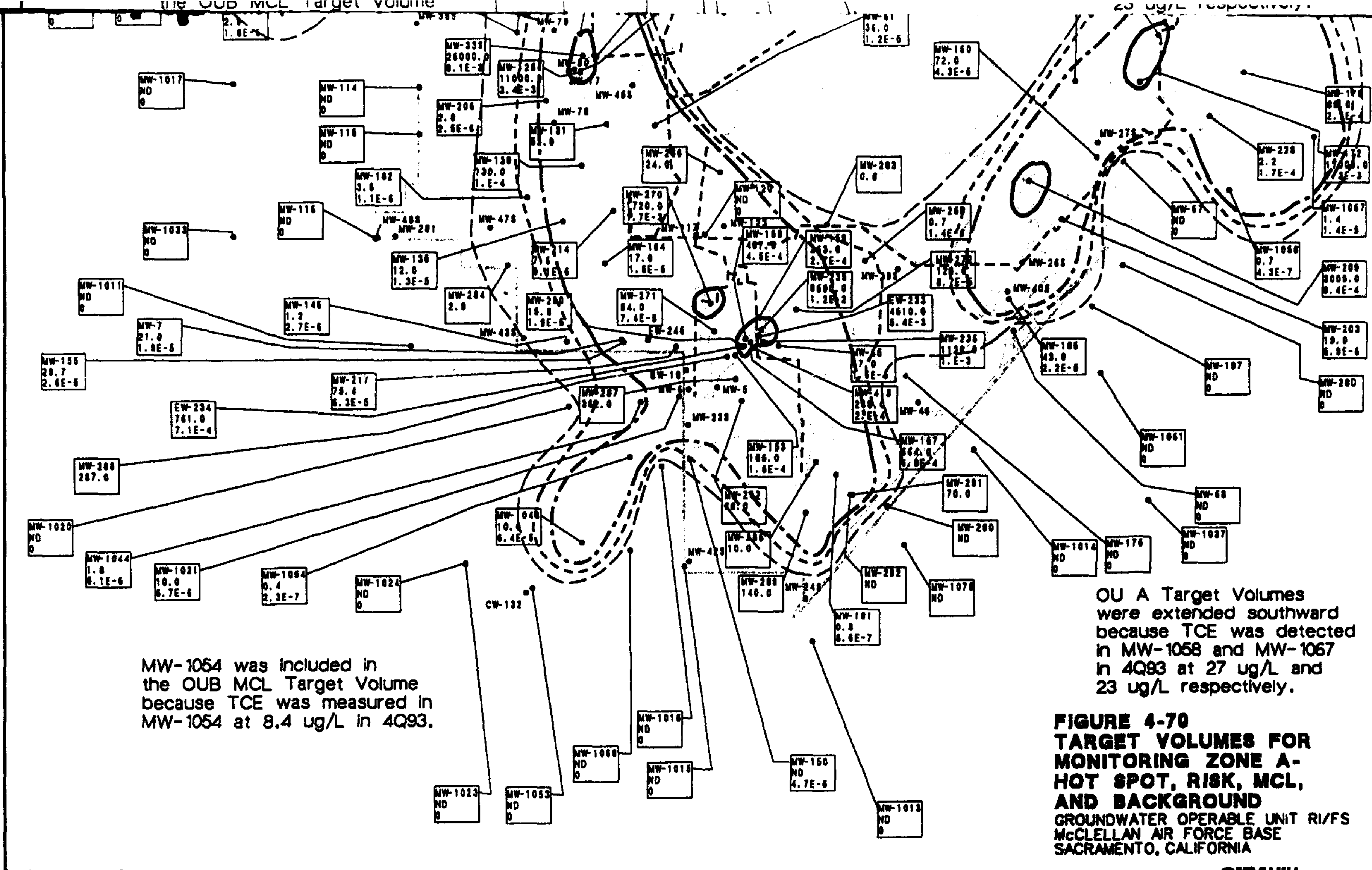
RDD1454
MEY94/4-65.DGN



LEGEND
Groundwater Monitoring Well Name, TCE concentration and Risk Value (All concentrations are in ug/l.)
Background Target Volume
Risk Target Volume
MCLTarget Volume
Hot Spots
INDUSTRIAL WASTE LINE
SOURCE AREAS (SCREENED)
MONITORING WELL
BASE WELL OR CITY WELL
EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
NOTES: 1. WELLS WITHOUT POSTED DATA WERE NOT INCLUDED IN THE DATASET BECAUSE THEY WERE LAST SAMPLED BEFORE 1988.
2. DATA FROM OU D EXTRACTION WELLS AND EW-144 WERE NOT INCORPORATED INTO THE TARGET VOLUME GENERATION BECAUSE THEIR SCREENED INTERVALS ARE LOCATED IN MORE THAN ONE MONITORING ZONE. WATER QUALITY FROM THESE WELLS ARE NOT REPRESENTATIVE OF A SINGLE MONITORING ZONE.
3. DATES OF SAMPLING ARE PRESENTED IN FIGURE 4-51.
4. CONTOURS BASED ON REPRESENTATIVE CONCENTRATIONS THAT WERE MEASURED FROM 1988 TO 1994. SELECTION OF REPRESENTATIVE CONCENTRATIONS IS DISCUSSED IN SECTION 4.6.1.
TCE was measured in MW-194 and MW-226 at 3 ug/L and .38 ug/l in 4Q93. Based on 4Q93 data, the OU G and OU H Target Volumes may be smaller.
MW-212 was not included in the TV; its elevated risk value is believed to be the result of method spikes. Radian quarterly data summary reports report nondetects for all VOCs.
The OU D MCL plume extended east of MW-89 because 1,1-DCE was measured at 210 ug/L



OU A Target Volumes
were extended southward
because TCE was detected



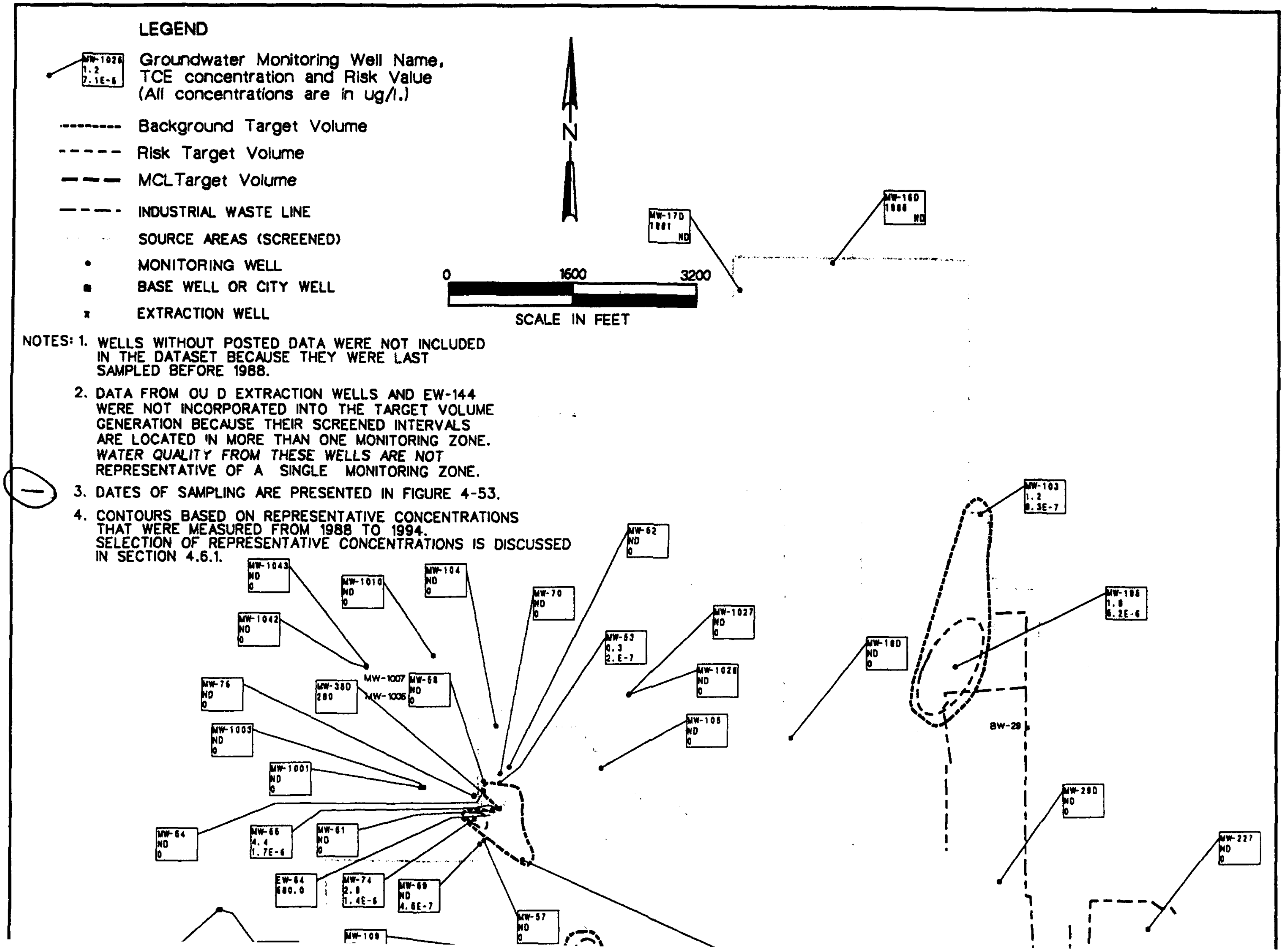
MW-1054 was included in the OUB MCL Target Volume because TCE was measured in MW-1054 at 8.4 ug/L in 4Q93.

OU A Target Volumes were extended southward because TCE was detected in MW-1058 and MW-1067 in 4Q93 at 27 ug/L and 23 ug/L respectively.

FIGURE 4-70
TARGET VOLUMES FOR MONITORING ZONE A-HOT SPOT, RISK, MCL, AND BACKGROUND
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454 MAY, 1994
MEY94/4-70.DGN

CH2M HILL

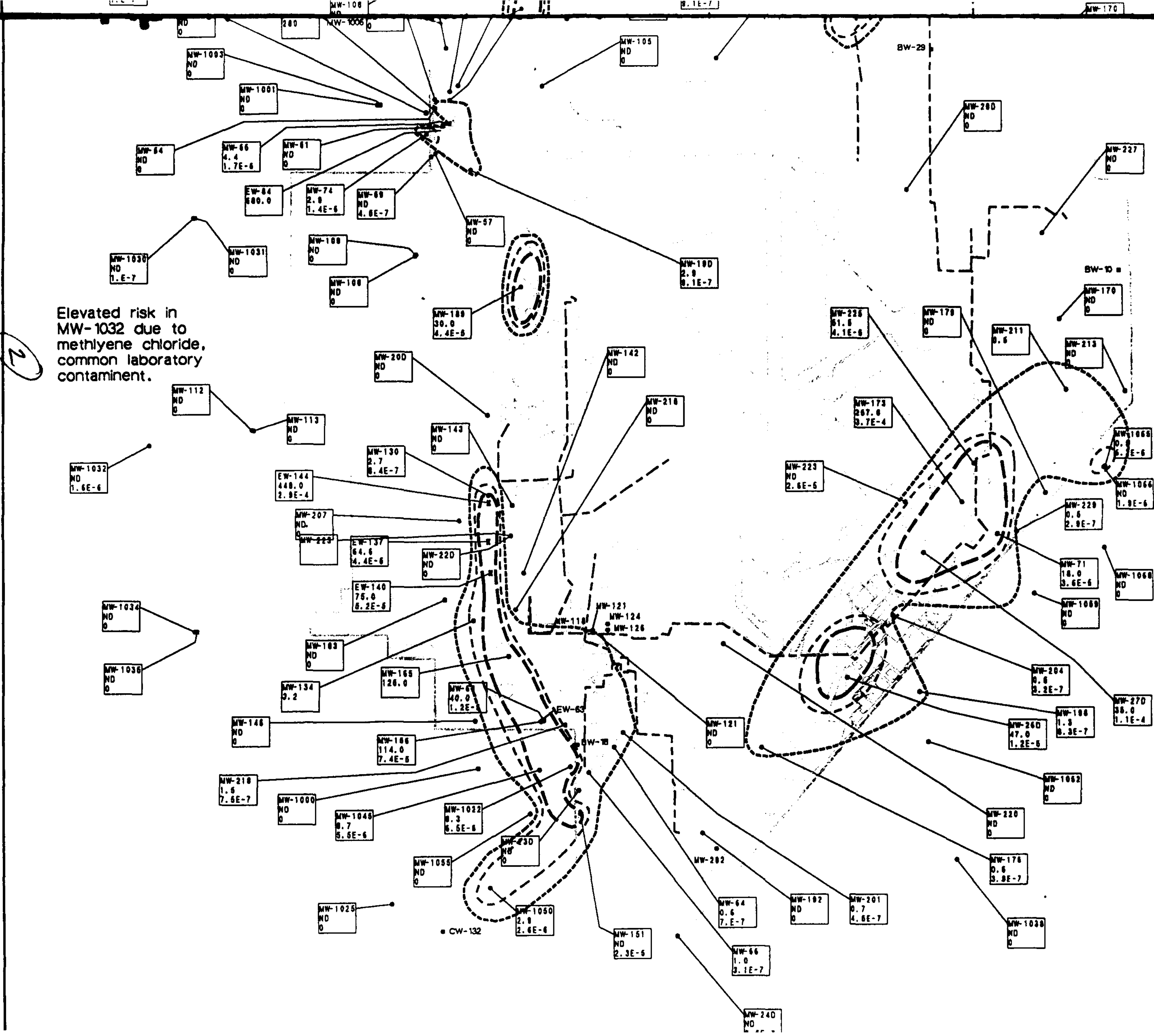


NOTES: 1. WELLS WITHOUT POSTED DATA WERE NOT INCLUDED IN THE DATASET BECAUSE THEY WERE LAST SAMPLED BEFORE 1988.

2. DATA FROM OU D EXTRACTION WELLS AND EW-144 WERE NOT INCORPORATED INTO THE TARGET VOLUME GENERATION BECAUSE THEIR SCREENED INTERVALS ARE LOCATED IN MORE THAN ONE MONITORING ZONE. *WATER QUALITY FROM THESE WELLS ARE NOT* REPRESENTATIVE OF A SINGLE MONITORING ZONE.

3. DATES OF SAMPLING ARE PRESENTED IN FIGURE 4-53.

4. CONTOURS BASED ON REPRESENTATIVE CONCENTRATIONS THAT WERE MEASURED FROM 1988 TO 1994. SELECTION OF REPRESENTATIVE CONCENTRATIONS IS DISCUSSED IN SECTION 4.6.1.


Elevated risk in MW-1032 due to methlyene chloride, common laboratory contaminent.
2
MW-1003 ND 0
MW-1001 ND 0
MW-105 ND 0
MW-64 ND 0
MW-66 4.4 1.7E-6
MW-61 ND 0
EW-84 580.0
MW-74 2.9 1.4E-6
MW-69 ND 4.6E-7
MW-57 ND 0
MW-1030 ND 1.E-7
MW-1031 ND 0
MW-108 ND 0
MW-109 ND 0
MW-19D 2.9 8.1E-7
MW-189 30.0 4.4E-6
MW-28D ND 0
MW-227 ND 0
BW-29
BW-10
MW-170 ND 0
MW-112 ND 0
MW-113 ND 0
MW-1032 ND 1.6E-6
MW-20D ND 0
MW-142 ND 0
MW-216 ND 0
MW-143 ND 0
MW-130 2.7 8.4E-7
EW-144 448.0 2.9E-4
MW-207 ND 0
MW-223
EW-137 64.6 4.4E-6
MW-220 ND 0
EW-140 75.0 5.2E-6
MW-1034 ND 0
MW-1036 ND 0
MW-183 ND 0
MW-134 3.2
MW-165 126.0
MW-146 ND 0
MW-166 114.0 7.4E-5
MW-218 1.5 7.5E-7
MW-1000 ND 0
MW-1046 8.7 5.5E-6
MW-1022 8.3 6.5E-6
MW-1055 ND 0
MW-230 ND 0
MW-1025 ND 0
MW-1050 2.9 2.6E-6
CW-132
MW-151 ND 2.3E-5
MW-121
MW-124
MW-126
MW-118
EW-63
SW-18
MW-121 ND 0
MW-226 51.5 4.1E-6
MW-179 ND 0
MW-211 0.5
MW-213 ND 0
MW-173 267.6 3.7E-4
MW-223 ND 2.6E-6
MW-1066 ND 1.9E-6
MW-229 0.5 2.9E-7
MW-71 18.0 3.6E-6
MW-1068 ND 0
MW-1069 ND 0
MW-204 0.6 3.2E-7
MW-270 35.0 1.1E-4
MW-186 1.3 8.3E-7
MW-26D 47.0 1.2E-5
MW-1062 ND 0
MW-220 ND 0
MW-176 0.5 3.9E-7
MW-282
MW-64 0.6 7.E-7
MW-192 ND 0
MW-201 0.7 4.6E-7
MW-1038 ND 0
MW-66 1.0 3.1E-7
MW-240 ND

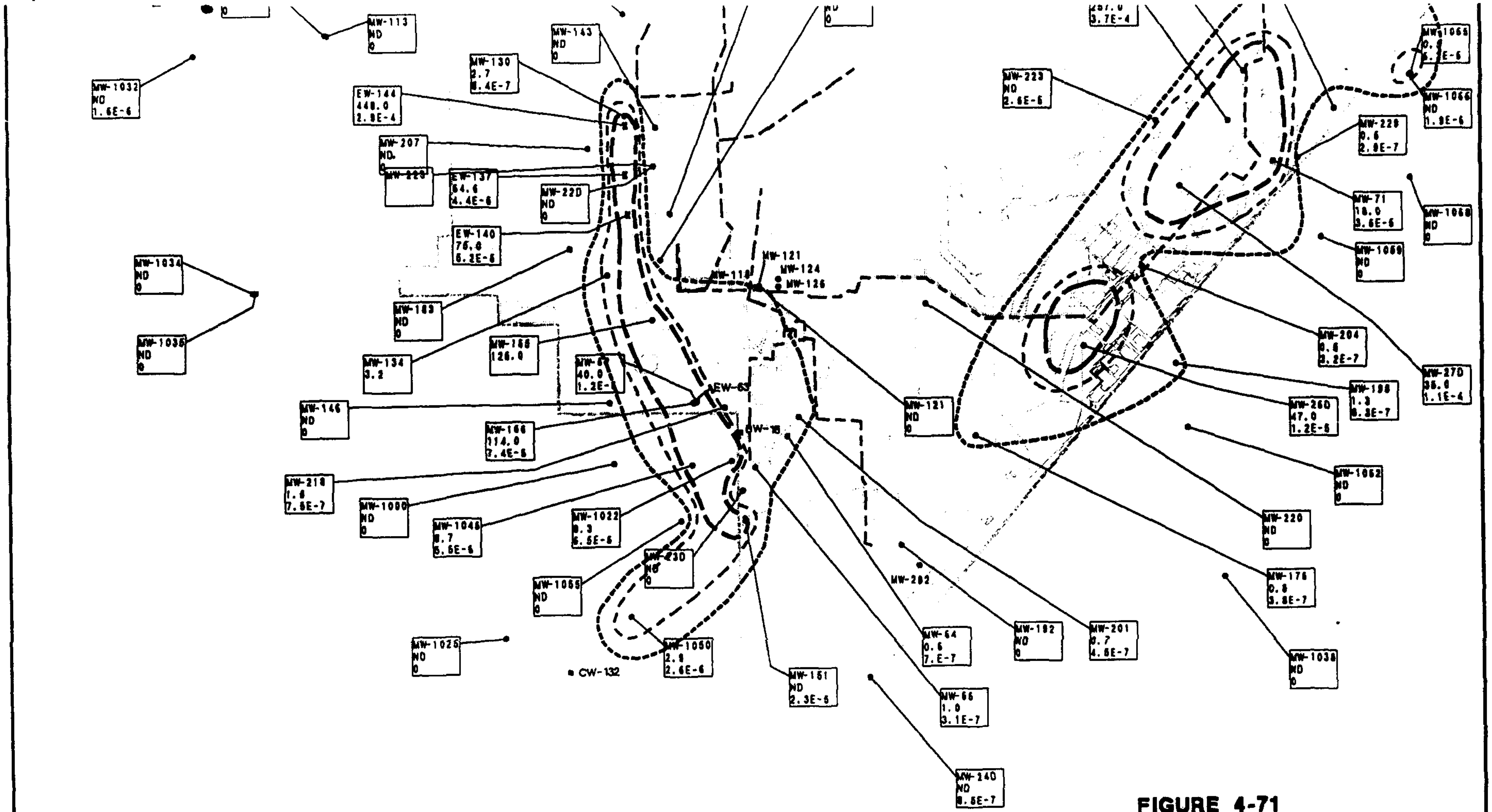
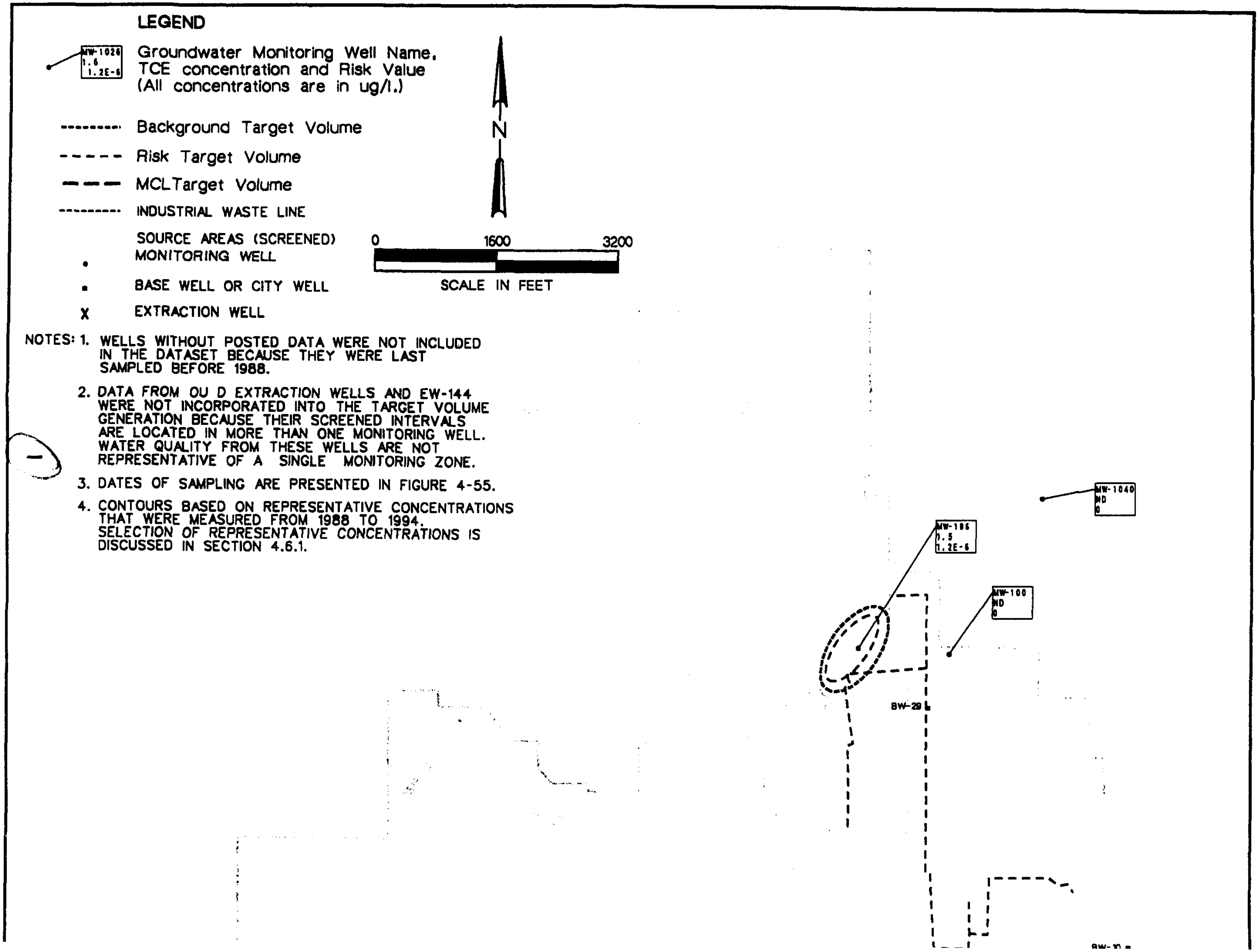
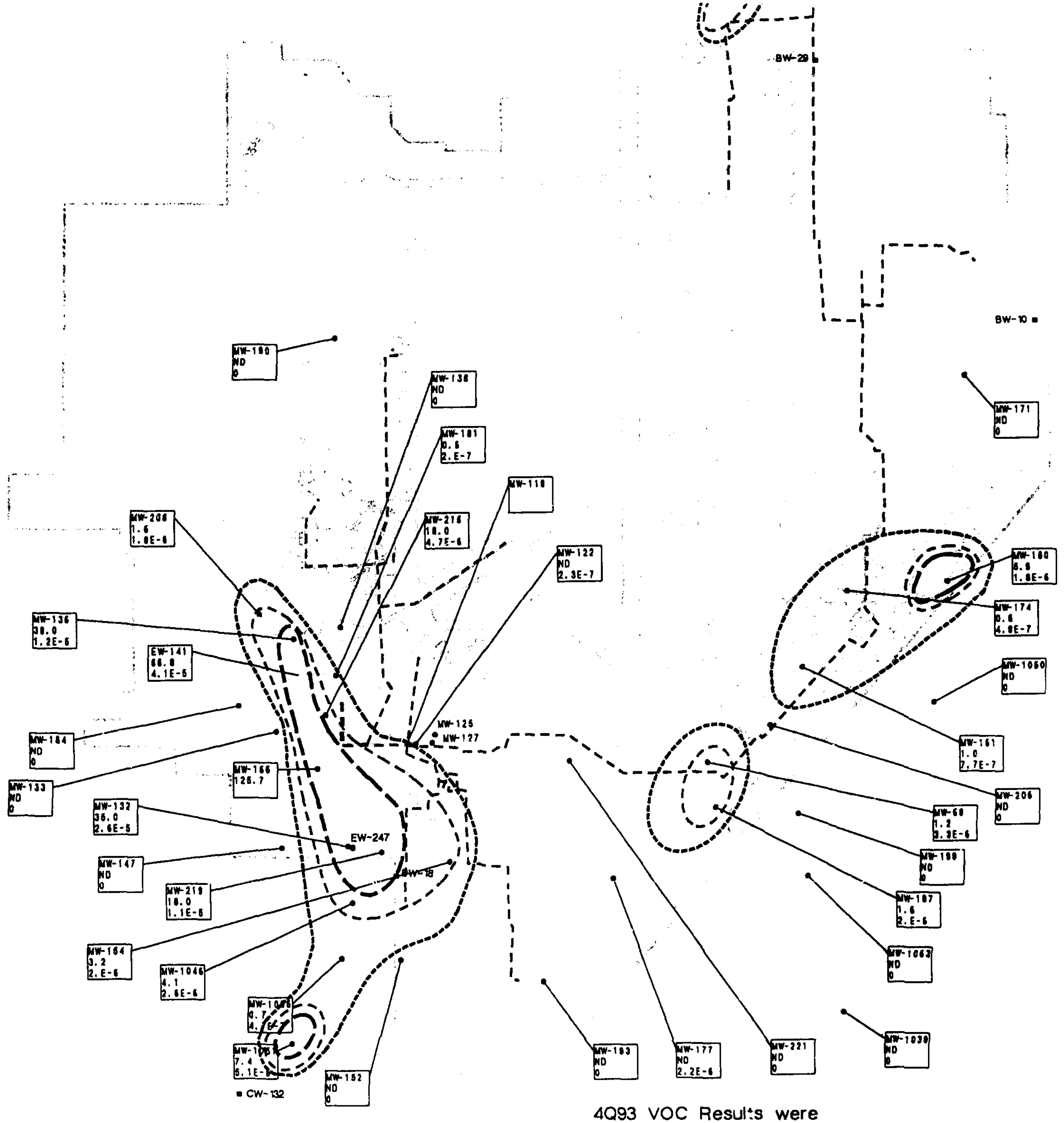


FIGURE 4-71
TARGET VOLUMES FOR MONITORING ZONE B-RISK, MCL, AND BACKGROUND
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454 MAY, 1994
may94/4-71.dgn


LEGEND
MW-1026
1.6
1.2E-6
Groundwater Monitoring Well Name, TCE concentration and Risk Value (All concentrations are in ug/l.)
Background Target Volume
Risk Target Volume
MCLTarget Volume
INDUSTRIAL WASTE LINE
SOURCE AREAS (SCREENED) MONITORING WELL
BASE WELL OR CITY WELL
X EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
NOTES: 1. WELLS WITHOUT POSTED DATA WERE NOT INCLUDED IN THE DATASET BECAUSE THEY WERE LAST SAMPLED BEFORE 1988.
2. DATA FROM OU D EXTRACTION WELLS AND EW-144 WERE NOT INCORPORATED INTO THE TARGET VOLUME GENERATION BECAUSE THEIR SCREENED INTERVALS ARE LOCATED IN MORE THAN ONE MONITORING WELL. WATER QUALITY FROM THESE WELLS ARE NOT REPRESENTATIVE OF A SINGLE MONITORING ZONE.
3. DATES OF SAMPLING ARE PRESENTED IN FIGURE 4-55.
4. CONTOURS BASED ON REPRESENTATIVE CONCENTRATIONS THAT WERE MEASURED FROM 1988 TO 1994. SELECTION OF REPRESENTATIVE CONCENTRATIONS IS DISCUSSED IN SECTION 4.6.1.
MW-1040
ND
0
MW-186
1.5
1.2E-6
MW-100
ND
0
BW-29



4Q93 VOC Results were nondetect. Risk and MCL Target Volumes in OUA [illegible] 4Q93 VOC results.

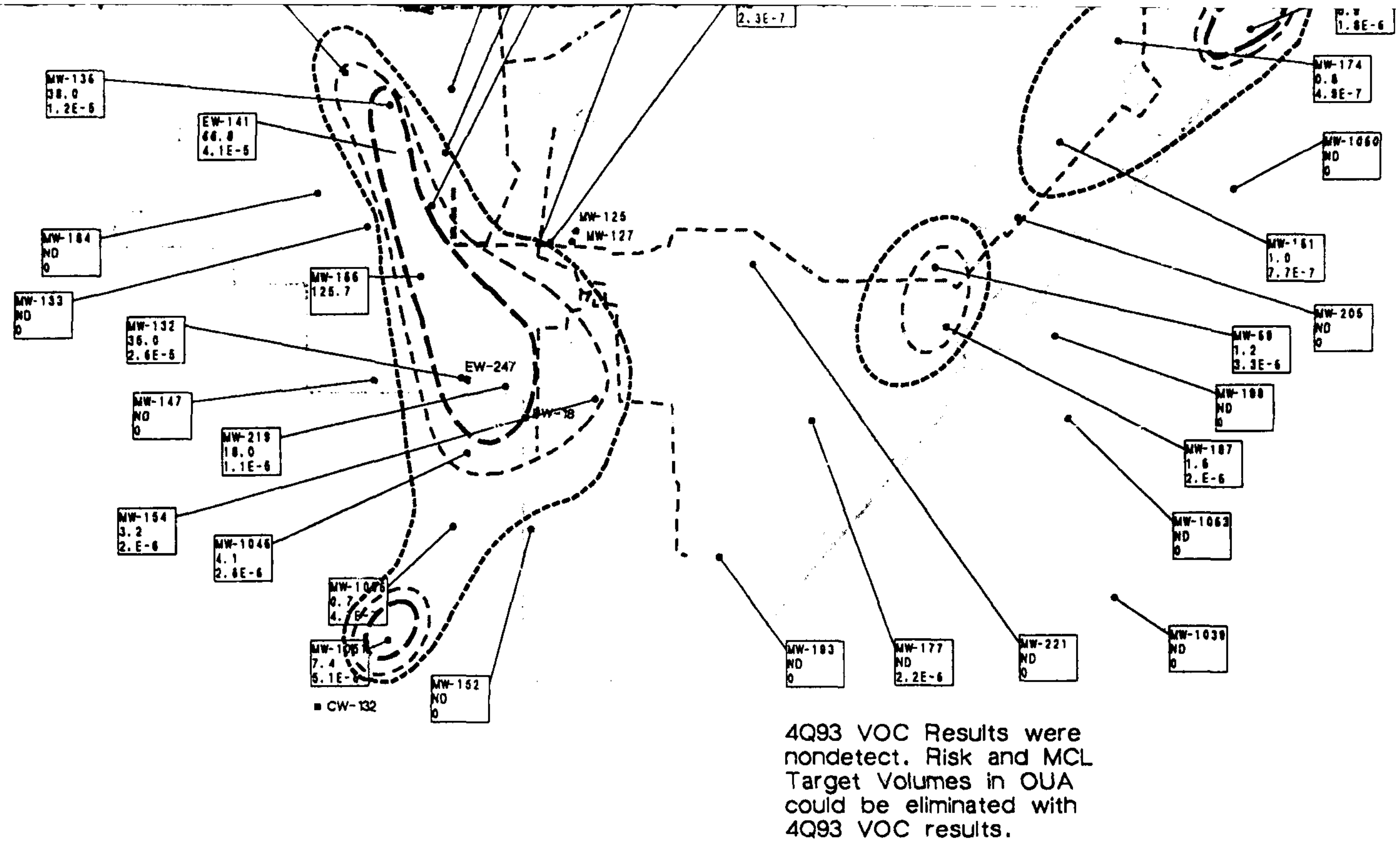
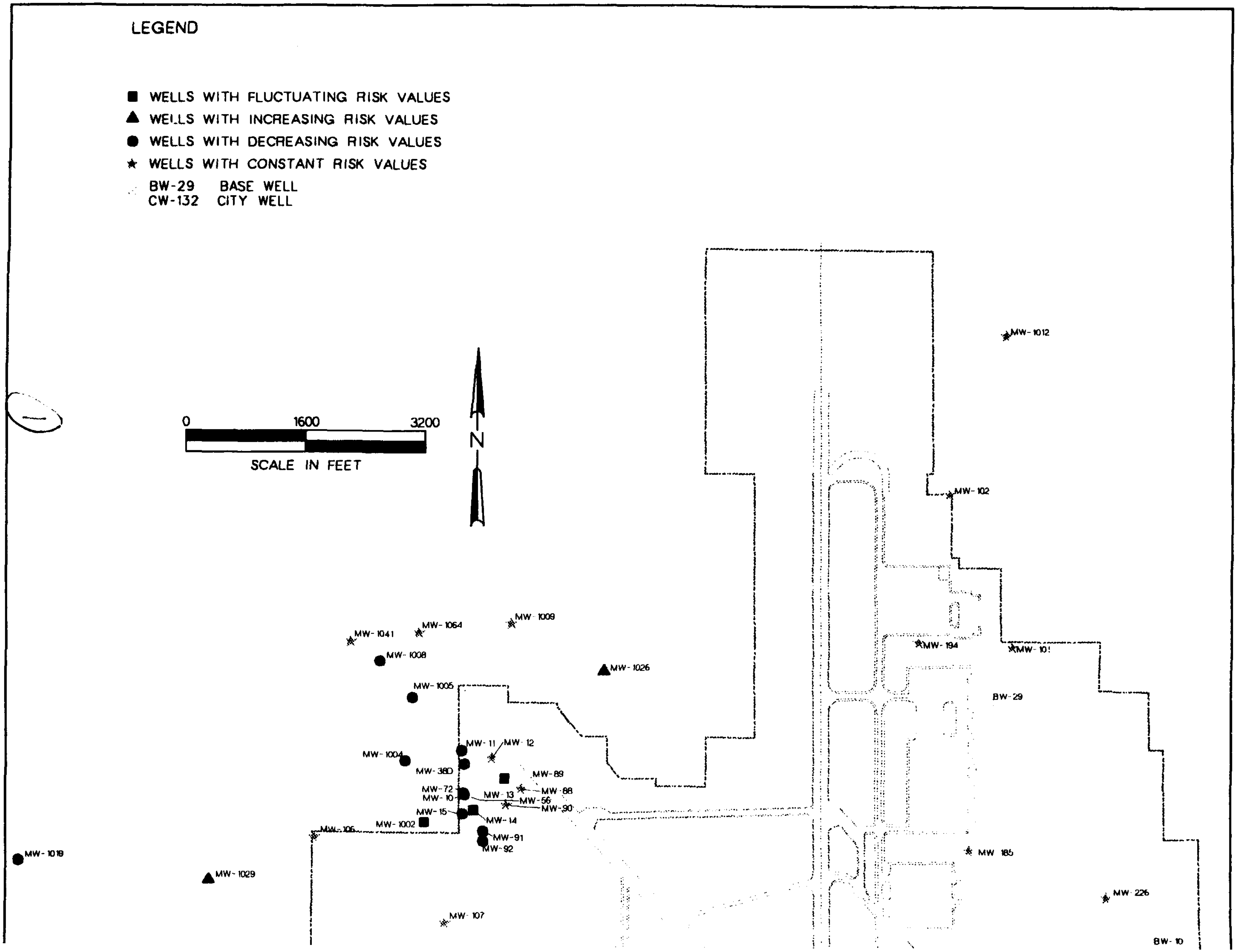


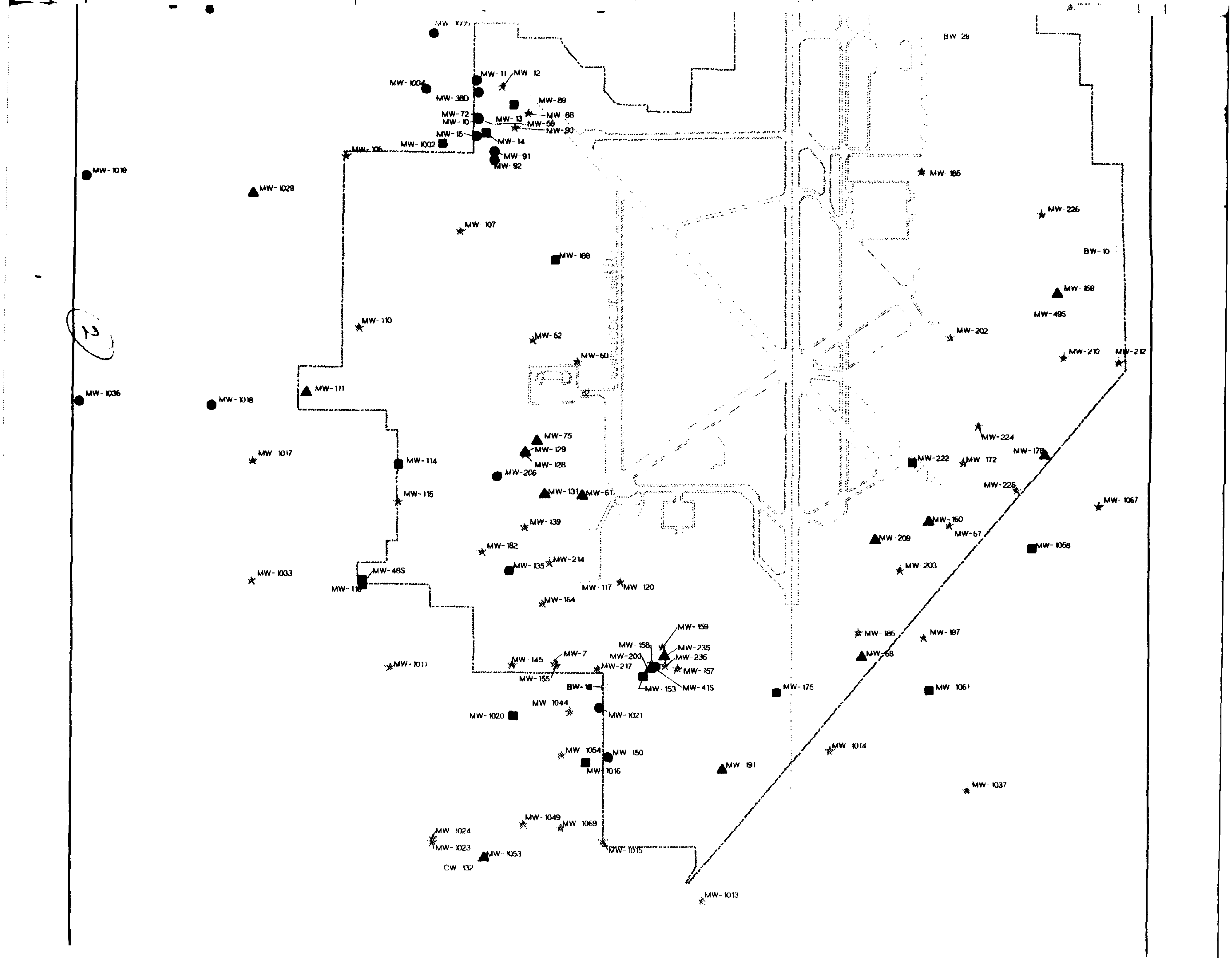
FIGURE 4-72
TARGET VOLUMES FOR MONITORING ZONE C RISK, MCL, AND BACKGROUND
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454 MAY, 1994
Mwy94/4-72.dgn



LEGEND
WELLS WITH FLUCTUATING RISK VALUES
WELLS WITH INCREASING RISK VALUES
WELLS WITH DECREASING RISK VALUES
WELLS WITH CONSTANT RISK VALUES
BW-29 BASE WELL
CW-132 CITY WELL
0
1600
3200
SCALE IN FEET
N
MW-1012
MW-102
MW-194
MW-101
BW-29
MW-1009
MW-1064
MW-1041
MW-1008
MW-1026
MW-1005
MW-11
MW-12
MW-1004
MW-38D
MW-89
MW-72
MW-10
MW-13
MW-88
MW-56
MW-90
MW-15
MW-14
MW-1002
MW-106
MW-91
MW-92
MW-1019
MW-1029
MW-107
MW 185
MW-226
BW-10


MW-1009
BW-29
MW-11
MW 12
MW-1004
MW-38D
MW-89
MW-72
MW-13
MW-88
MW-10
MW-56
MW-90
MW-15
MW-14
MW-1002
MW-105
MW-91
MW-92
MW-185
MW-1019
MW-1029
MW-226
MW-107
MW-188
BW-10
MW-169
MW-49S
MW-110
MW-62
MW-202
MW-60
MW-210
MW-212
MW-111
MW-1036
MW-1018
MW-75
MW-224
MW-129
MW 1017
MW-114
MW-128
MW-178
MW-222
MW 172
MW-206
MW-228
MW-115
MW-131
MW-61
MW-1067
MW-139
MW-160
MW-209
MW-67
MW-182
MW-1058
MW-214
MW-135
MW-203
MW-1033
MW-48S
MW-116
MW-117
MW-120
MW-164
MW-159
MW-158
MW-235
MW-186
MW-197
MW-200
MW-236
MW-7
MW-68
MW-1011
MW-145
MW-217
MW-157
MW-155
BW-18
MW-153
MW-41S
MW-175
MW 1061
MW 1044
MW-1020
MW-1021
MW 1054
MW 150
MW 1014
MW-191
MW 1016
MW-1037
MW-1049
MW-1069
MW 1024
MW-1023
MW-1015
MW-1053
CW-132
MW-1013
2

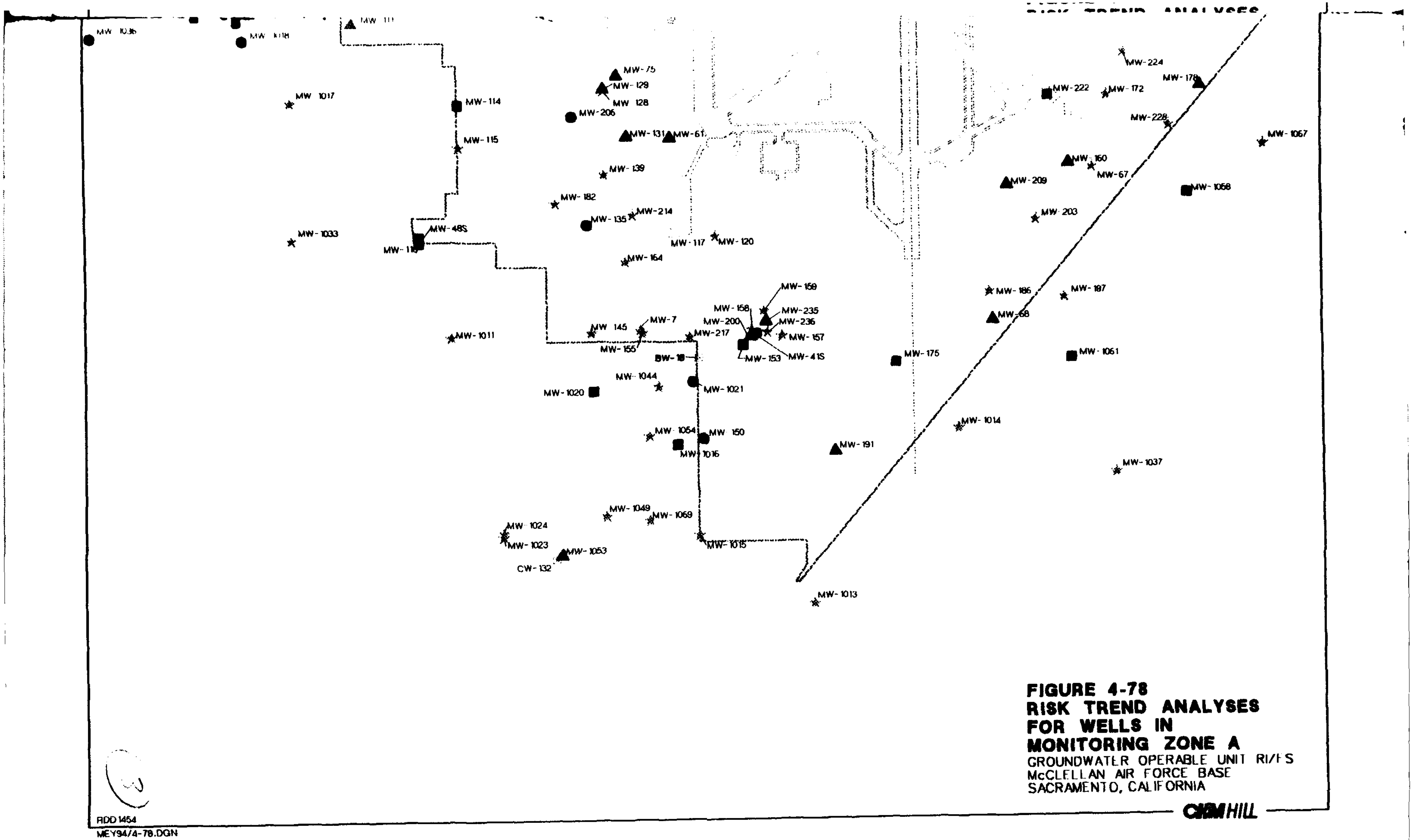
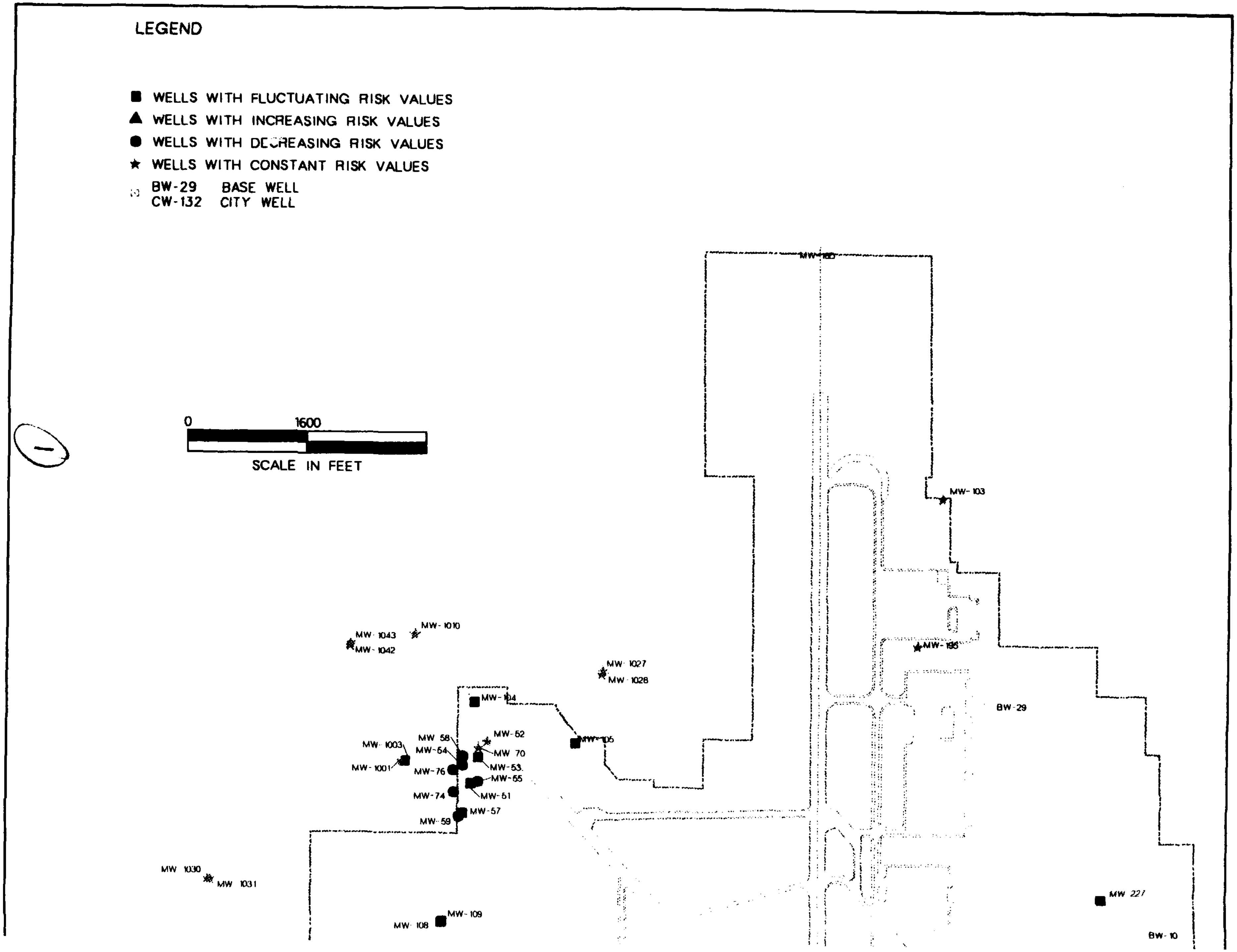
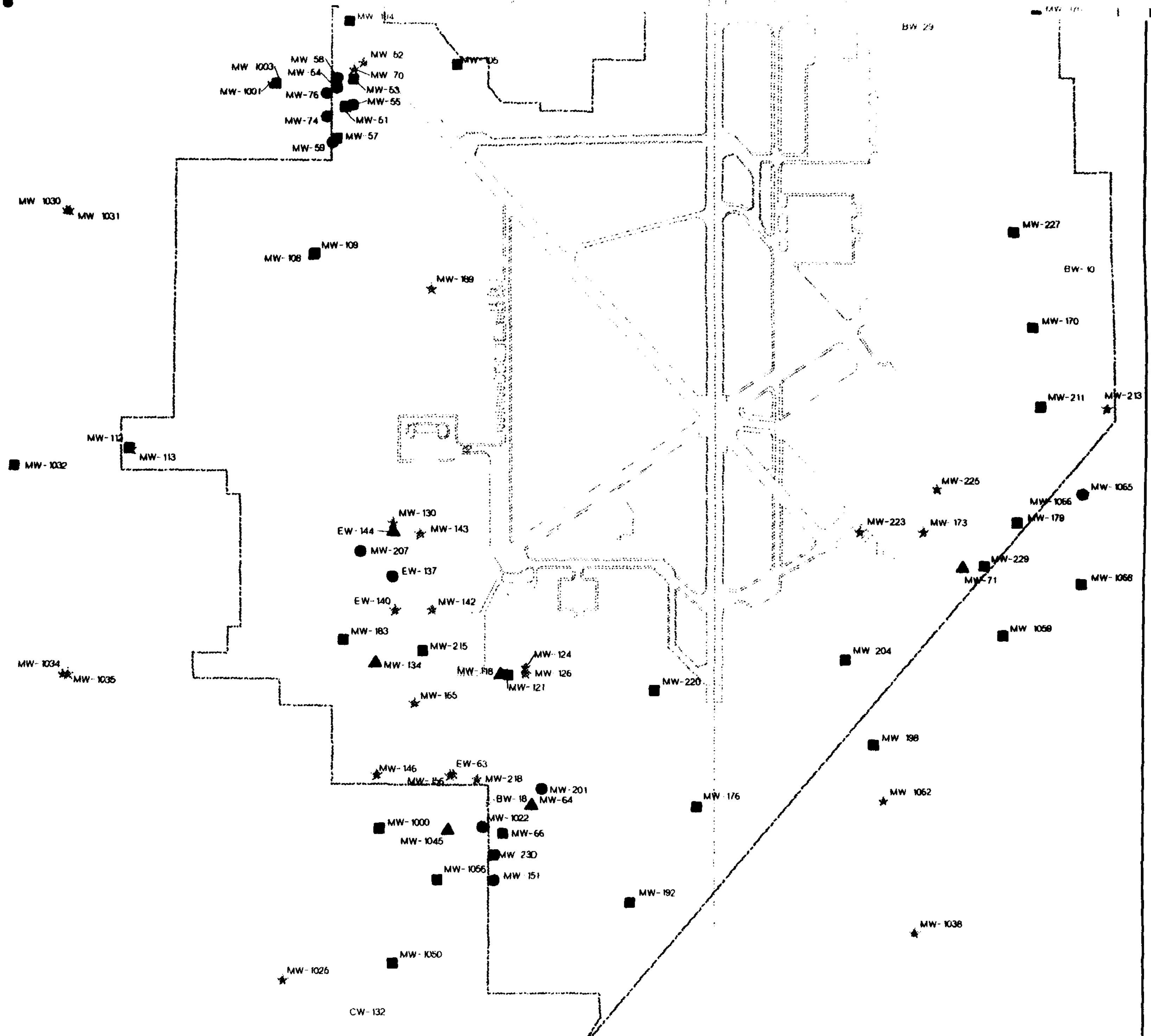


FIGURE 4-78
RISK TREND ANALYSES FOR WELLS IN MONITORING ZONE A
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


LEGEND
■ WELLS WITH FLUCTUATING RISK VALUES
▲ WELLS WITH INCREASING RISK VALUES
● WELLS WITH DECREASING RISK VALUES
★ WELLS WITH CONSTANT RISK VALUES
BW-29 BASE WELL
CW-132 CITY WELL
0
1600
SCALE IN FEET
MW-103
MW-195
BW-29
MW-1010
MW-1043
MW-1042
MW-1027
MW-1028
MW-104
MW-105
MW-52
MW 58
MW-64
MW 70
MW-53
MW-65
MW-61
MW-76
MW-74
MW-57
MW-59
MW-1003
MW-1001
MW 1030
MW 1031
MW-109
MW-108
MW 227
BW-10


MW 104
MW 105
MW 52
MW 58
MW 1003
MW-64
MW 70
MW-53
MW-1001
MW-76
MW-55
MW-74
MW-61
MW-57
MW-59
MW 1030
MW 1031
MW-109
MW-108
MW-189
MW-112
MW-113
MW-1032
MW-130
EW-144
MW-143
MW-207
EW-137
EW-140
MW-142
MW-183
MW-215
MW-124
MW-134
MW 126
MW-121
MW 1034
MW-1035
MW-165
MW-220
MW-146
EW-63
MW-218
MW-201
BW-18
MW-64
MW-1000
MW-1022
MW-1045
MW-66
MW 230
MW-1056
MW 151
MW 176
MW-192
MW-1050
MW-1026
CW-132
BW 29
MW-227
BW-10
MW-170
MW-211
MW-213
MW-225
MW-1065
MW-1066
MW-179
MW-223
MW-173
MW-229
MW-71
MW-1068
MW 1059
MW 204
MW 198
MW 1062
MW-1038

2

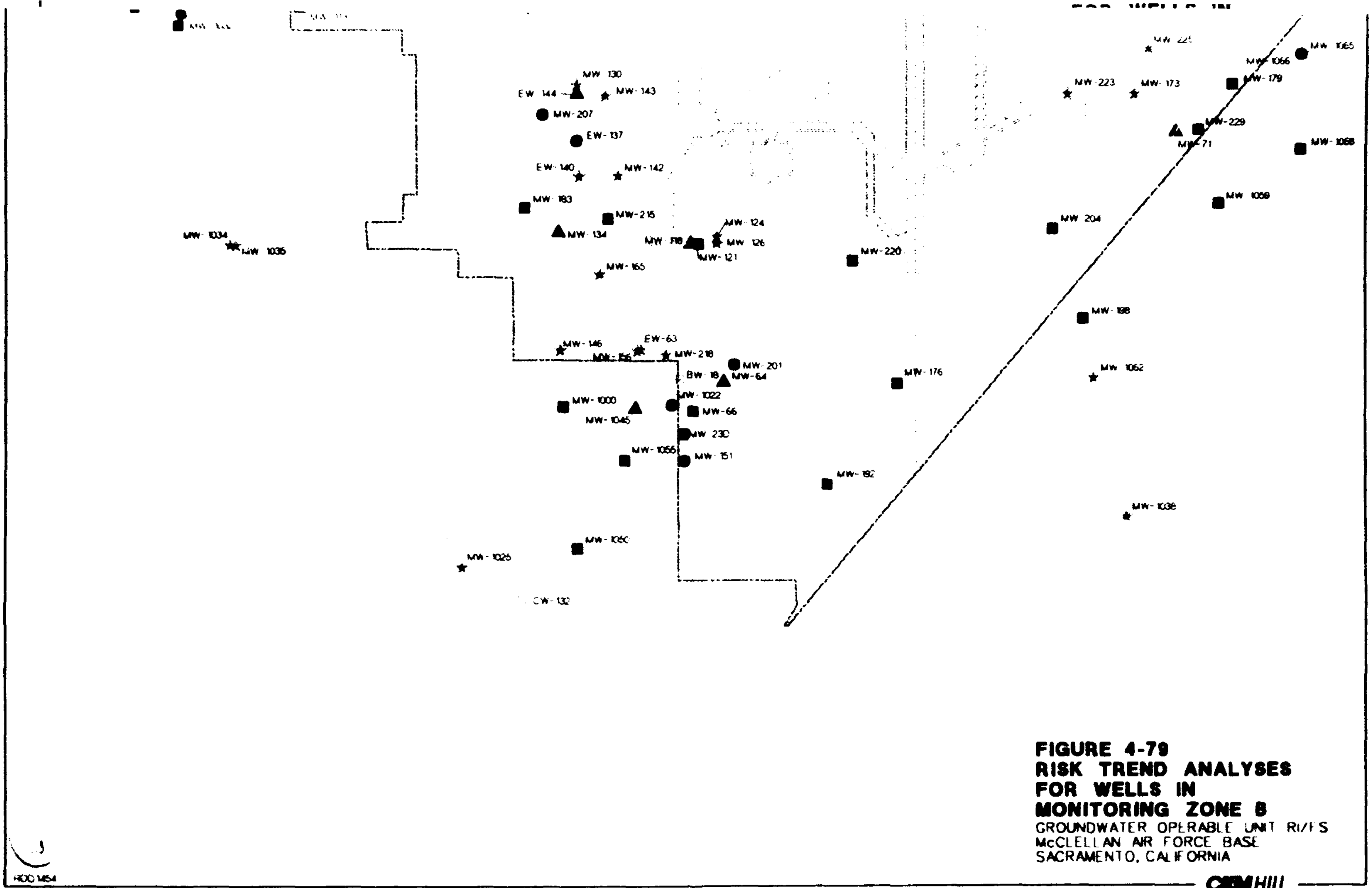
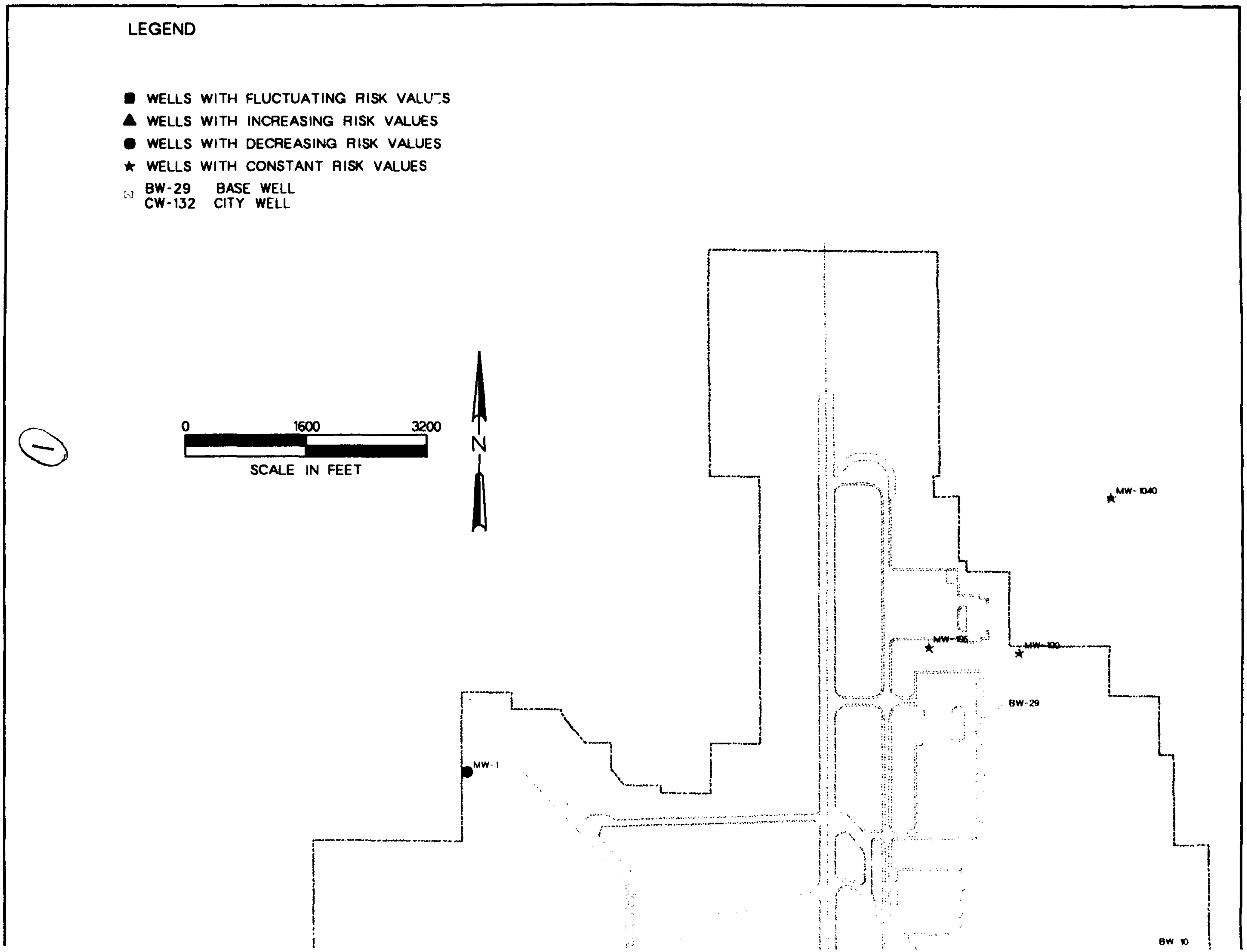


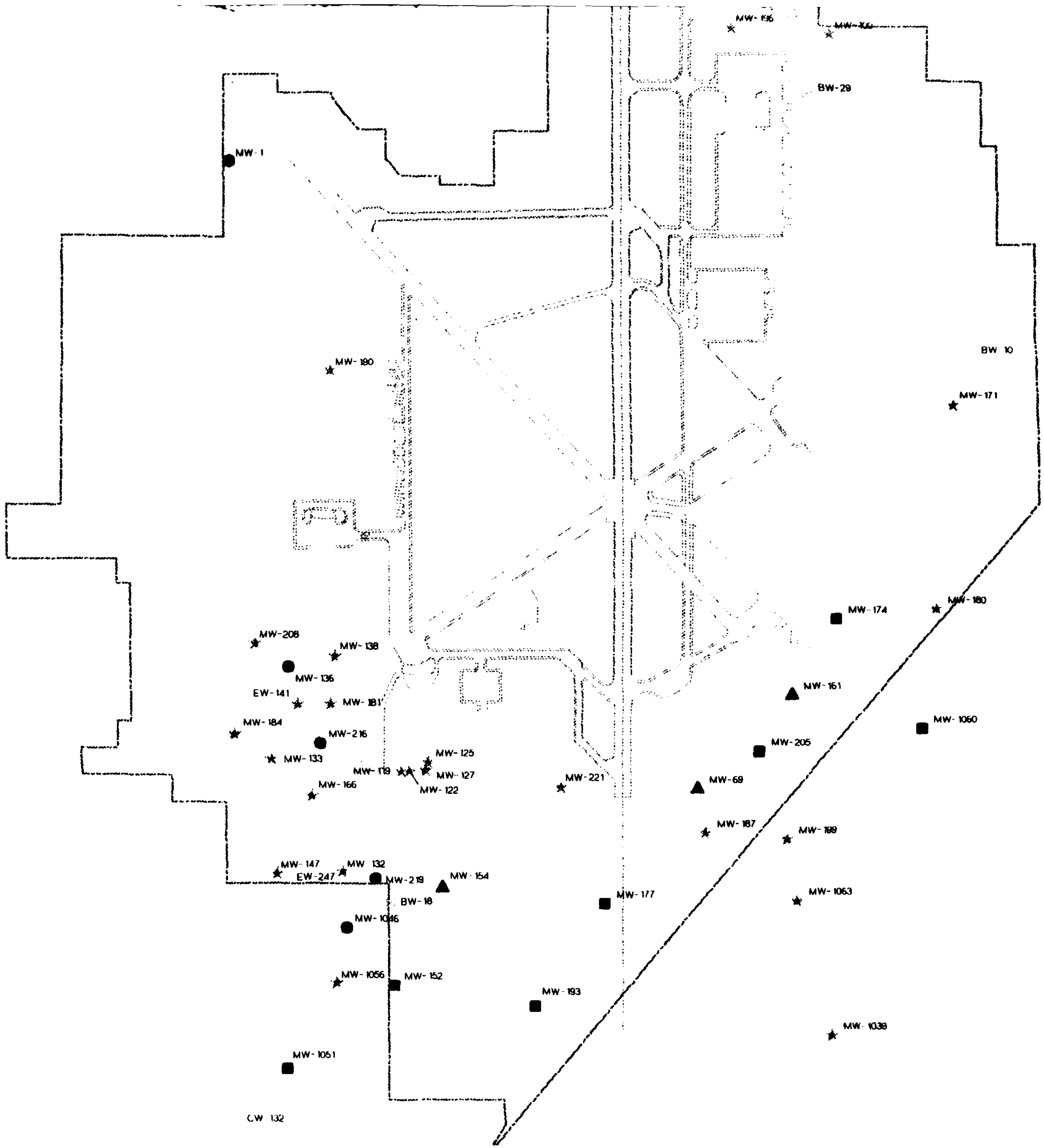
FIGURE 4-79
RISK TREND ANALYSES FOR WELLS IN MONITORING ZONE B
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD 1454
MEY94 4-79.DGN



LEGEND
WELLS WITH FLUCTUATING RISK VALUES
WELLS WITH INCREASING RISK VALUES
WELLS WITH DECREASING RISK VALUES
WELLS WITH CONSTANT RISK VALUES
BW-29 BASE WELL
CW-132 CITY WELL
0
1600
3200
SCALE IN FEET
N
MW-1040
MW-196
MW-100
BW-29
MW-1
BW 10



MW-196
BW-29
MW-1
BW 10
MW-171
MW-190
MW-174
MW-180
MW-208
MW-138
MW-136
MW-161
EW-141
MW-181
MW-1060
MW-184
MW-216
MW-205
MW-125
MW-133
MW-119
MW-127
MW-122
MW-221
MW-69
MW-166
MW-187
MW-189
MW-147
MW 132
EW-247
MW-219
MW-154
MW-177
MW-1063
BW-18
MW-1046
MW-1056
MW-152
MW-193
MW-1038
MW-1051
CW 132

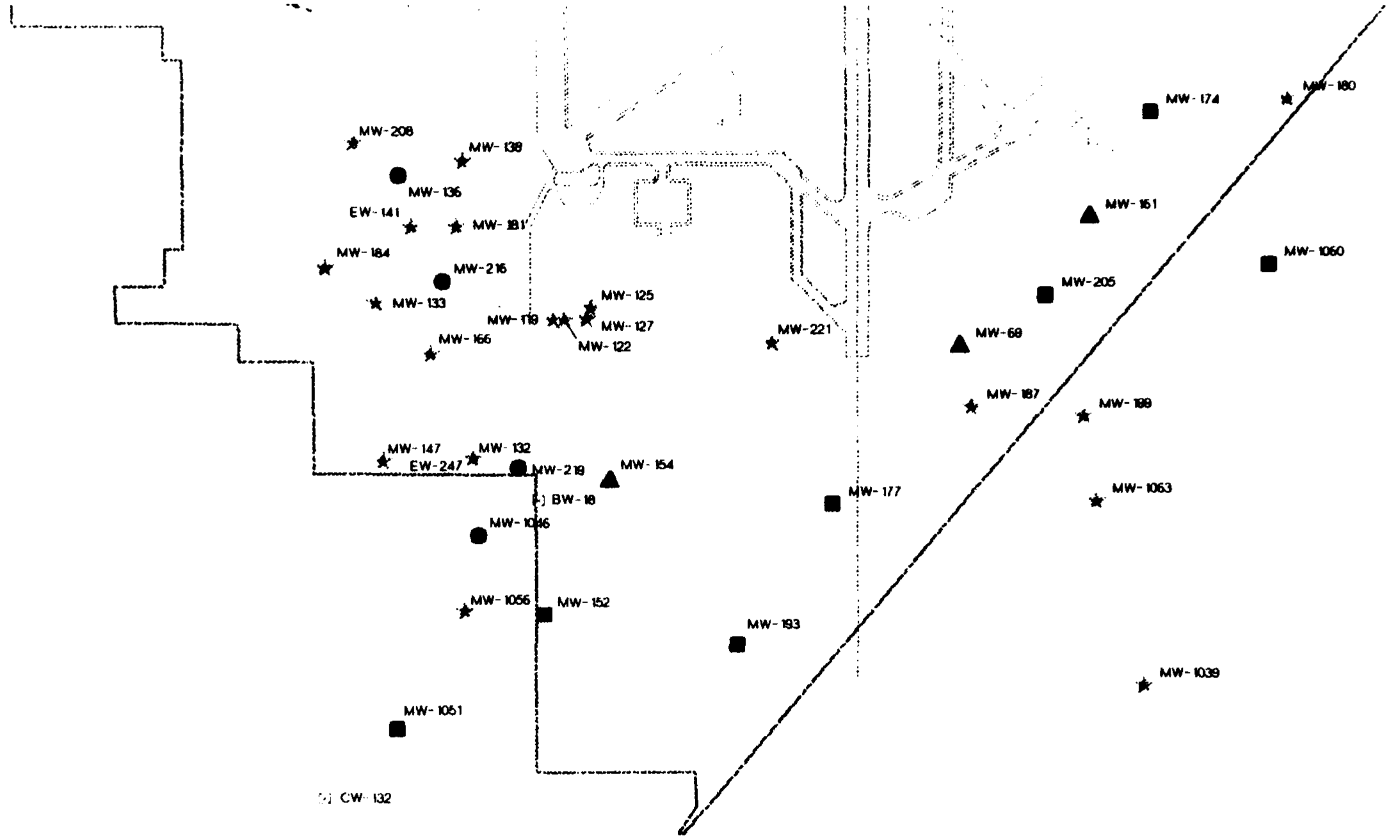
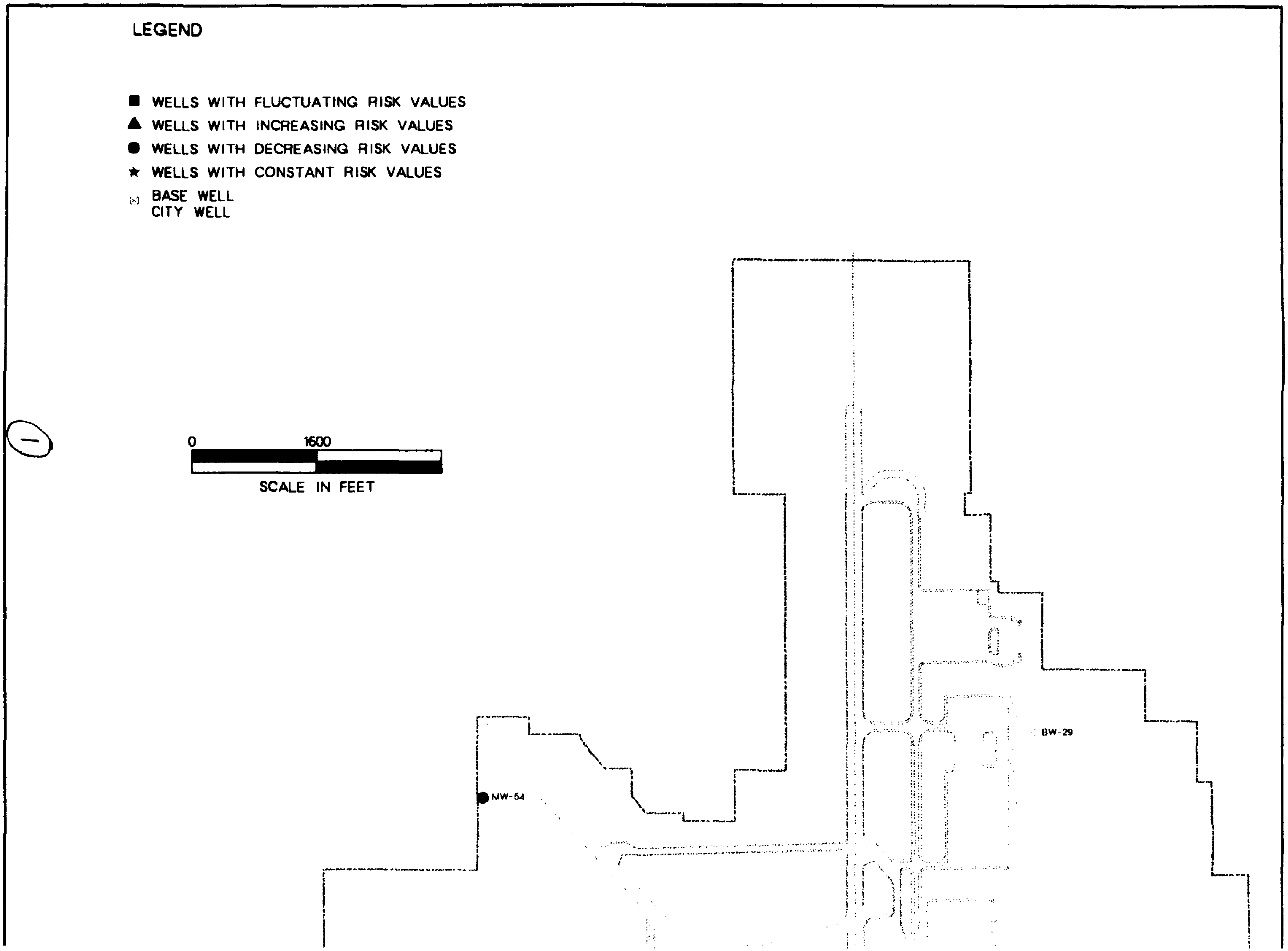
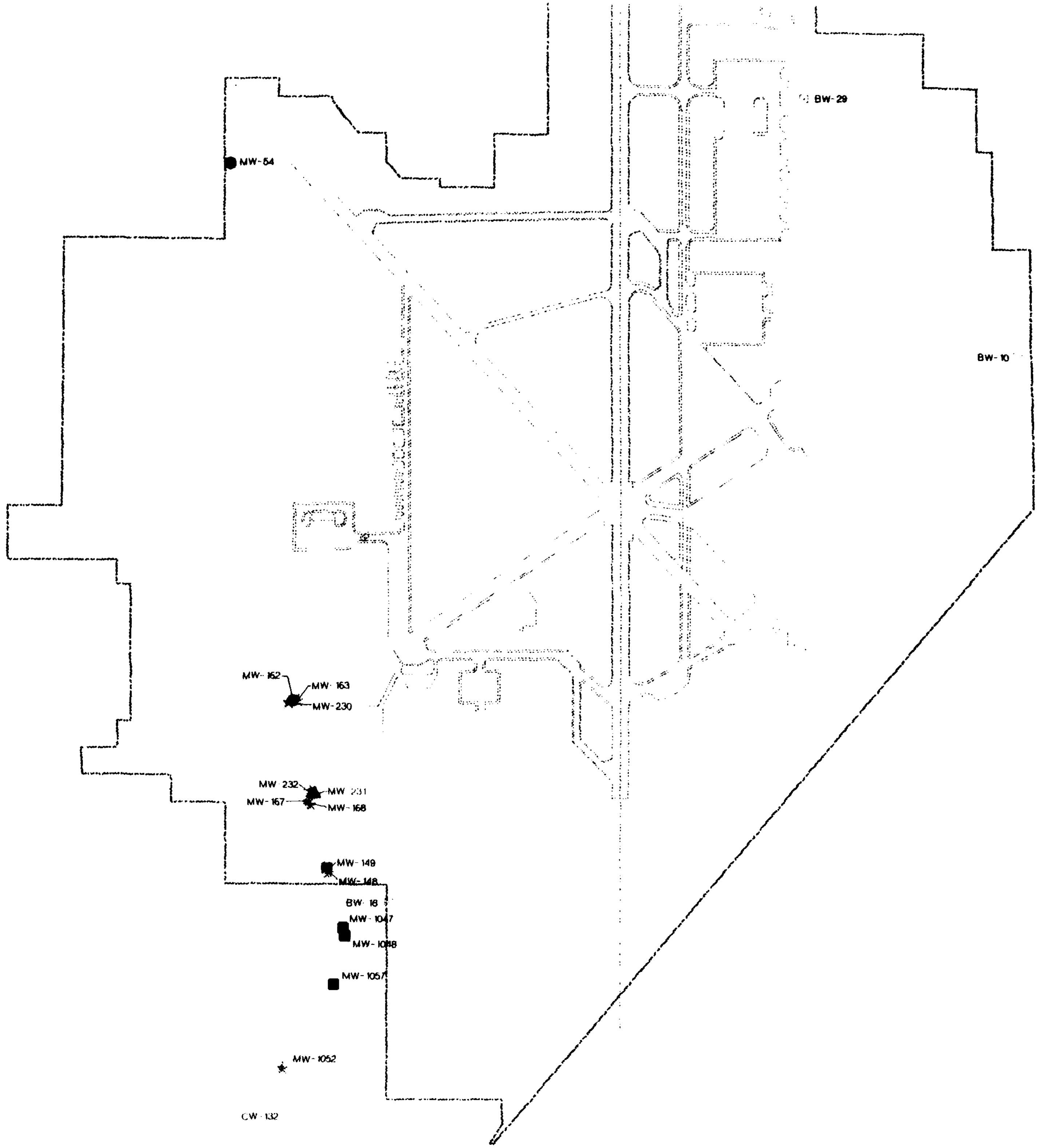


FIGURE 4-80
RISK TREND ANALYSES FOR WELLS IN MONITORING ZONE C
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD 1464
MEY94/4-80.DGN


LEGEND
WELLS WITH FLUCTUATING RISK VALUES
WELLS WITH INCREASING RISK VALUES
WELLS WITH DECREASING RISK VALUES
WELLS WITH CONSTANT RISK VALUES
BASE WELL
CITY WELL
0
1600
SCALE IN FEET
BW-29
MW-54


MW-84
BW-29
BW-10
MW-162
MW-163
MW-230
MW-232
MW 231
MW-167
MW-168
MW-149
MW-148
BW-18
MW-1047
MW-1048
MW-1057
MW-1052
CW-132

2

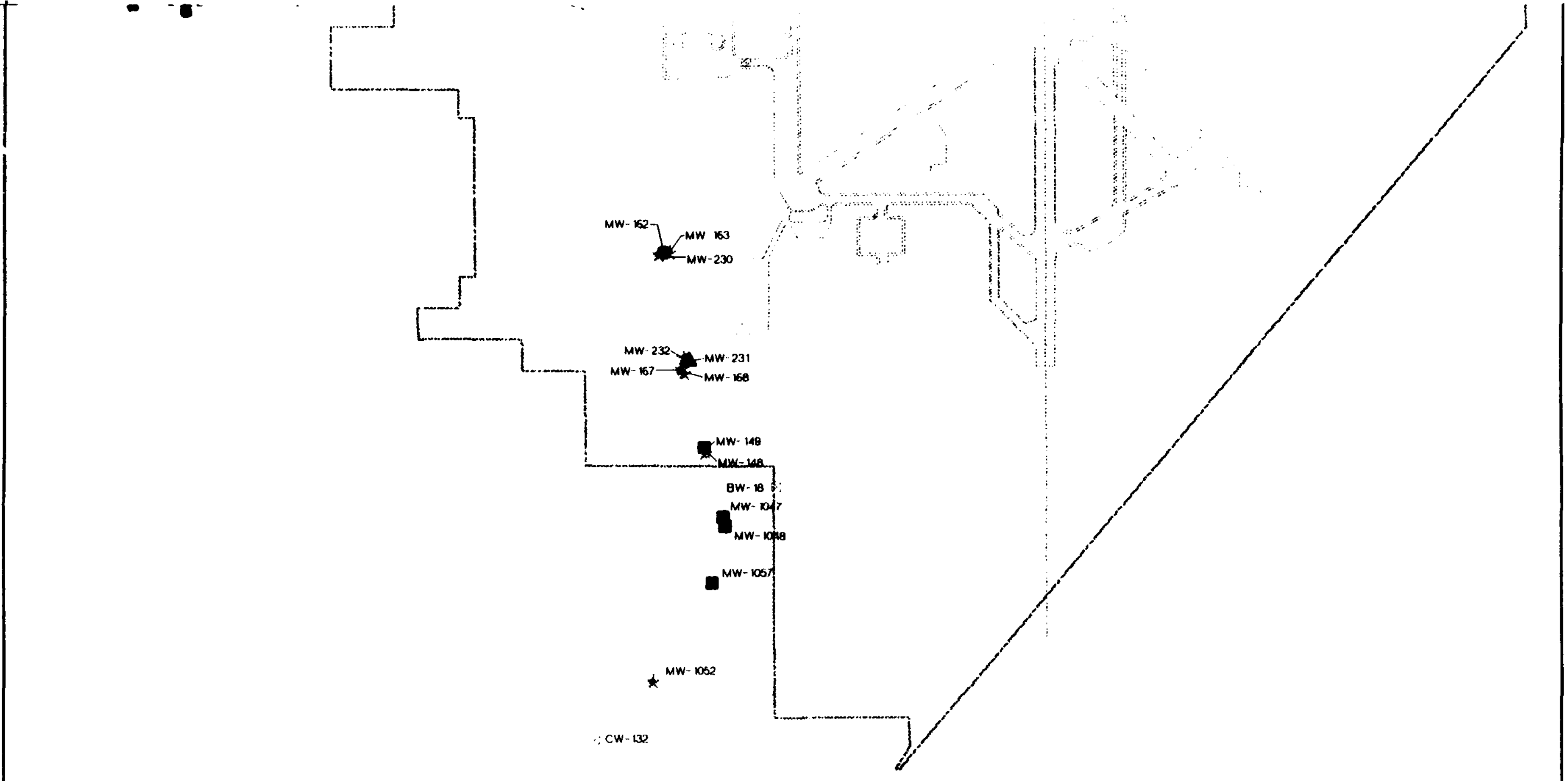


FIGURE 4-81
RISK TREND ANALYSES FOR WELLS IN MONITORING ZONE D
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD 1454
MEY94/4-81.DGN

Chapter 5
Risk Assessment and ARARs

5.1 Purpose of the Risk Assessment

The risk assessment addresses two primary needs in the RI/FS. First, it provides some of the necessary interpretations and calculations to support the development of target volumes for remedial actions. Target volumes represent volumes of groundwater with contaminants that could pose unacceptable risks to users should that water be used. Target volumes are then used in the development of remedial action alternatives. Second, it addresses the requirement for a baseline risk assessment in an RI/FS, as required by the NCP (40 CFR 300.430 (d)(1)). The primary purpose of the baseline risk assessment is to provide risk managers with an understanding of the actual and potential risks to human health and the environment posed by a site and any uncertainties associated with the assessment. This information may be useful in determining whether a current or potential threat to human health or the environment exists that warrants remedial action (U.S. EPA, 1990; U.S. EPA, 1991). This chapter presents a summary of the risk assessment methodology and findings. A more detailed presentation of the risk assessment can be found in Appendix B, Risk Assessment Methodology.

Response actions performed by McClellan AFB have reduced the likelihood that contaminated groundwater is being used in and around the Base. Therefore, there probably are no exposure pathways to human populations from groundwater contamination, based on the existing understanding of site conditions. However, this understanding is not complete. In particular, the lateral and vertical extent of contamination in OU A is inadequately defined. Contamination may extend offbase and is a potential threat to nearby municipal and industrial supply wells. No remedial action is in place in OU A for controlling potential exposures to groundwater contaminants. Also, it is uncertain if risks could increase with future use of groundwater. For example, there are few institutional controls on placement of a private domestic well within a contaminated aquifer. There are, however, several regulatory constraints prohibiting a municipal water purveyor from providing contaminated groundwater.

Completed pathways of exposure from groundwater contaminants to human populations (both onbase and offbase) may have existed in the past. Groundwater contaminant levels representing potential exposure concentrations may have been greater in the past than under existing conditions. The potential for adverse health effects associated with past exposures have been evaluated in a Health Assessment 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 (ATSDR, 1993). The findings from the Health Assessment have been addressed in this risk assessment using additional information collected during the RI/FS.

For calculating target volumes based on health risks, the risk assessment has used the assumption that residential use of groundwater and residential exposure pathways (ingestion or inhalation of VOCs) and dermal contact with groundwater) were possible at any location within the contaminant plumes, regardless of the constraints on groundwater use or reasonable consideration of the pathways of exposure. It must be strongly emphasized that numerical estimates of health risks used to support development of target volumes do not reflect the magnitude of potential health risks to the surrounding public, but simply represent a convenient method for characterizing the nature and extent of groundwater contamination within a standardized public health context. This means that different types and concentrations of contaminants can be standardized in terms of exposure and toxicity to allow comparison of groundwater contamination in different areas and to assist in setting priorities. For example, risk assessment can be used to compare relatively higher concentrations of a lower toxicity substance such as TCE along with relatively lower concentrations of a higher toxicity substance such as vinyl chloride.

5.2 Approach to Risk Assessment

This baseline risk assessment was based on exposure scenarios that estimated the reasonable maximum exposure (RME). The RME is defined as the highest exposure that is reasonably expected to occur at a site. RMEs are estimated for individual exposure pathways. If a population is exposed by way of 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 (U.S. EPA, 1989).

The elements of the risk assessment are as follows:

- Identification of the contaminants of potential concern (COPCs)
- Exposure assessment
- Toxicity assessment
- Risk characterization

These elements are presented in Figure 5-1. The exposure scenarios evaluated in the risk assessment fall into two categories: current and potential future pathways of exposure to groundwater contaminants identified from existing information, and a hypothetical future exposure scenario that assumes complete exposure pathways to groundwater contaminants. The current and potential future pathways of exposure were

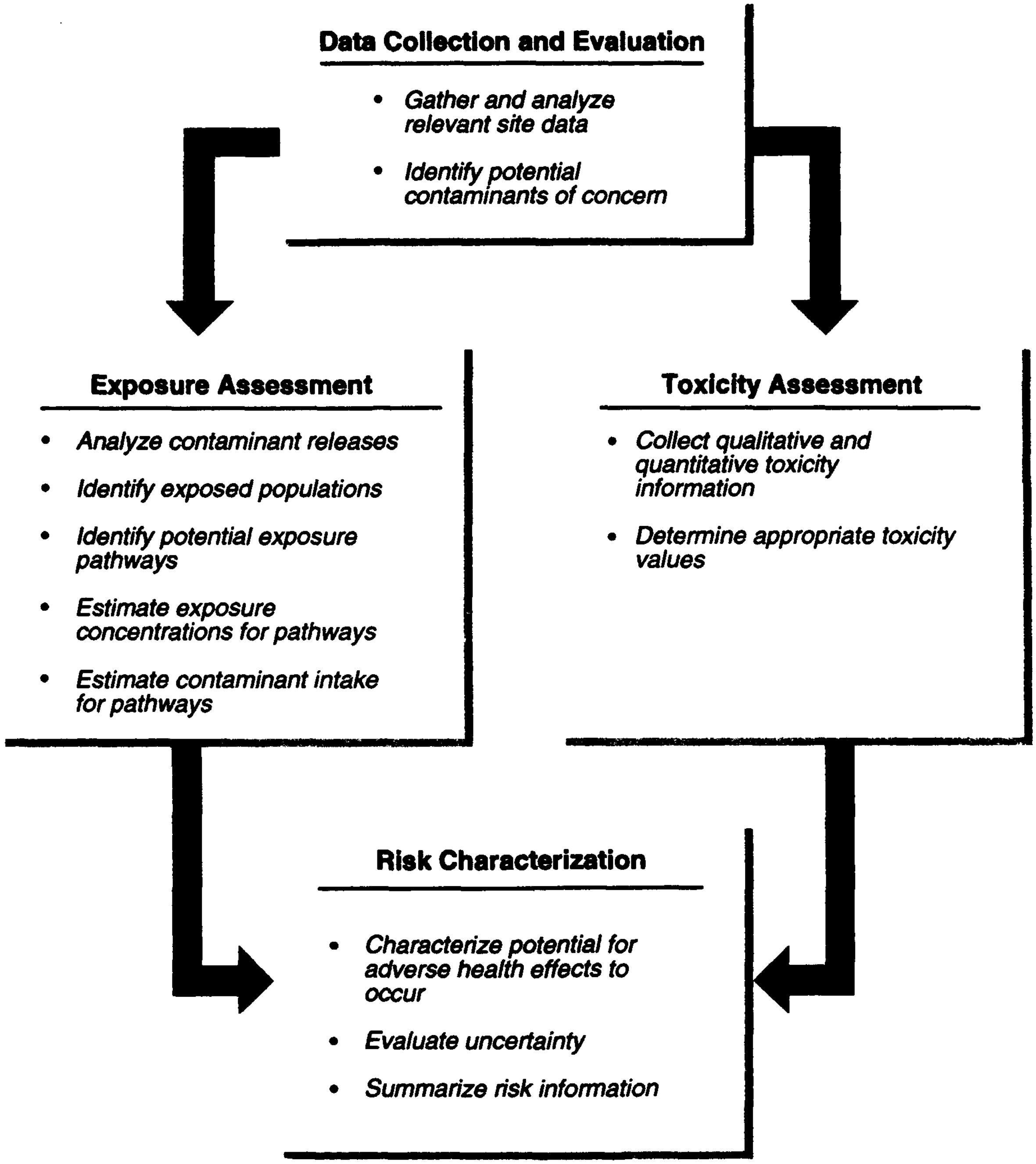


FIGURE 5-1
ELEMENTS OF RISK ASSESSMENT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDO1464_86

CH2M HILL

evaluated for comparison with the findings from the Health Assessment. The hypothetical scenario was used to develop risk-based target volumes.

COPCs consist of any contaminant detected in groundwater with available U.S. EPA or Cal-EPA toxicity criteria. As described below, health risks were characterized for each detected parameter in each sample collected between 1986 and 1993. These sample-specific risk calculations were used for developing risk-based target volumes.

Exposure refers to the potential contact of an individual with a chemical. Exposure assessment is the estimation of the magnitude, frequency, duration, and routes of exposure to a chemical. Human exposure to chemicals is typically evaluated by estimating the amount of a chemical that could come into contact with the lungs, gastrointestinal tract, or skin during a specified period of time. This exposure assessment is based on scenarios that define human populations potentially exposed to COPCs originating from the site. 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. Chemical intakes and associated risks have been quantified for all exposure pathways considered potentially complete.

Chemical intakes are expressed as the amount of chemical at the exchange boundary (i.e., skin, lungs, or gastrointestinal tract) and available for absorption. In accordance with EPA guidelines, intake for dermal exposure pathways is estimated in terms of absorbed dose and not quantity of chemical at the exchange boundary. Estimates of chemical intakes based on 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 U.S. EPA (U.S. EPA, 1989; 1990; 1991). The calculated intake rates are combined with toxicity criteria values (discussed in Section 6.3) 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 among these variables and chemical intake in humans is:

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

where:

I = Intake (mg/kg-day)

C	=	Average concentration in the contaminated medium contacted over the exposure period (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 6.3) to characterize potential health risks.

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 (U.S. EPA, 1989).

For purposes of the toxicity assessment, the COPCs have been classified into two broad categories: carcinogens and noncarcinogens. 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. U.S. EPA and Cal-EPA 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 based upon 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 groundwater contaminants.

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 toxicity threshold values and estimates of excess cancer risk. Risk characterization also considers the nature of 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; therefore, actual risks are likely to be lower than estimated and may even be zero.

5.2.1 Data Sources

Groundwater monitoring data used to develop risk-based target volumes were from the GSAP maintained by Radian Corporation. Data from the quarterly monitoring program from 1986 to 1993 were used to develop target volumes. Data from these years were selected because they represent a reasonable number of wells and parameters monitored to plot concentration contours and to provide a relatively long period to evaluate the changes in the spatial extent of estimated health risks over time.

5.2.2 Introduction to Sample-Specific Risk Assessment Methodology

When there is a single contaminant in groundwater, the contaminant levels in different wells can be compared to a contaminant-specific applicable or relevant and appropriate requirement (ARAR) or preliminary remediation goal (PRG) to distinguish areas requiring remediation from areas with concentrations that do not exceed ARARs or that do not pose unacceptable health risks. However, for the case of multiple contaminants detected in groundwater (as is present at McClellan AFB), the approach used is to integrate individual contaminant concentrations into cumulative increased lifetime cancer risks or hazard indexes, according to contaminant levels reported from each sample. Samples with cancer risks or noncancer hazard indexes exceeding a defined cut-point of acceptable levels may then be mapped to spatially define areas requiring either treatment or no further action. This approach is referred to as a sample-specific risk assessment methodology. Attributes of the sample-specific risk assessment methodology include:

- Characterizing health risks associated with chemical contaminants detected in each sample
- Using RME assumptions for each sample
- Summing risks across chemicals and pathways for each sample
- Representing only a small modification of current risk assessment guidelines
- Indicating acceptance for use by EPA Region IX

The integration of sample-specific risk assessment methodology within current U.S. EPA risk assessment guidelines and the benefits that the sample-specific methodology provide to the risk assessment for the GW OU FS are discussed in Appendix B.

The risk-based target volumes developed through sample-specific risk assessment identify areas of groundwater that could pose unacceptable health risks should that water be used in the future. Target volumes representing 10^{-6}, 10^{-4}, and 10^{-2} increased lifetime cancer risks and a noncancer hazard index exceeding 1.0 were mapped using groundwater monitoring data collected at McClellan AFB and risk calculations documented in Appendix B.

The calculations and assumptions used to prepare the risk-based target volumes represent health risks associated with a hypothetical future land use scenario, but do not address health risks potentially associated with current conditions in groundwater at McClellan AFB.

5.3 Data Interpretation

5.3.1 Description of Sample-Specific Risk Assessment Methodology

Health risks were characterized by spatially defining the area where groundwater contaminants were associated with risks that exceeded specified risk thresholds. Instead of generating a single-point estimate of risks sitewide, risks associated with groundwater contaminants were characterized by evaluating sample-specific risks. This approach retains information on the spatial distribution of risk in groundwater. Sample-specific risk or hazard index calculations use the same equations to estimate RME risks as defined in Risk Assessment Guidance for Superfund (RAGS) (U.S. EPA, 1989). Exposure parameter values and toxicity values are the same as those used in a conventional sitewide calculation. The only structural difference in calculating sample-specific versus sitewide risk lies in the concentration values used. Where the conventional sitewide approach uses the 95 percent upper confidence limit (UCL) of the mean concentration for all contaminants of concern, sample-specific risk calculations use concentrations reported from each individual site characterization sample of the relevant medium. However, the sample-specific risks are still considered to be RME because of the use of conservative assumed exposure parameters in the calculation of intake, including upper bound medium intake rates (e.g., 2 liters/day for drinking water), exposure frequencies (e.g., 350 days/year), exposure durations (e.g., 30 years), and averaging times (e.g., 70-year lifetime). These parameters are still applied in a multiplicative manner (as in the conventional approach), and risks from multiple pathways of exposure are summed. Therefore, the risk calculations retain their conservative nature. The sample-specific risk approach is presented in Figure 5-2.

The advantage of the sample-specific methodology is greatest when risks are attributable to multiple contaminants. An assumption inherent in the sitewide risk calculation is spatial co-variance of contaminant concentrations (i.e., the UCL concentrations of all contaminants detected at the site coincide spatially). Such spatial co-variance is rarely observed at complex sites. Applying sitewide risk calculations to a data set would yield higher risk estimates than the sample-specific risk estimates, unless the elevated concentrations did indeed coincide spatially.

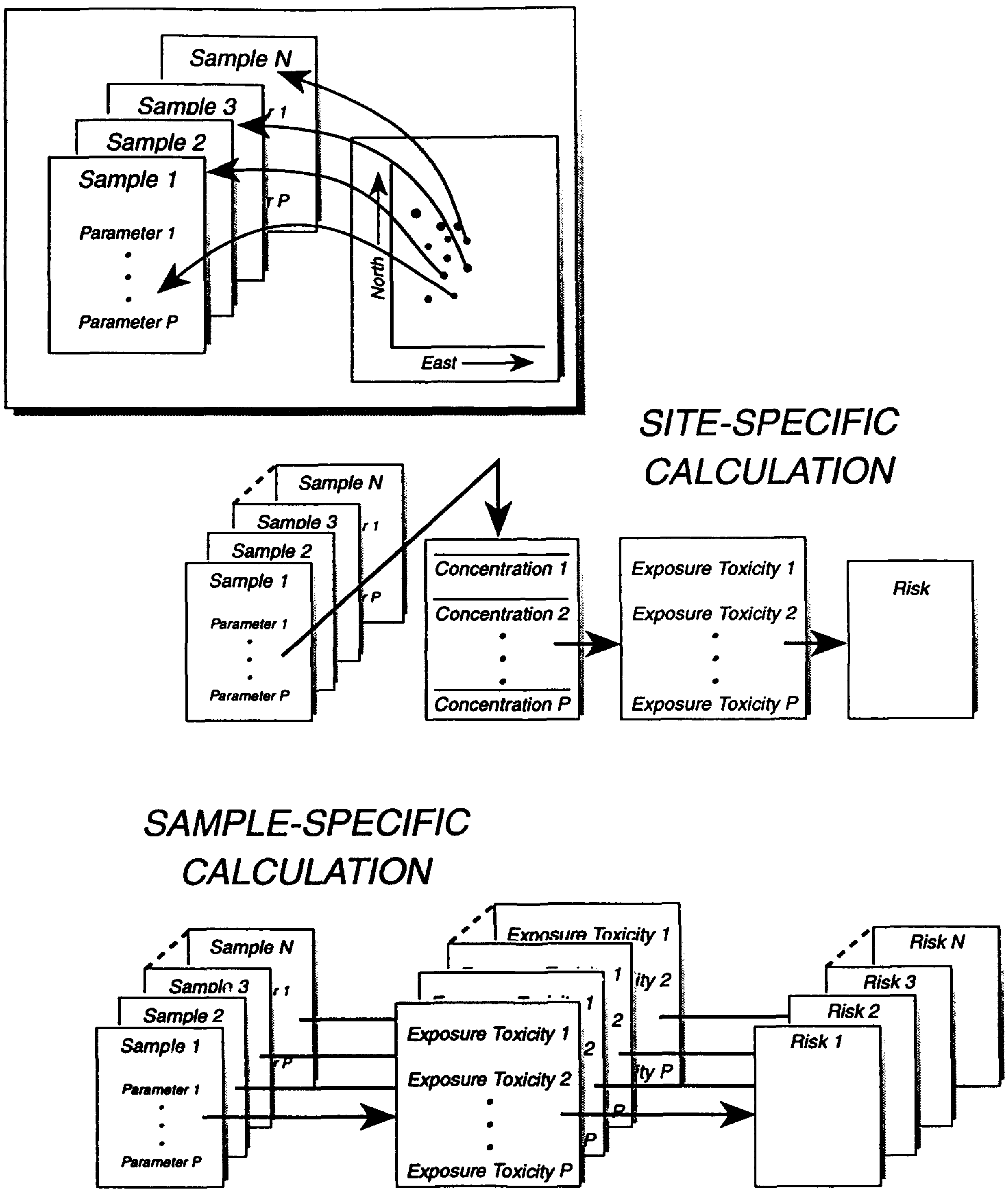


FIGURE 5-2
SAMPLE-SPECIFIC RISK ASSESSMENT METHOD
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_88

CH2M HILL

5.3.2 Groundwater Monitoring Data Assumptions

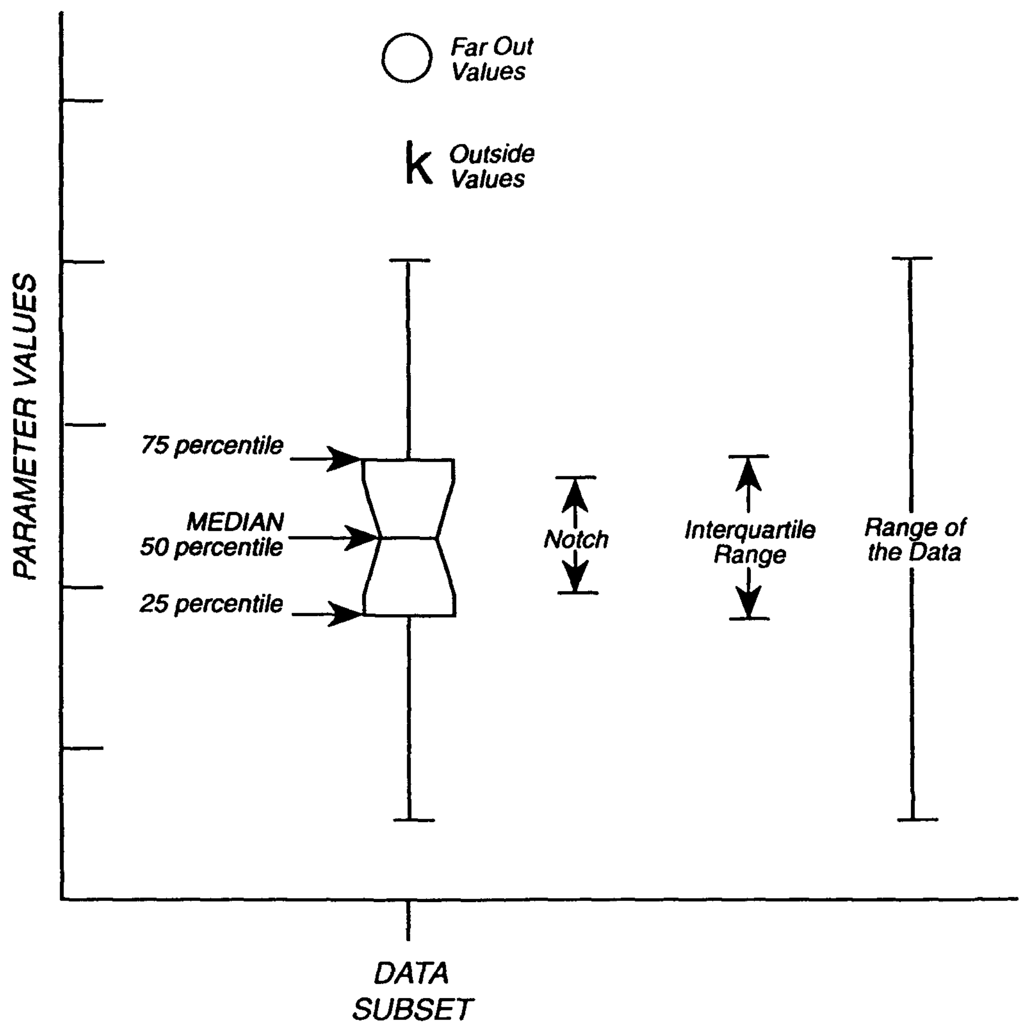
Several assumptions were applied to the groundwater monitoring data for developing the risk calculations and mapping the risk estimates. For purposes of generating risk contours, groundwater samples collected between 1986 and 1993 were grouped into periods corresponding generally to the monitoring periods in the quarterly monitoring program. Selected VOCs were not excluded as COPCs based on concentrations detected in blanks. Samples identified as field duplicates were excluded from the data prior to performing sample-specific risk calculations. Finally, parameters reported as not detected were assumed to be zero for purposes of contouring risks. Use of a surrogate concentration such as one-half of the detection limit would arbitrarily inflate risks, when *P*-parameter-specific risks were cumulated in a sample. This would result in estimated risk in samples where contaminants had never been detected.

5.3.3 Overall Inferences

VOCs represented the primary COPCs in groundwater at McClellan AFB. On the basis of the estimated lifetime cancer risks, potential for noncancer effects and extent of contamination in groundwater, the COPCs were TCE, chloroform, PCE, 1,2-DCA, and 1,1-DCE. Semi-volatile organic compounds (SVOCs), while associated with elevated risks in localized areas, generally were associated with lower levels of risk and a lesser extent of contamination when compared with VOCs. Risks estimated for SVOCs were not incorporated into the target volumes.

Variability of risks in each well was presented graphically using box plots. A generic box plot is presented in Figure 5-3. A box plot identifies the median (50 percentile value), the lower and upper quartiles (25 and 75 percentile values), and the extreme spread of the data. The edges of the box demark the 25 and 75 percentiles and therefore represent the middle 50 percent range (or interquartile range) of the parameter values. The line within the box is the median. The lines extending outward from the box demark the range of data, excluding outliers. Two outliers are defined, based on their distance from the nearest edge of the box (and relative to the range of the box). Outside values lie 1.5 to 3 interquartile ranges from the nearest box edge, and far outside values lie 3 or more interquartile ranges from the nearest box edge. The notch represents the approximate 95 percent confidence interval around the median.

A summary of the increased lifetime cancer risk estimates from the monitoring well data, grouped by OU and by monitoring zone, is presented in Figure 5-4. Figure 5-4 also presents median estimates of risks associated with VOCs across samples within each OU. Median risks in groundwater under OU A are relatively low, compared with OUs B, C, and D. This suggests that a significant fraction of the VOC mass in soil within OU A has not yet been released to groundwater. Median risks within the B zone in OU B are noticeably greater than risks within the



A box plot identifies the median (50 percentile value), the lower and upper quartiles (25 and 75 percentile values) and the extreme spread of the data.

The edges of the box demark the 25 and 75 percentiles, and so represent the middle 50 percent range (or interquartile range) of the range of values. The line within the box is the median.

The lines extending outward from the box demark the range of data, excluding outliers. Two outliers are defined, based on their distance from the nearest edge of the box (and relative to the range of the box).

Outside values lie 1.5 to 3 interquartile ranges from the nearest box edge, and far out values lie 3 or more interquartile ranges from the nearest box edge.

The notch represents the appoximate 95 percent confidence interval around the median.

FIGURE 5-3
BOX PLOT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_87

CH2M HILL

Operable Unit A				B	A	C
Operable Unit B		A		C	B	
Operable Unit C	[illegible]			A		B
Operable Unit D			A			B, C
Operable Unit E, F						All
Log Median Cancer Risk	-4.5 (3.2×10^{-5})	-5.5 (3.2×10^{-6})	-6.0 (1×10^{-6})	-6.2 (6×10^{-7})	-6.7 (2×10^{-7})	-8 (1×10^{-8})

NOTES:

A–A Zone
B–B Zone
C–C Zone
D–D Zone

FIGURE 5-4
OVERALL RISK RANKING OF OPERABLE UNITS AND GROUNDWATER MONITORING ZONES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454 85

CH2M HILL

underlying C and D zones, suggesting that vertical migration of contaminants from soil has more significantly impacted shallow aquifers rather than the deeper aquifers. One significant finding from this analysis is that median risks in OU C are noticeably greater in the deeper monitoring zones compared with the shallow monitoring zones. This suggests that contaminants in soils within OU C are not a significant contributor to groundwater contamination, and the contaminants in the deeper zones reflect lateral migration in groundwater, possibly from OUs B and D.

Figure 5-5 presents the box plots of risks across all samples grouped by OU and monitoring zone. The A-zone (shallow zone) results presented in Figure 5-4 indicate median risks generally between 10^{-6} to 10^{-5} with selected wells containing VOC concentrations associated with risks up to 10^{-2}, with little variability between OUs A through D. Results across the different monitoring zones for OU B show relatively little variability, suggesting that contamination is fairly consistent with increasing depth. Results for OU C show higher median risks within deeper monitoring zones, suggesting that observed risks (contamination) have not originated from vertical migration of contamination from soils within OU C. The results for OU D show significant outliers with elevated risks within the B zone; these elevated contaminant levels appear to be relatively confined to the B zone according to the results presented for the C zone.

5.4 Risk Characterization

5.4.1 Characterization of Numerical Results

The U.S. EPA considers action to be warranted at a site when cancer risks exceed 10^{-4}. Action is not specifically required for risks falling within 1×10^{-4} to 1×10^{-6}; however, this is judged on a case-by-case basis. Risks less than 1×10^{-6} generally are not of concern to regulatory agencies. A hazard index (the ratio of chemical intake to the reference dose [RfD]) greater than one indicates that there is some potential for adverse noncancer health effects associated with exposure to the contaminants of concern (U.S. EPA, 1991).

Interpretations of the data presented in the previous section indicate that the range of risks from contaminant concentrations falls between 10^{-4} to 10^{-6} in most of the monitoring wells. In selected wells, risks may be as high as 10^{-2}; generally, these risks are found in wells that have been placed within suspected contaminant source areas.

The numerical results presented in the previous section do not reflect expected pathways of exposure under either current or future conditions. These reflect a hypothetical scenario of a residence using contaminated groundwater that was developed for the purpose of estimating risk-based target volumes for remedial action. Under current conditions or forseeable future conditions at McClellan AFB, it is not likely that there would be pathways of exposure to the contaminants in groundwater as measured in the GSAP.

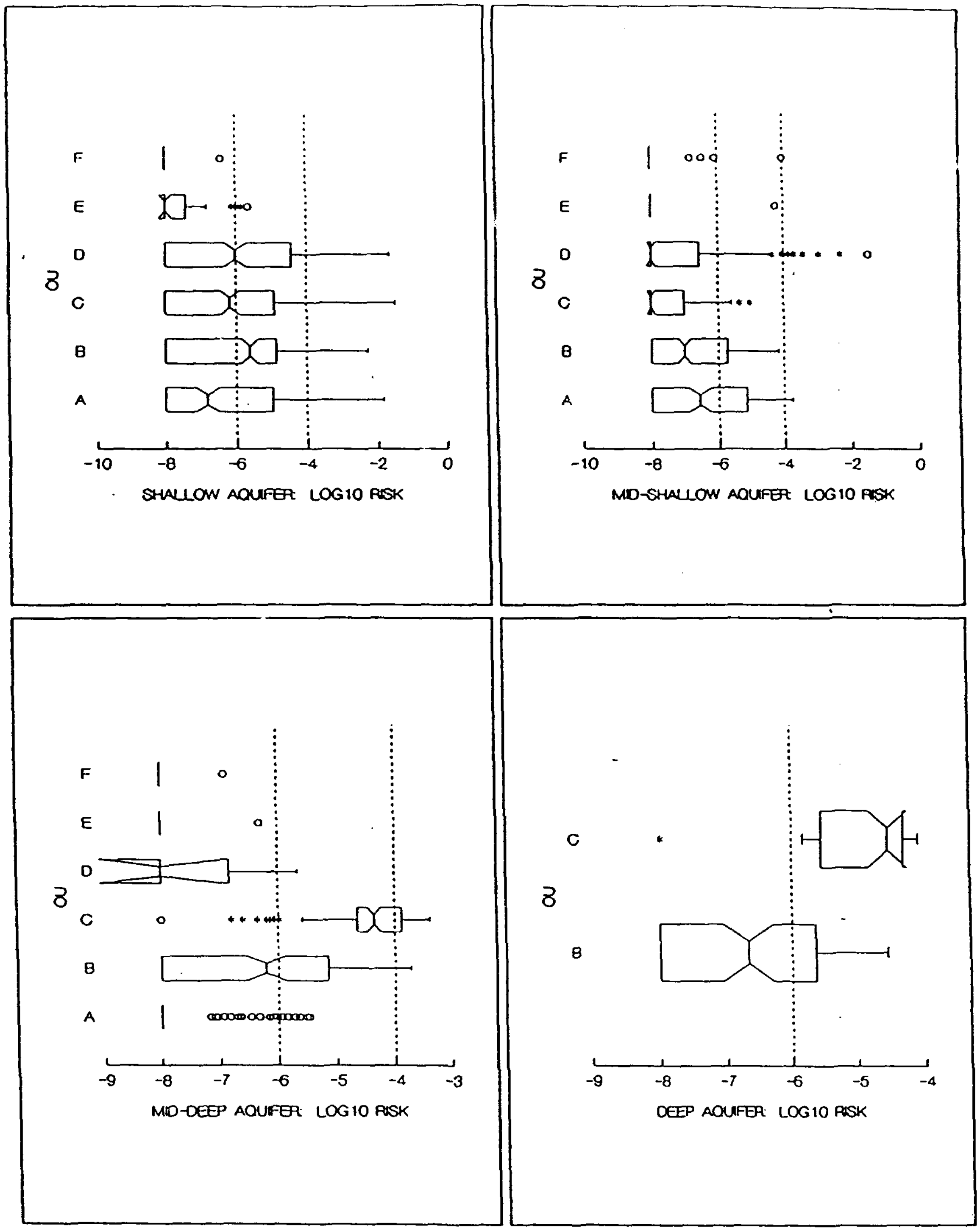


FIGURE 5-5
RISK ACROSS MONITORING ZONES AND OPERABLE UNITS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

5.4.2 Comparison with Health Assessment Findings

The results from the risk assessment were compared with the findings from the Health Assessment for McClellan AFB prepared by the ATSDR. In preparation of the Health Assessment, ATSDR collected and reviewed relevant health and environmental data for activities across the entire Base (ATSDR, 1993). ATSDR concluded that there have been complete exposure pathways in the past from groundwater contaminants to human populations, both onbase and offbase. The Health Assessment states that, while exposure pathways appear to be incomplete under current conditions, there is a lack of data to fully evaluate exposure pathways. In particular, ATSDR notes that there are no updated records on the current use of private wells by residences provided with the alternate water supply.

ATSDR speculated that it is possible that some residences may have reconnected their private wells because of water restrictions during the drought, though none reported using their private wells for potable purposes in the ATSDR public availability sessions. Individuals using private wells for irrigation purposes could be exposed by inhalation of contaminants from droplets of water spray in the air and by ingesting biota that have bioaccumulated contaminants. On the basis of a survey of a limited number of residences, ATSDR noted that contaminant concentrations in offbase wells had decreased considerably between 1985 and 1991.

ATSDR stresses in its report the uncertainties concerning potential adverse health effects associated with exposure to low levels of multiple environmental contaminants in groundwater. In a fashion similar to that presented in this risk assessment, ATSDR provides a quantitative evaluation of health risks associated with groundwater contaminants and, in several cases, reported that potential exposures exceeded acceptable levels. However, these estimates operate under the same constraint in that they are calculated in a manner that overestimates risk. Therefore, actual risks are likely to be lower than these estimates and may even be zero.

Data evaluating potential human health risks from exposure to groundwater contaminants are limited and indirect. Epidemiological studies of the cancer incidence possibly caused by exposure to trihalomethanes (THMs) originating from chlorination of water supplies best simulate the human exposure scenario, but do not correlate well exposure concentrations and observed cancer incidences. These studies do not conclusively relate observed cancer incidences with THM concentrations (shown to average 83 μg/l in previous studies), but are suggestive because they represent concentrations of chlorinated VOCs in groundwater at which elevations in cancer risk are barely detectable in several large epidemiological studies (Williamson, 1981; NRC, 1980; Shy, 1985).

Relatively few studies have evaluated the incidence of adverse effects in populations living near disposal sites, and these often have several limitations. While these studies have played a role in shaping the public debate concerning groundwater contamination, they generally have added little to our understanding of trends between adverse effects and contamination (Upton et al., 1991). However, a limited number of studies provide a useful example of the extent of groundwater contamination with VOCs considered to be associated with adverse health effects. In one case, prompted by health complaints from residents in Hardeman County, Tennessee, groundwater samples were collected from wells near a landfill where 300,000 barrels of pesticide manufacturing wastes were stored. The population previously exposed to contaminated well water exhibited hepatomegaly and abnormally high levels of hepatic enzyme levels. These effects decreased upon cessation of exposure. Concentrations of carbon tetrachloride detected in private wells serving the exposed individuals ranged from 61 to 18,700 μg/l, with a median level of 1,500 μg/l. The authors concluded that the findings indicated transitory liver injury probably related to contaminated groundwater (Clark et al., 1982).

Although there are limitations with the data, epidemiological studies of human exposure to groundwater contaminants provide some insight to the potential for adverse health effects at McClellan AFB. The studies of cancer incidences associated with exposures to THMs in chlorinated surface water indicate increased cancer risks that are barely detectable with epidemiological methods. While contaminant exposures were not quantified in these studies, a median THM concentration reported in U.S. surface water, during the time in which these studies were conducted, was 117 μg/l, with 83 μg/l of chloroform (Williamson, 1981). The NRC has concluded that the projected increases in mortality in these epidemiological studies is probably too small to distinguish in the presence of confounding factors, such as cigarette smoking (NRC, 1980). The human experience with exposure to groundwater contaminants, as it has been evaluated through epidemiological studies, combined with data characterizing the contaminant concentrations, suggests that there is a low likelihood of a perceptible association between adverse health effects and groundwater contamination at McClellan AFB.

5.5 Compliance with ARARs

The remedial alternatives discussed in this RI/FS are required to attain cleanup standards and/or standards of control of hazardous substances which comply with ARARs. These requirements include federal environmental laws and any more stringent state laws. Local regulations and guidelines must also be identified.

ARARs are divided into three categories: chemical-specific, location-specific, and action-specific requirements. The chemical-specific ARARs for the GW OU remedial actions define the concentration levels for contaminants in groundwater that trigger a problem and the concentration levels required for satisfactory treatment and end-use alternatives for treated groundwater. The location-specific ARARs relate to the geographical or physical location of the site, and the action-specific ARARs are requirements that define acceptable treatment and disposal procedures for hazardous substances. A detailed discussion of the potential and probable ARARs identified for the GW OU is provided in Appendix D, ARARs Analysis.

The No-Action Alternative will not meet ARARs. Site investigations conducted at McClellan AFB have concluded that the contamination in the groundwater underlying the Base currently does not meet applicable numerical criteria and other regulatory objectives and to-be-considered (TBC) criteria. The groundwater must be treated to meet federal and more stringent state standards.

The numerical values provided in the Safe Drinking Water Act (SDWA) are among some of the criteria which are exceeded at the Base. These numerical values, known as MCLs, are enforceable limits on the concentrations of certain hazardous materials in drinking water. Since the beneficial uses of the aquifer underlying the Base include municipal, industrial, agricultural, and domestic water supply, drinking water standards, including those found in the SDWA, apply. The presence of contaminants above MCLs have degraded these beneficial uses; therefore, treatment is required to restore the groundwater underlying the Base and protect drinking water supplies outside of the zone of influence.

Another ARAR which is exceeded at the Base is the State Water Resources Control Board (SWRCB) Resolution 68-16. This policy, which has been promulgated as regulation, states that water quality may not be allowed to be degraded below what is necessary to protect beneficial uses. The groundwater at the Base must be treated to a level that restores and protects all beneficial uses of the aquifer.

SWRCB Resolution 92-49, which is currently considered TBC criteria because it is not a promulgated regulation, states that the Regional Board is authorized to require cleanup of wastes discharged and restoration of affected waters to background levels. Cleaning up to background means that there should be no detectable concentrations of VOCs using a reliable analytical method. This can be accomplished by using EPA Methods 601 and 602 with a detection level of 0.5 μg/l. This policy also requires cleanup and abatement actions to conform to SWRCB Resolution 68-16, water quality control plans and policies, and applicable provisions of Title 23 California Code of Regulations (CCR), Division 3, Chapter 15, as feasible.

Title 23 CCR, Division 3, Chapter 15, Section 2550.4 provides a method for determining cleanup standards using background concentrations as a starting point. A cleanup level greater than background may be proposed only if the regional board finds that it is technically and economically infeasible to achieve background levels. If cleanup levels greater than background are proposed, it must be demonstrated that the contaminants will not result in excessive exposure to sensitive biological receptors.

Most of the VOCs detected in the groundwater exceed the Resolution 92-49 background level. Many of the contaminants inconsistently exceed MCLs in some monitoring wells while other contaminants exceed MCLs on a much more frequent and regular basis. Those compounds that consistently exceed MCLs are called contaminants of concern and include trichloroethene, cis-1,2-DCE, PCE, and 1,2-DCA.

In developing groundwater containment options, MCLs and the 0.5 $\mu g/l$ cleanup level were used to generate target volumes that identify areas where remediation is necessary. In addition, a third cleanup level was identified based on the 10^{-6} cancer risk, which was developed in the risk assessment. A detailed description of the groundwater containment options is provided in Chapter 8.

The ARARs for the GW OU have been identified in a sequential manner. First, the ARARs that impact remedial goals, independent of remedial alternatives, were identified. These are the chemical- and location-specific regulations and objectives that govern the release and need for remediation of specified hazardous materials and present how the physical location of the site can determine where and how a treatment facility can be constructed and operated. Next, the action-specific ARARs are identified for each remedial alternative. These define the performance requirements of the system and may impact cost and implementability of the alternative.

The ARARs presented and discussed in Appendix D were developed after examination of the contamination at the Base, details of each potential remedial alternative, and review of the solicited ARARs provided by various agencies. The potential ARARs have been identified for each remedial alternative while the probable ARARs are regulations and objectives that are applicable to the selected alternative. The ARARs developed in this RI/FS are preliminary. They represent the regulations and requirements that may apply to potential options and the proposed alternative. Final ARARs will be developed and selected after the RI/FS report has been reviewed by and discussed with the agencies. ARAR identification will eventually be documented in the Interim Record of Decision.

Chapter 6
Feasibility Study Approach

The groundwater remedial action at McClellan AFB must accomplish several goals. It must achieve remedial response objectives identified for the Base, it must be able to accommodate uncertainties in site conditions, and it must integrate with other remedial actions being performed at the Base.

The purpose of this chapter is twofold: first, to describe the strategy for groundwater remedial action, and second, to describe how the different elements of the FS were integrated to evaluate the pertinent data, understand the uncertainties in site conditions, and develop solutions to the problem of groundwater remediation at McClellan AFB. The strategy for groundwater remediation and the approach to the FS have unfolded through interactions between McClellan AFB and the regulatory agencies that have been ongoing throughout the RI/FS process, and reflect the consensus obtained between the Base and the agencies.

6.1 Nature of the Problem and Required Decisions

Prior to preparation of the Work Plan for the GW OU, a Strawman ROD was prepared that contained the best estimate of the decisions and uncertainties that would be addressed in the ROD for the GW OU. The Strawman ROD contained three major decisions:

- The necessity of remedial action
- The definition of target volumes for remedial action
- The selection of remedial actions to be applied to the selected target volumes

The conceptual model of the site, presented in Chapter 4, described the nature and extent of groundwater contamination at McClellan AFB. The risk assessment and ARARs analysis, presented in Chapter 5, concluded that interim remedial actions have substantially reduced existing risks to public health from groundwater contaminants. However, groundwater underlying the Base is contaminated and has degraded groundwater quality, as defined by State of California policies. It could pose an increased risk to human health should the groundwater be used in the future. These two latter conclusions show the necessity of remedial action. This RI/FS report addresses the other decisions: the definition of target volumes for remedial action, and the selection of remedial actions for the identified target volume.

6.2 Remedial Response Objectives

Remedial response objectives have been identified that guide the development of a strategy for remedial action and the selection of remedial action alternatives for groundwater contamination at McClellan AFB. These remedial response objectives are to:

- Contain the contamination by stopping lateral migration offbase and vertical migration to deeper aquifers
- Apply innovative technologies to reduce the duration and cost of remedial action
- Protect public health and the environment
- Achieve compliance with ARARs

There are several possible strategies for remedial action. The following section discusses these strategies and identifies the strategy that achieves the remedial response objectives.

6.3 Strategies for Remedial Action

Several remedial action strategies could be taken to remediate the contaminated groundwater beneath McClellan AFB. In developing a Basewide remedial strategy, any of these potential groundwater remedies could be implemented along with a remedy to address vadose zone contamination. Because vadose zone contamination is a continuing source of contaminants to groundwater, the success of any of the following groundwater remedies is dependent on the implementation of an associated vadose zone remedy. Possible strategies for the remediation of contaminated groundwater, along with their possible outcomes and times to meet remedial objectives, are summarized in Table 6-1. Comparison of the potential effectiveness of each strategy in terms of reducing the volume of contaminated groundwater over time is presented in Figure 6-1. These potential strategies for groundwater remediation are:

- Pure containment of contaminated groundwater, minimizing the flow rate of extracted groundwater
- Pure containment of contaminated groundwater, minimizing the number of extraction wells required
- Containment with aggressive flushing of the target volumes
- Containment with hot spot isolation and aggressive flushing of the target volumes

Table 6-1 Possible Groundwater Remedial Action Strategies		
Strategy	**Possible Outcome**	**Approximate Time to Complete Remedial Action**
Containment	No further migration of groundwater contamination	> Centuries
Containment and aquifer flushing	No further migration of groundwater contamination, and some reduction in contaminated groundwater volume	> 100 years
Containment, aquifer flushing and hot spot isolation/ remediation	No further migration of groundwater contamination, more rapid reduction in contaminated groundwater volume and source removal	< 100 years
Containment, aquifer flushing, hot spot remediation, and vadose zone remediation (SVE)	No further migration of groundwater contamination, more rapid reduction in contaminated groundwater volume, groundwater source removal, and vadose zone source removal	10 to 50 years

Two different pure-containment strategies for contaminated groundwater could be implemented at the Base. The first is a containment strategy that minimizes the flow rate of extracted groundwater requiring treatment, but still prevents the further lateral or vertical migration of contaminants from their present location. This remedial strategy would consist of a sufficient number of extraction wells located so that any downgradient movement of contamination is halted, as well as any vertical movement downward into aquifers that are currently uncontaminated. This alternative would not effectively flush hot spot areas or low concentration areas, and the time required for site remediation would be on the order of centuries. This strategy is not likely to achieve compliance with ARARs because there is no reduction in the volume of contaminated groundwater, and the potential exists for further degradation of surrounding high quality groundwater.

The second type of pure-containment strategy that could be implemented at the Base would have the objective of containing the entire volume of contaminated groundwater with a minimum number of extraction wells. This strategy would require the construction of a relatively small number of extraction wells screened throughout the entire thickness of contaminated aquifer at the site. The main advantage of this strategy is that it minimizes the cost associated with the construction of numerous extraction wells and associated pipelines. The main disadvantage of this strategy is that it will drive contaminants that currently reside in the shallow aquifers downward into aquifers that are not currently contaminated. Another disadvantage is that these large extraction wells will draw large quantities of clean water from the deeper regional aquifer

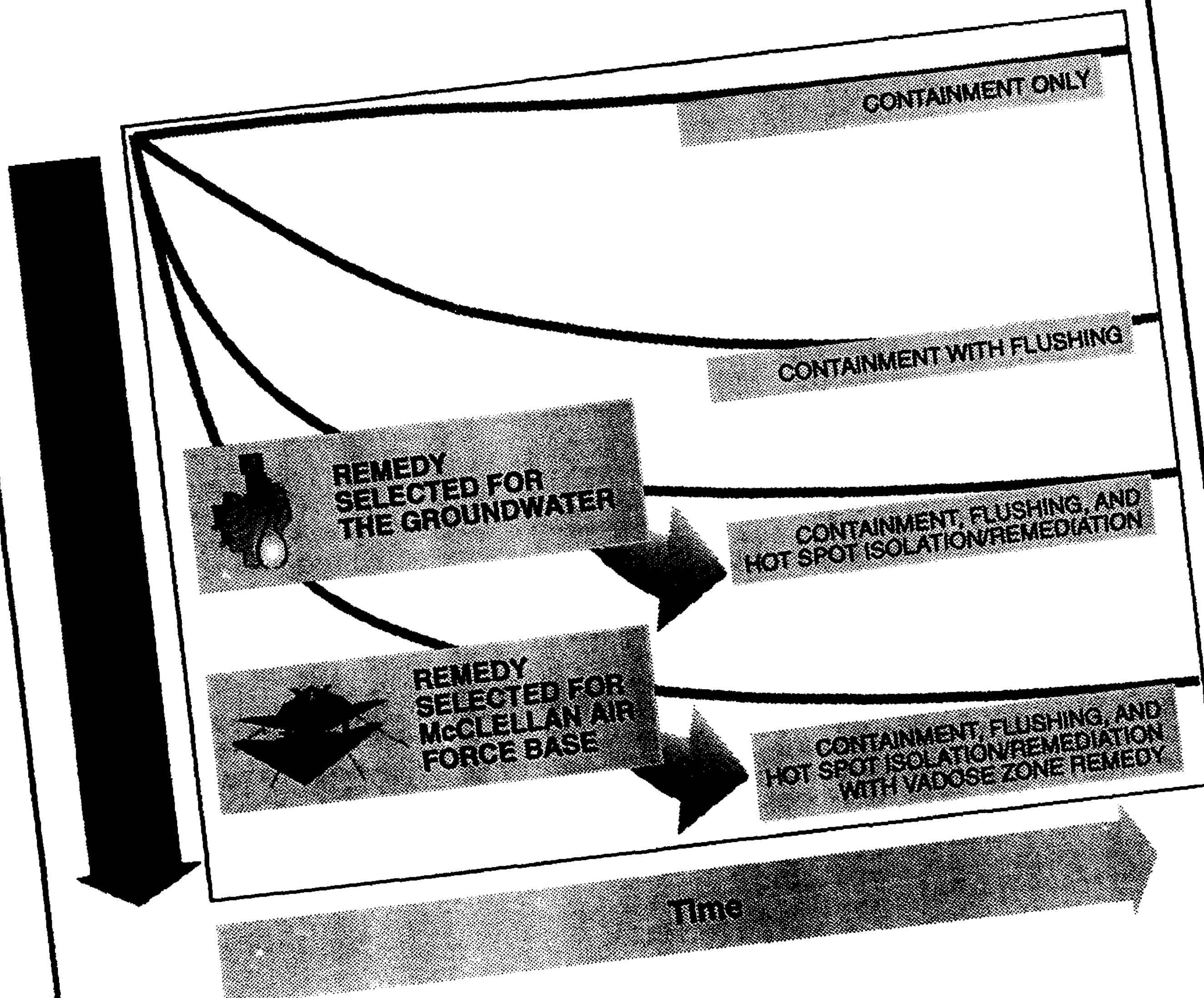


FIGURE 6-1
STRATEGIES FOR GROUNDWATER REMEDIAL ACTION
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1454_175

and produce a large volume of low-concentration water that will require treatment. Since hot spot areas are not addressed individually, groundwater with extremely high contaminant concentrations and possibly DNAPLs will be drawn downward into the B-zone and C-zone aquifers. This will act to extend the time required for site remediation because the high concentration areas will become more widespread. This strategy will not likely achieve compliance with ARARs, especially the California aquifer non-degradation policy.

A more aggressive remedial strategy is to construct a sufficient number of extraction wells such that all of the contaminated groundwater is contained, and the time required to flush one pore volume through the target area is reduced to 10 years or less. This scenario will provide a much more rapid remediation of the target volumes, but still lacks aggressive remediation of the highly contaminated hot spot areas. This is a significant disadvantage to this remedial strategy since highly contaminated groundwater may be drawn into lower concentration areas, significantly extending the time required for remediation.

The most aggressive remedial strategy for the Base would consist of the aggressive containment strategy described above, coupled with designated extraction wells that contain and flush the hot spot areas directly. This scenario will provide relatively rapid flushing of the lower concentration areas and will prevent the highly contaminated groundwater from leaving the current hot spot areas. This strategy will result in the low concentration portions of the target volumes reaching remedial action objectives fairly quickly (15 to 30 yrs), while isolating the portions of the aquifer that will require longer remediation times (hot spots).

6.4 Groundwater OU Strategy and FS Approach

6.4.1 Groundwater OU Strategy for Remedial Action

Containment and flushing, with hot spot isolation and remediation, will achieve the remedial response objectives. Contaminated groundwater volume would be reduced over time when hot spots are isolated. Innovative technologies, such as in situ bioremediation processes, could be applied once hot spots are isolated. Since groundwater would already be hydraulically controlled, the testing and trial implementation of innovative technologies would provide minimal risk to the overall remedial action. This has been the strategy selected for the GW OU. This strategy integrates with a Basewide SVE remedy that addresses continuing sources of contamination in the vadose zone. Figure 6-2 presents an idealized site setting for the remedial action strategy. This figure depicts the relationships between sites at McClellan AFB, vadose zone contamination, smear zone contamination, groundwater hot spots, and the contaminated volume of groundwater. Figure 6-3 depicts the relationships between the GW OU and other remedial actions at the Base.

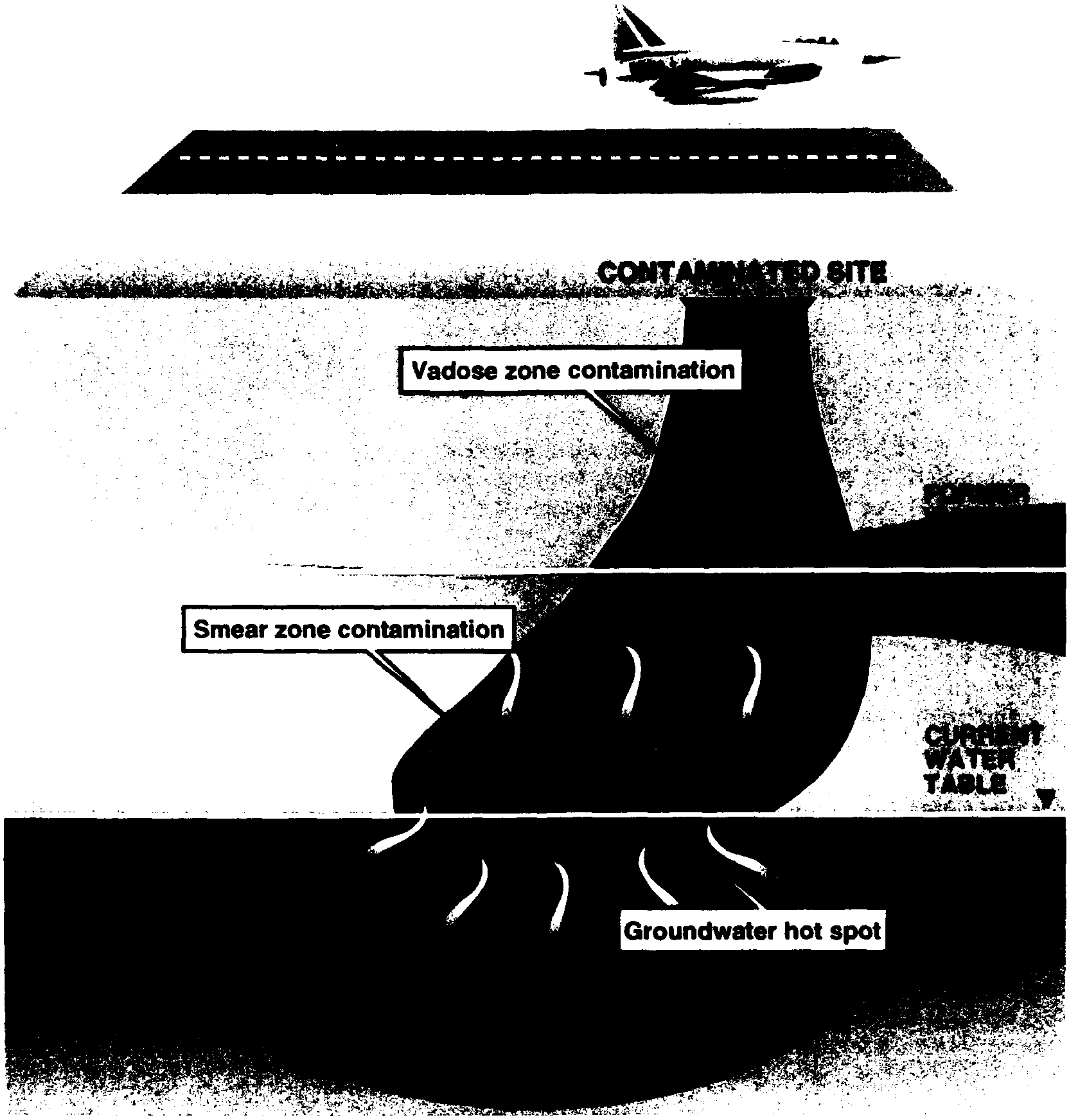


FIGURE 6-2
SITE SETTING FOR REMEDIAL ACTION STRATEGY
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454 176

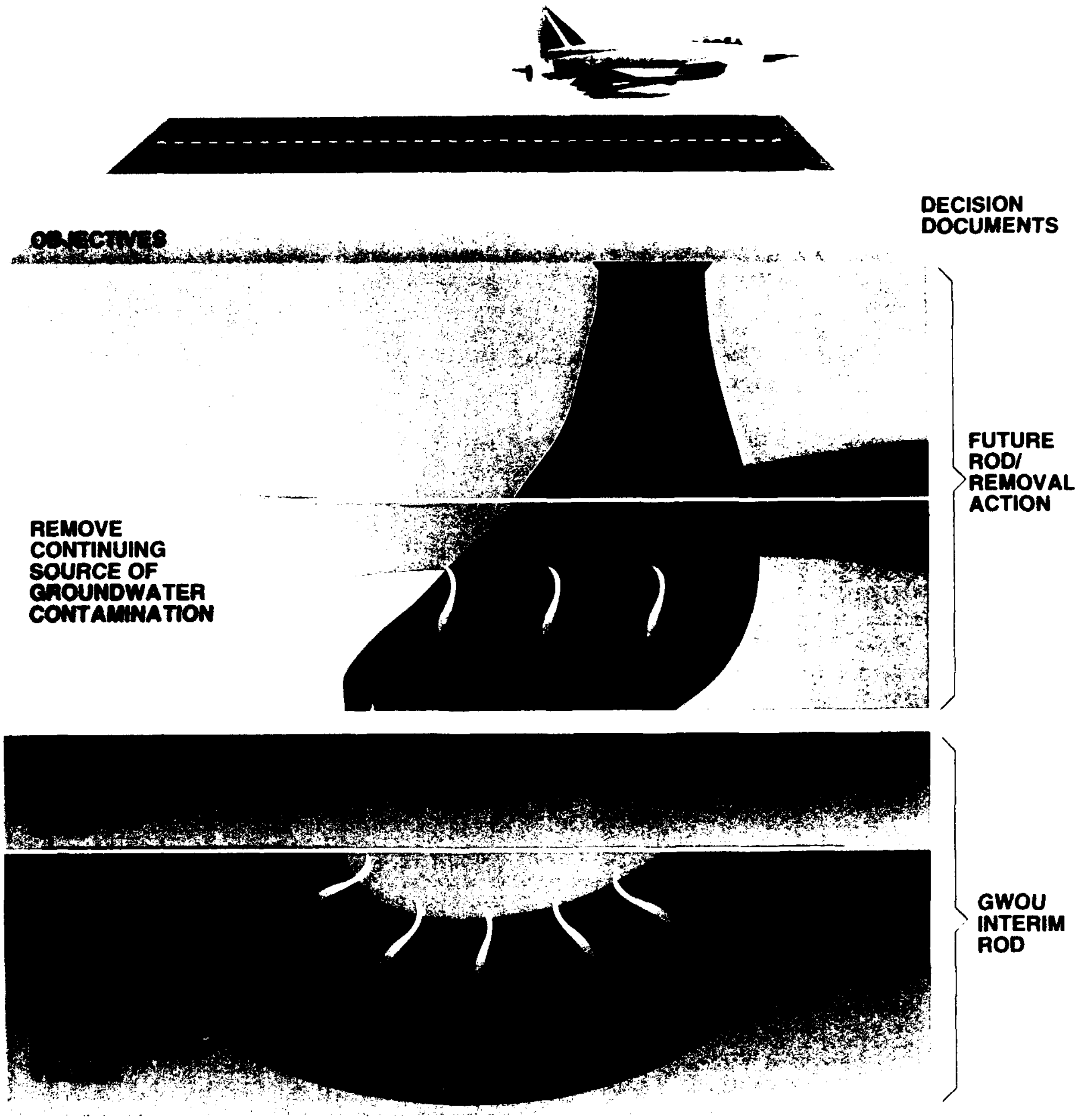


FIGURE 6-3
IMPLEMENTATION OF REMEDIAL ACTION STRATEGY
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_177

CH2M HILL

The Interim ROD resulting from the GW OU RI/FS would address migration of groundwater contaminants and reduction of the contaminated volume. The Interim ROD also would address reduction of contaminant diffusion from groundwater hot spots and removal of contaminant mass through the application of innovative technologies, as well as additional characterization of the extent of contamination and the groundwater system. SVE applied to vadose zone (including smear zone) contamination would remove the continuing source of contamination to groundwater. SVE removal actions have been initiated at some sites at the Base, through the use of Engineering Evaluation/Cost Analyses (EE/CA), with the goal of using SVE for Basewide vadose zone contamination. Removal of vadose zone contamination and isolation/remediation of hot spots could significantly reduce the time required to remediate contaminated groundwater. If these sources are allowed to remain in place, then the groundwater remedy at best would achieve containment of the contamination.

6.4.2 Approach to Remedial Actions and Innovative Technologies

The approach for development of remedial actions and innovative technologies is designed to support the goal of early risk reduction and containment of offbase contaminant migration. The approach involves conducting only those tasks necessary for and leading to this goal. A key objective is that the ROD achieve early risk reduction through basic, known technology, but be capable of implementing innovative technologies as they become appropriate. Innovative technologies bring the possibility of reducing overall operating costs, the duration of remedial action, and overall costs of environmental restoration. The benefit of this approach is a streamlined remedial action development process that is focused on the goal of a timely decision, while maintaining the ability to incorporate advances in remedial technology to enhance remedial action performance. Consensus between McClellan AFB and the regulatory agencies on this approach has been obtained through several workshops and discussions.

A range of cleanup strategies were identified to guide development of remedial action alternatives. These strategies were reflected in the development of the target volumes presented in Chapter 4. The target volumes, hence possible cleanup strategies, were:

- Hot spots, 500 μg/l or greater TCE
- MCL, 5 μg/l TCE (several compounds exceed MCLs; however, the MCL target volume is largely controlled by the extent of TCE in groundwater)
- Health risk, 10^{-6} increased lifetime cancer risk
- Background, 0.5 μg/l, determined largely by the extent of TCE in groundwater

Note that a hot spot target volume does not strictly reflect a cleanup strategy, but was considered in the FS to better evaluate the relationship between contaminant mass removal and remedial action costs. Consensus on these target volumes was obtained between McClellan AFB and the regulatory agencies during a workshop held in July 1993.

The approach to the FS was based on the understandings that remedial action alternatives shared common elements of groundwater pumping, treatment and end use, and that there are several options for each of these elements. The approach to the FS involved evaluating and screening the different options based on data that were either immediately available or could be obtained readily. Chapter 8 presents the development of groundwater containment and extraction options based on the selected target volumes and the evaluation of the available hydrogeological data. Chapter 9 presents the evaluation and screening of groundwater treatment options. Screenings and selection of treatment technologies were finalized during a murder board workshop, attended by McClellan AFB and the regulatory agencies in July 1993. End-use options are presented in Chapter 11. Possible end uses were identified during an August 1993 workshop attended by local water districts and other interested individuals. Final screening of all of the different options was performed during an alternatives development workshop held in August 1993. The screened groundwater containment, treatment, and end-use options were then assembled into remedial action alternatives, as discussed in Chapter 12. Detailed analysis and comparison of the screened remedial action alternatives is performed in Chapter 13. The alternatives are compared with each other, and with EPA's evaluation criteria, to identify the optimal alternative. Chapter 13 also presents budget-level cost estimates for each alternative.

Innovative technologies are new and promising treatment technologies for site remediation. By definition, they are relatively unproven compared with standard treatment technologies. However, as discussed previously, innovative technologies may offer potential benefits compared with standard technologies. Once groundwater containment, treatment, and end uses are in place, innovative technologies can be incorporated to reduce the treatment burden. In situ processes could be used to treat or accelerate the extraction of contaminant hot spots. Ex situ processes could be used to reduce the costs of treating extracted groundwater. Because the groundwater would already be hydraulically controlled, the testing and trial implementation of innovative technologies would involve minimal risk to the overall remedial action. As described in Chapter 10, the evaluation, screening, and development of innovative technologies follows a parallel track to the development of remedial action alternatives (due to their unproven nature, they were not compared directly with standard technologies). Innovative technologies converge with the remedial action alternatives during the development of implementation plans presented in Chapter 13. The implementation plans identify the testing at the bench-, pilot-, or field demonstration-scale required to fully evaluate the feasibility of innovative technologies or identify design and operating criteria. Selection of the innovative technologies to be evaluated in the FS was made during the alternatives development workshop held in August 1993.

The remedial action alternatives are developed based on existing and readily available information. Additional data that would influence the remediation of contaminated groundwater cannot be fully anticipated at this time. These data could become available in the future. Two approache. used in the FS to address this issue were the evaluation of the possible uncertainties that could influence groundwater remediation, including the use of decision analysis (presented in Chapter 12), and development of a data collection and management plan (Chapter 7). These approaches provide the means of monitoring potential changes in site conditions and support the design of a remedial action with sufficient flexibility to accommodate pertinent new developments.

6.5 Addressing Uncertainties in the Groundwater OU FS

Decisions for the Groundwater OU will be made under conditions of uncertainty. While collection of additional data could reduce the uncertainty, the effort and expense of such data collection is unrealistic. The objective of the RI/FS process is not the unobtainable goal of removing all uncertainty, but rather to collect sufficient information to make an informed decision about which remedy is most appropriate for a given site.

6.5.1 Uncertainties Identified in the Project

In planning the GW OU FS, it was recognized that McClellan AFB had collected a considerable amount of data, and the challenge was to provide an approach that would lead to a strategically correct decision given the uncertainties. Several uncertainties were identified at the time of the preparation of the work plan:

- The full extent of the groundwater problem is not known for the following reasons:
  - There is uncertainty associated with the potential contaminant source areas in the vadose zone.
  - The full extent of contamination is unknown.
  - The potential transformation products of contaminants in groundwater could change the risks.
  - Some areas of the Base may have new contaminants.
  - There is uncertainty in several toxicity-based water quality criteria.
- The precise response of the groundwater system to further remedial action is not known.

- The future hydrogeological conditions are not known, in particular the long-term water levels and flow directions.

- The performance and cost of innovative technologies are not always known, and future technologies may be, and should be, superior to those available today.

- The remedial action for the vadose zone contamination and source areas at the Base is unknown.

Additional uncertainties identified during the course of the FS process were the following:

- It is not known if the quality of treated groundwater will be compatible with identified end uses.

- It is not known if there are air permitting problems with emissions from selected treatment technologies.

- It is not known how a mission change for McClellan AFB would influence decisions made for remedial action.

These uncertainties, qualitative descriptions of the bounds on the uncertainties, potential outcomes, and actions taken in the FS to address these outcomes are summarized in Table 6-2. A principal focus of this FS is the analysis of these uncertainties and the development of remedial action alternatives and implementation plans with sufficient flexibility to accommodate uncertainties in site conditions. The following section describes briefly how this was accomplished in the FS document.

6.5.2 Process of Addressing Uncertainties

A five-step process was used in the FS to identify, evaluate, and accommodate uncertainties that could be encountered during groundwater remediation at McClellan AFB. These five steps are:

- Identify uncertainties.
- Define their bounds.
- Identify or estimate potential impacts.
- Measure outcomes.
- Adjust operations.

Accomplishing these steps within the FS was facilitated by using decision analysis. Decision analysis depicted the relationships between decisions to be made in groundwater remediation and the uncertainties, and analyzed all possible combinations of decisions and uncertainties to select an optimal remedial action strategy. The use of decision analysis in the FS is discussed further in Chapter 12. A detailed presentation of the decision analysis process and modeling methodology is presented in Appendix H.

Table 6-2
Addressing Uncertainties in the Groundwater OU FS

Uncertainty	Current Bounds	Potential Outcome	Actions in the FS
Potential contaminant sources in the vadose zone have not yet been fully identified. Remedial actions for vadose zone contamination are not yet known.	Source areas under investigation in other OUs.	Vadose zone and smear zone contamination represents a potentially continuing source of contamination to groundwater.	Integrate the FS with other remedial actions onbase (including SVE EE/CA).
Full extent of contamination is not known.	Small hot spot areas with elevated concentrations in groundwater (>500 μg/l TCE, for example). Larger groundwater volumes with lower concentrations (20 to 40 μg/l TCE). Lateral and vertical extent not yet defined in some areas (OU A, OU B, OU C).	Uncertainties in extent of contamination could result in inadequate containment. Inadequate delineation or remediation of hot spots could result in long times to complete remedial action.	Develop a range of target volumes and remedial action strategies that bound the uncertainty. Perform a trend analysis of variability in existing contaminant concentration data to identify data gaps and focus on additional data needs. Incorporate the use of innovative technologies for hot spots into implementation plans for remedial action.
Potential transformation products of contaminants in groundwater could change the risk.	Wastes that have principally migrated to groundwater are chlorinated solvents such as TCE, PCE, and 1,1,1-TCA. Higher toxicity degradation products of these include 1,2-DCA and vinyl chloride.	Certain transformation products will affect selection of treatment technologies (e.g., vinyl chloride is removed from water more efficiently by air stripping compared with granular activated carbon). Transformation products generally oo not influence the extent of contamination.	Perform a sample-specific risk assessment to identify the contaminants of concern and their distribution in groundwater. Develop reasonably conservative estimates of influent concentrations for developing and sizing treatment technologies.
Some areas of the Base may have new contaminants.	Not applicable.	Remedial action may not be designed to address a contaminant of concern.	Perform a sample-specific risk assessment to identify the contaminants of concern and their distribution in groundwater.
There are uncertainties in several toxicity-based water quality criteria.	Currently available toxicity criteria (carcinogenic slope factors and Reference Doses) developed for use in risk assessment by EPA and Cal-EPA.	Values may change between the time that the FS is issued and the time that the ROD is issued.	Most conservative values of the set available from state and federal agencies were used in the risk assessment

Table 6-2
Addressing Uncertainties in the Groundwater OU FS

Uncertainty	Current Bounds	Potential Outcome	Actions in the FS
The precise response of the groundwater system to further remedial actions is not known.	Current understanding of aquifer response to local and regional pumping based on RI data.	Additional extraction wells would be require to contain the plume if response to the system is less than anticipated.	Perform hydrogeological modeling based on data collected from existing extraction wells to develop a reasonable estimate of aquifer response to pumping.
The future hydrogeological conditions are not known, in particular the long-term water levels and flow directions.	Current understanding of long-term water levels and flow directions based on RI data.	Increased water levels will allow higher rates of pumping. Lower water levels will restrict pumping to the point that shallow aquifers will dewater; alternative remedial action alternatives (SVE or dual-phase extraction) will have to be considered. Changing flow directions could result in inadequate containment.	Develop remedial action alternatives with sufficient flexibility to address changes in water levels as they are observed. Design an extraction network that is robust with respect to changes in flow direction.
The performance and cost of innovative technologies is not always known, and future technologies may be, and should be, superior to those available today.	Identification of available innovative technologies.	Application of innovative technologies could accelerate degradation of contaminants in situ, increase contaminant removal from groundwater, or accomplish groundwater treatment in areas where standard technologies would not be feasible. Use of innovative technologies is restricted by a lack of performance or cost data.	Develop implementation plans that incorporate the selection and use of innovative technologies.
It is not known if the quality of treated groundwater will be compatible with end uses.	Water quality requirements of surrounding water districts. Mineral and elemental concentrations in groundwater at the point of injection. Mineral and elemental concentrations in treated groundwater.	Injection may not be possible if there is a difference in water quality between treated groundwater and the injection aquifer. Water districts would require treatment of water with granular activated carbon prior to acceptance.	Use decision analysis to analyze costs and uncertainties associated with different end-use options, and identify the least-cost option.

Table 6-2
Addressing Uncertainties in the Groundwater OU FS

Uncertainty	Current Bounds	Potential Outcome	Actions in the FS
It is not known if there are air permitting problems with emissions from treatment technologies.	Basewide emissions limits. Estimated emissions from offgas treatment units.	Selected treatment technologies may be less acceptable due to inability to meet air permit requirements.	Use decision analysis to analyze the effects of air permitting costs on selection of the optimal treatment technology.
The mission of McClellan AFB may change due to Base realignment and closure.	Mission change would likely involve dual use, with portions of the Base changed over to civilian use.	Certain treatment technologies may become less favorable, if portions of the Base are converted to civilian use.	Use decision analysis to analyze the effects of additional permitting complexity associated with a mission change on selection of the optimal treatment technology.

Identification of the uncertainties began with development of the work plan and continued throughout development of the FS. In many cases, effectiveness of remedial action and cost were factors in identifying uncertainties. For example, extracted groundwater flow was identified as a factor that influenced cost of groundwater treatment and discharge to end uses. Groundwater flow also is an uncertainty influenced by target volume size, permeability, hydraulic conductivity, and water levels. These related uncertainties, addressed in the hydrogeological model developed in Chapter 8, helped define the range of values for groundwater flow. In turn, groundwater flow, as an uncertainty in the decision analysis model, was a factor in selecting an optimal remedial action alternative.

Once identified, the next step is to identify the bounds, or possible range of values, for each uncertainty (a qualitative description of these is presented in Table 6-2). These are estimated through calculations performed during the FS; for example, flow rates required to maintain capture of groundwater contaminants or order-of-magnitude cost estimates of treatment technologies or end uses. These bounded values were used in the decision analysis model to evaluate potential impacts associated with remedial action alternatives; or, correspondingly, select the optimal remedial action alternative with the smallest potential impacts.

Potential impacts associated with selection of a remedial action alternative were calculated using sensitivity analyses. Sensitivity analyses were then performed to identify the key parameters that impact the strategy. A criterion for sensitivity in decision models is whether any decision (e.g., selection of a remedial action alternative) changes when an uncertain parameter is set to its extreme points (i.e., its 10th and 90th percentile values) while holding all other parameters at their nominal values. If no decisions are changed, the uncertainty of this parameter is relatively less important to decisionmaking compared with other uncertainties. The sensitivity analyses focused attention on those uncertainties with the greatest impact and helped prioritize data collection. Sensitivity analyses also identified those remedial action strategies that were robust, or that were feasible under conditions of great uncertainty.

Measurement of outcomes is a step that occurs beyond the RI/FS, during remedial design/remedial action (RD/RA). This step involves collection of data (e.g., groundwater monitoring data) that will identify actual outcomes associated with groundwater remediation. This step is described in greater detail in the data collection and management plan presented in Chapter 7 of the RI/FS report. Analyses performed during the FS, such as trend analyses of groundwater contaminant data and the decision analysis, have roles in identifying those data most useful in reducing uncertainties associated with groundwater remediation. Finally, design or operation of the groundwater remedial action can be adjusted based on the results obtained through the data collection and management plan. Some of these measurements (e.g., collection of additional groundwater monitoring data to refine the extent of target volumes) will allow for verification or adjustment of remedial designs before they are installed. Measurements of performance of the remedial action will then continue to facilitate continuous process improvement.

There are portions of the contaminated groundwater where the extent of contamination has not been sufficiently defined to estimate a target volume for hydraulic control. The most prominent area where this occurs is the deep groundwater contamination (Monitoring Zones D and E) in OUs B and C. Because this volume of contaminated groundwater cannot be estimated, a specific capture analysis was not performed. To accommodate the probable need to capture a substantial quantity of groundwater beyond the target volumes developed in Chapter 4, the decision analysis model was developed to evaluate the uncertainty of total flow to achieve capture.

Appendix H contains a complete description of the decision analysis model. The FS will not specifically develop a capture analysis for the deep contamination at OUs B and C, but any change in treatment or water end-use strategy due to the need to capture the deep contamination will be identified by the decision analysis model.

The presence of metals in the groundwater above the action levels of the three target volumes remains a data gap at this time. Based on recent unfiltered samples, there are metals at concentrations above MCLs. The issue is not whether the metals are present, but whether they are present at concentrations greater than background due to McClellan's operations. This is relevant to the need for McClellan to remediate the aquifers due to metals contamination. Whether McClellan needs to perform a groundwater remedy due to metals or not, the groundwater to be extracted to control the VOC target volumes may contain metals at concentrations higher than allowed by the selected water end use.

There is some uncertainty regarding the long-term metal concentrations from extraction wells pumping continuously. Filtered groundwater samples seldom exceed MCLs, and unfiltered samples routinely exceed MCLs for chromium and nickel. Which sampling technique is more representative of the extracted groundwater is debatable, so rather than include metals treatment for all alternatives, it will be included as a potential contingency measure. Initially the extracted water from each well will be treated to remove metals until it is determined if the concentraations will be above or below the water end use discharge limits.

Chapter 7
Data Collection and Management

Successful implementation of the groundwater remedy requires the collection of additional information and incorporation of information from the operation of the remedy and from other operable units. Given the potential long-term commitment that McClellan AFB is about to undertake, it is imperative that data collection and management be planned to minimize costs and to allow the use of Total Quality Management methods to minimize the cost of the groundwater remedy.

Additional information is necessary for the following reasons:

- Reducing the uncertainties prior to design of the groundwater remedy
- Monitoring and reporting compliance of the remedy to the appropriate agencies
- Monitoring the effectiveness of the remedy
- Measuring the critical performance and cost parameters so continuous process improvement can be applied

This chapter discusses the scope of each of these data collection efforts, the process for managing the data, and the method for providing information to the decisionmakers and the public.

7.1 Data Collection Efforts

The following section describes the data collection efforts for the remedial design, regulatory compliance, effectiveness measurement, and process improvement measurements. A complete description of the monitoring programs is available in Appendix E, Monitoring Programs, and monitoring locations are provided for each alternative in Chapter 13.

7.1.1 Remedial Design

The uncertainties that need to be resolved during the design of the remedy are:

- Extent of the contamination that exceeds the groundwater cleanup goal
- Yield of the aquifers under pumpage, particularly in OUs B/C and A

The extent of the groundwater contamination may be addressed by Hydropunch sampling of the Monitoring Zone A. Monitoring wells will be installed as part of the remedy. Aquifer tests will be performed in

OUs A, B, and C to measure the aquifer's yield and response to extraction. The aquifer tests will be of a longer duration than previously performed, most likely 24 to 72 hours pumping and 72 hours recovery, and monitoring will be performed in multiple wells and zones. Three aquifer tests should be performed in OU A and up to six should be performed in the OU B/C plume.

7.1.2 Compliance Monitoring of the Remedy

A ROD states the performance requirements for the selected remedy. For a typical extraction, treatment, and end-use remedy, such as that required at McClellan AFB, the compliance monitoring will include:

- Demonstrating hydraulic control by measuring water levels and interpreting the flow paths
- Monitoring water quality in the aquifer
- Monitoring the treatment plant influent and effluent concentrations
- Monitoring the flow to the treatment plant and to the end use
- Monitoring the operation time and down time of the system

7.1.3 Monitoring of the Effectiveness of the Remedy

Every remedial action has a fundamental purpose for its implementation. Progress towards this fundamental purpose of environmental restoration must be measured to assess the effectiveness of the remedy. In addition, the various remedies that will be implemented across the Base need to be evaluated compared to each other. To perform this objectively, data concerning the effectiveness of each action are needed.

In planning the Groundwater OU, the Remedial Project Manager team was questioned as to how effectiveness should be defined for the groundwater remedy. The following factors were recommended:

- Risk reduction factors
  - Level of contamination contained by the remedy
  - Reduction of potential exposure
  - Reduction of concentrations in the groundwater
  - Reduction of mass in the groundwater
  - Reduction of risk to the environment
- Effectiveness factors
  - Comparison of remedial action goals
  - Time to achieve goals

- Progress towards goals
- Reduction of mass in the groundwater
- Reduction of target volume
- Continued assessment of risk via the baseline risk assessment
- Reduction of contaminant concentration
- Mass removed from the groundwater
- Continued system efficiency and the ability to reduce action and cost
- Beneficial use of the extracted groundwater

Effectiveness measurements will continue over the life of the remedial action. The effectiveness and the compliance measurements are different because they have different purposes.

7.1.4 Process Improvement Measurements

A groundwater remedy will span many years using today's technologies. McClellan AFB is committed to implementing innovative technologies today and in the future to reduce the overall cost of the restoration program. Using technologies available today, locations for implementation of the innovative technologies can be identified for the remedy today. But new remedial action technologies will be developed continuously in the future, and the areas where the greatest benefit of adding innovative technologies need to be identified. In addition, the remedy can always be made more efficient by continuous process improvement. These two factors, insertion of future innovative technologies and applying continuous process improvement, make process improvement measurements necessary. The process improvement measurements are dependent on the remedy, but in general are as follows:

- Power cost for pumping and treatment unit
- Maintenance cost by system component (treatment unit, pipelines, pumps, wells)
- Operations labor
- System downtime and cause

7.1.5 Monitoring Well Locations

The groundwater monitoring networks developed for the recommended remedial action alternatives are designed to achieve two major objectives:

- Better define the spatial distribution of contaminants at the Base and allow refinement of the remedial action target volumes

- Provide an adequate network of monitoring points to assess the effectiveness of the extraction network in containing contaminated groundwater, or in monitoring the groundwater flow in potentially contaminated areas where remedial actions are not yet in place

New recommended well locations are classified by their primary function:

- Groundwater quality wells, designed to improve the understanding of the spatial distribution of contamination at the Base. In many cases, target volumes could be substantially reduced with strategic placement of some additional monitoring wells

- Hydraulic containment monitoring wells, designed to provide monitoring of the hydraulic containment of contaminated groundwater created by the extraction network

Conceptual layouts of groundwater monitoring networks, identifying numbers of wells and proposed locations, for each of the target volumes are provided in Appendix E.

7.2 Data Management

Information flow from the field and laboratory to the decisionmakers is critical to the success of groundwater remediation at McClellan AFB. The data management system assists this process by providing a means to track, catalog, and organize information. A description of the data management plan for the Groundwater OU is presented in Appendix F.

7.2.1 Database Description

The database will be use to store, organize, and retrieve historical and new data collected as a part of groundwater remediation at McClellan AFB. The database will consist of the following types of data files (or tables):

- Primary data, such as spatial data (describing locations), temporal data (describing events), and measurement data (quantitative measurements). Spatial data would include well locations; temporal data would include sampling dates; and quantitative data would include contaminant concentrations or water levels.

- Lookup data (or referential data) that provide additional information to help in cross-referencing primary data.

- Dictionary data that describe the structure of the database.

7.2.2 Data Management Procedures

An established set of data management procedures is required to ensure consistency among data sets; integrity of the database; and verified, usable data sets. The data management procedures will consist of the following:

- Data mapping, which involves defining proper names for data elements.

- Electronic data interchange, the procedures to facilitate data interchange between McClellan AFB, regulatory agencies, and contractors. This would also include procedures for data interchange with Installation Restoration Program Information Management System (IRPIMS) and Technical Information Staff (TIS).

- Data entry and verification, the process of ensuring that data are correctly entered into the database. Verification would be enhanced by reliance on electronic transfers, though procedures for manual entry and verification of hard copy data are also included in the data management plan.

- Data presentation and analysis, the presentation of data in a clear and logical format to aid data analysis and decision-making. Types of reports that could be prepared are presented below in Section 7.2.3. See Figure 7-1 for a diagram of the project information flow.

- Data administration, procedures to reduce the likelihood of errors. This would include control of data redundancy, operations and maintenance, and documentation.

The Data Management Plan for the GW OU is provided in Appendix F.

7.2.3 Reports

Compliance

Compliance reports for the existing Groundwater Treatment Plant (GWTP) include a monthly report to the agencies on the influent and effluent water quality and the water levels with the wellfield.

Compliance reports for the groundwater remedy will be different for three reasons. The first reason is the scope of the project. The groundwater remedy will be considerably larger than the existing extraction systems and treatment facilities. The second reason is the components of the remedy may be different, especially the end use of the treated water. The third reason is the turnaround time from compliance monitoring to compliance reporting can be shortened considerably given current information technology.

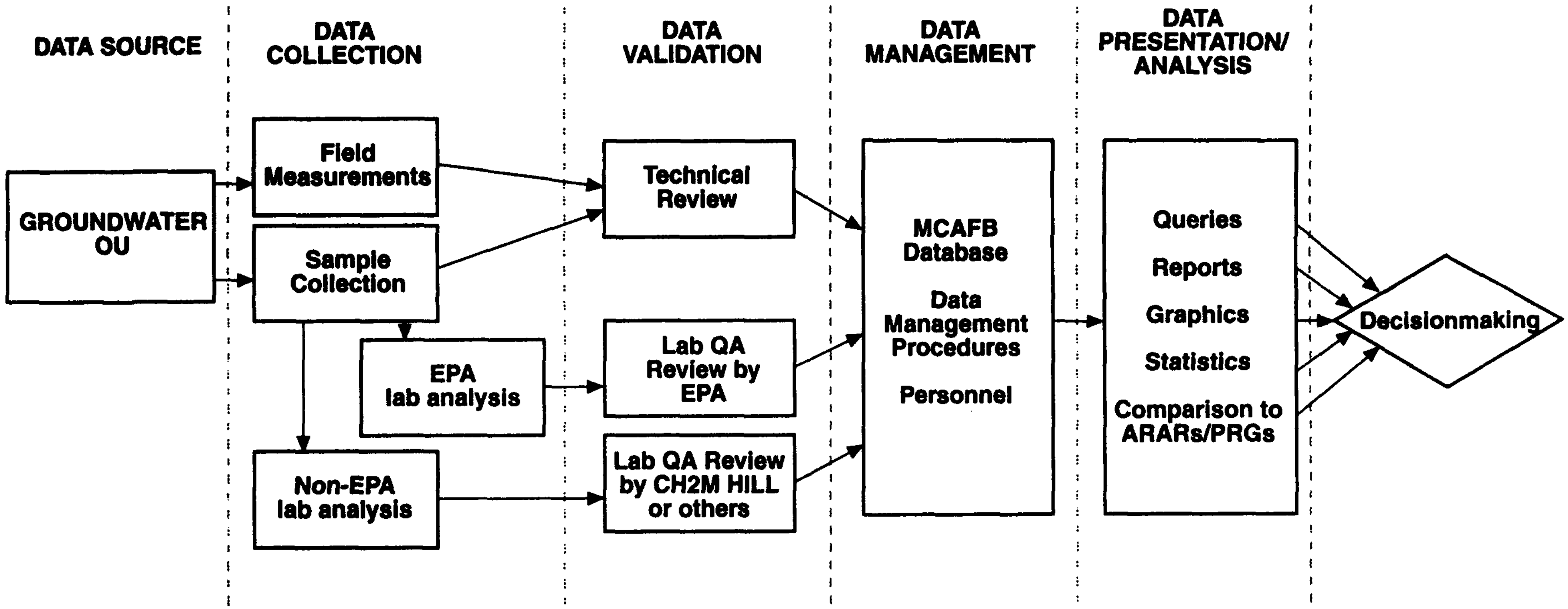


FIGURE 7-1
PROJECT INFORMATION FLOW
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

1312_801

CH2M HILL

The proposed compliance reports for the groundwater remedy will have the following attributes and information:

- Optional electronic format for delivery, as well as hardcopy
- Time series analysis of the last six monitoring events or 6 months, whichever is greater
- Control chart style analysis of the chemical data (selected VOCs and metals), physical property data (pH, temperature) and well-specific risk data
- Operational measurements, including pumping rate by well, total influent, and maintenance activities
- Presentation of the capture zone (maps and cross sections)
- Assessment of the extraction system's effectiveness with respect to the remedy's objectives
- Recommendations of modifications, if necessary

Management Information

The management information provided to McClellan Environmental Management Restoration Division (EMR) for management and operation of the groundwater remedy will include:

- Summaries and time series analysis of the measurements related to risk reduction and effectiveness listed in Section 7.1.3.
- Summaries and time series analysis of the process improvement measurements listed in Section 7.1.4.

7.2.4 Data Descriptions

Chemical Data

Chemical data will be collected during remedial design and operation of the remedy. The analyses will be refined over the life of the project. The chemical data will be collected for different objectives, depending on the phase of the project and the component of the remedy being monitored. The groundwater monitoring program currently collects groundwater samples for VOC analysis quarterly for most wells, metals analysis annually, and VOC analysis annually for the remaining wells. Chemical data to be collected during the remedy will include additional wells to address data gaps, wells to address performance of the remedy, wells to address the boundary conditions of the remedy, and wells to address source control and reduction. The philosophy of the monitoring program will shift during remedial action as compared to the current remedial investigation program. Given the long-term commitment to remediation, the monitoring of chemicals in the aquifer should be reduced to annually with the exception of the wells along the target volume boundary, which should be monitored quarterly at the start of the remedy and reduced to annually within 2 years (unless the variability is excessive).

Water Level Data

Water levels are currently measured quarterly using water level sounders. McClellan AFB currently expends 15 person-days a quarter (300 wells at 20 wells a day) measuring the water levels, followed by data entry and interpretation. A superior system would allow the collection of water levels for the monitoring network at a single time. This would provide more comparable water level data. In addition, given the regional pumping influences and the strategy of hydraulic containment, the water level measurement program needs to be bolstered. Transducers are available for the wells that are critical to monitoring hydraulic control, and they are capable of transmitting pressure readings nearly continuously. For the remedial action, it is recommended the water levels from the transducers be recorded daily, reported in a weekly time trend to EMR, and reported monthly to the agencies. This program would generate approximately 36,500 water level records each year.

Treatment System Data

Currently, treatment system data include analytical requirements based on the National Pollutant Discharge Elimination System (NPDES) permit, which requires weekly sampling of influent and effluent VOCs; conductivity; pH; and other variables such as turbidity. In addition, monthly sampling of influent and effluent metal is required including nickel, zinc, lead, and four others. Semivolatiles and pesticides are sampled for twice a year. Current analytical costs reported by the GWTP operations contractor are approximately $40,000 per year. Air emissions from stripper offgas control devices will require initial performance testing via stack sampling and analysis. Requirements for operation and offgas control link the offgas emission measurement to the water influent quality and incinerator process variables and therefore do not require periodic stack sampling.

Alternatives developed in this study identify use of the existing or expanded GWTP, and . second facility on the east side of the Base using similar technologies for groundwater treatment. For these future operations, sampling and analytical requirements for each facility are anticipated to be similar to those described above.

Similar to existing data collection at the GWTP, intermediate process streams may require sampling to maintain good control of the facility. The quantity and frequency of these samples will vary with the treatment technology. However, these analyses, which serve to identify individual unit operation performance within the treatment facility, are only recommended on a periodic basis to assist in troubleshooting problems identified through other analytical or process measurement means.

Process data such as liquid levels, differential pressures, and flow rates should be recorded through an automated data collection and logging system. A summary of these variables can be archived on a weekly basis to document treatment plant operation.

Chapter 8
Groundwater Containment Options

As a convenience to the reader, all oversize figures (11" x 17" or larger) have been located at the end of the chapter.

This section describes the groundwater flow model used to develop extraction networks to contain and extract contaminated groundwater from Monitoring Zones A, B, and C at McClellan AFB. Extraction networks were developed for the target areas defined by the MCLs, the 10^{-6} cancer risk, and the background VOC concentrations (0.5 μg/l). A detailed description of the development of the target volumes is presented in Section 4.6. The following sections in this chapter briefly describe the construction and calibration of the groundwater flow model. Appendix J, Groundwater Model Development, provides a more detailed description.

8.1 Overview of Groundwater Extraction Technology

Extraction of contaminated groundwater coupled with groundwater treatment is the most common remedial action implemented at hazardous waste sites with groundwater contamination problems. While the process of extracting contaminated groundwater through extraction wells conceptually appears to be a simple process, the success of this technology at meeting project objectives depends on many complex factors. These factors can be loosely grouped into characteristics of the contaminated aquifer (physical factors) and characteristics of the particular contaminants present (chemical factors). The following section discusses the critical physical and chemical factors that must be considered to develop a successful groundwater extraction remedial action. It should be understood that while groundwater extraction is an effective strategy for containing large volumes of contaminated groundwater, it is a rather poor strategy for remediation of areas with high contaminant concentrations, free product, or low permeability materials.

8.1.1 Physical Factors

The process of extracting groundwater containing contaminants requires a three-dimensional framework of interconnected pores to allow the contaminant molecules to move from their original positions into an extraction well. The primary aquifer properties that determine how efficiently a contaminant molecule moves to a nearby extraction well include the tortuosity of the flow path, the presence of dead-end pore space, the heterogeneity of the aquifer material, and the anisotropy in permeability produced by the layered nature of sediments.

Tortuosity is an important factor in the movement of contamination because it is a measure of how directly a molecule can move to an extraction well. If flow paths are tortuous, interstitial groundwater velocities are often reduced, and there is an increased probability that contaminants will interact with the aquifer solids or enter dead-end pore space. The presence of dead-end pore space has a significant impact on the length of time required for a contaminated aquifer to reach a particular cleanup goal. As shown in Figure 8-1, contamination present in the free flowing pores is removed relatively rapidly by the process of liquid advection, or aquifer flushing. Alternatively, contamination present in the dead-end pore space must first flow out of the dead-end pores by molecular diffusion before it can be flushed into the extraction wells by advection (Figure 8-2). Because molecular diffusion is driven solely by concentration gradients, the movement of contaminants out of the dead-end pores will not occur until late in the remediation, when groundwater concentrations in the flushed pores has declined significantly. The driving force for diffusion will also decrease as concentrations drop, resulting in a slow decline in groundwater contaminant concentrations near the end of the remedial action. This process is partially responsible for the "tailing" of groundwater contaminant concentrations often seen in the late stages of a remedial action.

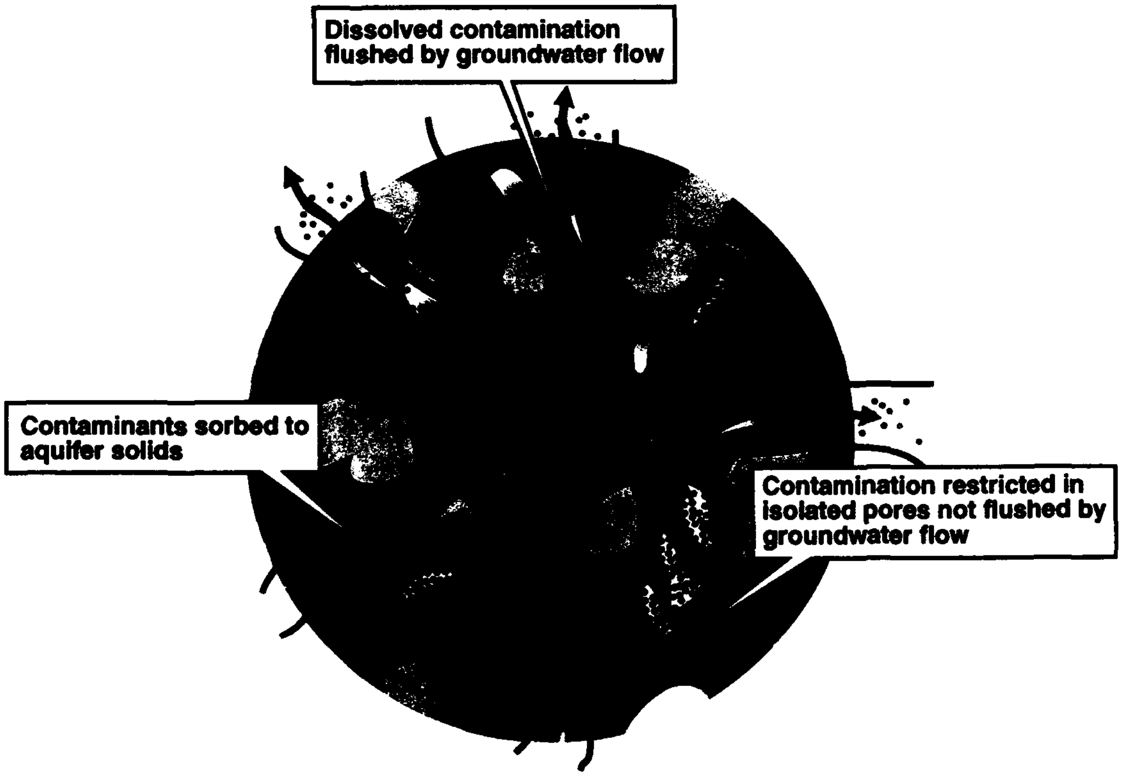


FIGURE 8-1
ADVECTION CONTROLLED REMOVAL OF CONTAMINATION EARLY IN GROUNDWATER EXTRACTION
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_460

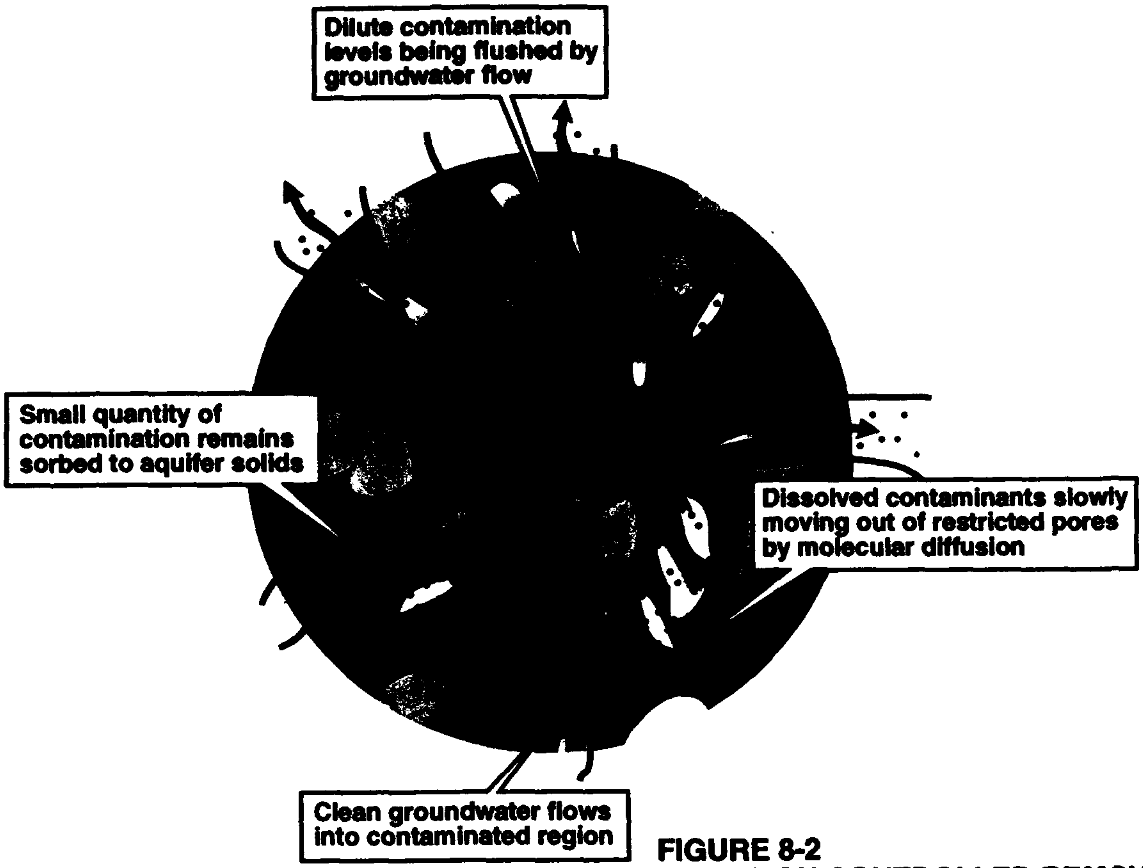


FIGURE 8-2
DIFFUSION CONTROLLED REMOVAL OF CONTAMINATION LATE IN GROUNDWATER EXTRACTION
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_462

Heterogeneity and anisotropy can also act to slow the progress of a remedial action. Both of these factors, inherent in layered sediments, will impede the progress of contaminant movement to an extraction well if the contaminants reside at depths other than that through which the extraction well is screened, as shown in Figure 8-3. Contamination moving upward or downward to a nearby extraction well will be forced to move through lower permeability material or take a more tortuous path to reach the extraction well. The shape of the capture zone created by an extraction well in heterogeneous sediments may differ considerably from what would be predicted assuming isotropic, homogeneous conditions. As a result, careful monitoring of the aquifer response to pumping is required to ensure that the desired aquifer target volume is indeed captured.

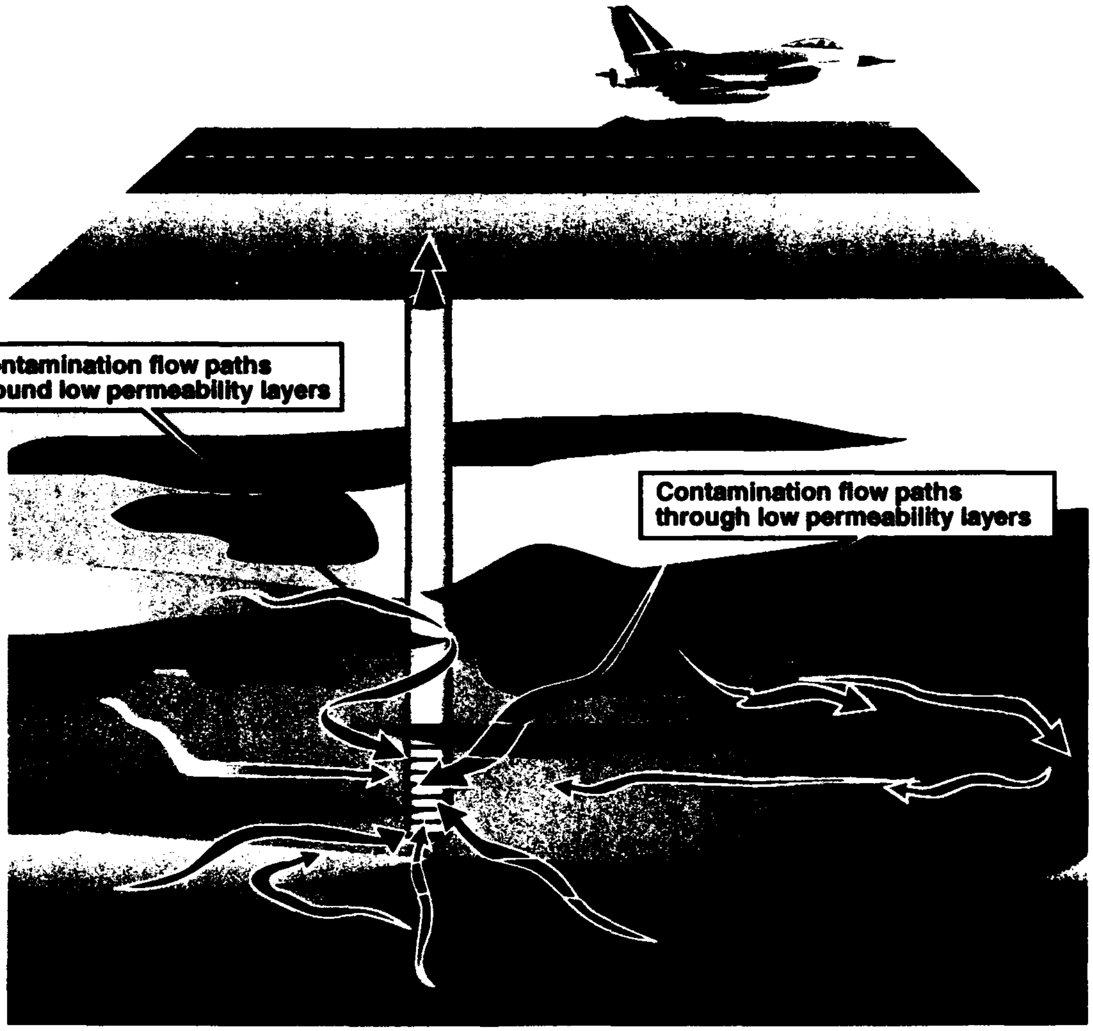


FIGURE 8-3
EFFECTS OF HETEROGENEITY IN SOIL PROPERTIES AND ANISOTROPY DURING GROUNDWATER EXTRACTION
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_461

CH2MHILL

8.1.2 Chemical Factors

The main chemical factors that influence the success of a groundwater extraction remedy are the affinity of a particular contaminant to interact (adsorb) with aquifer solids, the solubility of the contaminant, and the molecular diffusion coefficient of the contaminant.

Adsorption occurs when a contaminant molecule has a higher affinity for the organic matter on the aquifer mineral grains than for the water flowing through the pores. The extent to which contamination will adsorb to the organic material is directly proportional to the concentration of the contaminant in the aqueous phase (water). The mass of contamination adsorbed to organic material will remain until the aqueous phase contaminant concentration drops to low levels. The subsequent removal of contaminant mass from the organic carbon phase can be slow and will increase the time required for remediation.

The solubility of a contaminant is important because it determines the likelihood that free product will exist in the aquifer. A compound with a low solubility is more likely to occur as a free product, while a contaminant with a high solubility is more likely to occur in the dissolved phase. If free product does exist in the aquifer, and it is denser than water, a DNAPL pool may form. The presence of DNAPL will greatly increase the time required for remediation. DNAPL pools dissolve slowly in groundwater and require only a small mass of free product to sustain groundwater concentrations of 10 to 20 percent of contaminant solubility for hundreds of years (Cohen and Mercer, 1993, Section 4.7).

The molecular diffusion coefficient of a contaminant is a measure of the tendency for a molecule to diffuse through the liquid phase. While this property is less critical to the success of groundwater remediation than those discussed above, it is still important because it affects the rate at which contamination present in dead-end pore space will migrate into the free flowing pores and be extracted.

8.2 Uncertainties in Groundwater Containment Alternatives

The process of developing a mathematical model of a complex physical system requires that a simplifying assumption be made regarding the site characteristics. Site characteristics that are routinely simplified for the purpose of numerical analysis are the spatial variability of aquifer properties, the spatial distribution of contamination, and the temporal variation in recharge and groundwater pumping.

The use of a groundwater flow model to develop extraction network designs necessarily makes the resulting extraction networks subject to these same uncertainties. The most significant uncertainties in the site characteristics used to construct the groundwater flow model for McClellan AFB are as follows:

- The geometry of the monitoring zones undergoing remediation

- The spatial distribution of aquifer properties across the site

- The spatial distribution of contamination

- Future hydrologic conditions that may alter the effectiveness of the extraction system.

While all of these uncertainties do exist in the input data to the groundwater flow model, the model is still a valuable tool in the comparison of alternatives that require containing and extracting varying volumes of contaminated groundwater. Since all of the evaluations are based on the same set of assumptions, all of the alternatives will be affected equally by any discrepancies between the site conceptual model and actual site conditions. This results in relative comparisons that are valid, regardless of any reasonable deviation between actual site conditions and the conceptual model. The uncertainties, along with their potential effect on extraction system performance, will be discussed in the following sections.

8.2.1 Monitoring Zone Geometry

As described in Section 4.2, the definition of the monitoring zones is based on the interpretation of electrical geophysical logs obtained from testing of selected boreholes across the site. The correlation of the monitoring zone contacts in areas between data points is performed using professional judgement and knowledge of the type of depositional environment that existed when the sediments were deposited. Because of the highly variable nature of the sediments beneath the Base, the definition of the monitoring zones used in the groundwater model is a significant simplification of actual site conditions. However, because the method used to define the monitoring zones did not exclude any of the sediments present beneath the site, groundwater extraction networks developed under these assumptions will be effective at containing contaminated groundwater present in the target volumes.

8.2.2 Distribution of Aquifer Properties

Available information was considered in estimating the distribution of aquifer properties in each monitoring zone, but it is impossible to define all of the variability that actually exists at the site. If the sediments are more permeable than what was assumed in the model, less wells will be needed to achieve capture, and each well will be capable of producing more water than what was simulated in the model. Conversely, if sediments are less permeable than model assumptions, more wells will be required to achieve capture, and each well will produce less water.

The strategy used to address the uncertainty in aquifer yield was to strongly weight the performance of existing extraction wells at the Base and assume that wells constructed in the future will have similar performance characteristics. Although the theoretical interpretations of some aquifer test results suggested that extraction wells could produce higher quantities of water than what was assumed in the model, field observations do not support these interpretations. Therefore, these results were weighed less heavily. This approach will result in the design of an extraction system that will be effective, even if aquifer properties in certain areas result in higher well capacities than expected.

8.2.3 Distribution of Contamination

The uncertainty regarding the distribution of contamination at the site was addressed by using all available groundwater sampling data through the fourth quarter of 1993. However, significant uncertainty remains in areas where well coverage is sparse. Information obtained from the construction of additional monitoring wells at the site will be used to refine the target volumes during the initial phase of the implementation of the groundwater remedy. If this information indicates that contamination is more widespread than the current target volumes indicate, additional extraction wells will be constructed to contain that contamination.

8.2.4 Future Hydrologic Conditions

The last uncertainty discussed is the influence of future hydrologic conditions on the performance of the extraction network. This is an uncertainty impossible to resolve at this time because it is dependent on future activities near the Base, such as groundwater production practices and natural and artificial groundwater recharge. The influence that rising water levels will have on the extraction network is to require increased pumping rates from the extraction wells to achieve the same level of containment. If water levels decline significantly, certain portions of Monitoring Zone A will dewater and contamination once present in groundwater will remain in the soil profile. The extent of this contaminated soil layer will depend on the magnitude of the water level decline. The most effective strategy to remediate this contaminated soil would be to install soil vapor extraction wells and remove the contaminants in the vapor phase. It is likely that the proposed groundwater extraction wells can be converted to soil vapor extraction wells once the water levels fall below the screened interval. Another possible strategy would be to design wells in areas of limited saturated thickness, such as dual-phase extraction wells. This will allow the proposed extraction system to also address vadose zone contamination with minimal effort and cost.

8.3 Groundwater Flow Model

The groundwater flow model selected to evaluate the groundwater extraction alternatives is the three-dimensional, finite-element code MicroFem. This program is publicly available and has been fully verified. The model was used to simulate the regional groundwater flow system around McClellan AFB, encompassing an area of approximately 100 square miles. The extent of the regional model grid with respect to McClellan AFB is shown on Figure 8-4. The sources of data used as input to the model varied depending on proximity of the Base. Regional information (transmissivity, aquifer thickness, and water levels) were obtained from the regional flow model of the same general area developed by S.S.

Papadopulos and Associates (1987) for Radian Corporation. Site-specific information was obtained from independent interpretation of aquifer tests conducted on wells at the Base and from information presented in the Preliminary Groundwater Operable Unit Remedial Investigation (Radian, 1992). The groundwater model used in this analysis does not account for the influence of dead-end pore spaces on remediation discussed in Section 8.1.1. A more detailed description of the development, calibration, and use of groundwater flow model is included as Appendix J.

8.3.1 Groundwater Containment Simulations

The groundwater flow model is used to evaluate various extraction scenarios for differing volumes of contaminated groundwater. Target volumes have been defined based on where groundwater contamination levels exceed federal MCLs, where risk from groundwater contamination exceeds an additional 10^{-6} cancer risk, where contamination levels exceed the assumed background concentration for VOCs (0.5 μg/l), and the volume of groundwater where TCE exceeds 500 μg/l (hot spots). The following discussion presents the number of wells and pumping rates required to contain these estimated target volumes.

It was assumed in these simulations that the groundwater elevations across the site would remain constant during the course of remediation. If regional water levels continue to decline, the saturated thickness of certain portions of the A monitoring zone may become extremely small, or the sediments may become completely dewatered. If this occurs, remediation by extraction wells will become impossible. The areas most susceptible to dewatering are east of the runway in OU A, and are shown on Figure 8-5. This area of the Base is especially susceptible to dewatering for two reasons. The first is that it is a low transmissivity area, and groundwater extraction will create more drawdown in this area than in adjacent higher transmissivity areas. The second reason is that the base of Monitoring Zone A is at a shallower depth in this area, providing less saturated thickness from which to extract groundwater (see Figure 3-29 in the Preliminary GW OU RI for the base elevation of the A zone across the site). In the event that a portion of Monitoring Zone A does dewater, existing extraction wells will be converted to soil vapor extraction wells, and contamination will be removed in the vapor phase if it is a potential continuing source to the groundwater. As an alternative, extraction wells constructed in areas of limited saturated thickness may be constructed at dual-phase extraction wells.

8.3.2 Operational Strategy

Each groundwater containment alternative was governed by a similar operational strategy. The main elements of these strategies are summarized below:

- Each extraction system must completely contain the specified target volume, and most contamination must be captured in the monitoring zone where it resides. Containment is defined as the prevention of any contaminated groundwater from leaving a specified target volume.

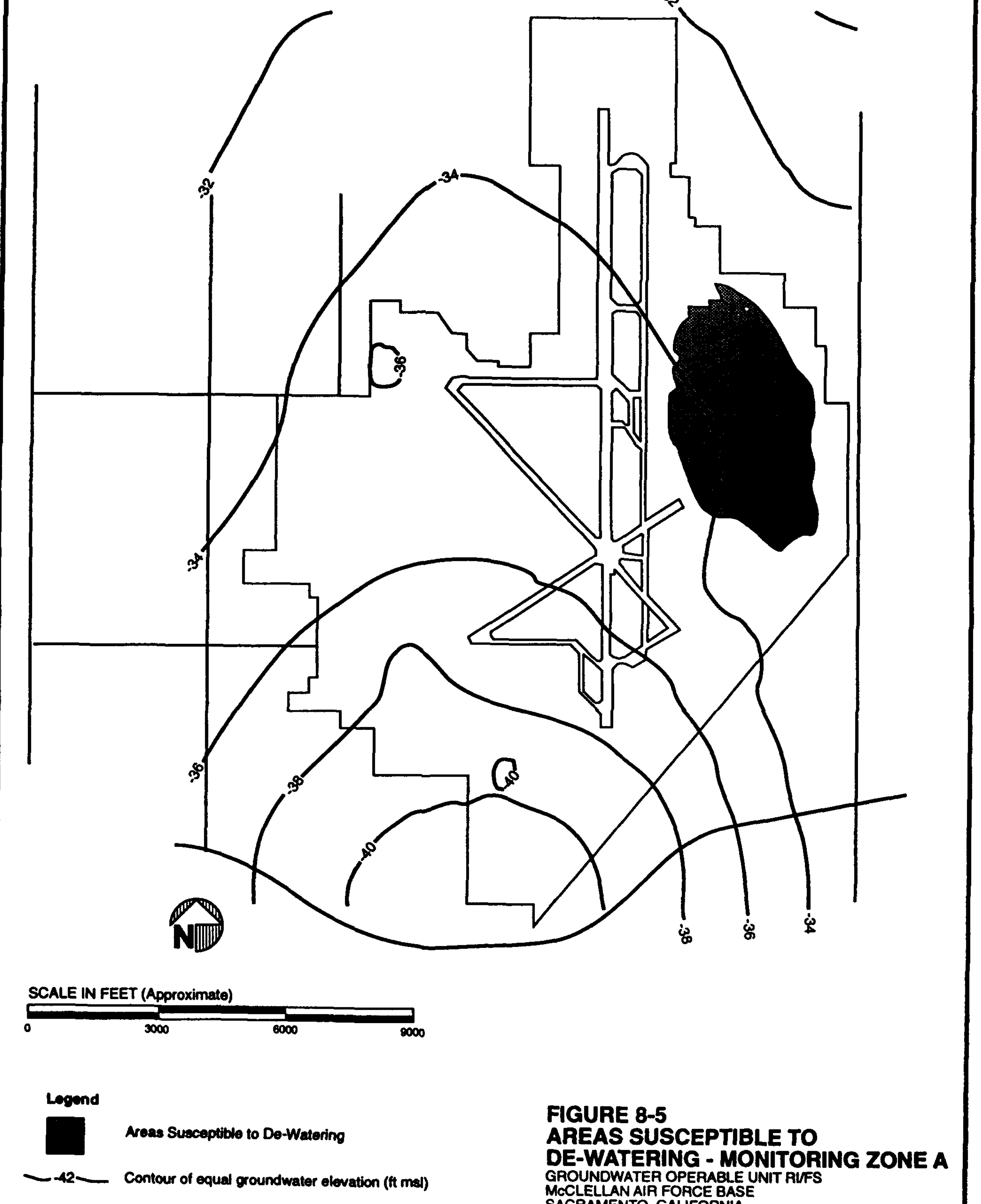


FIGURE 8-5
AREAS SUSCEPTIBLE TO DE-WATERING - MONITORING ZONE A
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

- A limited quantity of contamination is allowed to move between monitoring zones as long as the location where contaminants enter the receptor monitoring zones is within the target volume for that aquifer.

- In no case should contamination be allowed to leave a contaminated aquifer and enter an adjacent aquifer outside of the specified target volume.

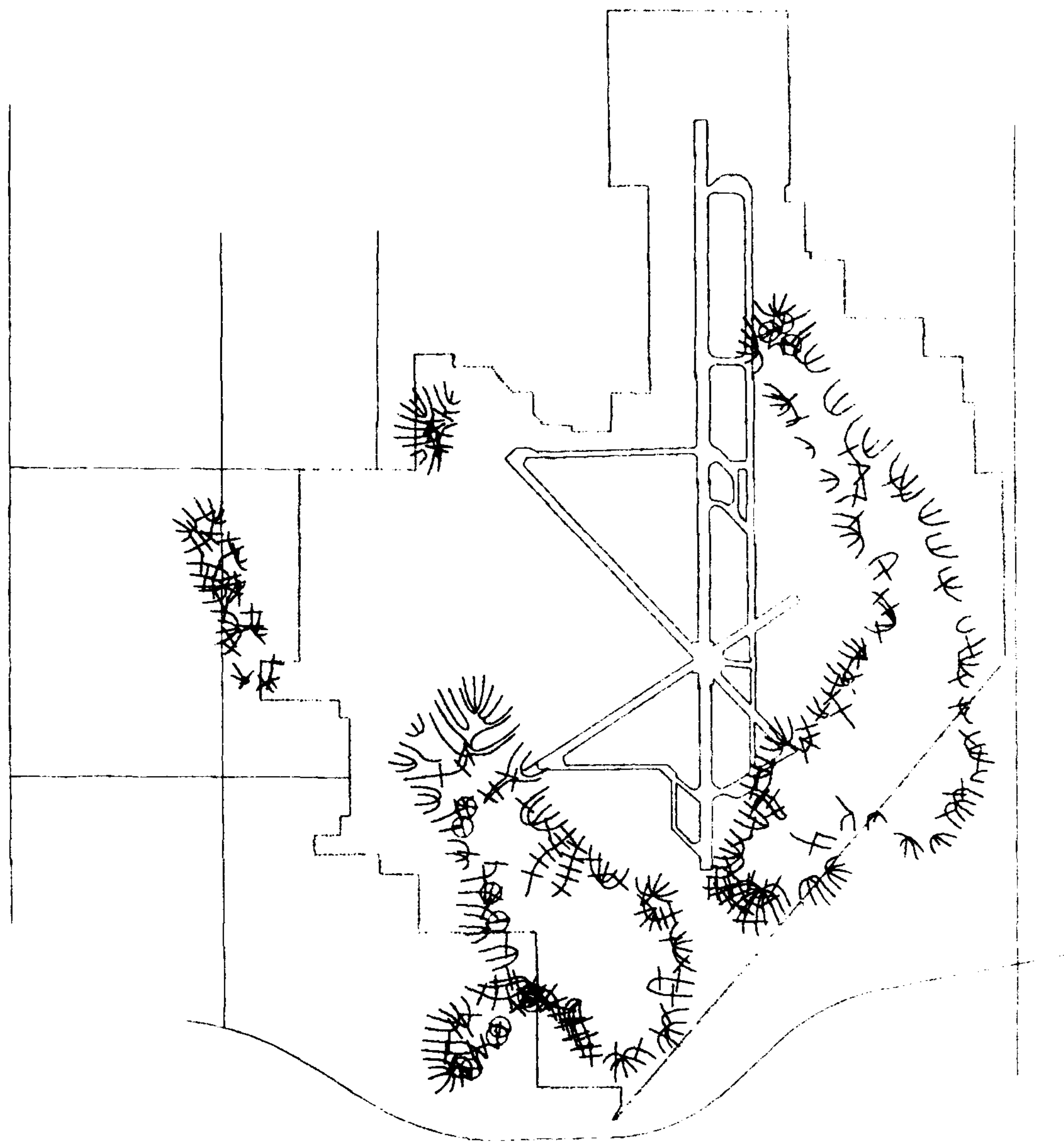
8.3.3 Containment Criteria

The definition of groundwater containment used in the extraction alternatives is that a flow line started at any location within the target volume, at any depth in the aquifer, moves toward and into an extraction well. The extraction well locations were determined on the basis of the groundwater flow directions, target volumes, and vertical hydraulic gradients. A small number of wells was simulated initially, and additional wells were added to capture portions of the target volume that were moving downward or outward past the simulated extraction wells. The well locations were adjusted until the entire target volume was captured. A sample set of flow lines for each monitoring zone assuming the risk target volume is presented in Figures 8-6 through 8-8. These figures show the movement of groundwater from the boundaries of the target volumes into the groundwater extraction wells. The colors of the flow lines represent the vertical position of the flow lines in the aquifer system. Blue flow lines are moving through Monitoring Zone A, green flow lines through Monitoring Zone B, and red flow lines through Monitoring Zone C. It is apparent that all contaminated groundwater within the target volumes eventually moves to, and is removed by, the extraction wells. Also apparent is that a majority of the contaminated groundwater is extracted in the monitoring zone in which it resides. Similar plots were used to verify that the other extraction networks discussed here are effective at completely capturing and removing contaminated groundwater at the Base. A complete set of figures containing the flow lines for each extraction network is included in Appendix J.

Another significant characteristic of all extraction networks is that the highly contaminated portions (hot spots) of Monitoring Zone A are isolated independently and removed by dedicated extraction wells. This is done to isolate groundwater with concentrations as high as 1,000 times the concentrations observed in other portions of the plume. These areas are also locations where DNAPLs are suspected to reside. It is advantageous to control DNAPL-based contamination near the source area as opposed to inducing this high concentration contamination to flow through areas of the aquifer with much lower contaminant concentrations. Five areas of high groundwater concentrations have been identified in Monitoring Zone A. These locations are shown on Figure 8-9.

8.3.4 Evaluation of Alternatives

The alternatives evaluated in this report are grouped according to common elements. The first set of groundwater containment alternatives consist of basic containment of each of the target volumes described above, with hot spot extraction by designated wells. The next set of



0 3200 6400 9600
SCALE IN FEET- APPROXIMATE

Legend

Flow Line in the A-zone

Flow Line in the B-zone

Flow Line in the C-zone

FIGURE 8-6
FLOWLINES SHOWING
CAPTURE IN MONITORING
ZONE A - RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_128

CH2MHILL

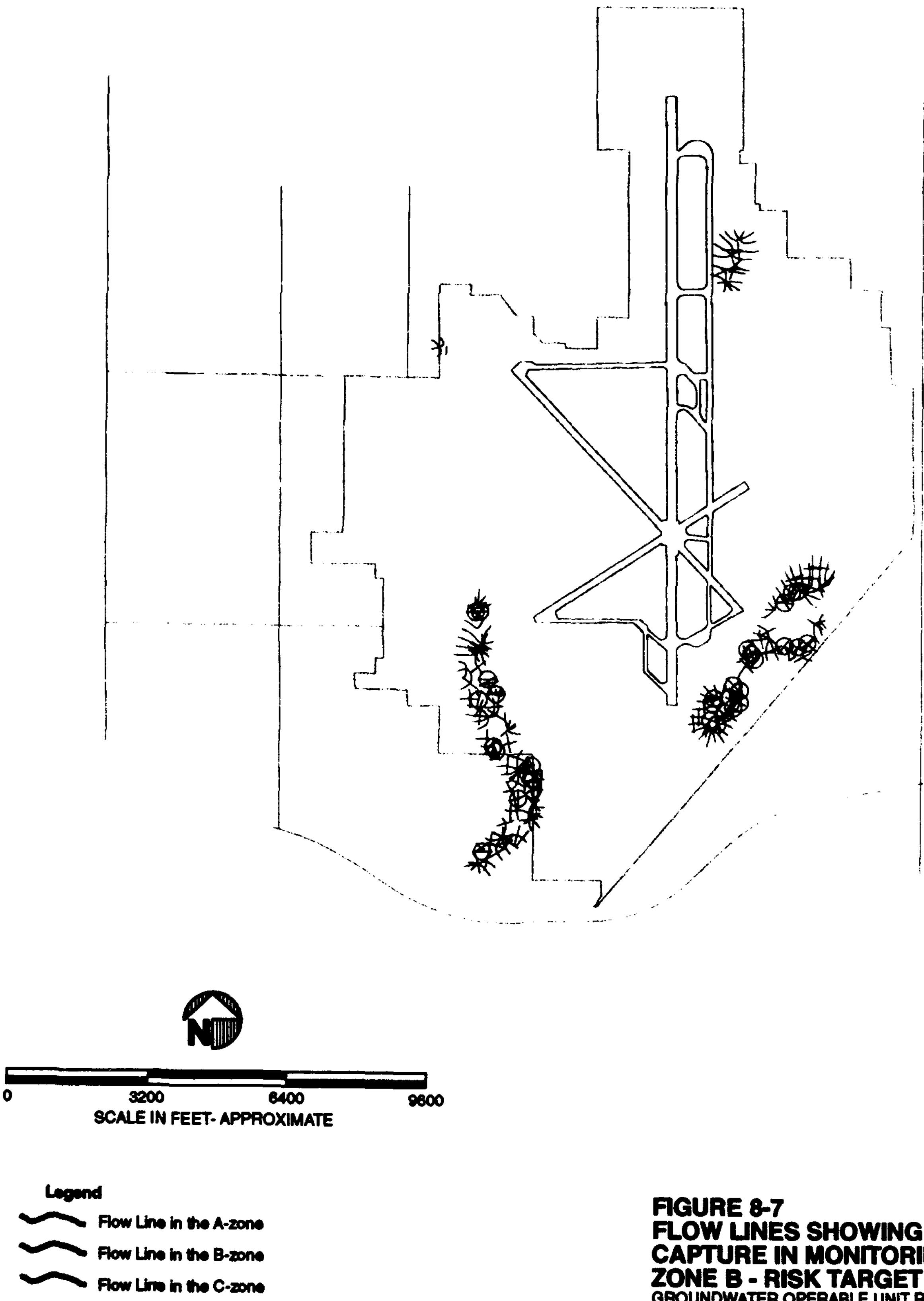
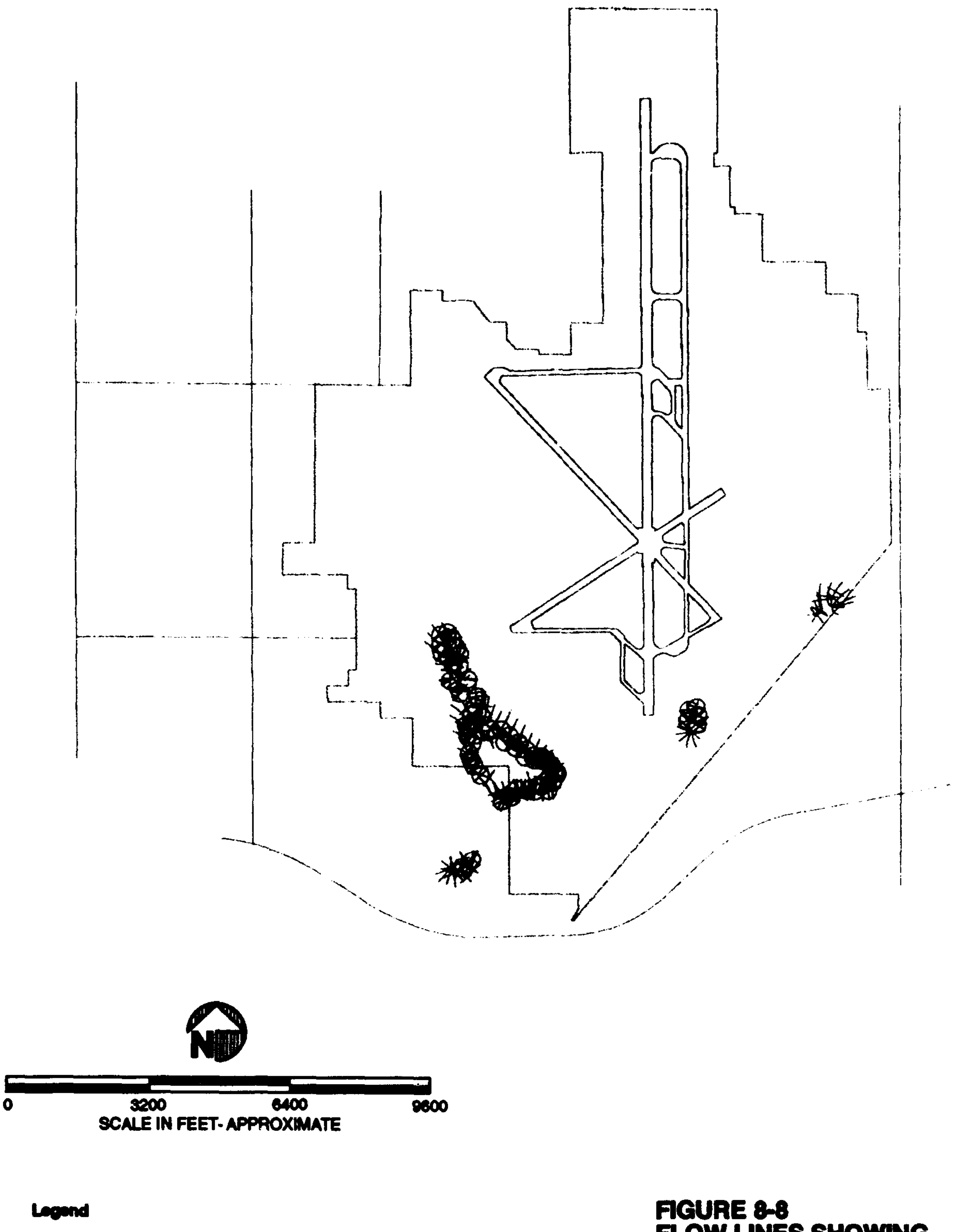


FIGURE 8-7
FLOW LINES SHOWING CAPTURE IN MONITORING ZONE B - RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1464_129

CH2MHILL



RDD1454_130

FIGURE 8-8
FLOW LINES SHOWING CAPTURE IN MONITORING ZONE C - RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

extraction alternatives are the basic containment alternatives, coupled with injection end-use of the treated groundwater outside of the plumes. It was necessary to quantitatively evaluate reinjection of the treatment plant effluent into the regional aquifer to ensure that the injection will not alter the hydrogeologic conditions enough to compromise the containment of the extraction network designs.

Another possible remedial strategy is the placement of injection wells surrounding the hot spot contamination areas so that the flushing of the hot spots could be augmented with reinjected treated groundwater. A comparison of average time per pore volume flushed with and without hot spot reinjection is provided in Table 8-1.

Table 8-1
Comparison of Average Time per Pore Volume Flushed with and without Hot Spot Reinjection

Hot Spot Location	Time Per Pore Volume (yrs)	
	Without Reinjection	With Reinjection
OU A - North	1.1	0.8
OU A - South	0.9	0.4
OU B	1.5	0.5
OU C	1.0	0.4
OU D	4.7	1.7

Note:
Flow times based on assumptions of the groundwater model presented in Appendix J and an effective porosity of 0.15.

The results of the groundwater modeling analysis were used to investigate the potential benefit of reinjecting treated groundwater on the perimeter of the hot spot extraction systems. The potential benefit of reinjecting the treated groundwater is to increase the available drawdown in the vicinity of the hot spot extraction wells, increasing the sustainable pumping rate in the extraction wells. This evaluation assumed that the quantity of water extracted from the hot spots for containment would be reinjected into the A zone through injection wells located around the perimeter of the hot spots. These assumed injection well locations are included on the well location maps presented for the alternatives including hot spot reinjection.

The assumed pumping rate of the hot spot extraction wells was then allowed to double. The resulting water levels under these increased pumping rates were evaluated with respect to the base of the A zone. The results suggest that the higher extraction rates are sustainable in all but one of the extraction wells located in the southern OU A hot spot. The extraction rate of this well was increased by 75 percent to ensure that a minimum of 3 feet of available drawdown remained during extraction. These results apply to all of the hot spot reinjection alternatives, independent of the target volume assumed. It should be noted that because these predictions are based on the results of the modeling analysis, all of the assumptions used to construct the groundwater model (presented in Appendix J) also apply to this evaluation.

The extraction alternatives evaluated using the groundwater flow model are summarized below:

- The No-Action Alternative with Base Well BW-18 abandoned.
- Containment of the background target volume.
- Containment of the background target volume with reinjection of treated groundwater through an injection well located northwest of the runway.
- Containment of the 10^{-6} incremental cancer risk target volume.
- Containment of the 10^{-6} incremental cancer risk target volume with reinjection of treated groundwater through an injection well located northwest of the runway.
- Containment of the MCL target volume.
- Containment of the MCL target volume with reinjection of treated groundwater through an injection well located northwest of the runway.

Background Target Volume

The background target volume comprises all groundwater where VOCs have been detected above 0.5 μg/l, which is the detection level for most of the contaminants of concern. The extent of this target volume in Monitoring Zones A, B, and C is shown in Figures 8-10 through 8-12, respectively. The groundwater reinjection wells surrounding the hot spots shown on Figure 8-10 only apply to alternatives including hot spot reinjection. Included on these figures is the number of extraction wells that are required to contain the associated target volume, in conformance with the operational strategies described above. The number of extraction wells required for containment of each monitoring zone and the extraction rate of high concentration versus low concentration contaminated groundwater are summarized in Table 8-2. Table 8-3 includes the approximate capital and operations and maintenance costs (O&M) of the extraction network required to contain this target volume, with and without hot spot injection. The pumping capacity of each extraction well was assumed to be 10, 15, and 20 gpm in Monitoring Zones A, B, and C, respectively. This is based on actual pumping rates observed from existing extraction wells at the Base. The only exception to this rule is in areas of Monitoring Zone A with limited saturated thickness. Wells in these areas were limited to a pumping rate that resulted in a drawdown of 75 percent of the initial saturated thickness. Existing wells were simulated at pumping rates that reflect current operation.

Table 8-2
Summary of Groundwater Modeling Runs
Containment of Target Volume with Isolated Hot Spot Containment

	Monitoring Zone							
	A		**B**		**C**		**Per OU**	
Operable Unit	**No. Wells**	**Q (gpm)**	**No. Wells**	**Q (gpm)**	**No. Wells**	**Q (gpm)**	**No. Wells**	**Q (gpm)**
Background Target Volume[a]								
OU A and OU G	62	390	15	220	5	100	82	710
OU B/C & Offsite	72	700	12	190	15	310	99	1,200
OU D	7	40	7	60	0	0	14	100
Totals	141	1,130	34	470	20	410	195	2,010
Risk Target Volume[a]								
OU A	55	340	11	170	4	80	70	590
OU B/C & Offsite	44	430	12	190	5	100	61	720
OU D	7	40	7	60	0	0	14	100
Totals	106	810	30	420	9	180	145	1,410
MCL Target Volume[a]								
OU A and OU G	50	280	10	150	1	20	61	450
OU B/C	34	340	10	150	4	80	48	570
OU D	7	40	6	30	0	0	13	70
Totals	91	660	26	330	5	100	122	1,090
Hot Spot Flows (Basic Containment and End-Use Reinjection)								
OU A	6	30	N/A	N/A	N/A	N/A	6	30
OU B/C	10	90	N/A	N/A	N/A	N/A	10	90
OU D	5	68	N/A	N/A	N/A	N/A	5	68
Totals	21	188	N/A	N/A	N/A	N/A	21	188
Hot Spot Flows (Hot Spot Reinjection)—Extraction Flows								
OU A	6	60	N/A	N/A	N/A	N/A	6	60
OU B/C	10	180	N/A	N/A	N/A	N/A	10	180
OU D	5	136	N/A	N/A	N/A	N/A	5	136
Totals	21	376	N/A	N/A	N/A	N/A	21	376
Hot Spot Flows (Hot Spot Reinjection)—Injection Flows								
OU A	6	30	N/A	N/A	N/A	N/A	6	30
OU B/C	11	120	N/A	N/A	N/A	N/A	11	120
OU D	5	80	N/A	N/A	N/A	N/A	5	80
Totals	22	230	N/A	N/A	N/A	N/A	22	230

[a]These flows include existing Base extraction and hot spot flows for basic containment and end-use reinjection options.

Note:
N/A = Not applicable.

Table 8-3 Extraction System Cost		
Target Volume	**Capital Cost ($)**	**O&M Cost ($)**
Without Hot Spot Injection		
MCL	6,600,000	360,000
Risk	8,900,000	490,000
Background	12,800,000	710,000
With Hot Spot Injection		
MCL	7,700,000	440,000
Risk	10,000,000	570,000
Background	13,900,000	790,000

10^{-6} Incremental Cancer Risk

The 10^{-6} incremental cancer risk target volume includes all areas where the cumulative cancer risk posed by groundwater contamination exceed one in one million. Figures 8-13 through 8-15 include the locations of extraction wells required to contain this target volume. The groundwater reinjection wells surrounding the hot spots shown on Figure 8-13 only apply to alternatives including hot spot reinjection. The number of extraction wells and pumping rates are summarized in Table 8-2. The capital and O&M costs associated with this target volume extraction system, with and without hot spot injection, are summarized in Table 8-3. The assumed extraction well pumping capacities for each zone are identical to that assumed for the background target volume.

MCL Target Volume

The MCL target volume comprises all groundwater that contains any contaminants above the federal or state MCL. Figures 8-16 through 8-18 include the target volume boundaries and the extraction well locations required to contain this target volume. The groundwater reinjection wells surrounding the hot spots shown on Figure 8-16 only apply to alternatives including hot spot reinjection. The results of the simulations performed assuming this target volume, including pumping rates, are summarized in Table 8-2. The cost associated with an extraction system to contain this target volume, with and without hot spot injection, are summarized in Table 8-3.

8.3.5 Collection System Conceptual Design

A conceptual design has been prepared to convey contaminated groundwater from the extraction wells to the eastern and western treatment units. The collection systems vary depending on the target volumes described earlier. The collection system would consist of single wall pipelines installed beneath the ground surface with approximately 3 feet of cover over the top of the pipe. It is anticipated that a majority of the pipelines would be installed in existing streets. The main conveyance pipeline and extraction wells for the background target volumes, the 10^{-6} risk target volumes, and the MCL target volumes are presented in Figures 8-19, 8-20, and 8-21, respectively. The lateral pipelines from each well to the main conveyance pipelines have not been shown.

Order-of-magnitude costs associated with the piping for the collection system are included in the costs presented in Table 8-3.

8.3.6 No-Action Alternative

The No-Action Alternative was investigated to develop a baseline set of conditions with which to measure the benefit that any additional groundwater remedial action will have on conditions at the Base. In this simulation, BW-18 was assumed to be abandoned because state agencies and the EPA have expressed concern that this well is a potential conduit for cross-contamination between aquifers and should be abandoned. The existing extraction wells currently operating at the Base were included in this simulation. Predicted groundwater elevations under this alternative, existing extraction well locations, and all target volumes for a particular monitoring zone are shown in Figures 8-22 through 8-24. It is apparent from these figures that contamination in all of the aquifers would continue to migrate to the south-southwest and threaten downgradient groundwater production wells. Predicted vertical gradients from this simulation are predominantly downward over the Base, indicating that contamination will also move downward into deeper aquifers as it continues to move to the south and southwest.

8.4 Groundwater Model Accuracy

In evaluating the required accuracy of a numerical groundwater model, it is necessary to consider the purpose for which it was developed. The groundwater flow model was constructed for the following purposes:

- Estimating the number of extraction wells required to contain various target volumes of contaminated groundwater
- Estimating the pumping rates from each extraction well
- Estimating the response of the groundwater system to potential remedial actions

These estimates will be used to develop budget level cost estimates for the competing remedial alternatives. While it is important to include all of the key components of the natural hydrologic system so that the performance of proposed extraction systems will be simulated appropriately, it is not necessary to match the magnitude of observed water levels exactly.

The components of the groundwater system that most significantly affect extraction system performance are available saturated thickness from which to pump, the gradient and direction of groundwater flow, and the hydraulic conductivity of the materials in the vicinity of the extraction

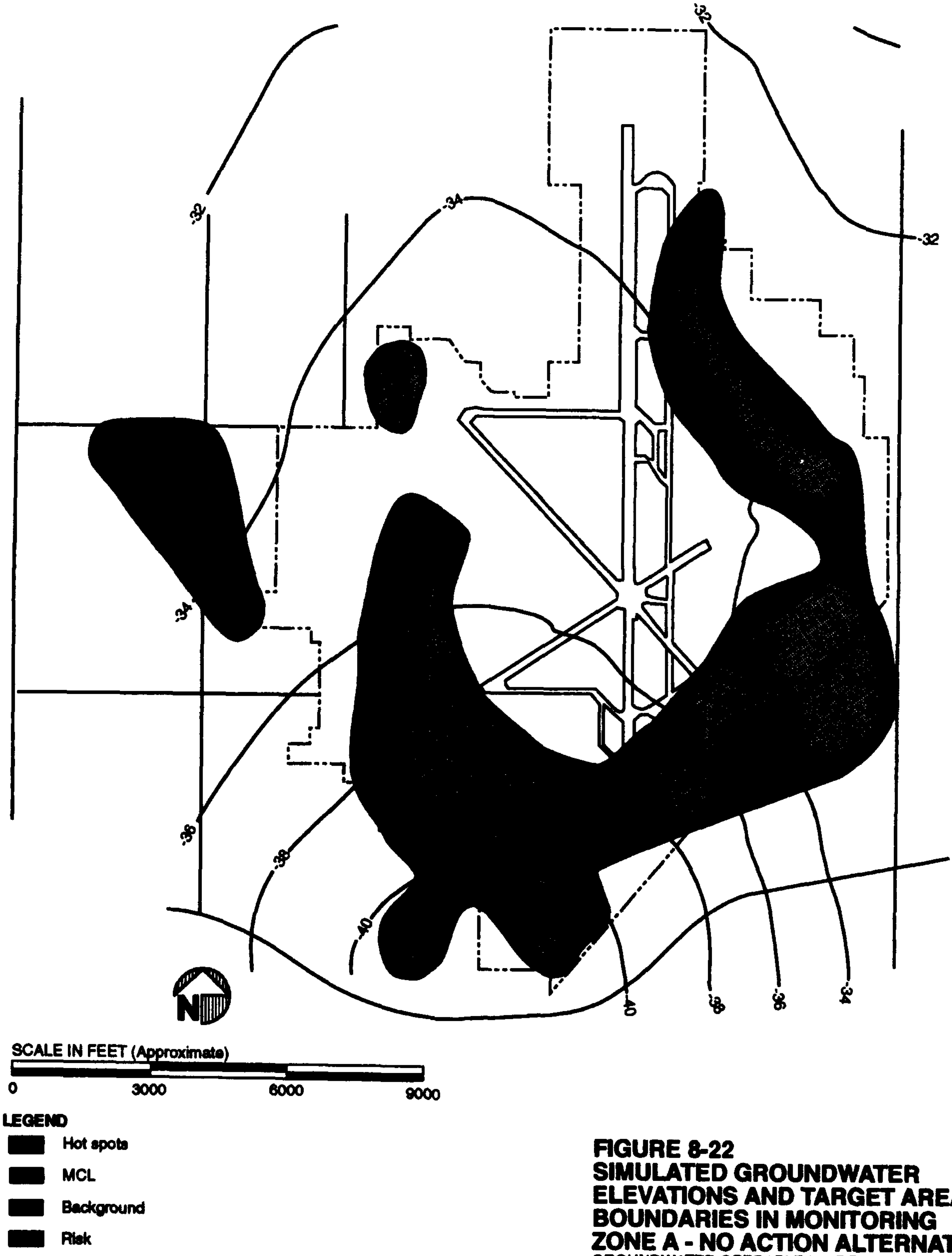


FIGURE 8-22
SIMULATED GROUNDWATER ELEVATIONS AND TARGET AREA BOUNDARIES IN MONITORING ZONE A - NO ACTION ALTERNATIVE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2MHILL

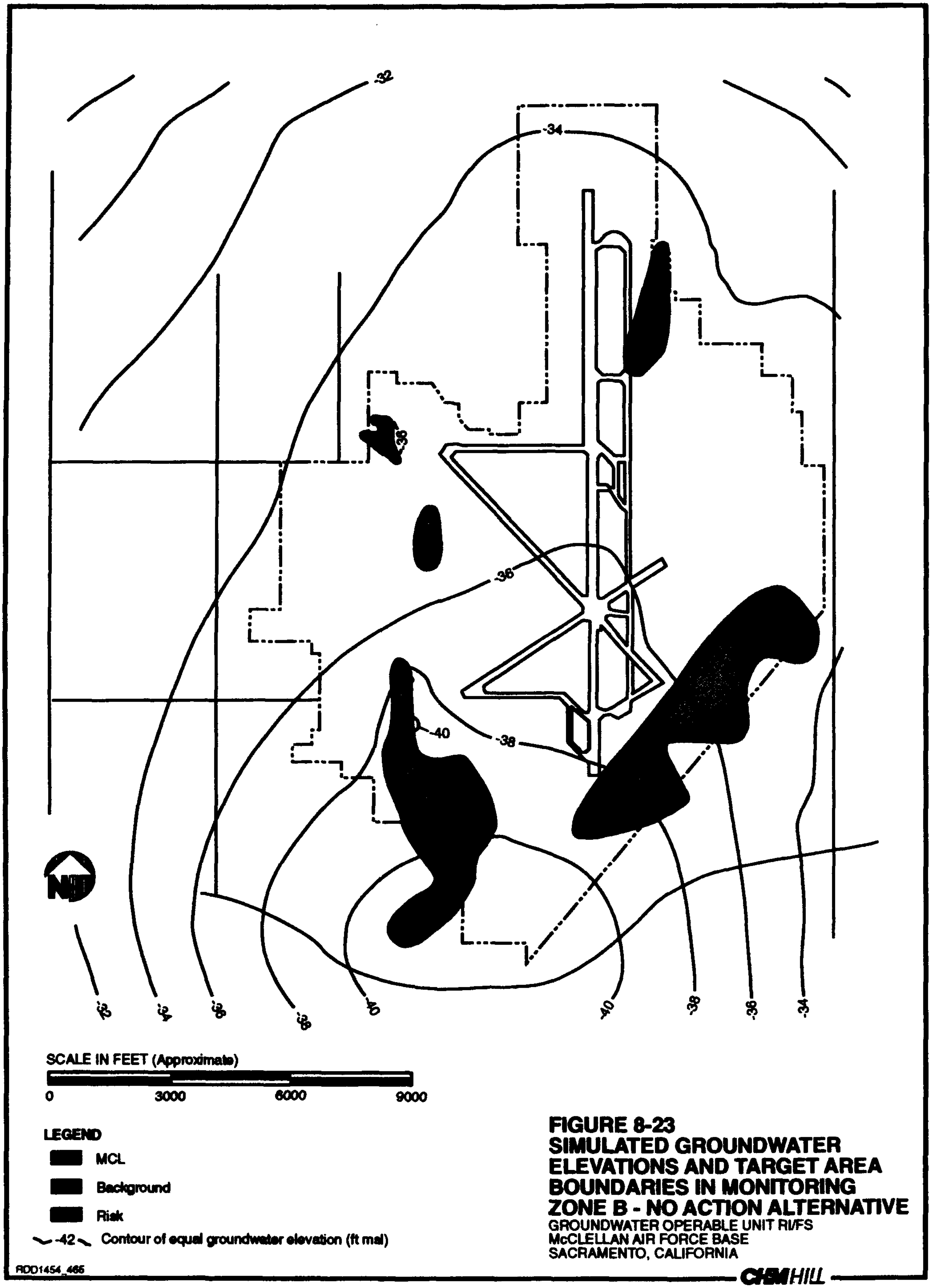


FIGURE 8-23
SIMULATED GROUNDWATER ELEVATIONS AND TARGET AREA BOUNDARIES IN MONITORING ZONE B - NO ACTION ALTERNATIVE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2MHILL

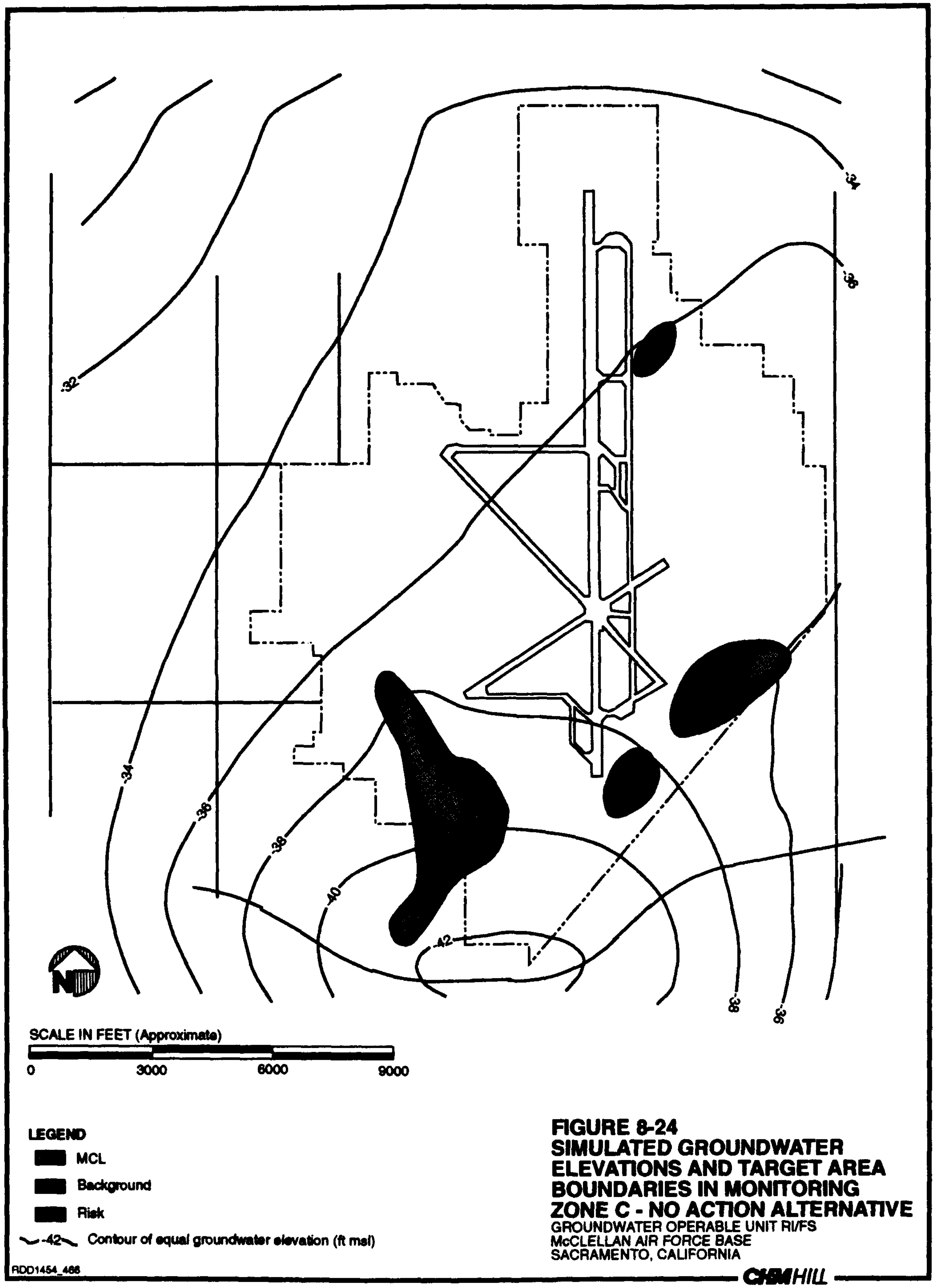


FIGURE 8-24
SIMULATED GROUNDWATER ELEVATIONS AND TARGET AREA BOUNDARIES IN MONITORING ZONE C - NO ACTION ALTERNATIVE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

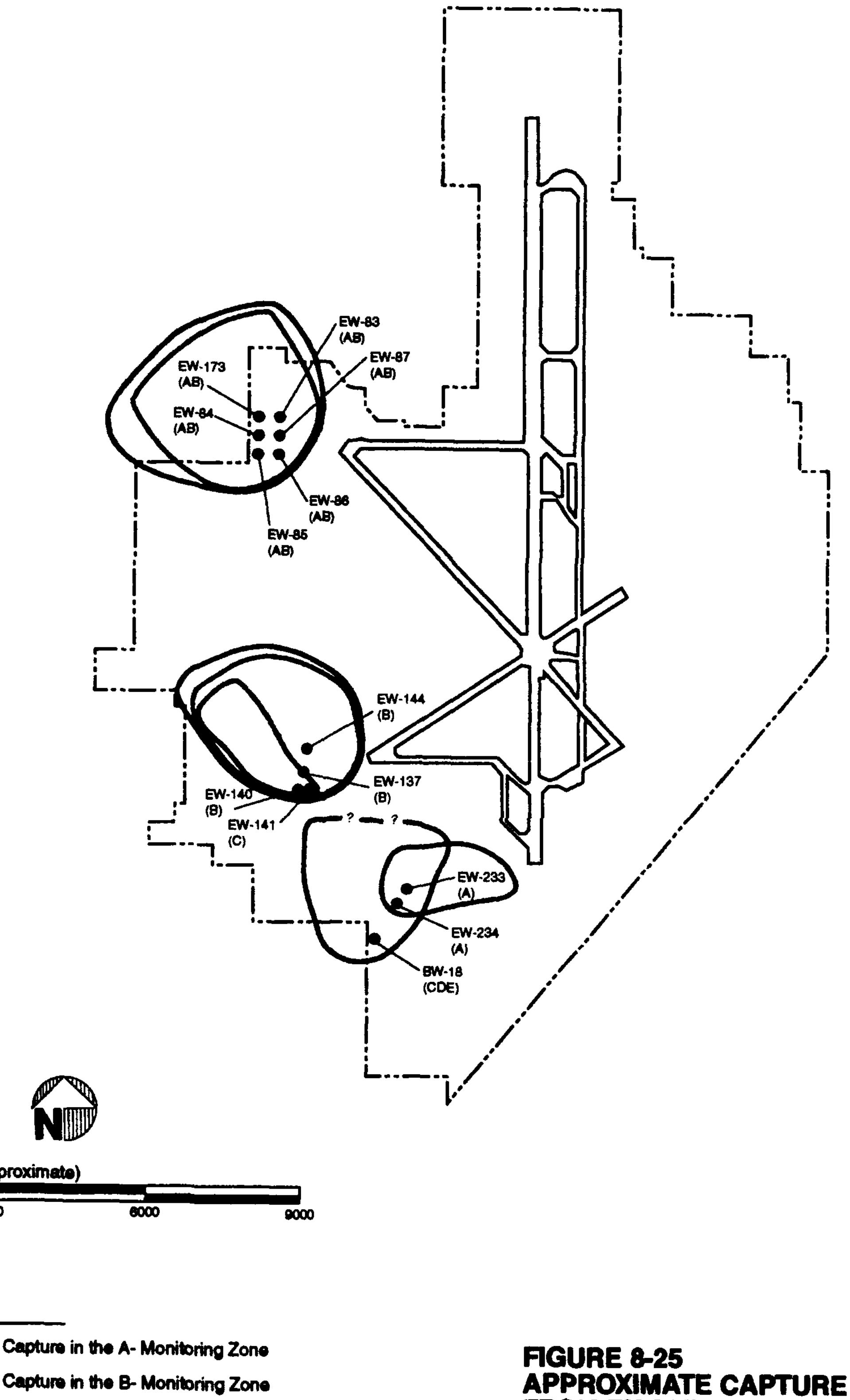
system. All of these parameters can be accurately simulated even if the predicted groundwater elevations depart from the observed from 1 or 2 feet. Since the performance of all of the extraction systems evaluated will be compared using the same assumptions regarding these parameters, comparisons between competing alternatives will be valid even if the assumed site characteristics do not exactly match site conditions.

8.5 Inadequacy of the Existing Extraction System

The existing extraction system at McClellan AFB captures a small portion of the groundwater contamination present at the site. The extent of the approximate capture zones created by existing extraction in Monitoring Zones A, B, and C is shown in Figure 8-25. The five most contaminated areas of the A zone discovered to date are also shown in Figure 8-25. It is apparent that only one of the five highly contaminated areas are addressed by existing extraction; therefore, the majority of the contaminant mass in the groundwater will continue to move downgradient and threaten nearby municipal supply wells. The number of extraction wells that are currently in operation at the Base represents less than 10 percent of the total number of extraction wells estimated necessary to effectively contain the smallest target volume (MCL). These estimated capture zones for the existing extraction wells were developed assuming that BW-18 is abandoned. This is based on agency concerns that BW-18 is a potential conduit for cross-contamination between aquifers. If BW-18 remains in service, much of the OU B and OU C plume may be contained by the influence of this pumping. However, the use of BW-18 as an extraction well is not an effective means of removing contaminated groundwater. BW-18 produces approximately 1,000 gpm, most of which is extracted from the relatively uncontaminated Monitoring Zone D. This flow is similar to the entire flow of the MCL target volume extraction system (1,190 gpm). Therefore, the use of this well will result in a much larger volume of low concentration groundwater requiring treatment, instead of a smaller volume of higher concentration contaminated groundwater.

8.6 New Groundwater Contamination

The distribution and extent of groundwater contamination is one of the most fundamental factors in the definition of the conceptual model and therefore the determination of the necessary remedial action. The present conceptual model regarding the extent of contamination is a function of the monitoring network that is currently in place. As new monitoring points are added to the network, the conceptual model will be revised to include the new data. As a result, it is critical that the conceptual model be flexible and that a mechanism be developed for the smooth integration of new information into the site profile.



LEGEND

- Extent of Capture in the A- Monitoring Zone
- Extent of Capture in the B- Monitoring Zone
- Extent of Capture in the C- Monitoring Zone
- ● EW-83 (AB) Monitoing Well Name (Zones where well is screened)

RDD1454_280

FIGURE 8-25
APPROXIMATE CAPTURE ZONES FROM EXISTING EXTRACTION IN THE A, B, AND C ZONES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Before a methodology can be developed for addressing a modified understanding of the extent of contamination, two types of contamination need to be defined: additional and new. **Additional** contamination is defined as contamination discovered in areas adjacent to existing target areas. This type of contamination simply refines the boundaries of an area already suspected of containing contaminated groundwater. New contamination on the other hand is defined as contamination discovered in an area entirely separate from existing known contamination areas. This type of contamination suggests a new and isolated source area in portions of the Base previously considered clean. The uncertainties that govern these contamination types, along with the method by which they will be integrated into the conceptual model of the site, will be discussed below.

8.6.1 Additional Contamination

Additional contamination will be the result of uncertainty in the representativeness of groundwater contaminant concentrations measured at a particular well. Since the distribution and extent of contamination is determined based on interpolation between known data points, it must be assumed that each measured data point is representative of a particular portion of the monitored aquifer. Where this assumption is invalid, samples collected from newly constructed monitoring wells will provide a basis for modifying the target volume in the vicinity. This modified target volume will then be incorporated into the site conceptual model. The course of action required to address the discovery of additional contamination will be to install additional extraction wells so that the zone of containment is extended to encompass the newly defined target volume. Another possible manner by which additional contamination could be addressed is by increasing the extraction rate from existing extraction wells located near the additional contamination. The success of this approach will be constrained by the maximum pumping rate that can be achieved by individual extraction wells. This will be evaluated on a case-by-case basis according to field data.

8.6.2 New Contamination

New contamination will only be discovered during investigation in areas previously considered uncontaminated, or where no investigation has been conducted. The main uncertainty that will result in this type of contamination being discovered is whether the developed target volumes encompass all of the potential source areas at the site. The discovery of new contamination strongly suggests that a source area exists in an area not previously identified as a potential threat to groundwater. The course of action that will be required to address new contamination will be more involved than that required for additional contamination. The approximate horizontal and vertical extent of contamination will need to be defined before the scope of the remedial action can be ascertained. This information is necessary to decide whether extracted groundwater can be conveyed to existing treatment facilities or whether the contaminated area is large enough to warrant construction of a new treatment facility at the site. Once the extent of contamination is determined, the appropriate remedial action can be implemented. If it appears that a significant vadose zone source is related to the groundwater contamination, vadose zone remediation may be warranted to accelerate required cleanup times.

8.6.3 Cleanup Time Required

The time required to clean up a contaminated aquifer is dependent upon several variables. Contaminant type, initial concentration, remedial target concentration, and aquifer characteristics all affect cleanup time. The following equation is used to estimate concentration decay of a conservative constituent with time and proves to be an effective tool to estimate the required time to remediate a contaminated aquifer.

$$C_i = C_o e^{-k \frac{t}{T_{PV}}}$$

C_i = Influent Concentration
C_o = Initial Concentration
k = Leaching Efficiency
t = Time to Cleanup
T_{PV} = Time to Pump One Pore Volume

Calculations were performed to estimate the time required to remediate TCE contamination at the Base. To apply this equation at McClellan AFB, values for each of the parameters listed above were estimated. The initial concentrations used are representative of groundwater contamination levels detected in the plumes outside of the hot spots at the Base. The leaching efficiency value is a surrogate parameter that reflects the lithology through which the contaminants move. Porous materials such as sand, that flush efficiently, have high values of k (0.6). Material that is slow to flush, such as silt and clay, has lower k values (0.2) (ILRI, 1973). The time to pump one pore volume (2 to 11 years) was estimated based on the groundwater flow model described earlier. With all of these parameters estimated, the equation was used to estimate the concentration in the aquifer (C_i) over time for various combinations of these parameters. An approximate time to remediate was then estimated by selecting a final remedial action concentration (MCL or background) and selecting the corresponding time. It must be noted that the above equation estimates time to clean up for a conservative tracer only. To apply these calculations to a contaminant that interacts with the aquifer solids, the retardation factor for that contaminant must be considered. The actual remediation time is directly proportional to the retardation factor for that chemical. A retardation factor of 2 was assumed for TCE, which resulted in the cleanup time for TCE being twice that estimated for the conservative tracer.

The results of these time to cleanup calculations are summarized in Figures 8-26 and 8-27 and Table 8-4. Figures 8-26 and 8-27 show contrasting decay curves for two sediment types, an assumed initial TCE concentration of 40 μg/l, and flushing rates of 2 and 6 years per pore volume. Table 8-4 also presents estimates of the time required to reach two different remedial objectives (MCL and background) under varying assumptions. These results indicate that the performance of a groundwater extraction system is strongly dependent on the flushing efficiency (time per pore volume) induced in the contaminated aquifer. If flushing rates of approximately 2 years per pore volume can be

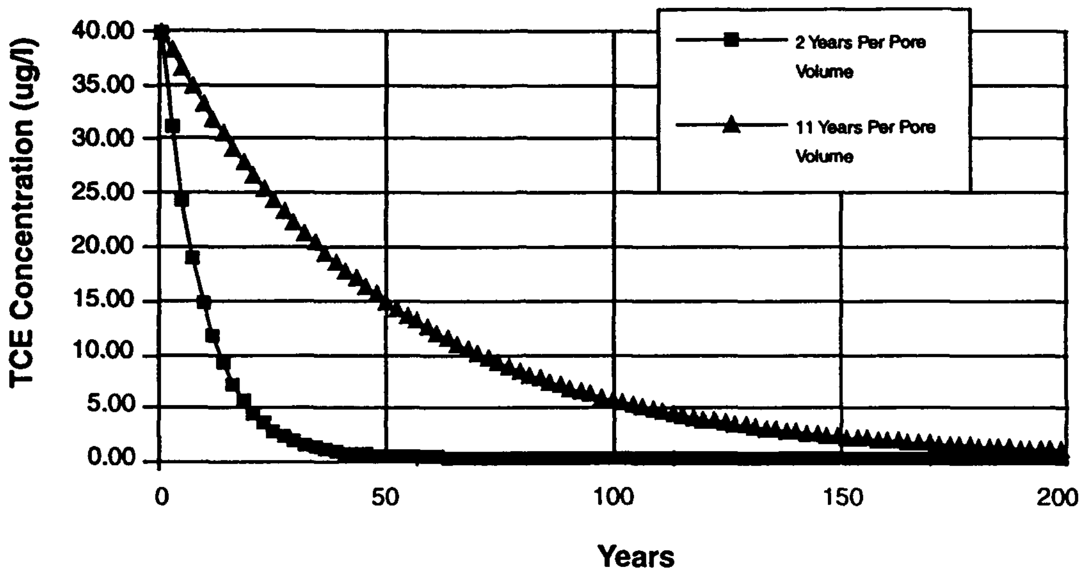


FIGURE 8-26
ESTIMATED TCE CONCENTRATION DECAY CURVES FOR SANDY MATERIAL
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_708

CH2M HILL

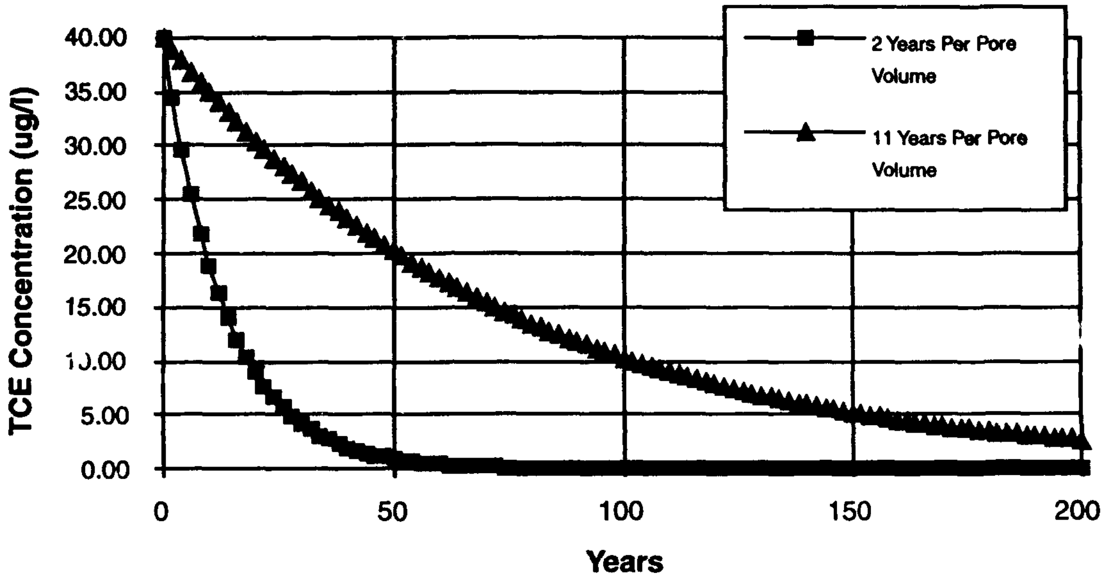


FIGURE 8-27
ESTIMATED TCE CONCENTRATION DECAY CURVES FOR SILTY MATERIAL
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_707

CH2M HILL

Table 8-4 **Summary of TCE Time to Cleanup Calculations**						
Estimated Time to Reach TCE MCL in Years (5 $\mu g/l$)						
	Silty Material			**Sandy Material**		
Initial TCE Concentration ($\mu g/l$)	**2 yrs/ Pore Vol.**	**6 yrs/ Pore Vol.**	**11 yrs/ Pore Vol.**	**2 yrs/ Pore Vol.**	**6 yrs/ Pore Vol.**	**11 yrs/ Pore Vol.**
20	20	60	100	12	35	60
40	28	85	155	18	50	95
60	34	100	185	20	60	110
Estimated Time to Reach TCE Background in Years (0.5 $\mu g/l$)						
	Silty Material			**Sandy Material**		
Initial TCE Concentration ($\mu g/l$)	**2 yrs/ Pore Vol.**	**6 yrs/ Pore Vol.**	**11 yrs/ Pore Vol.**	**2 yrs/ Pore Vol.**	**6 yrs/ Pore Vol.**	**11 yrs/ Pore Vol.**
20	50	150	270	30	90	165
40	60	175	320	35	105	195
60	65	190	350	40	115	210

Notes:

1. These time to cleanup estimates are based entirely on the assumptions stated here and the equation presented above. Actual field results may vary considerably because of site-specific field conditions.

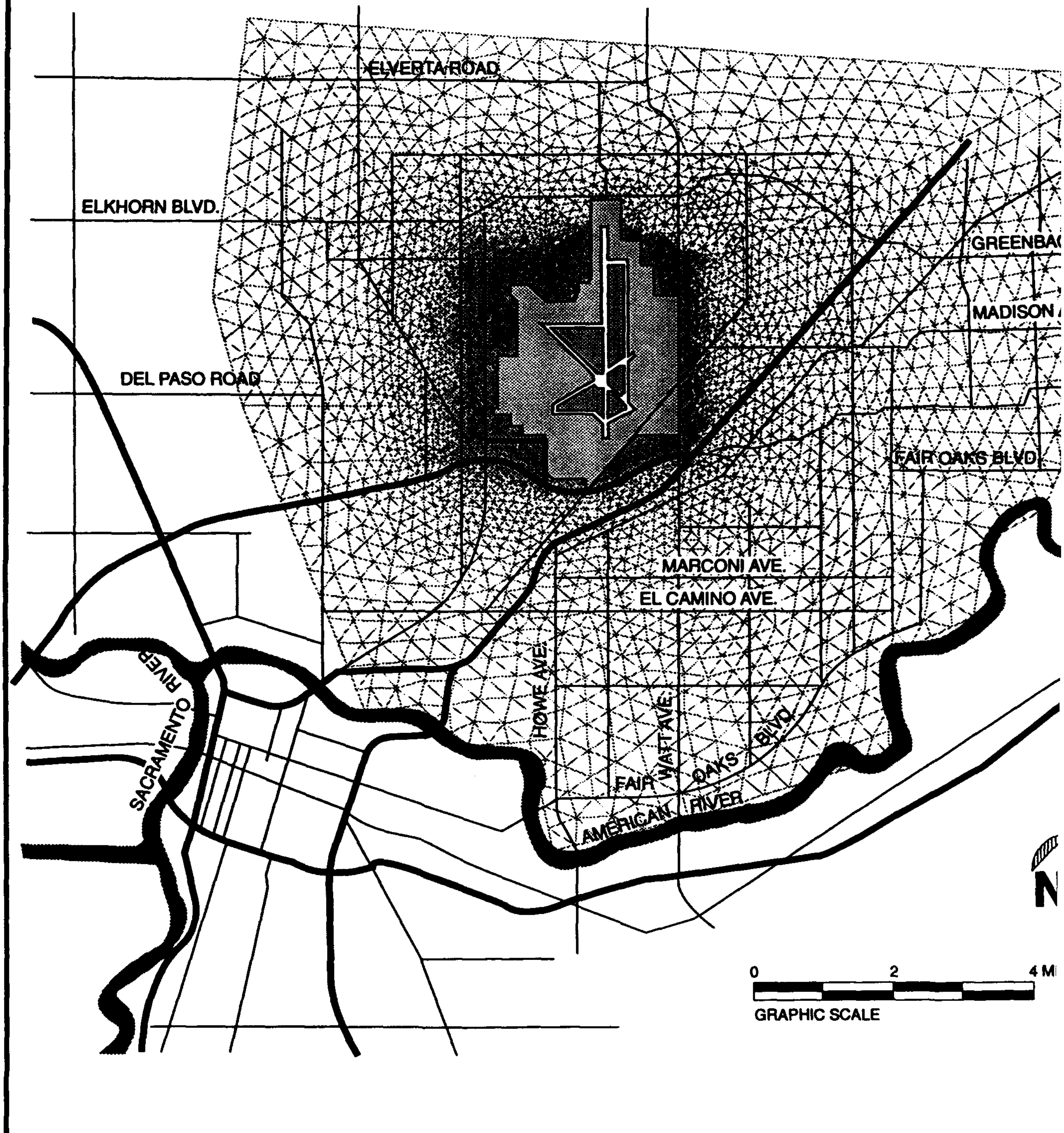
2. This analysis assumes a retardation factor for TCE of 2.0. The actual retardation factor experienced at a particular site will depend on the organic carbon content of the site soils.

achieved, cleanup times of 15 to 60 years could theoretically be achieved. However, site conditions at McClellan AFB suggest that this rate of flushing is not achievable with a reasonable number of extraction wells. According to groundwater model simulations, flushing rates through most of the target volumes at McClellan AFB are in the range of 2 to 6 years for the extraction networks presented. Small areas of the target volumes do have lower flushing rates of approximately 10 to 12 years. This suggests that the time required to completely remediate the contaminated aquifers to MCLs will likely approach 100 years, and the time required to reach background levels will likely exceed 100 years.

These estimates are presented only to bound the amount of time that may be required to remediate the contaminated aquifers at McClellan AFB. The actual time to cleanup depends on many site-specific factors that are not accounted for in this simplified analysis. Biodegradation of contaminants, the presence of DNAPL, physical constraints on effective flushing such as low permeability, and the desorption kinetics of particular contaminants will influence the actual concentration decay behavior observed in the field. Because of this great degree of uncertainty, the actual progress of cleanup observed during remediation may be significantly different from the rates presented here.

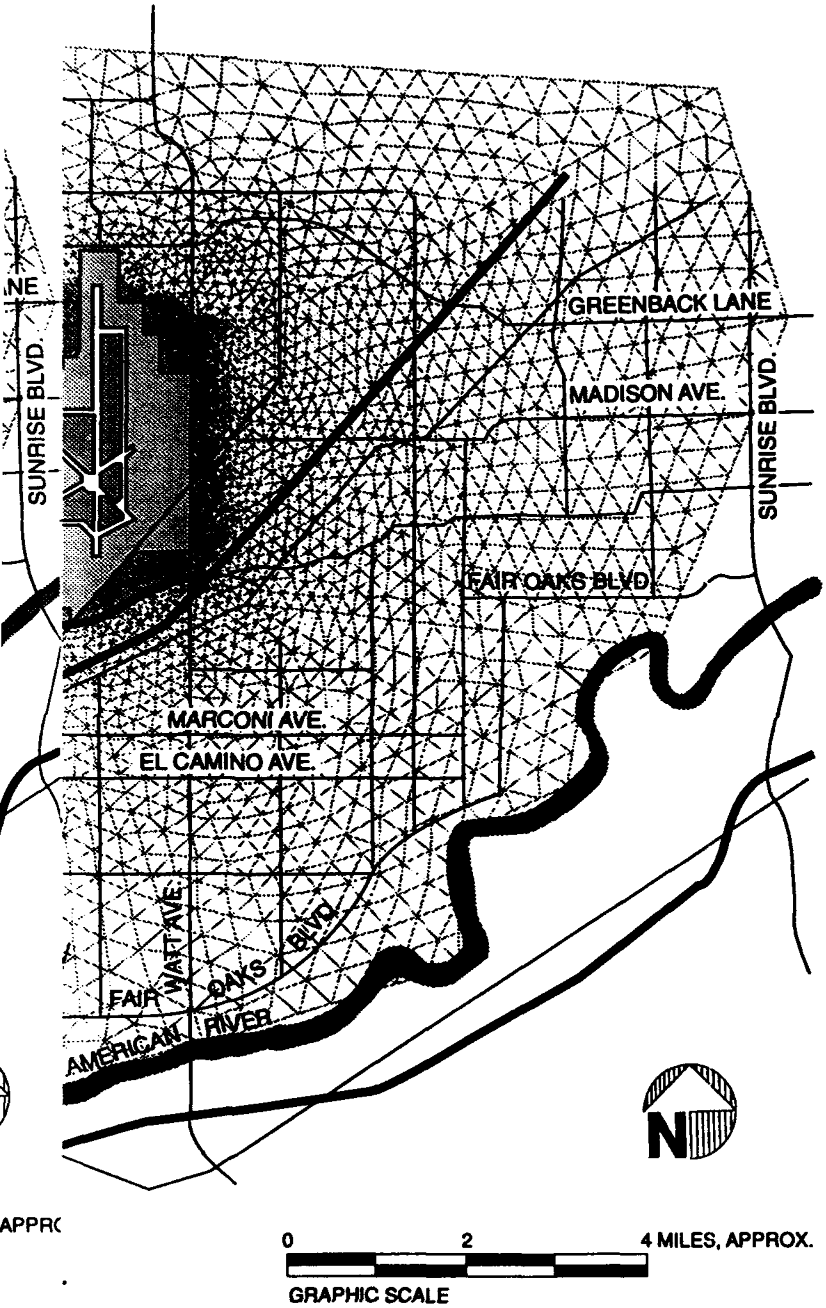
8.6.4 Order-of-Magnitude Extraction Cost Estimate

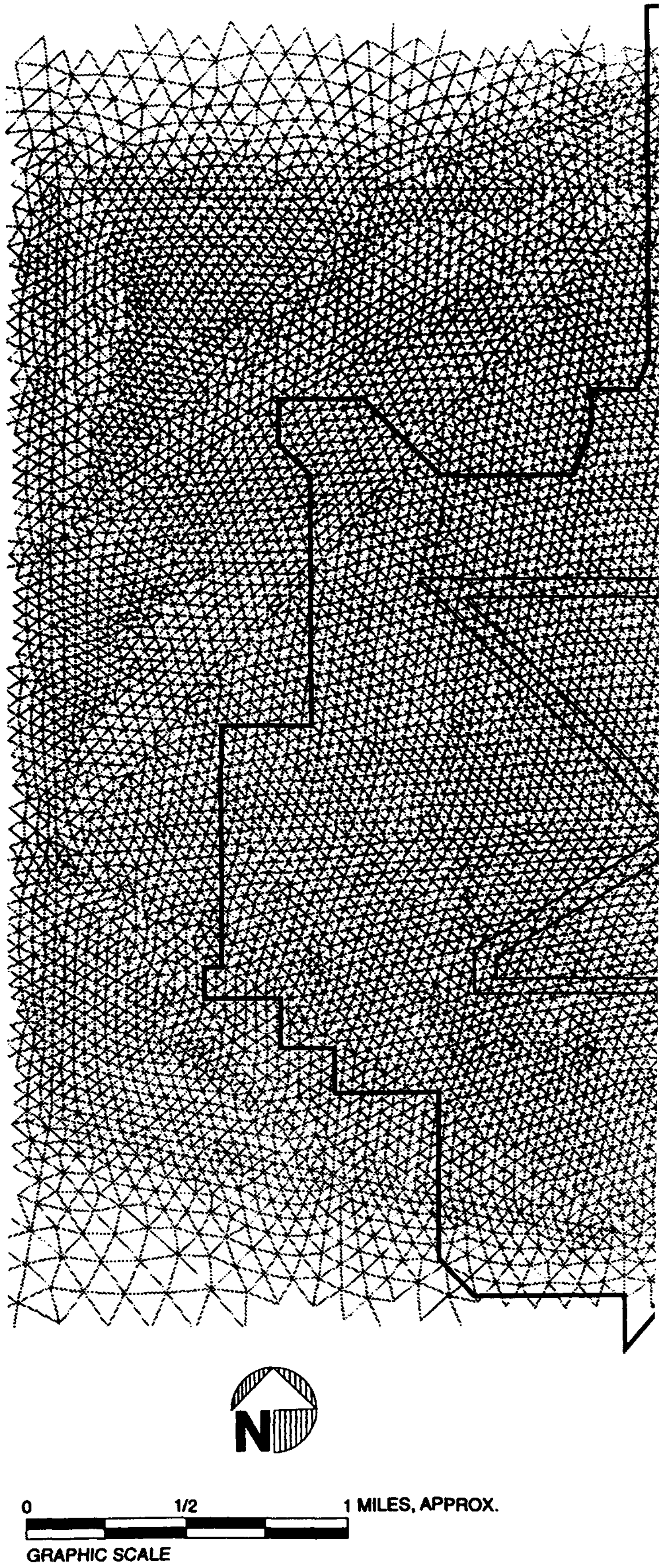
Order-of-magnitude cost estimates were prepared. Cost curves were developed using well construction and pipeline sizes specifically for McClellan AFB extraction alternatives. These estimates are expected to be accurate within +50 percent to -30 percent. Table 8-3 summarizes capital and O&M costs for extraction systems in each target volume. O&M costs include pumping and power costs.


ELVERTA ROAD
ELKHORN BLVD.
GREENBA
MADISON A
DEL PASO ROAD
FAIR OAKS BLVD.
MARCONI AVE.
EL CAMINO AVE.
HOWE AVE.
WATT AVE.
FAIR
OAKS
BLVD.
AMERICAN
RIVER
SACRAMENTO
RIVER
N
0
2
4 MI
GRAPHIC SCALE

RDD1388_50

(1)


GREENBACK LANE
MADISON AVE.
SUNRISE BLVD.
SUNRISE BLVD.
FAIR OAKS BLVD.
MARCONI AVE.
EL CAMINO AVE.
WATT AVE.
FAIR OAKS BLVD.
AMERICAN RIVER
N
0
2
4 MILES, APPROX.
GRAPHIC SCALE


N
0
1/2
1 MILES, APPROX.
GRAPHIC SCALE

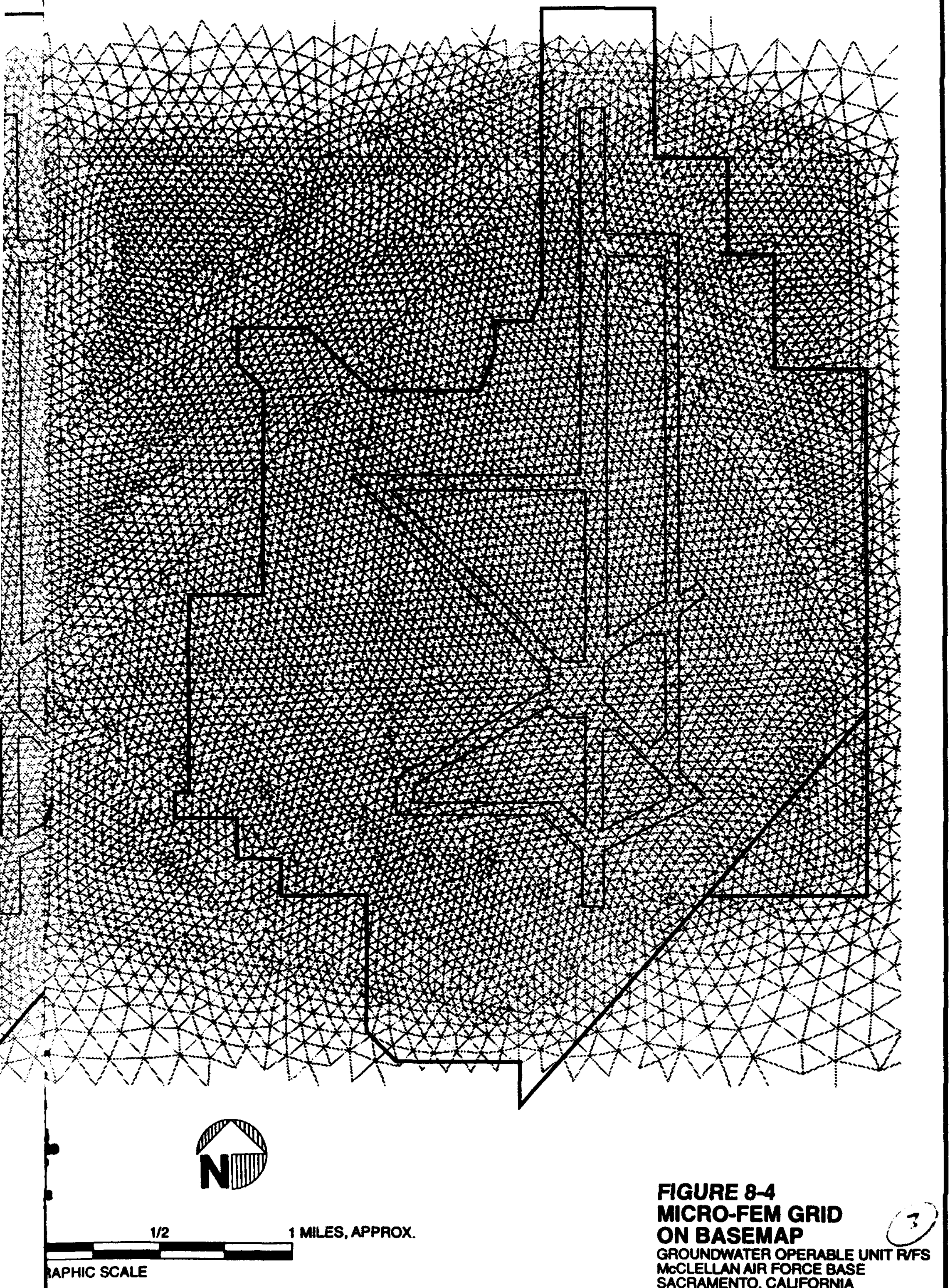
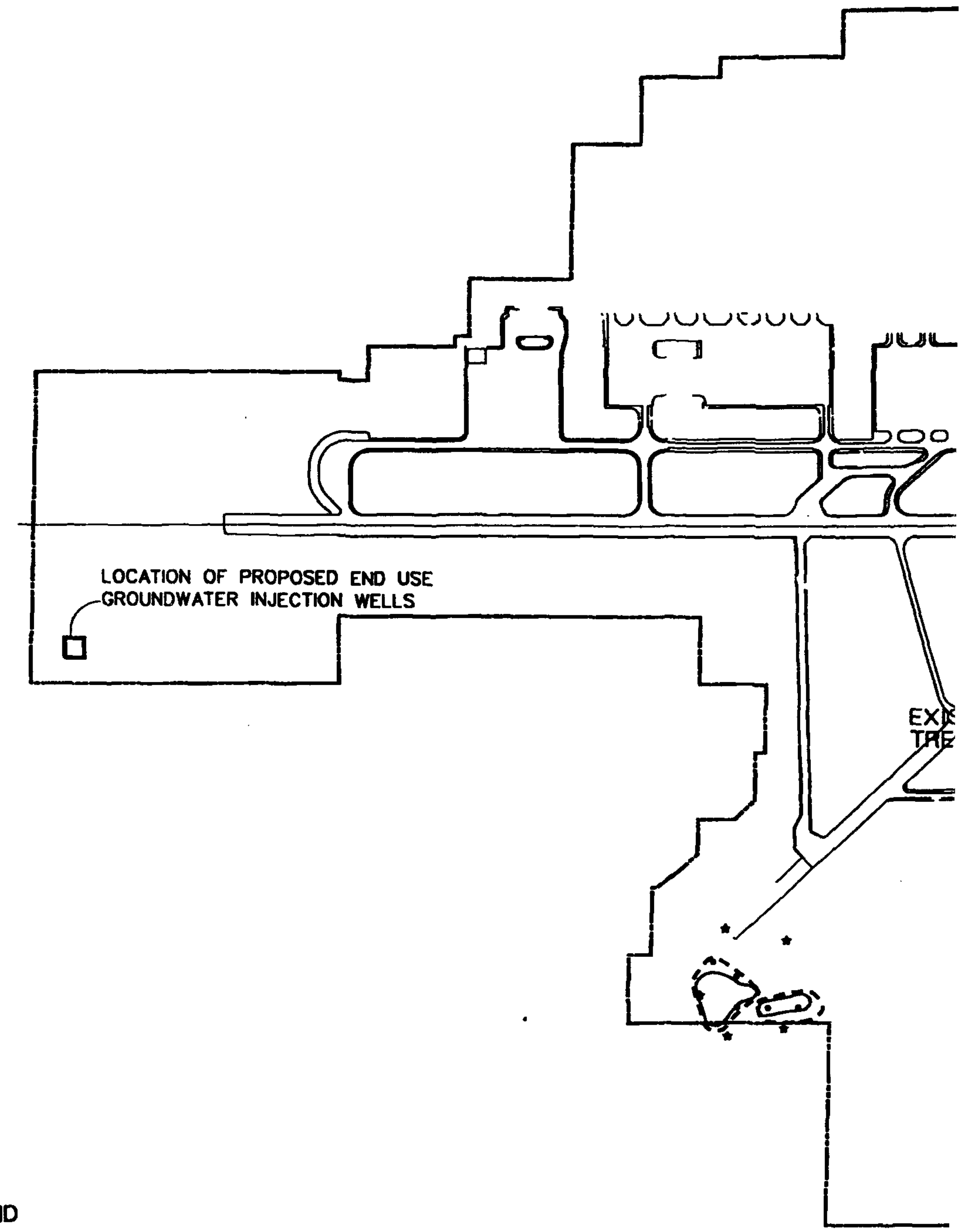


FIGURE 8-4
MICRO-FEM GRID ON BASEMAP
GROUNDWATER OPERABLE UNIT R/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



LEGEND

- ★ Injection Well
- Hot Spot Boundaries Estimated from Water Quality Data
- Hot Spot Boundaries Assumed for Groundwater Modeling Simulations (Adjusted Due to Loc[illegible] of Model Nodes)
- • Extraction Well

1

RDD1454
MEY94/8-9.DGN (J-13-LEV 62)

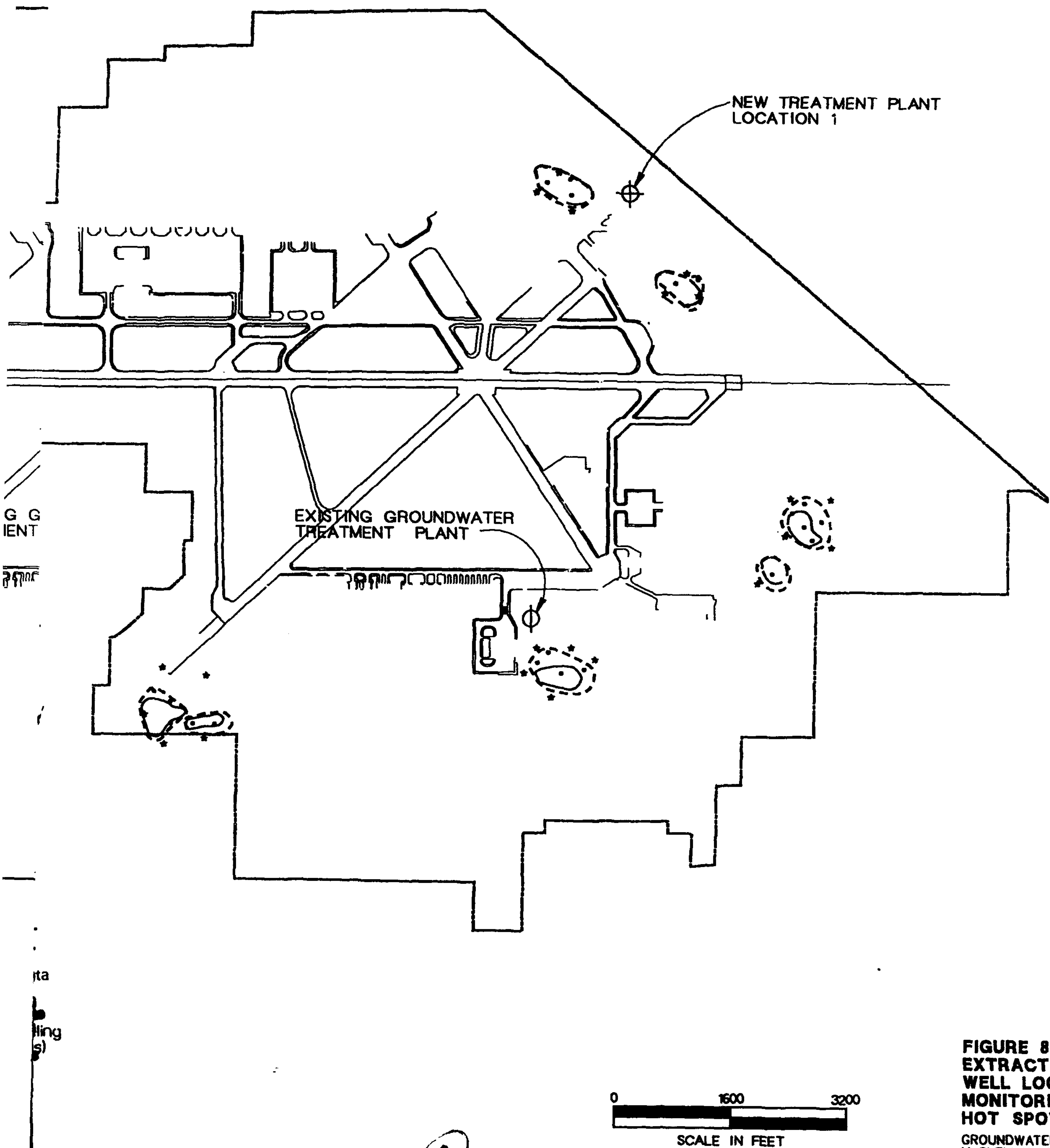
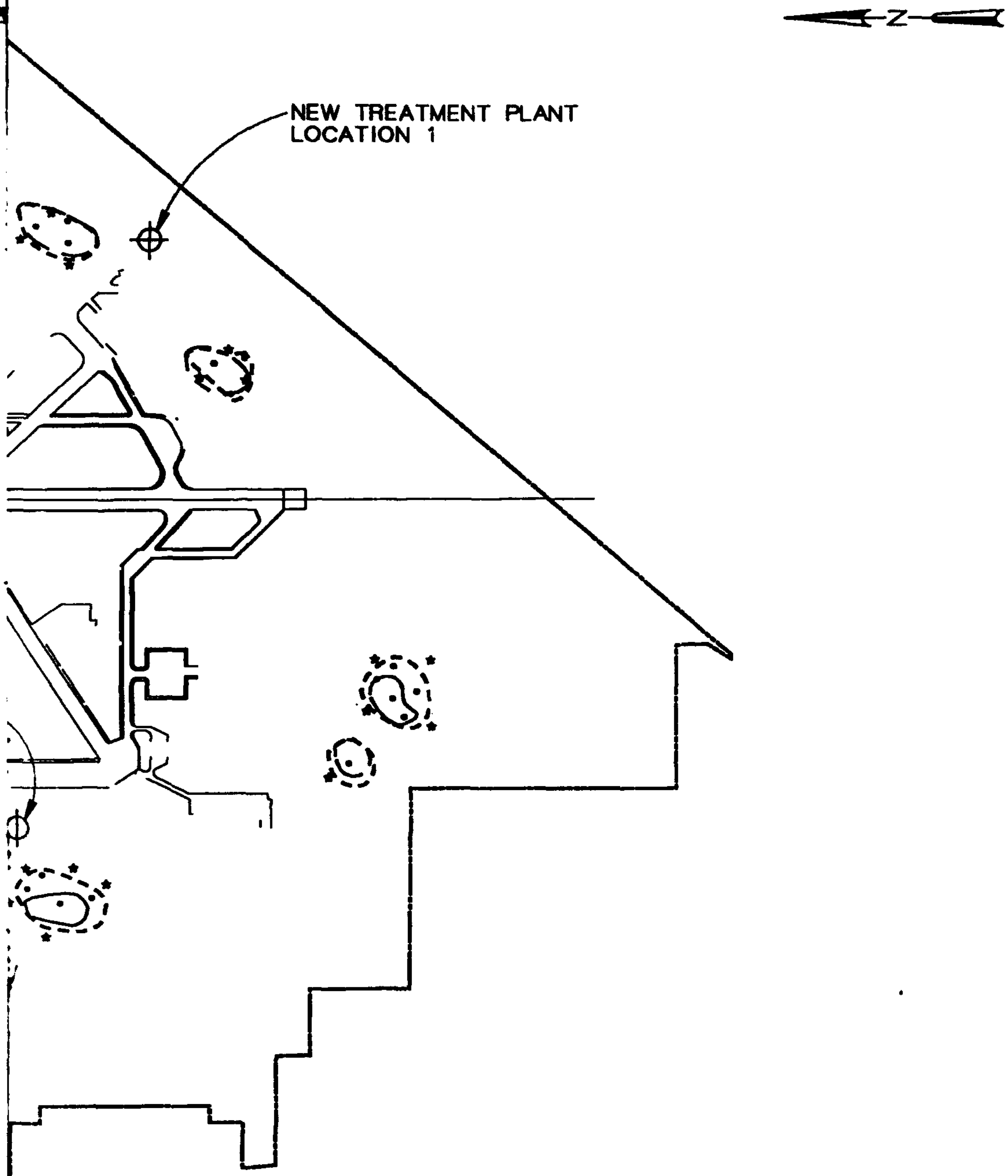


FIGURE 8-(
EXTRACTI(
WELL LOC.
MONITORIN
HOT SPOT

GROUNDWATER
McCLELLAN AI
SACRAMENTO, (

(2)



0 1600 3200
SCALE IN FEET

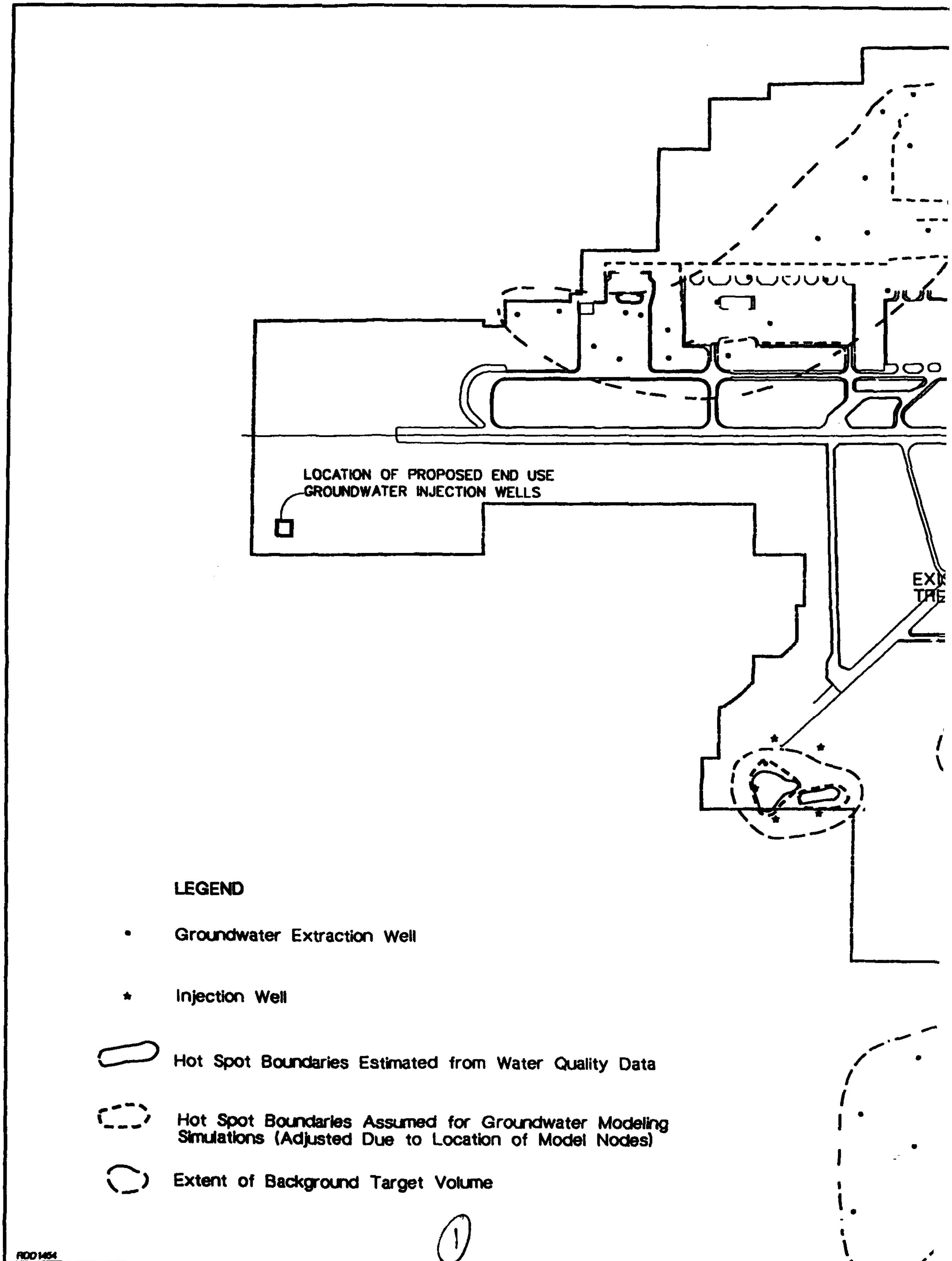
AND
ONS
ZON
RABLE
RCE B
ORNIA

FIGURE 8-9
EXTRACTION AND INJECTION
WELL LOCATIONS
MONITORING ZONE A
HOT SPOTS

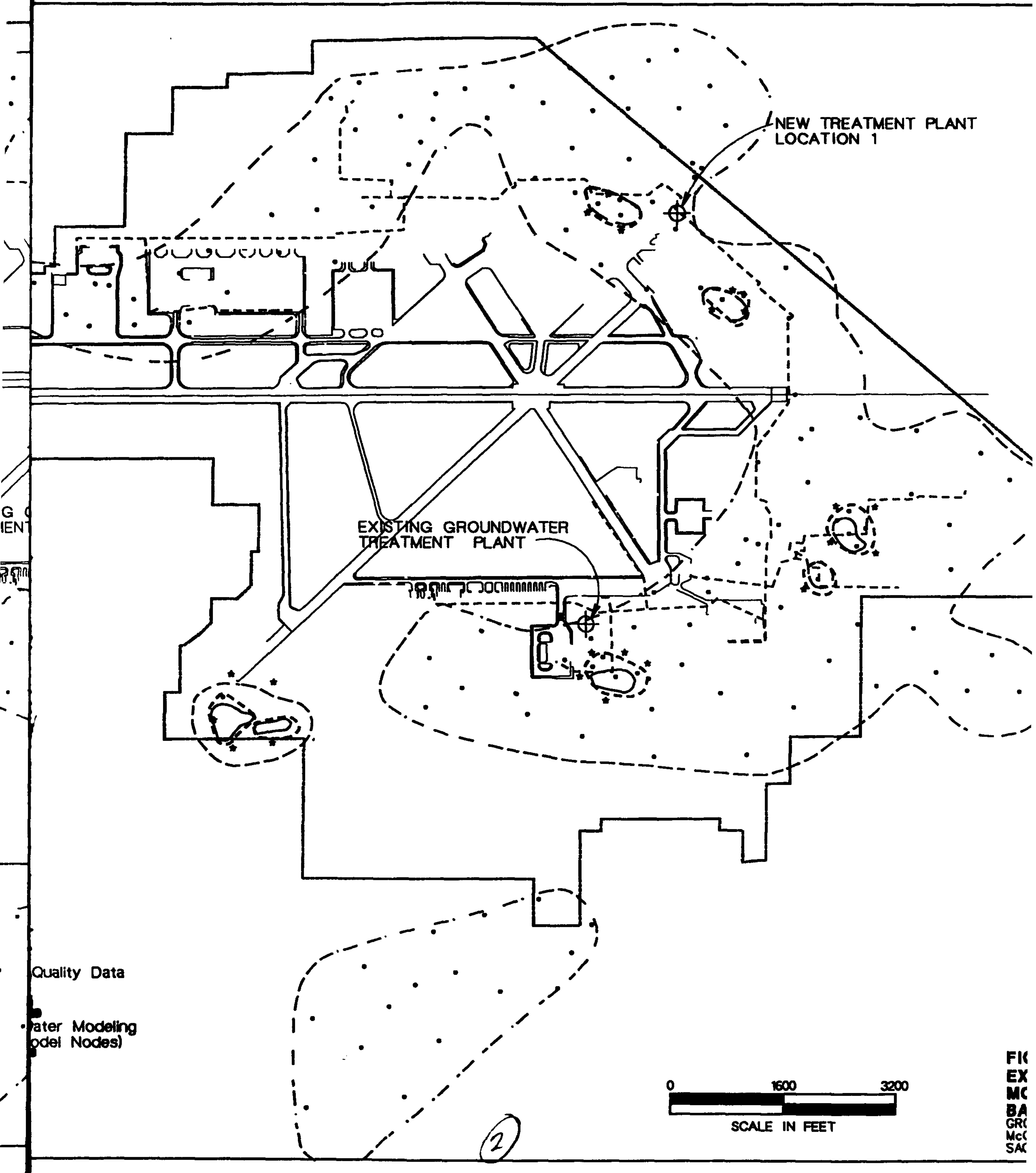
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

3

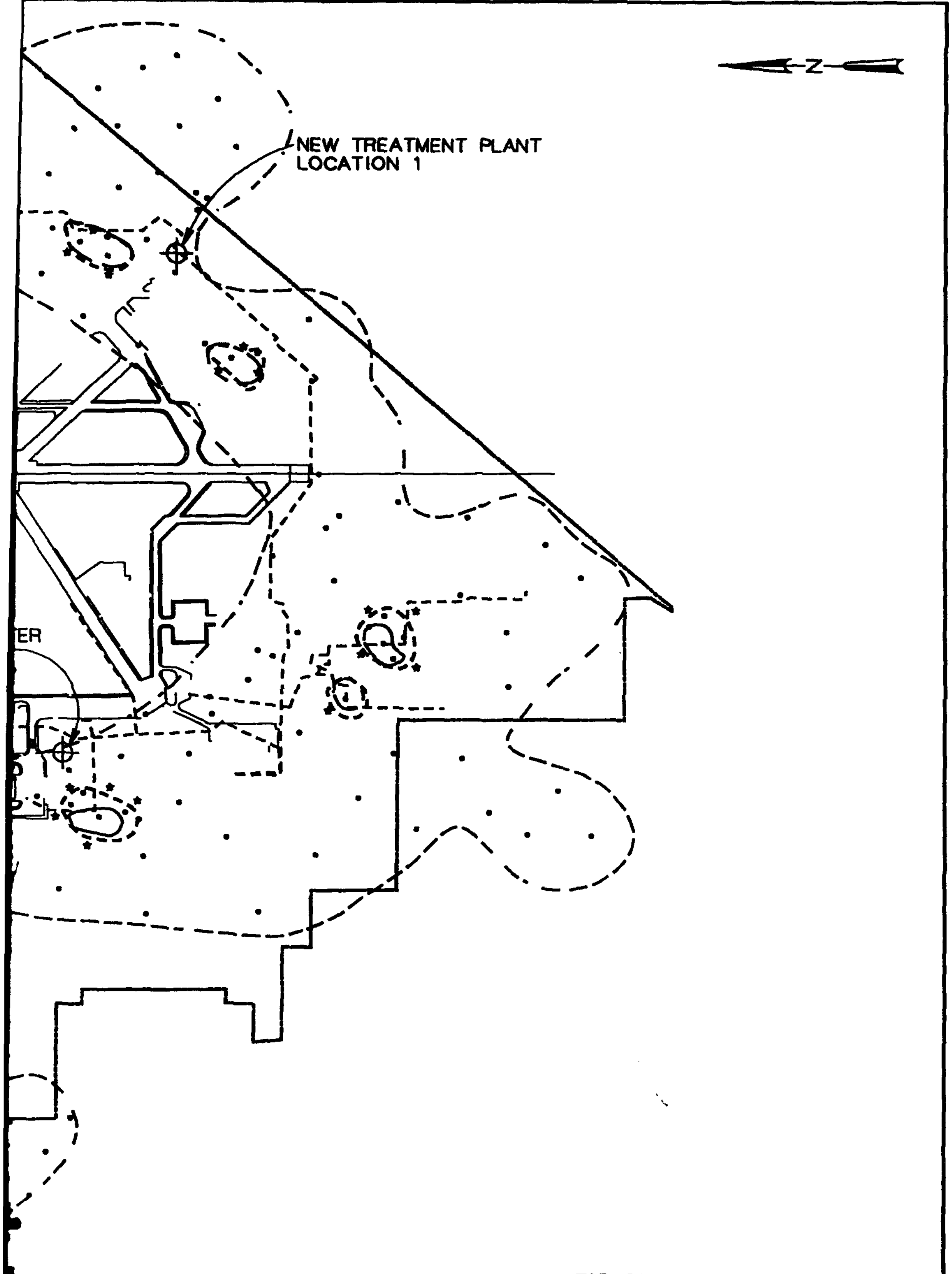


MEY94/8-10.DGN (J-14-LEV 62)



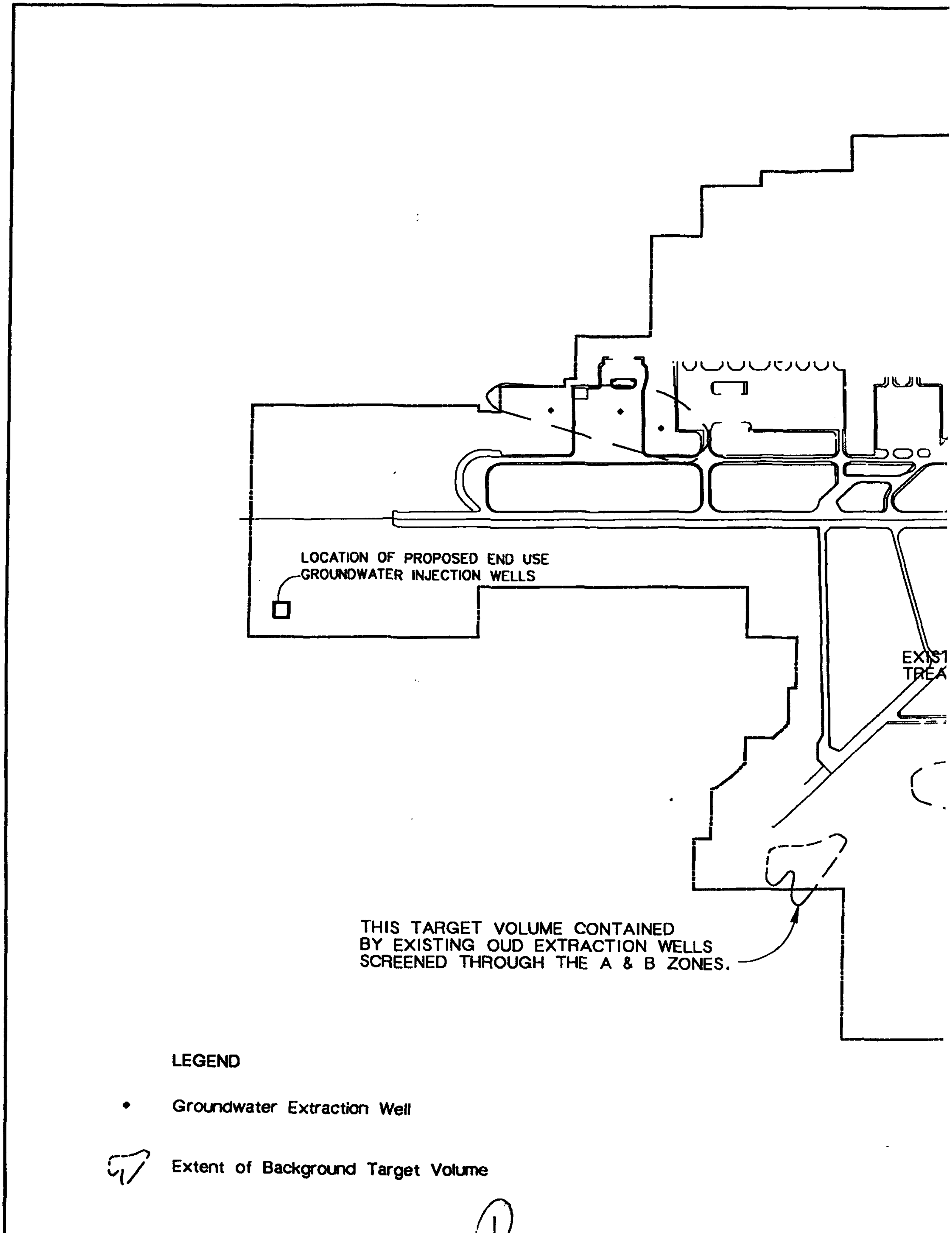
NEW TREATMENT PLANT
LOCATION 1
EXISTING GROUNDWATER
TREATMENT PLANT
Quality Data
ater Modeling
odel Nodes)
0
1600
3200
SCALE IN FEET
FI
EX
MC
BA
GR
Mc
SA

(2)

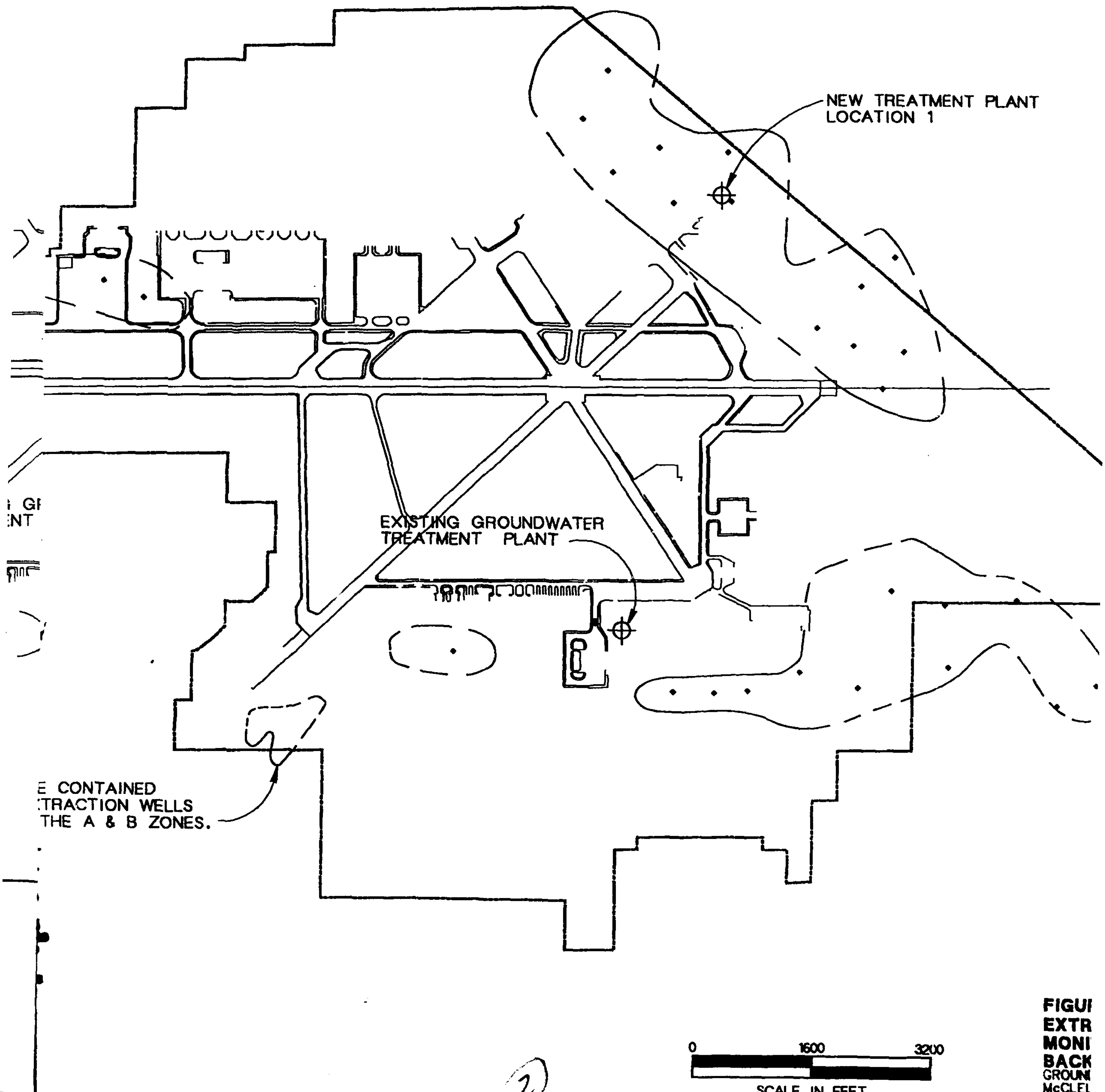


0 1600 3200
SCALE IN FEET

FIGURE 8-10
EXTRACTION WELL LOCATIONS
MONITORING ZONE A
BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA
CH2M HILL
(3)

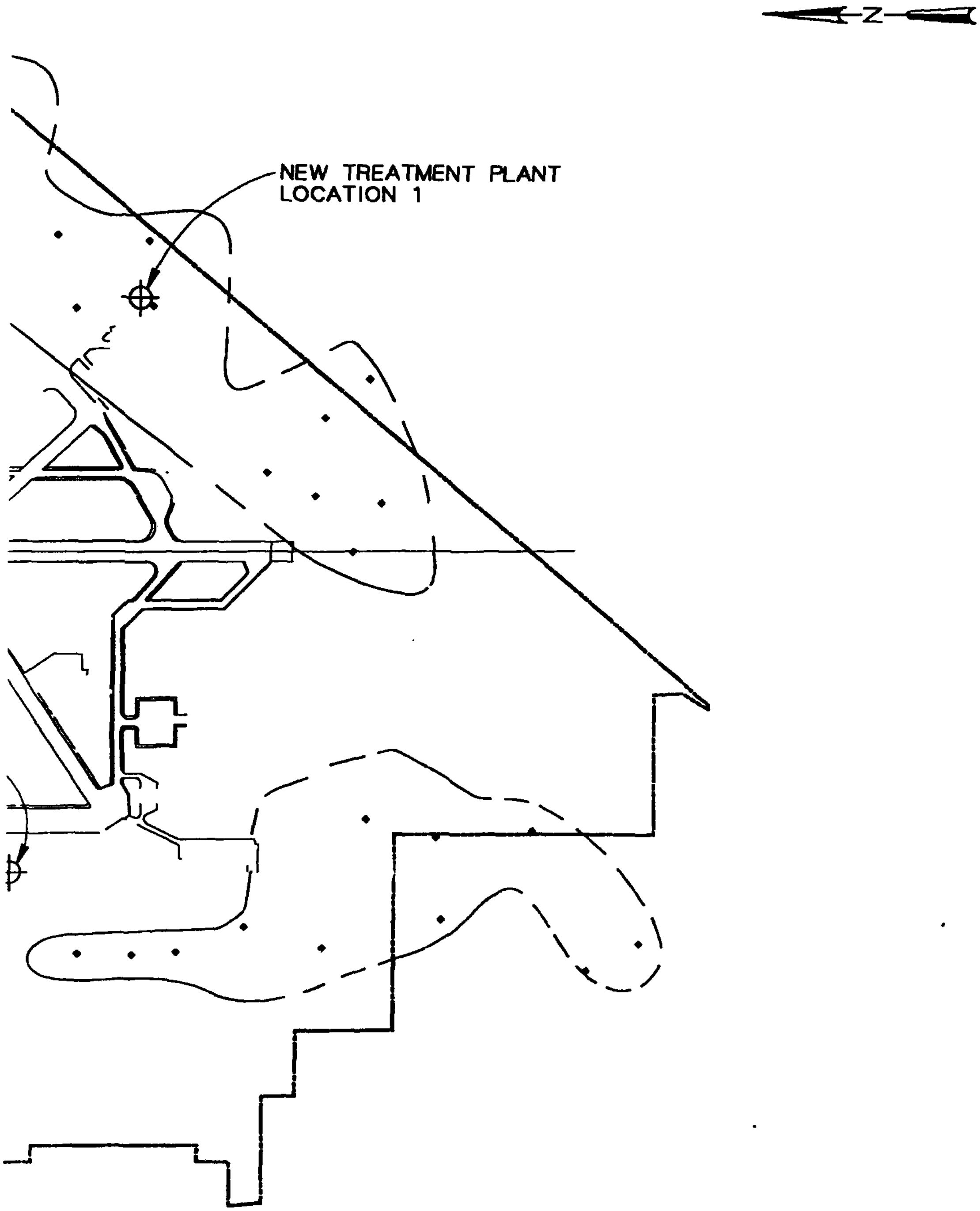


RDD1464
MEY94/8-11.DGN (J-15-LEV 62)



FIGU
EXTR
MONI
BACK
GROUN
McCLEL
SACRA

(2)



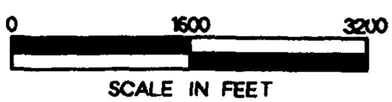
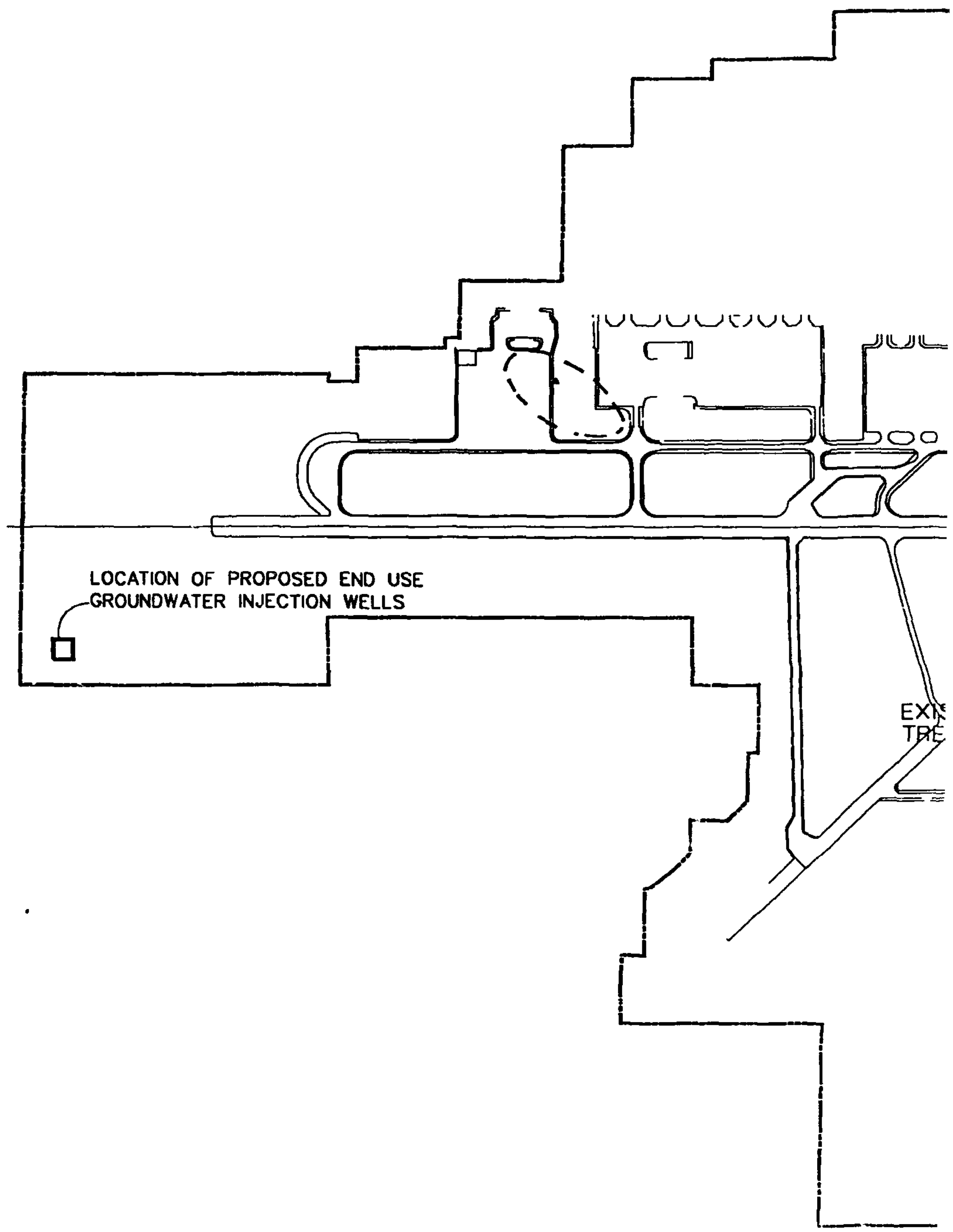


FIGURE 8-11
EXTRACTION WELL LOCATIONS
MONITORING ZONE B
BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



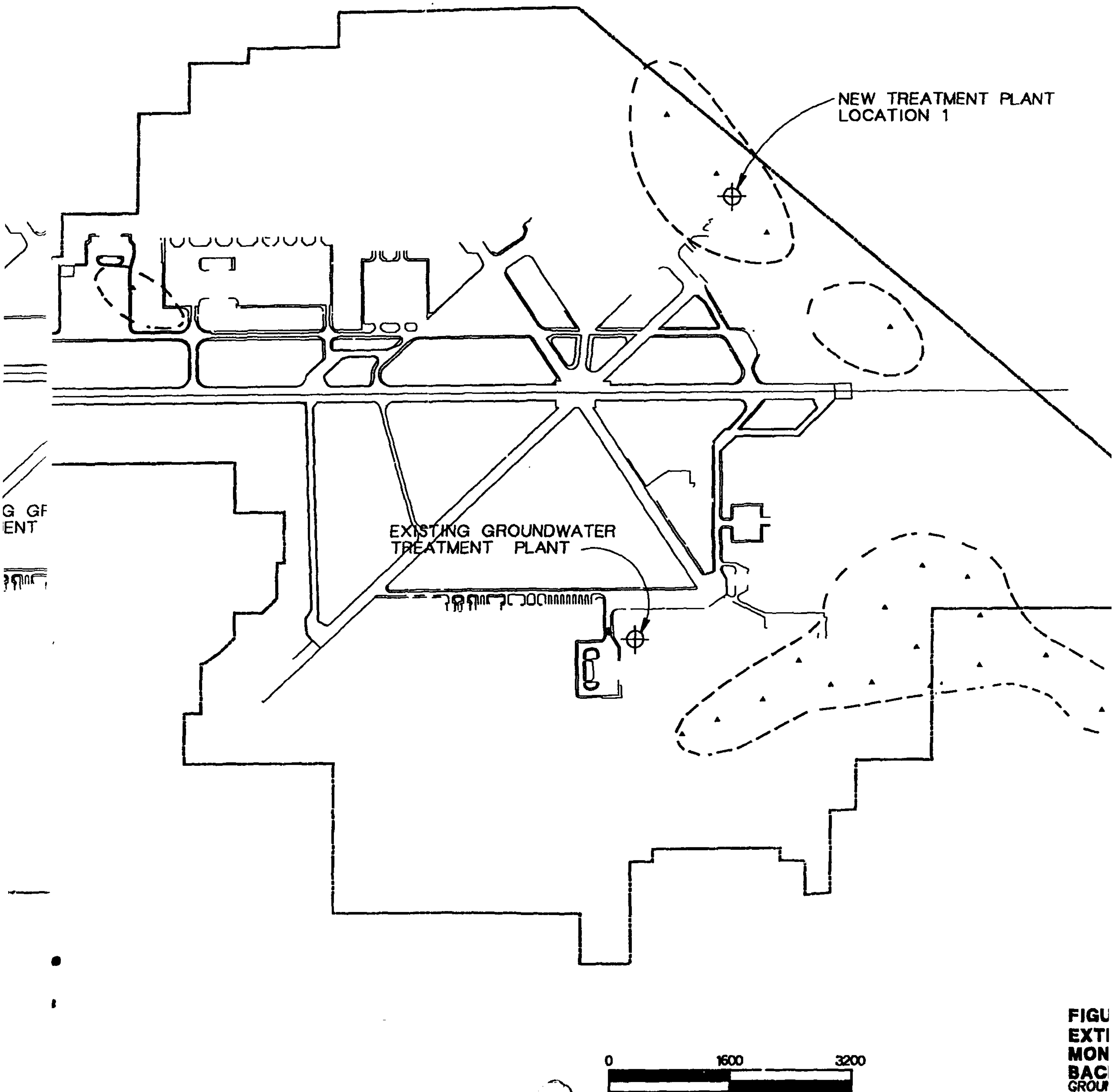
LEGEND

▲ Groundwater Extraction Well

Extent of Background Target Volume

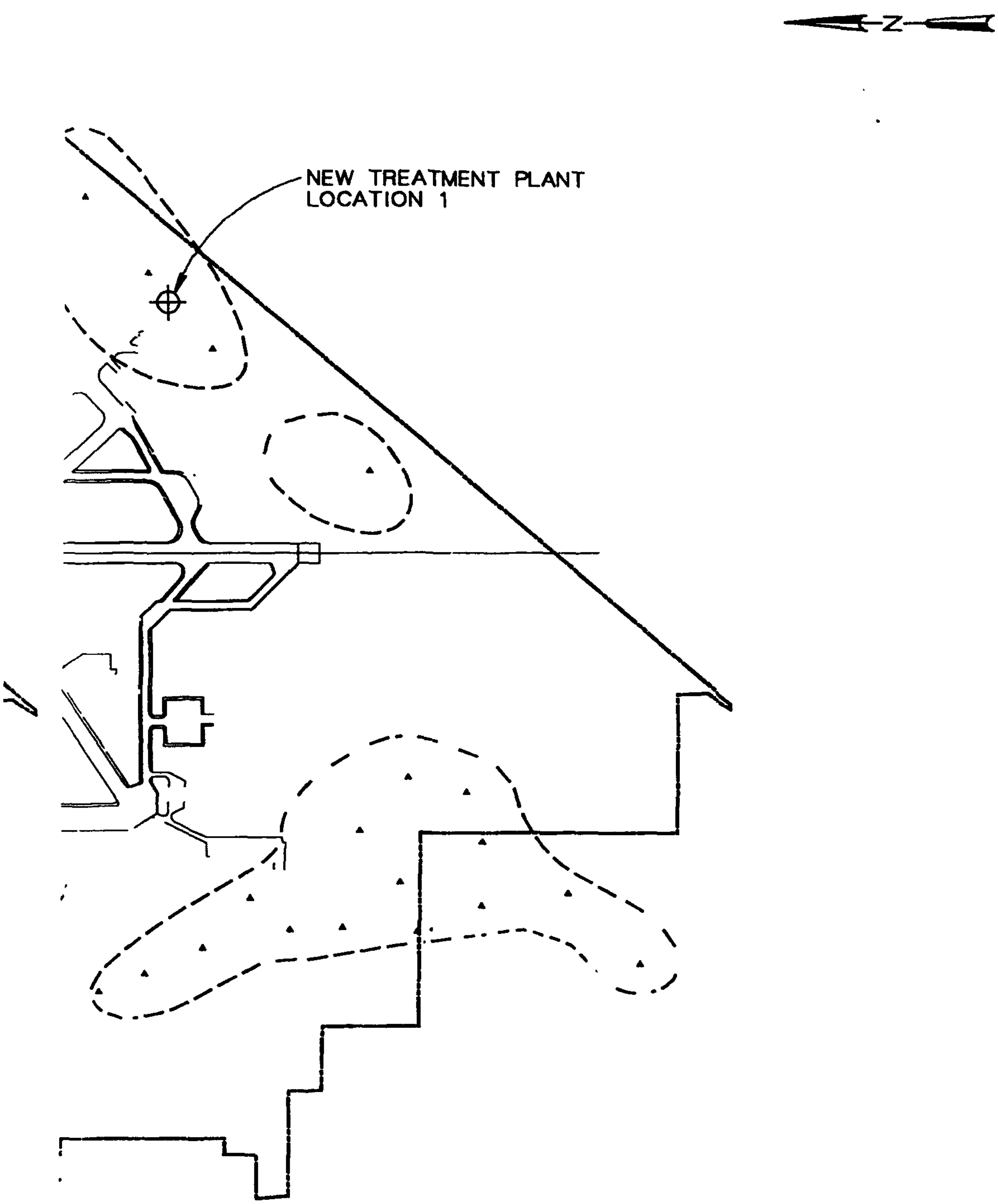
RDD 1464

MEY94/8-12.DGN (J-15=LEV 62)



FIGU
EXTI
MON
BAC
GROU
McCLE
SACR

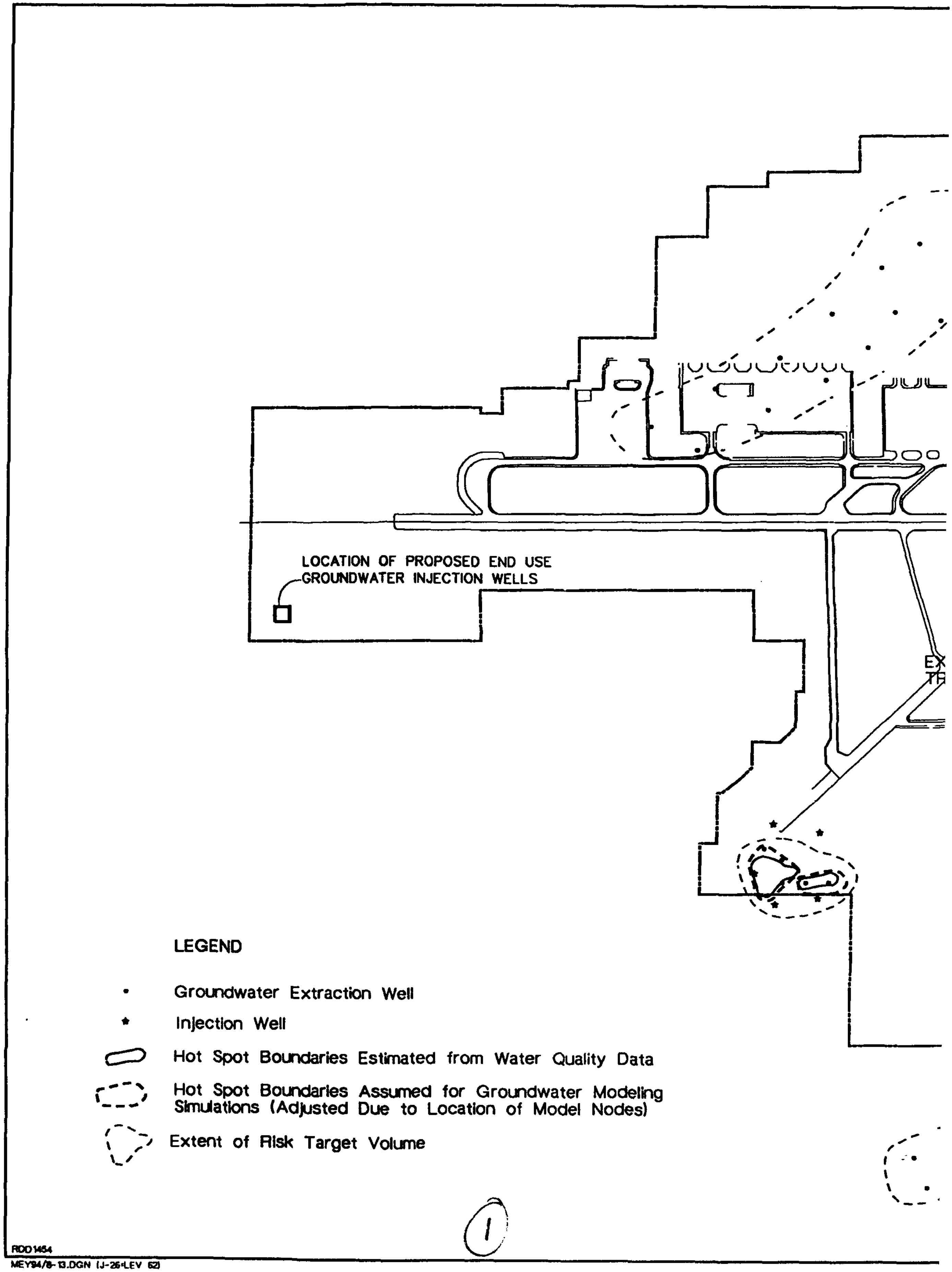
2



1600 3200
SCALE IN FEET

FIGURE 8-12
EXTRACTION WELL LOCATIONS
MONITORING ZONE C
BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


LOCATION OF PROPOSED END USE GROUNDWATER INJECTION WELLS
LEGEND
Groundwater Extraction Well
Injection Well
Hot Spot Boundaries Estimated from Water Quality Data
Hot Spot Boundaries Assumed for Groundwater Modeling Simulations (Adjusted Due to Location of Model Nodes)
Extent of Risk Target Volume
RDD1454
MEY94/8-13.DGN (J-26+LEV 62)

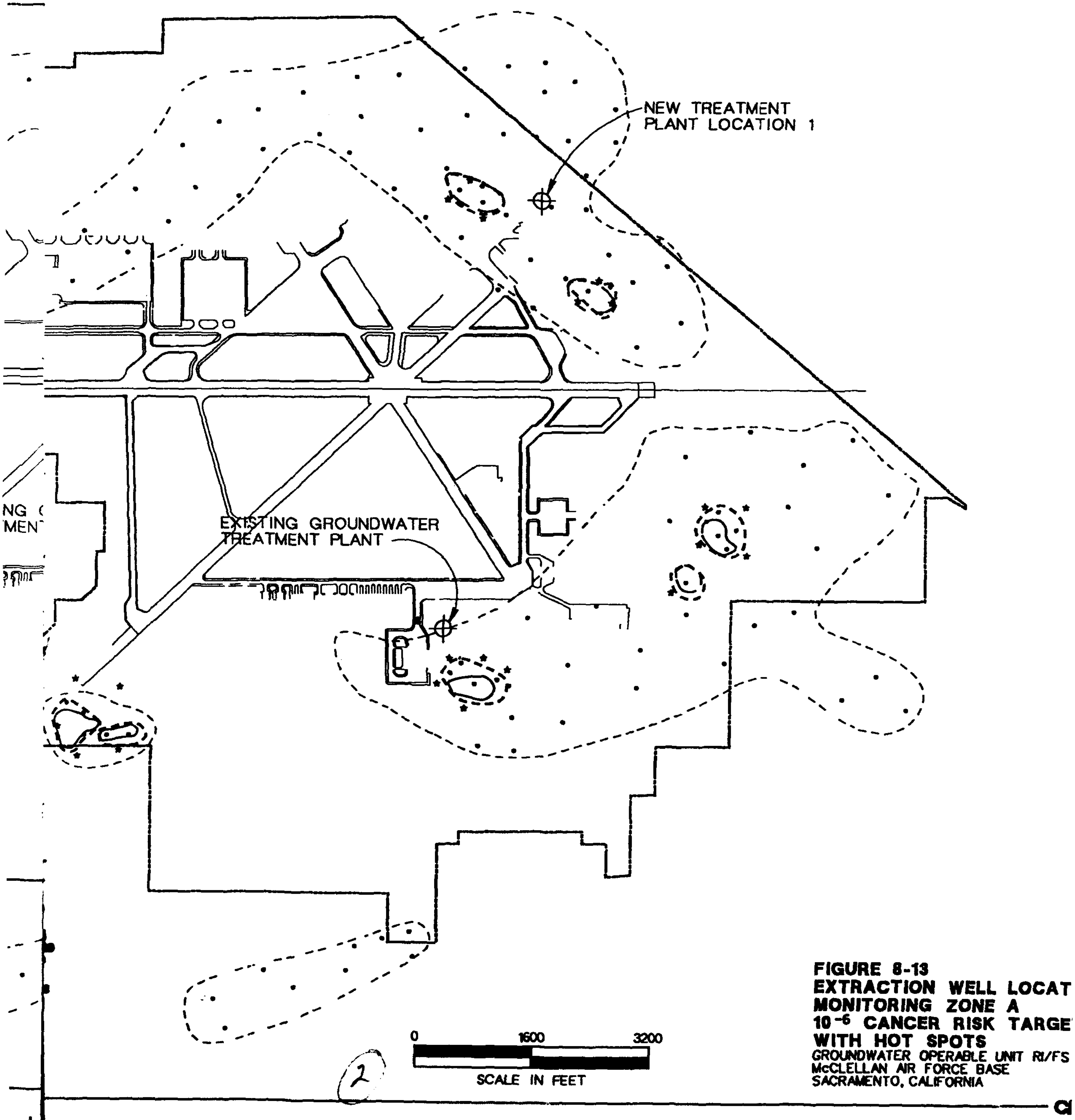
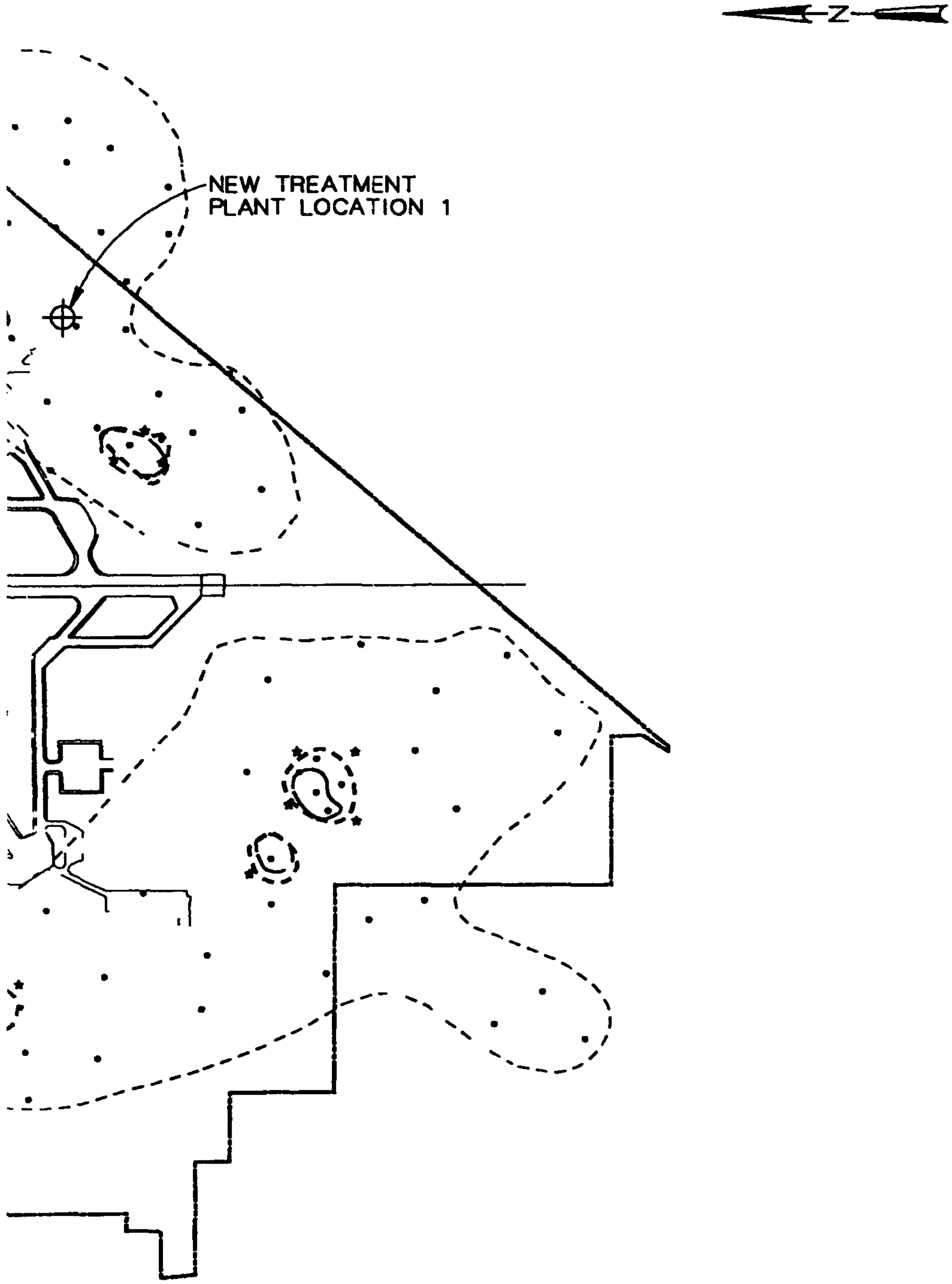


FIGURE 8-13
EXTRACTION WELL LOCAT
MONITORING ZONE A
10^{-6} CANCER RISK TARGE
WITH HOT SPOTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



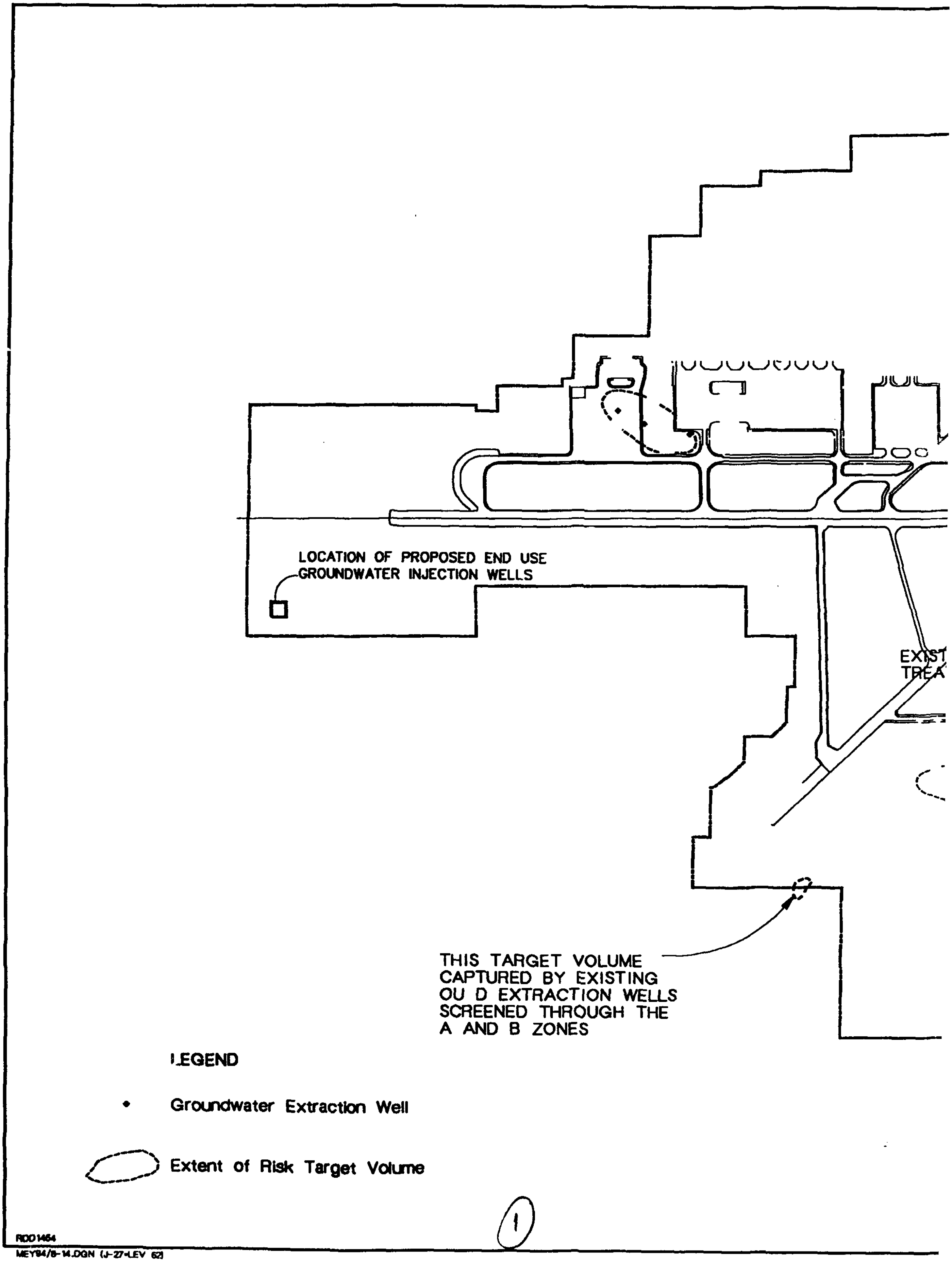
OLU

1600 3200

ALE IN FEET

FIGURE 8-13
EXTRACTION WELL LOCATIONS
MONITORING ZONE A
10^{-6} CANCER RISK TARGET VOLUME
WITH HOT SPOTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


LOCATION OF PROPOSED END USE GROUNDWATER INJECTION WELLS
THIS TARGET VOLUME CAPTURED BY EXISTING OU D EXTRACTION WELLS SCREENED THROUGH THE A AND B ZONES
LEGEND
Groundwater Extraction Well
Extent of Risk Target Volume
1
ROD1464
MEY94/8-14.DGN (J-27-LEV 62)

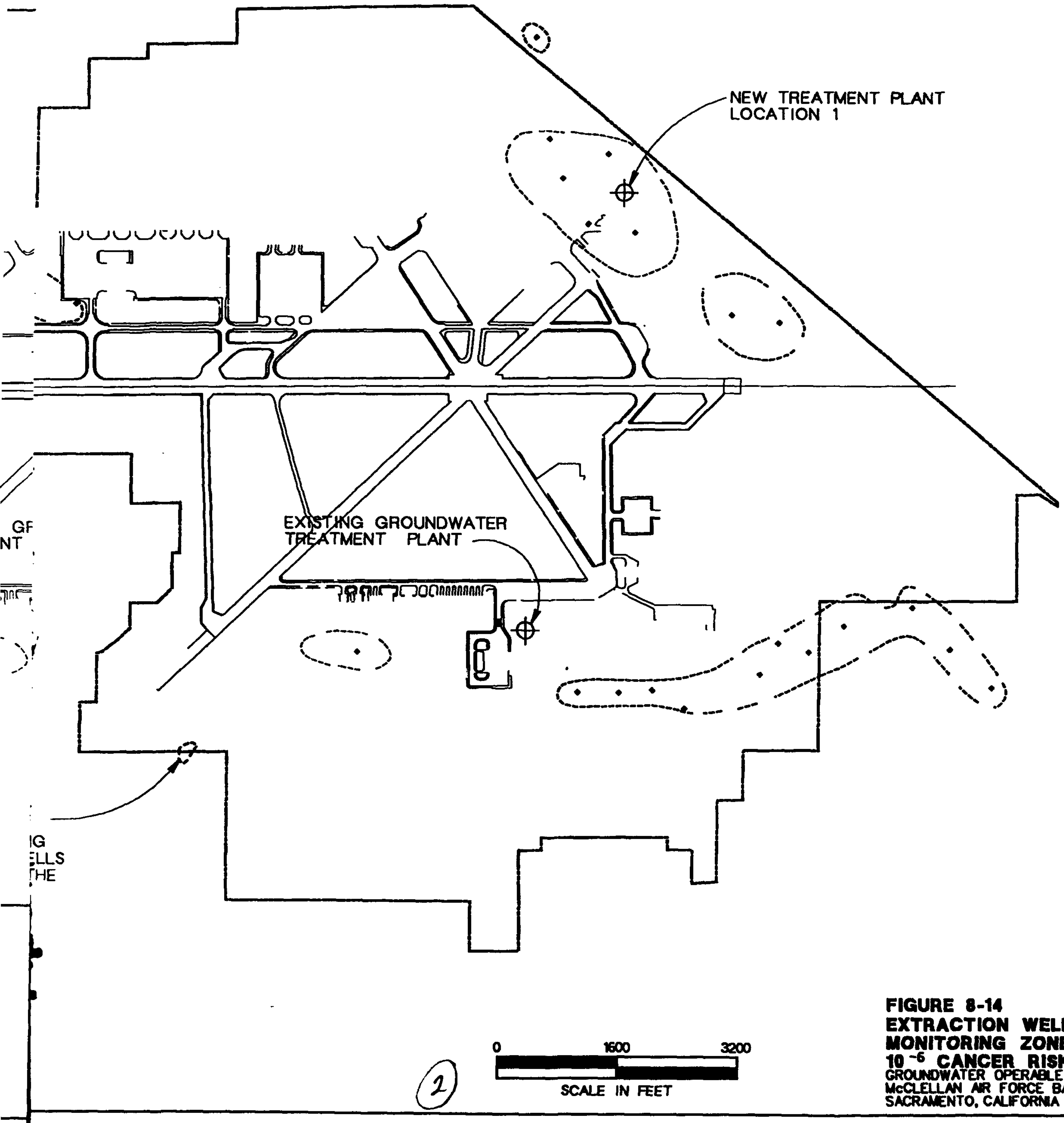


FIGURE 8-14
EXTRACTION WELL L
MONITORING ZONE B
10^{-6} CANCER RISK
GROUNDWATER OPERABLE UN
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

(2)

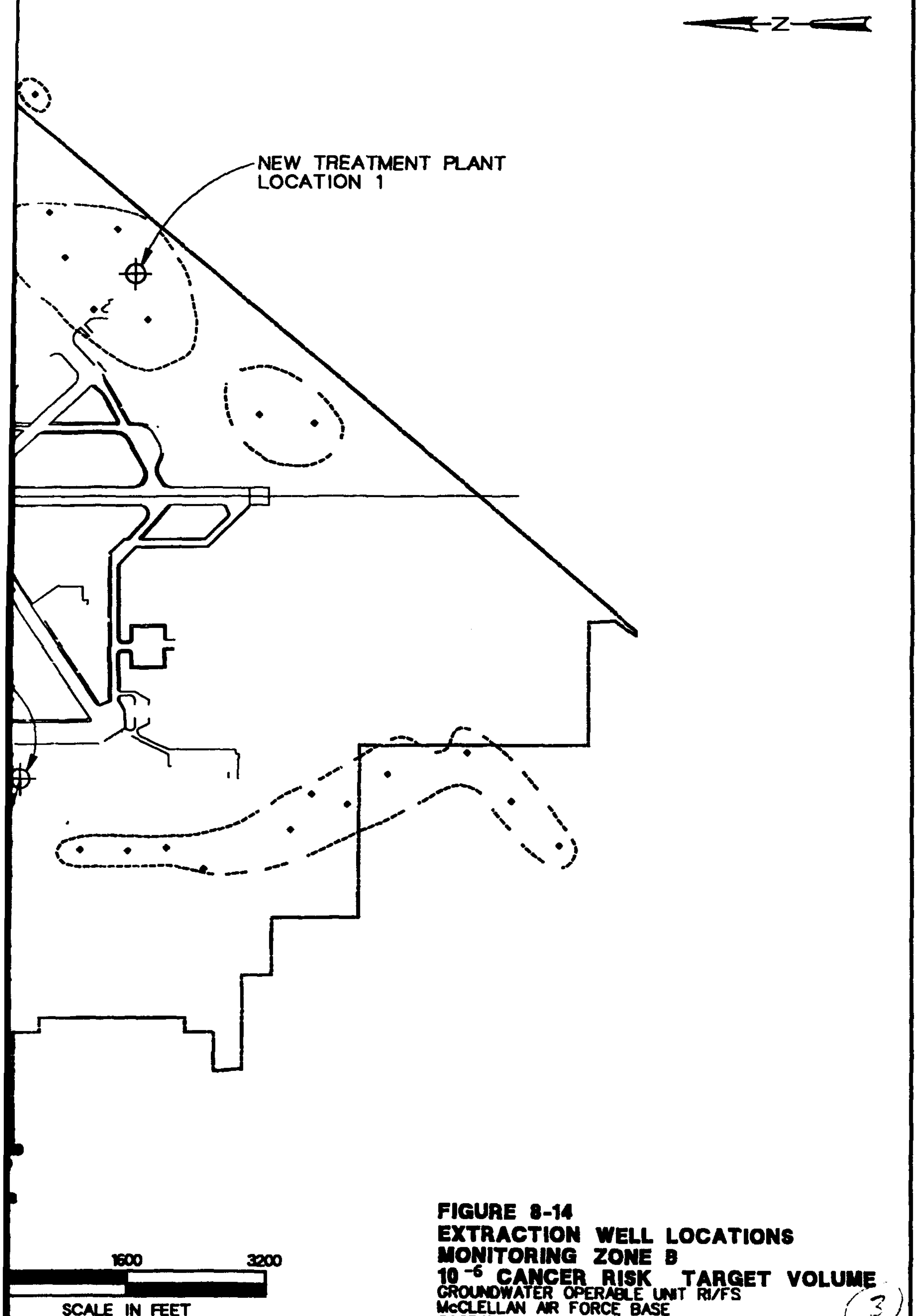
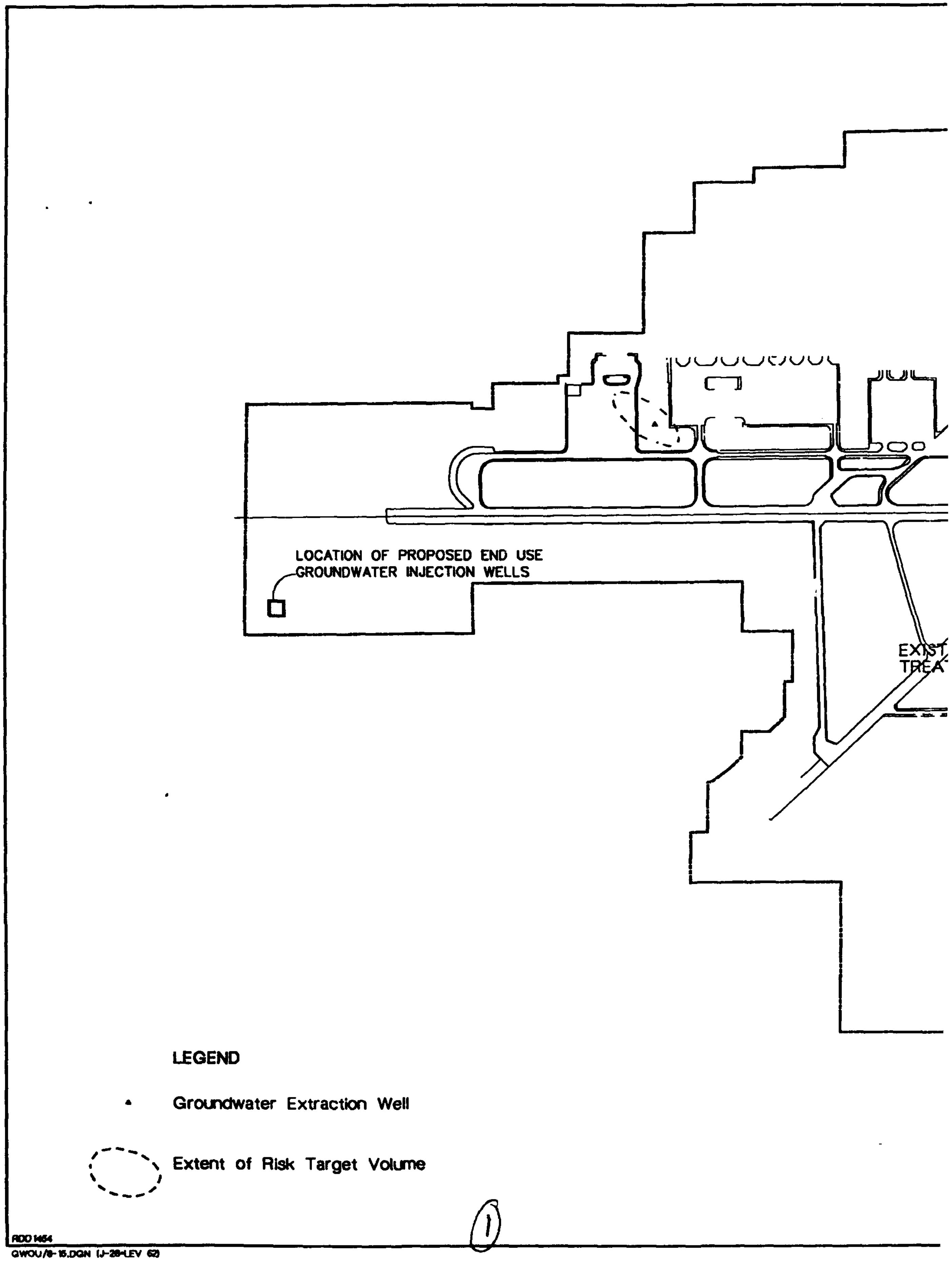


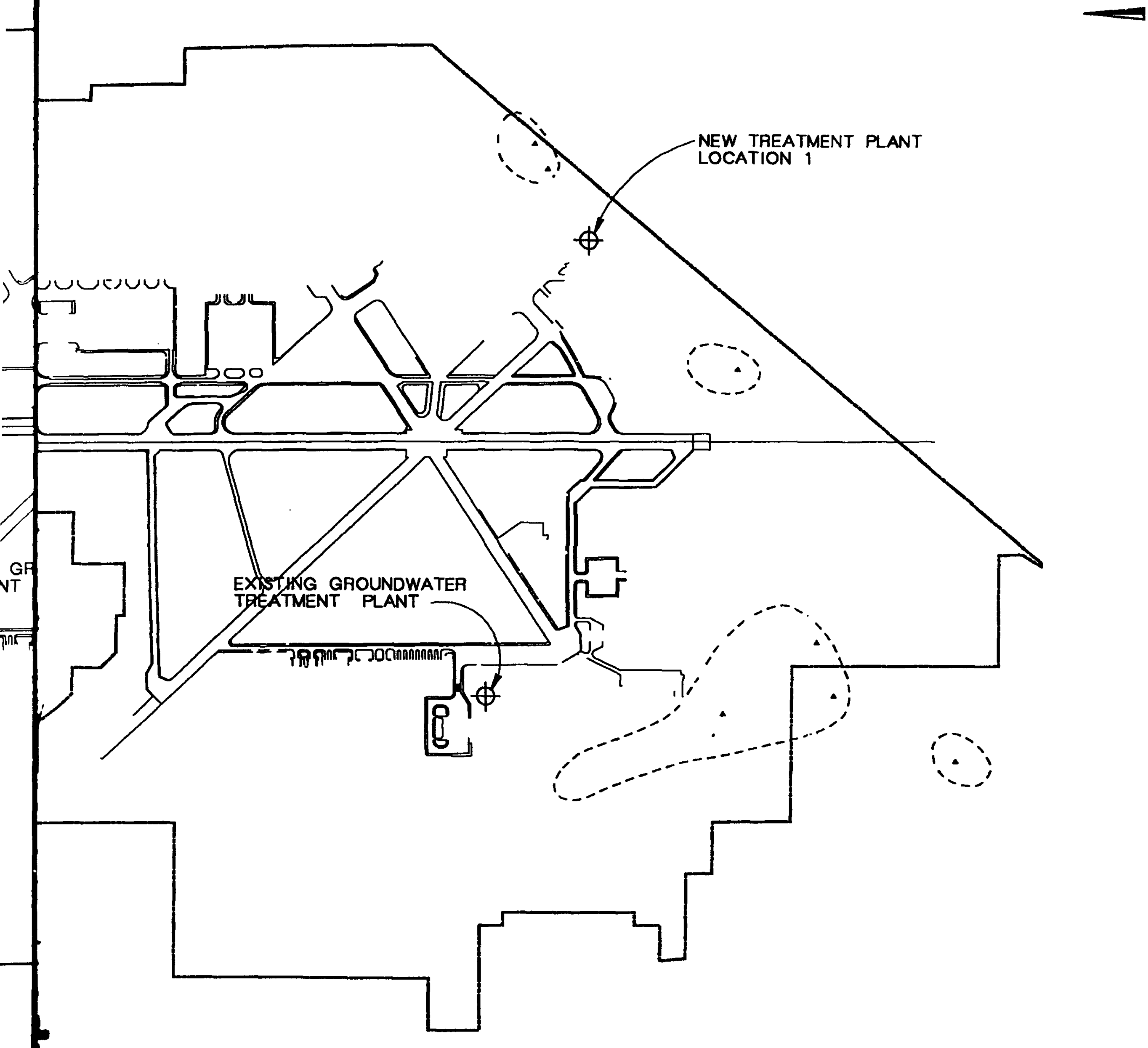
FIGURE 8-14
EXTRACTION WELL LOCATIONS
MONITORING ZONE B
10^{-6} CANCER RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

(3)



RDO 1454
GWOU/8-15.DGN (J-28-LEV 62)



0 1600 3200
SCALE IN FEET

2

FIGURE 8-15
EXTRACTION WELL
MONITORING ZONE
10^{-6} CANCER RISK
GROUNDWATER OPERABLE U
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

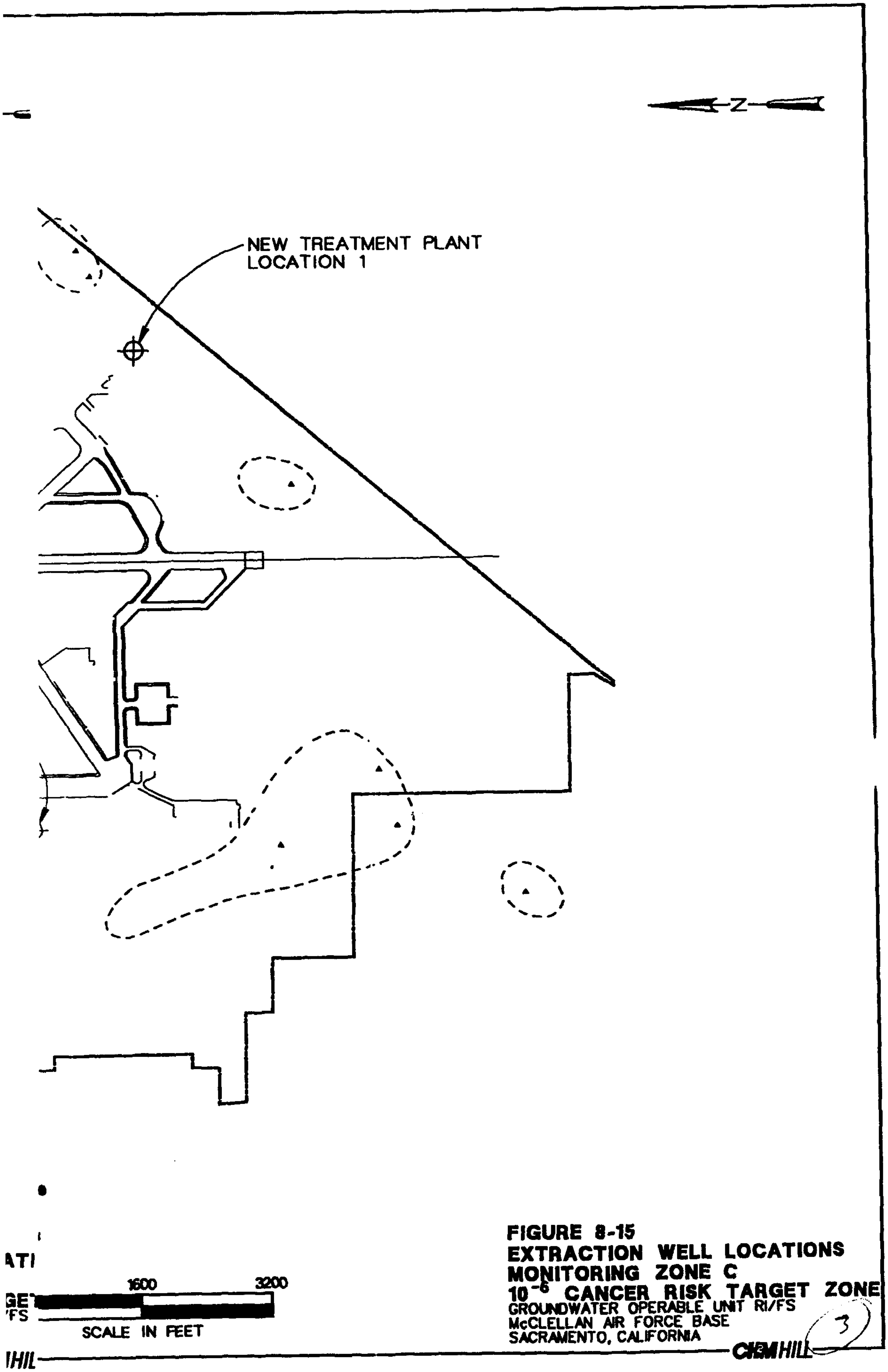
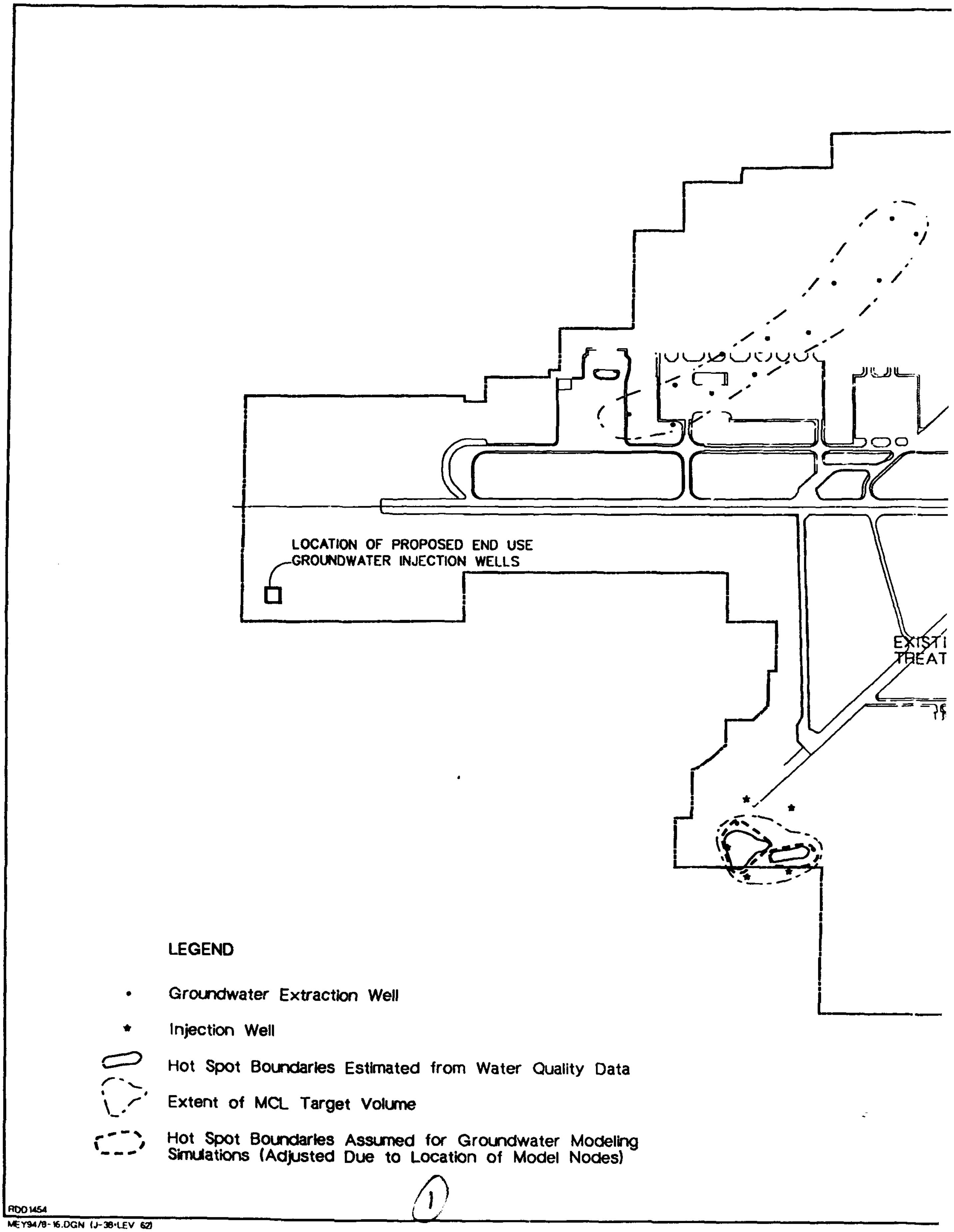


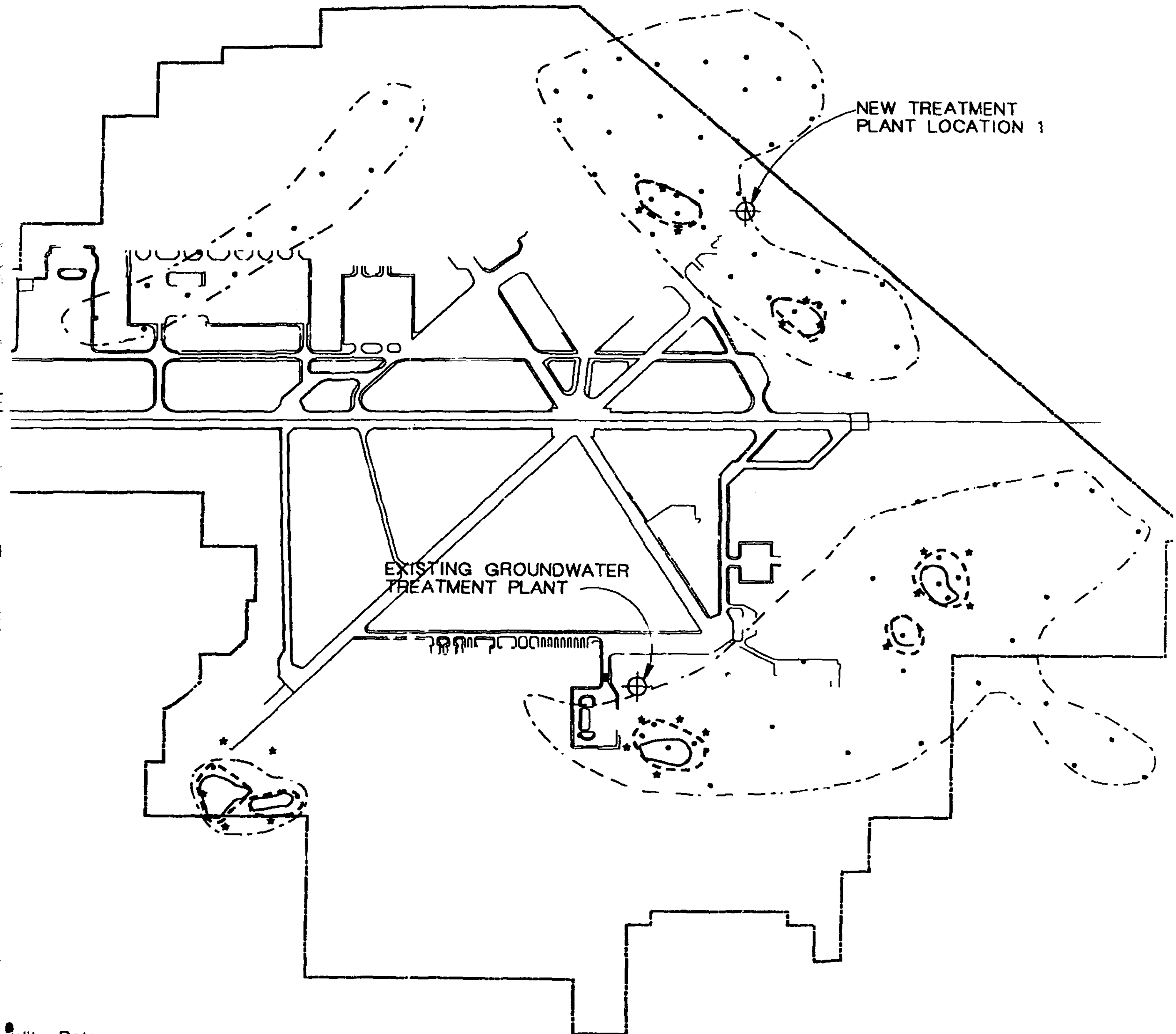
FIGURE 8-15
EXTRACTION WELL LOCATIONS
MONITORING ZONE C
10^{-6} CANCER RISK TARGET ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

3



MEY94/8-16.DGN (J-38-LEV 62)



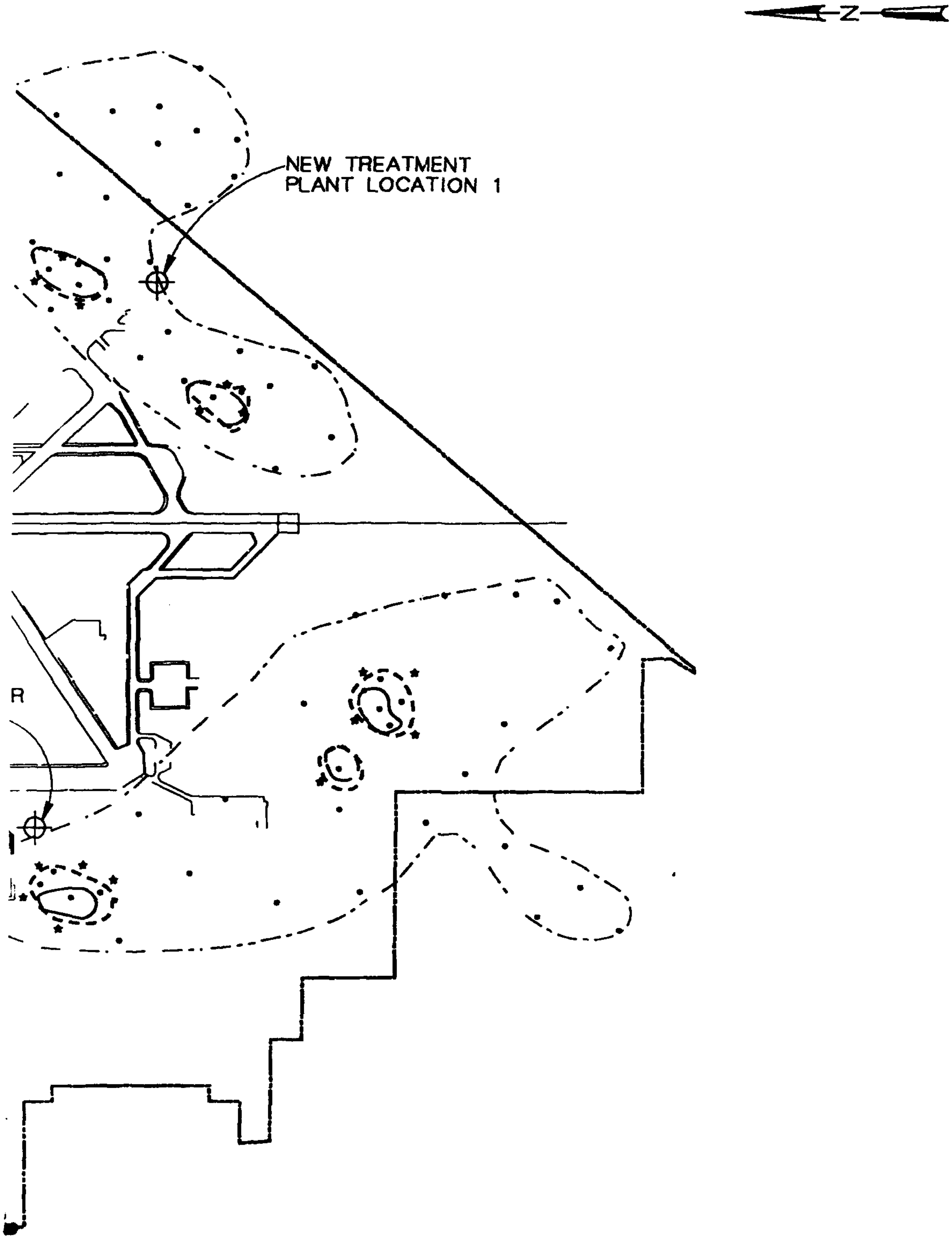
GI
IT

Jality Data

er Modeling
iel Nodes)

0 1600 3200
SCALE IN FEET

FIGURE
EXTRA
MONITO
MCL T
WITH
GROUNDW
McCLELLA
SACRAMEN

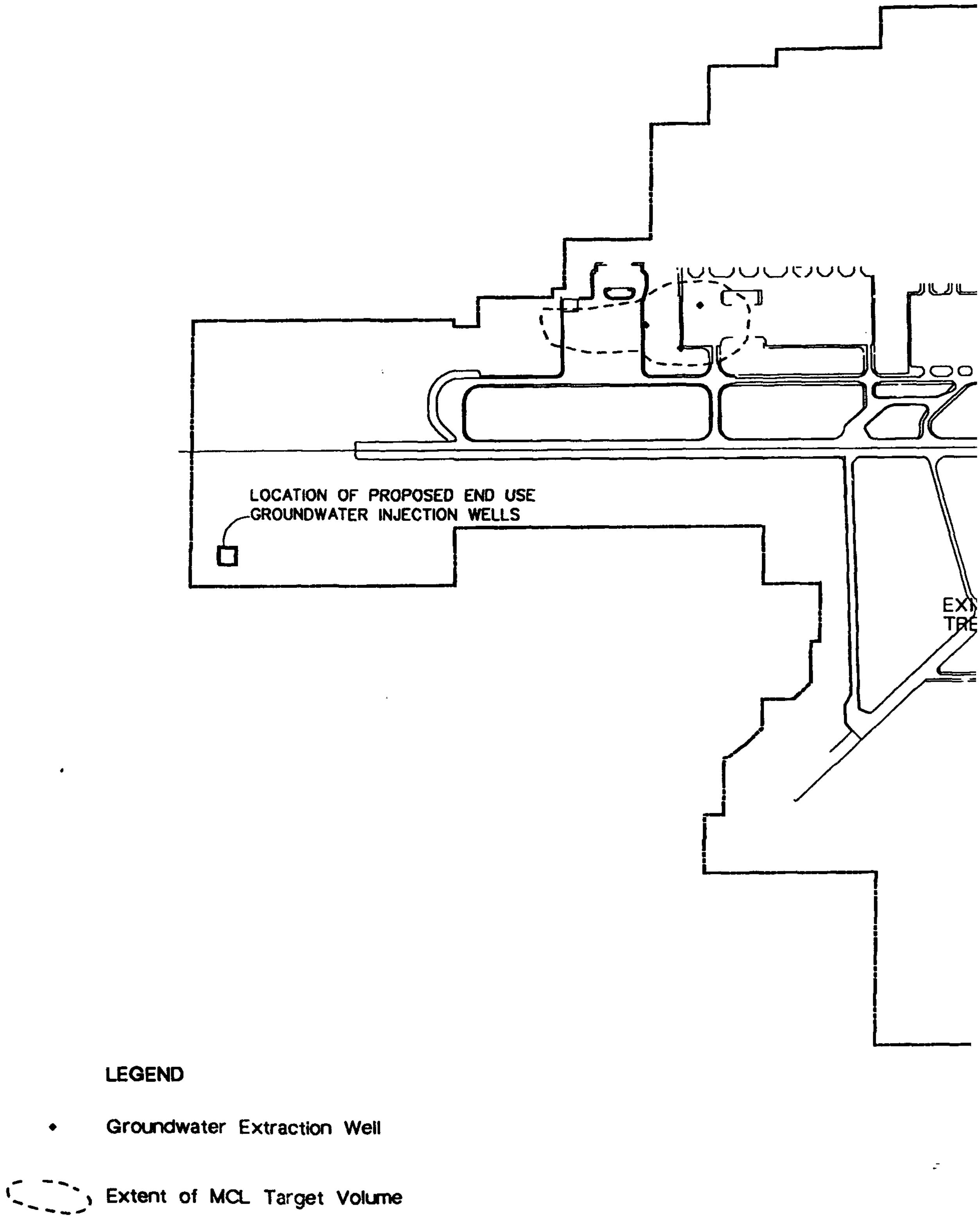


1600 3200
SCALE IN FEET

FIGURE 8-16
EXTRACTION WELL LOCATIONS
MONITORING ZONE A
MCL TARGET VOLUME
WITH HOT SPOTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

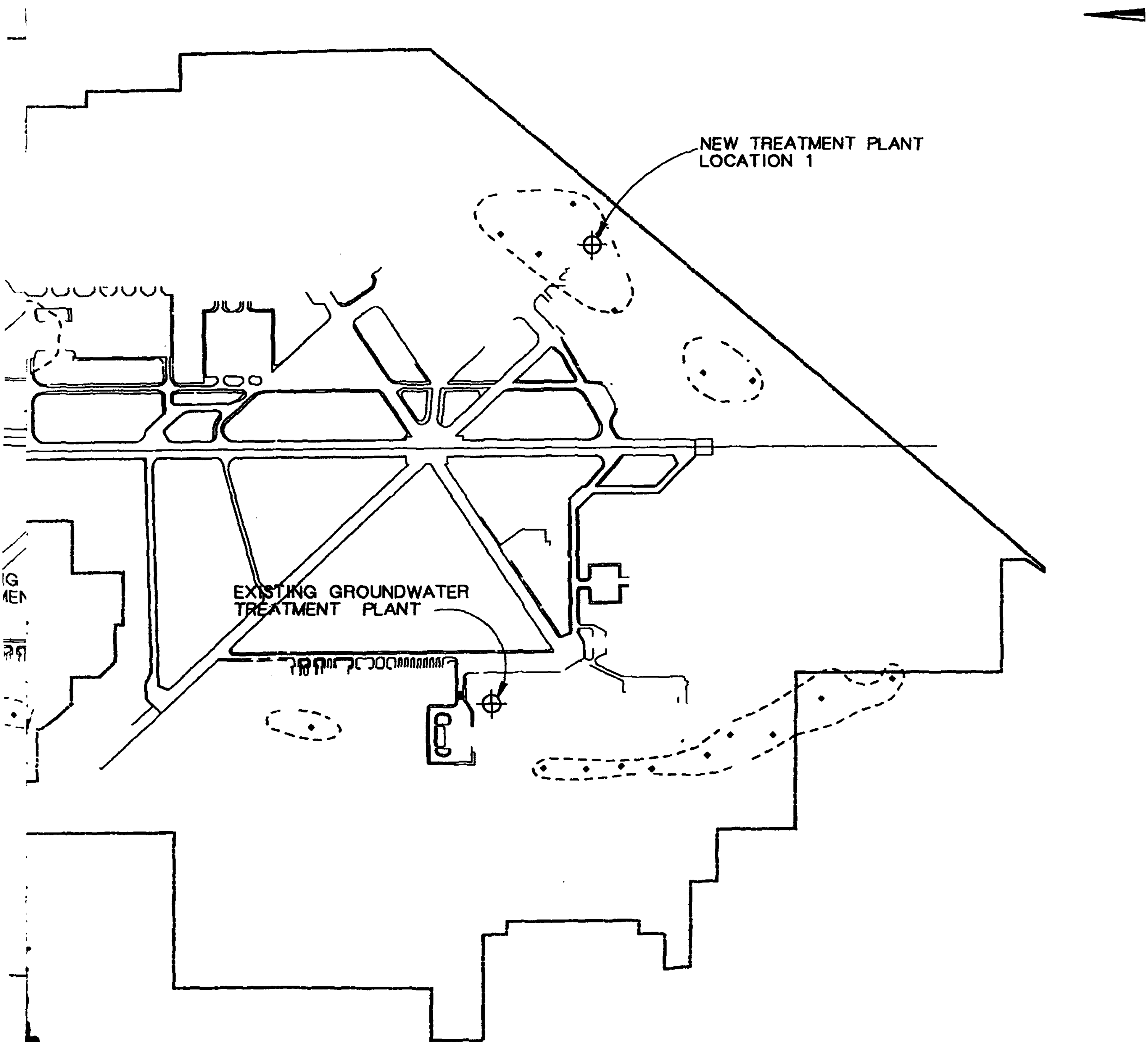
CH2M HILL

(3)



RDD 1464

MEY94/8-17.DGN (J-39 • LEV 62)



0 1600 3200
SCALE IN FEET

(2)

FIGURE 8-17
EXTRACTION WELL
MONITORING ZONE
MCL TARGET VOLU
GROUNDWATER OPERABLE U
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

1

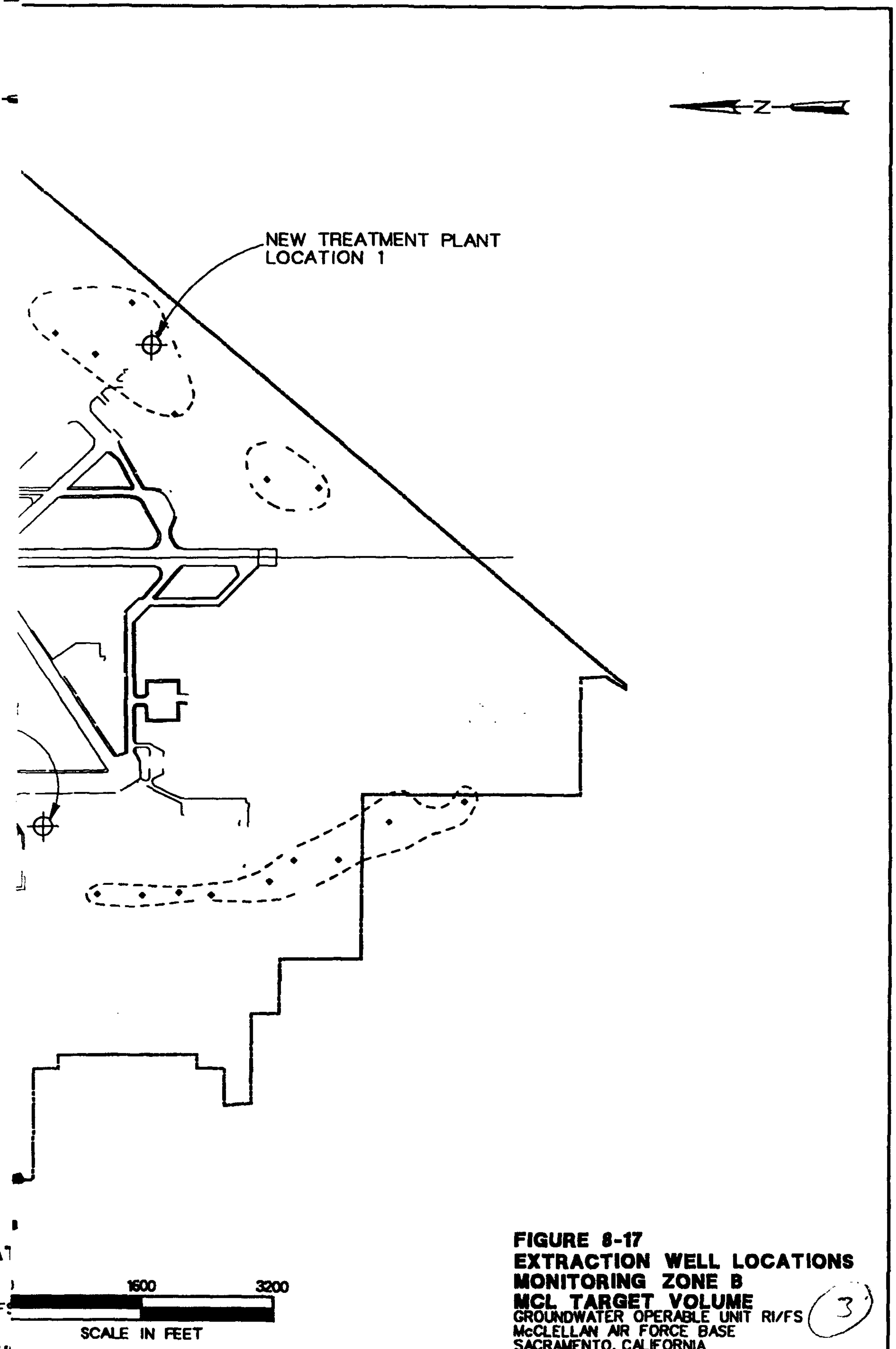
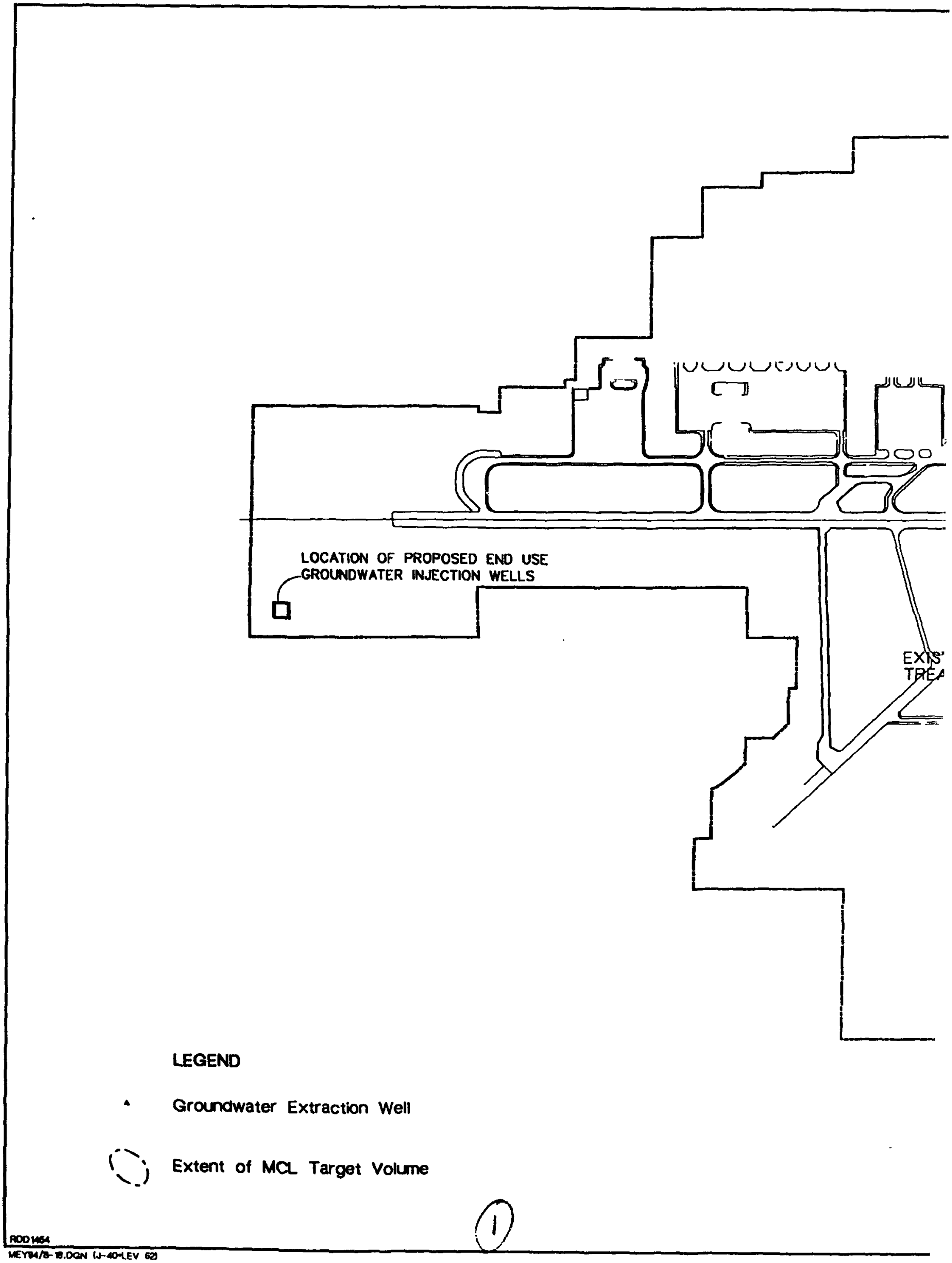
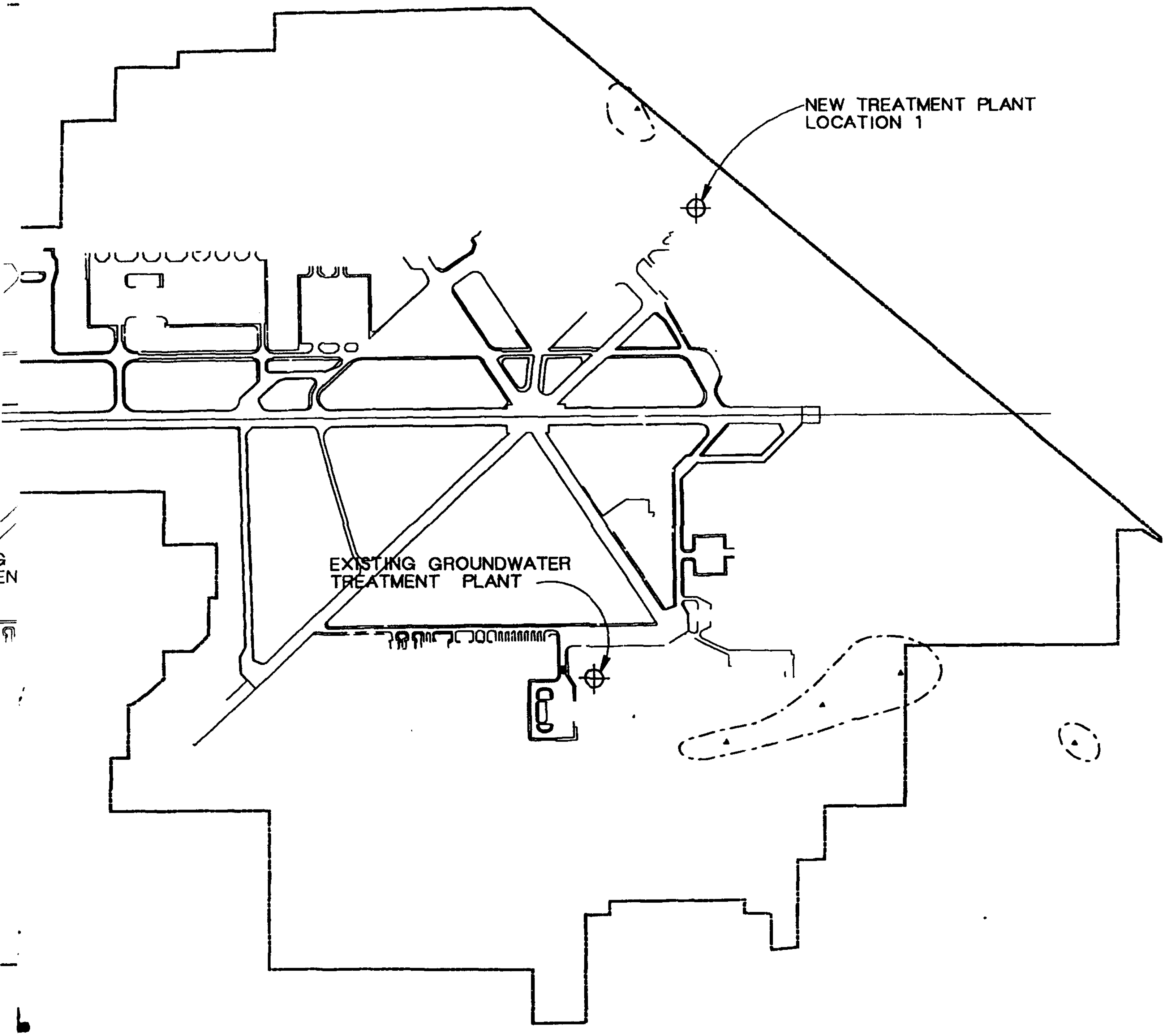


FIGURE 8-17
EXTRACTION WELL LOCATIONS
MONITORING ZONE B
MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

(3)

CH2M HILL


LOCATION OF PROPOSED END USE GROUNDWATER INJECTION WELLS
LEGEND
Groundwater Extraction Well
Extent of MCL Target Volume
RDD 1464
MEY94/B-18.DGN (J-40-LEV 62)



0 1600 3200
SCALE IN FEET

(2)

FIGURE 8-1
EXTRACTIO
MONITORIN
MCL TARGE
GROUNDWATER
McCLELLAN AIR
SACRAMENTO, C

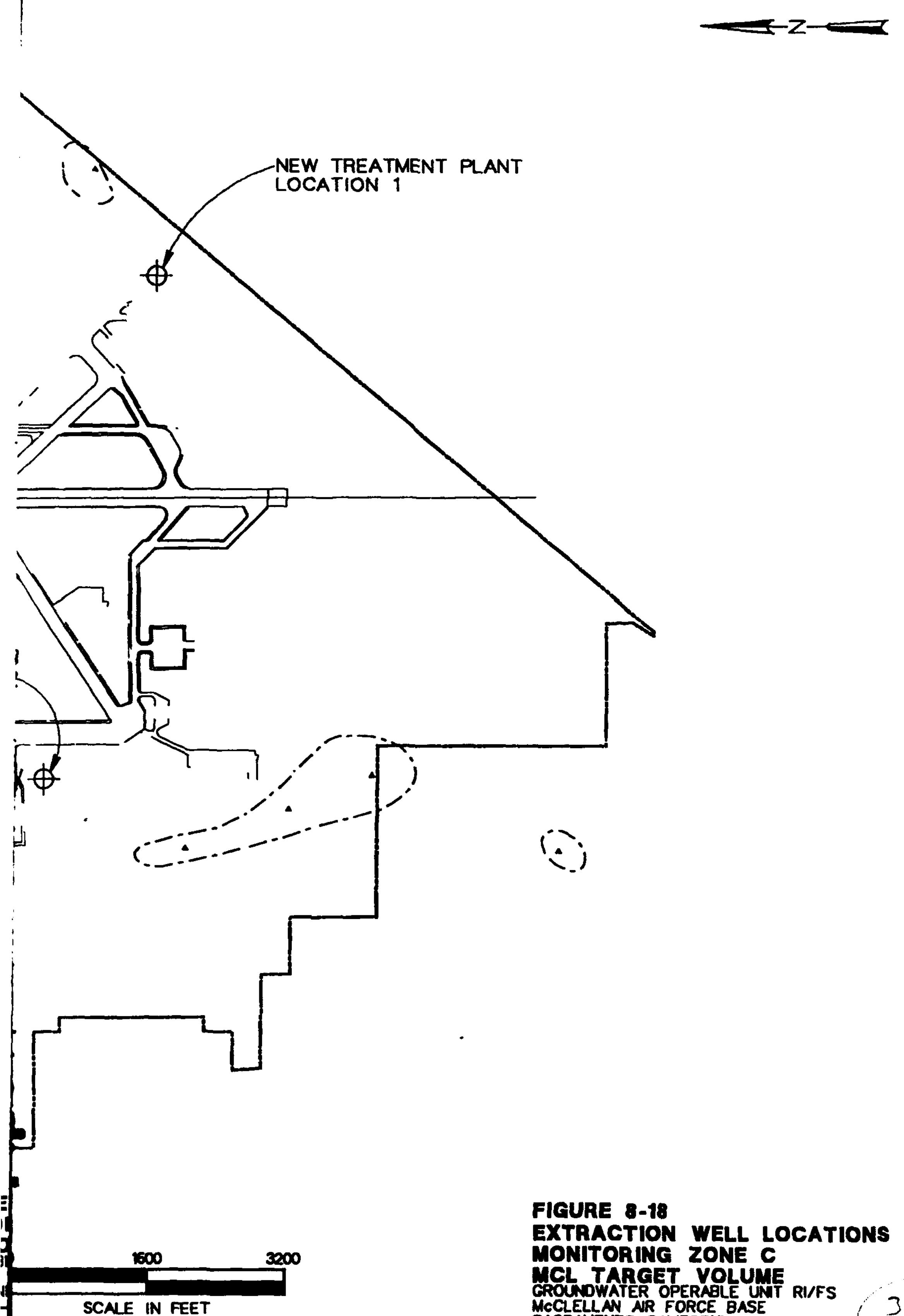
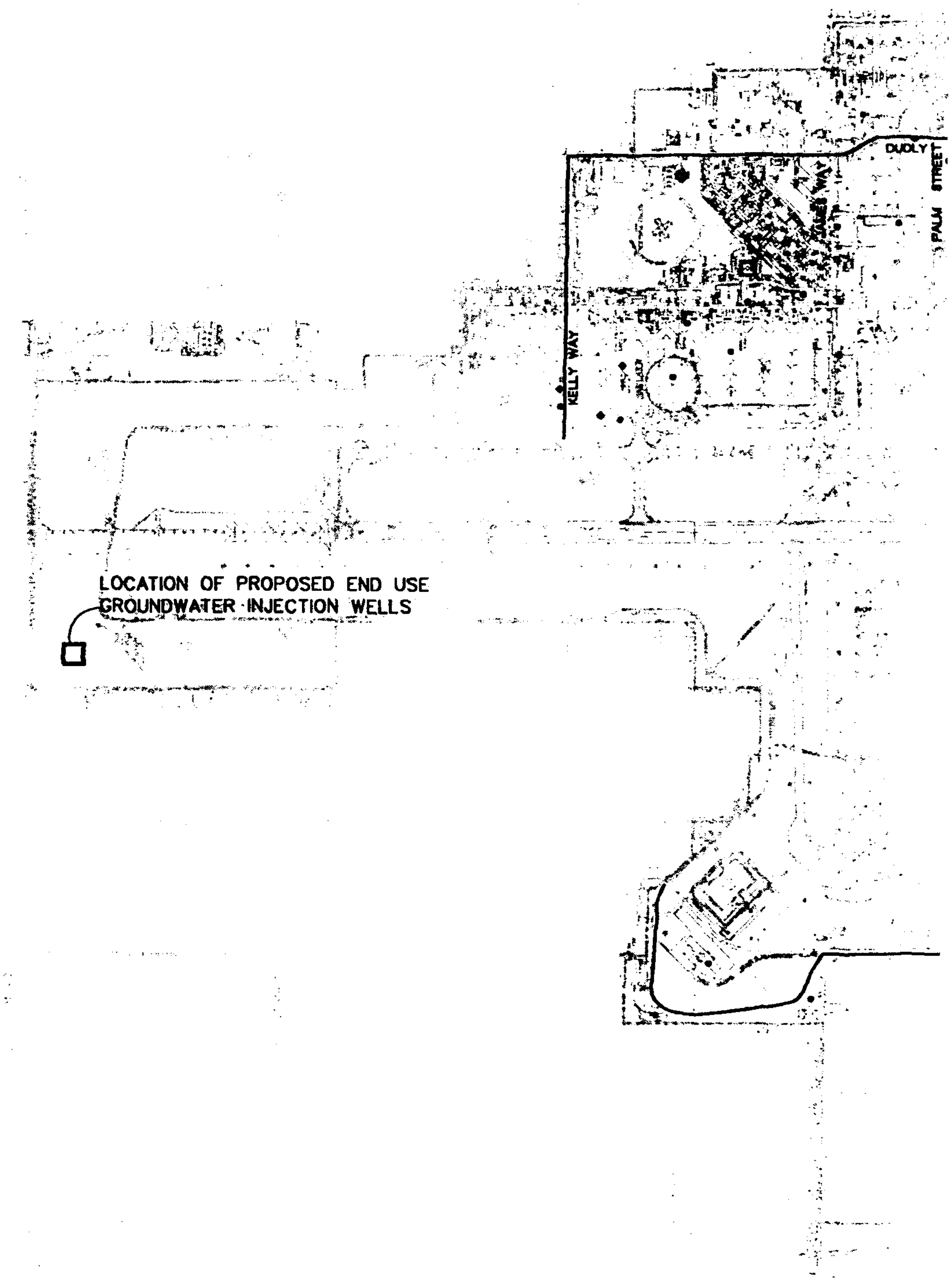


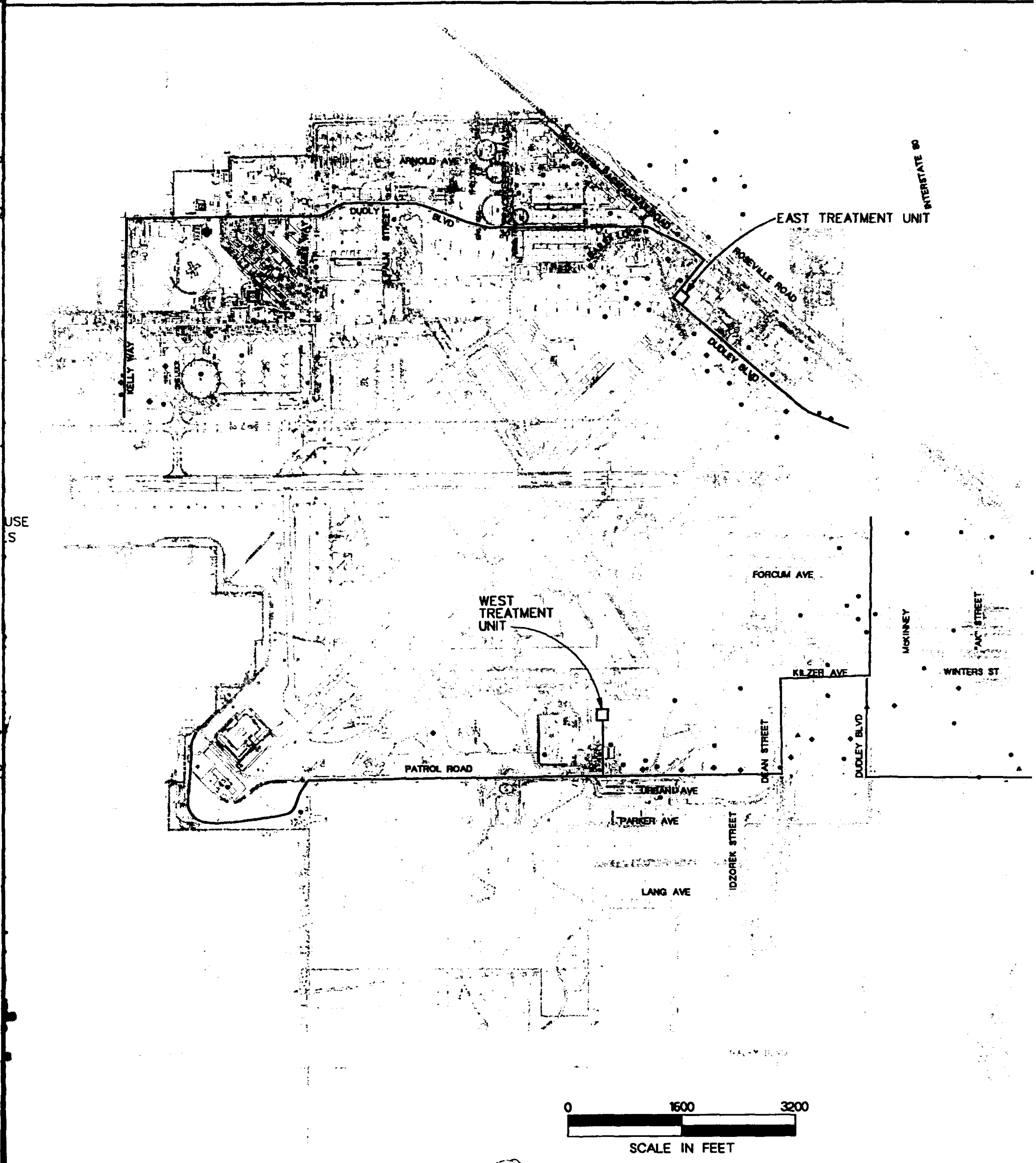
FIGURE 8-18
EXTRACTION WELL LOCATIONS
MONITORING ZONE C
MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA
CH2M HILL



LEGEND

- A-ZONE EXTRACTION WELLS
- B-ZONE EXTRACTION WELLS
- C-ZONE EXTRACTION WELLS
- CONVEYANCE PIPELINE

ROD 1454
GWOU/8-19.dgn



ARNOLD AVE
DUDLY
BLVD
KELLY WAY
INTERSTATE 80
EAST TREATMENT UNIT
ROSEVILLE ROAD
DUDLEY BLVD
USE
S
FORCUM AVE
WEST
TREATMENT
UNIT
McKINNEY
"AK" STREET
KILZER AVE
WINTERS ST
DEAN STREET
DUDLEY BLVD
PATROL ROAD
PARKER AVE
IDZOREK STREET
LANG AVE
0
1600
3200
SCALE IN FEET

2

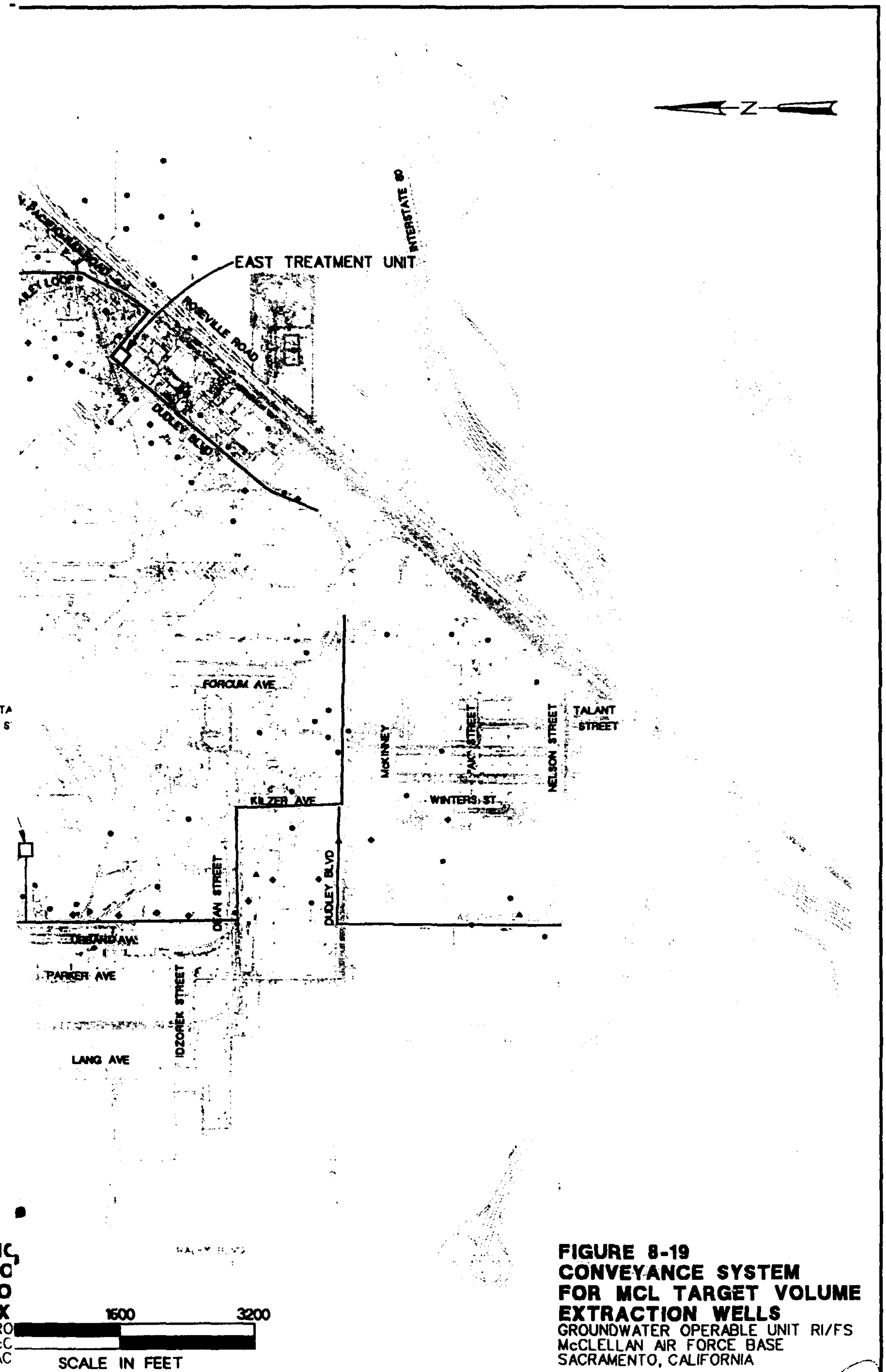
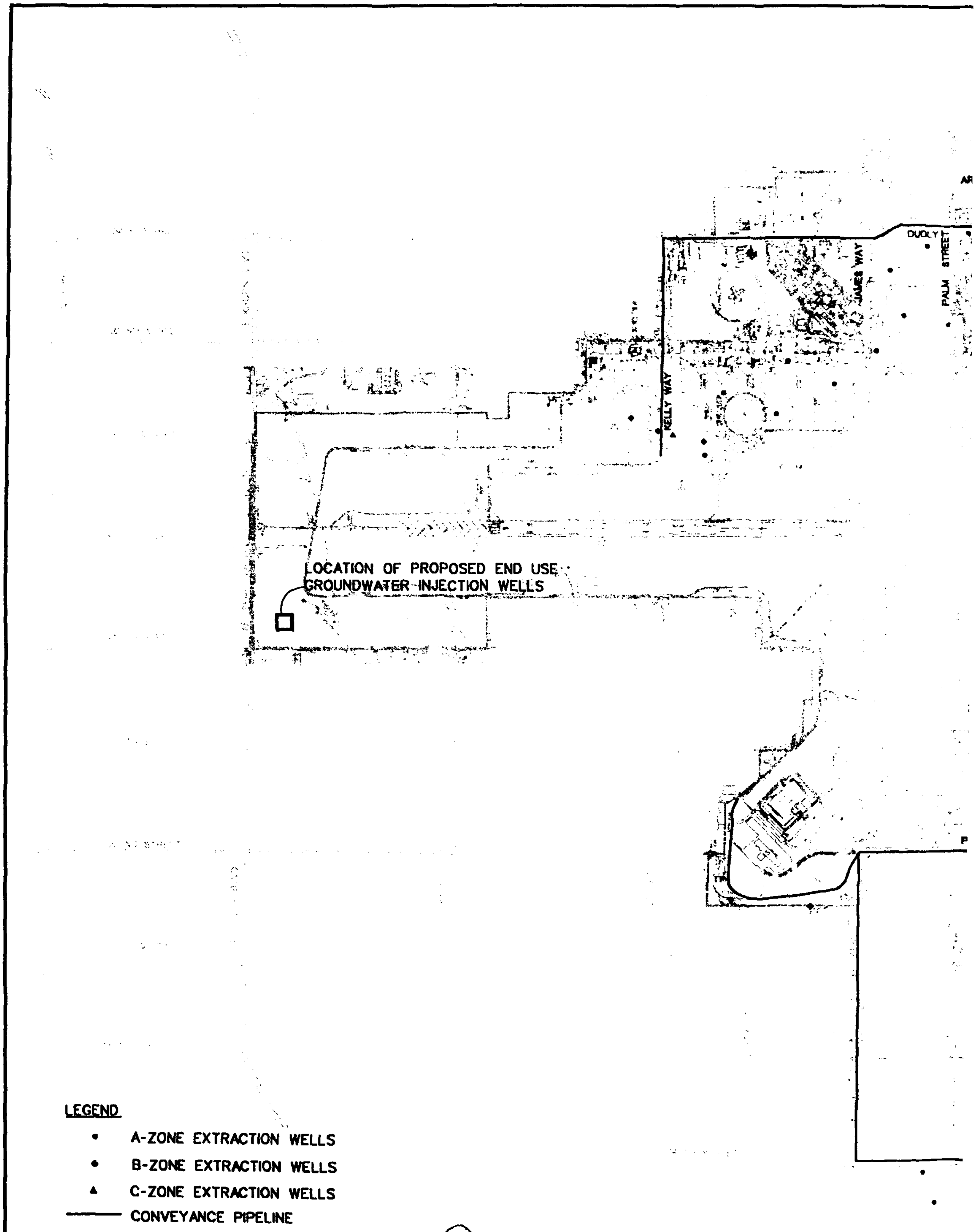


FIGURE 8-19
CONVEYANCE SYSTEM FOR MCL TARGET VOLUME EXTRACTION WELLS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



1

R001454
MAY94/8-20.dgn

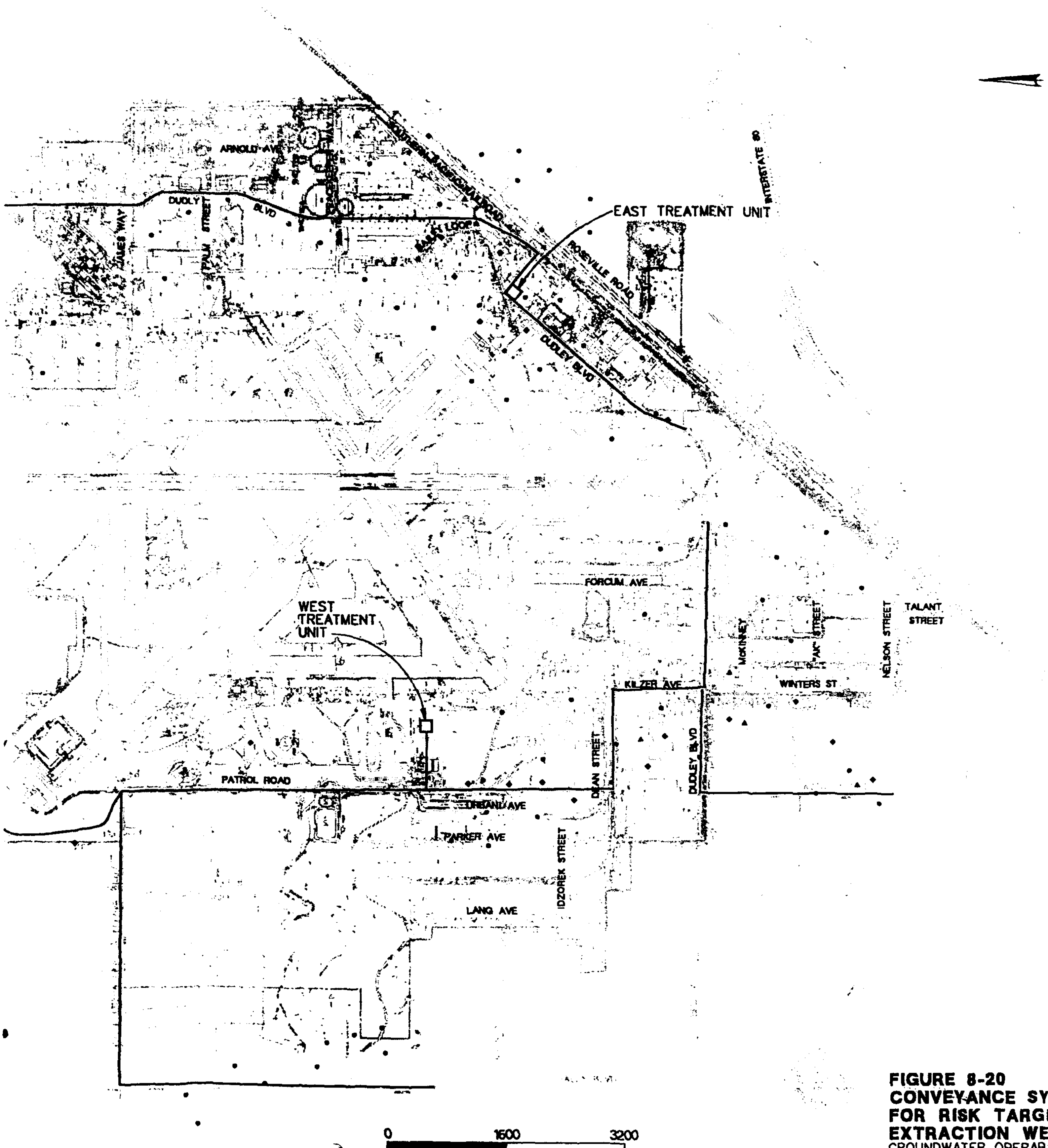


FIGURE 8-20
CONVEYANCE SYS
FOR RISK TARGE
EXTRACTION WEL
GROUNDWATER OPERAB
McCLELLAN AIR FORCE
SACRAMENTO, CALIFORN

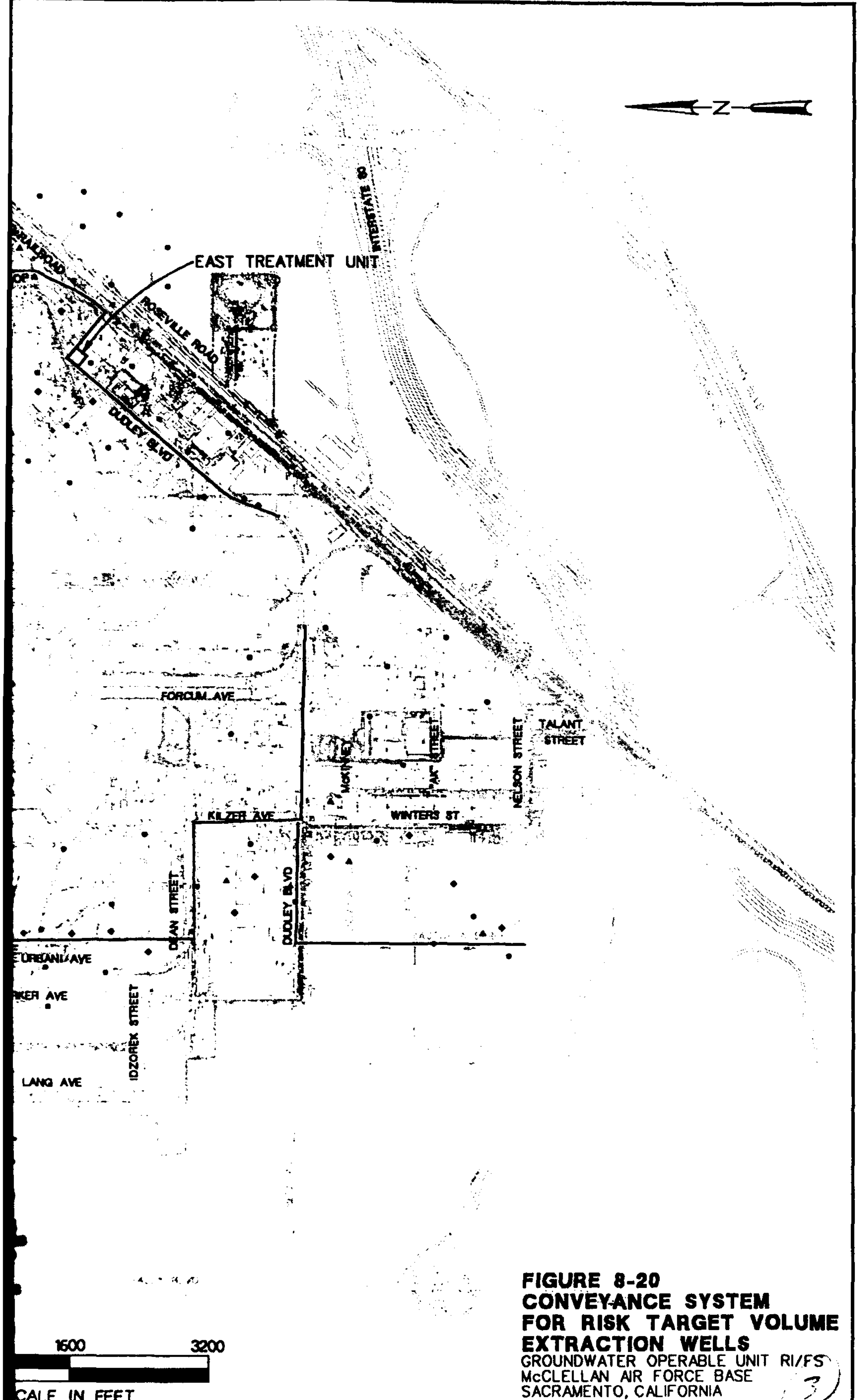
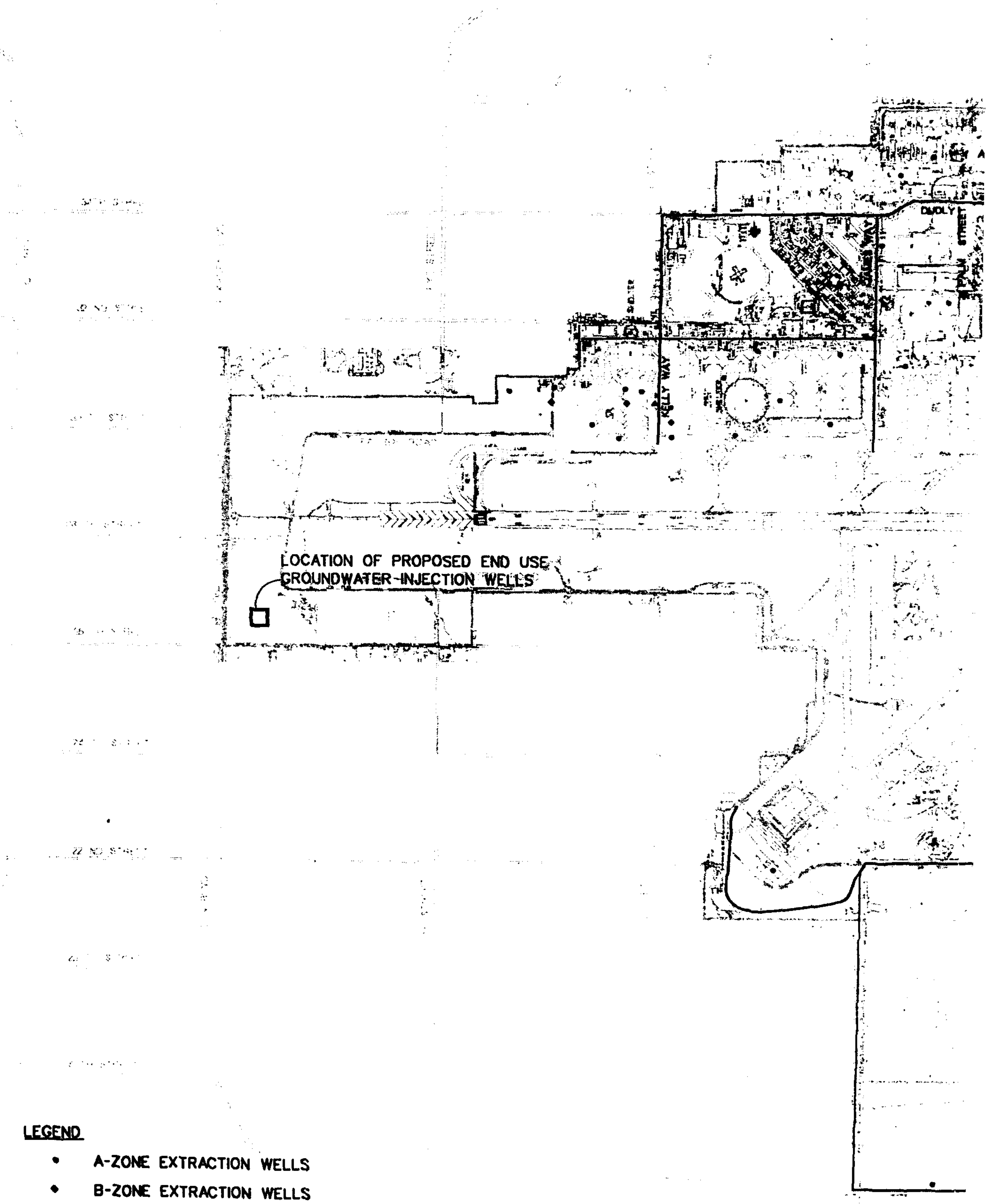


FIGURE 8-20
CONVEYANCE SYSTEM FOR RISK TARGET VOLUME EXTRACTION WELLS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



LEGEND

- A-ZONE EXTRACTION WELLS
- B-ZONE EXTRACTION WELLS
- C-ZONE EXTRACTION WELLS
- CONVEYANCE PIPELINE

(1)

RDD1454
GWOU/8-21.dgn

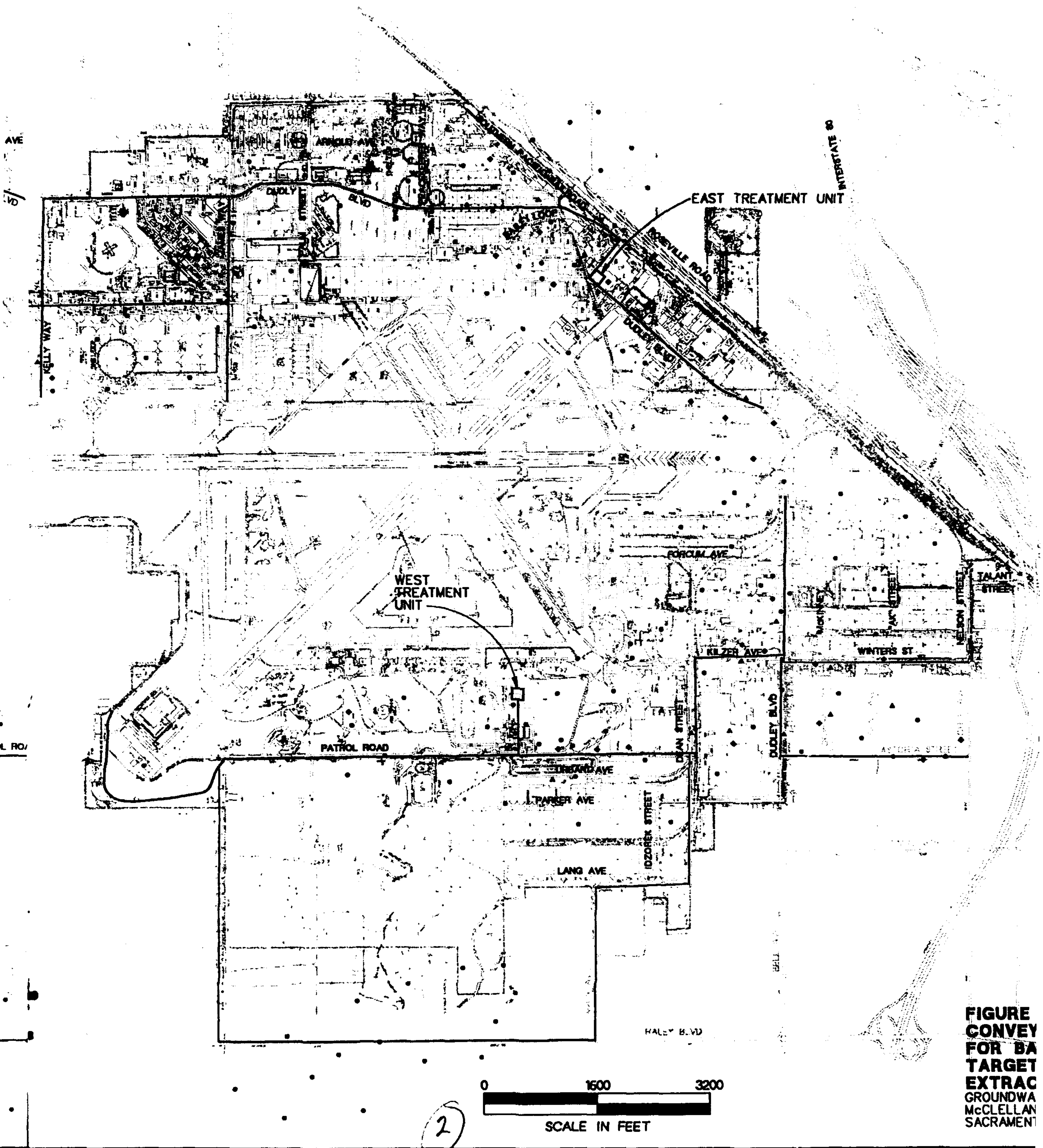


FIGURE
CONVEY
FOR BA
TARGET
EXTRAC
GROUNDWA
McCLELLAN
SACRAMENT

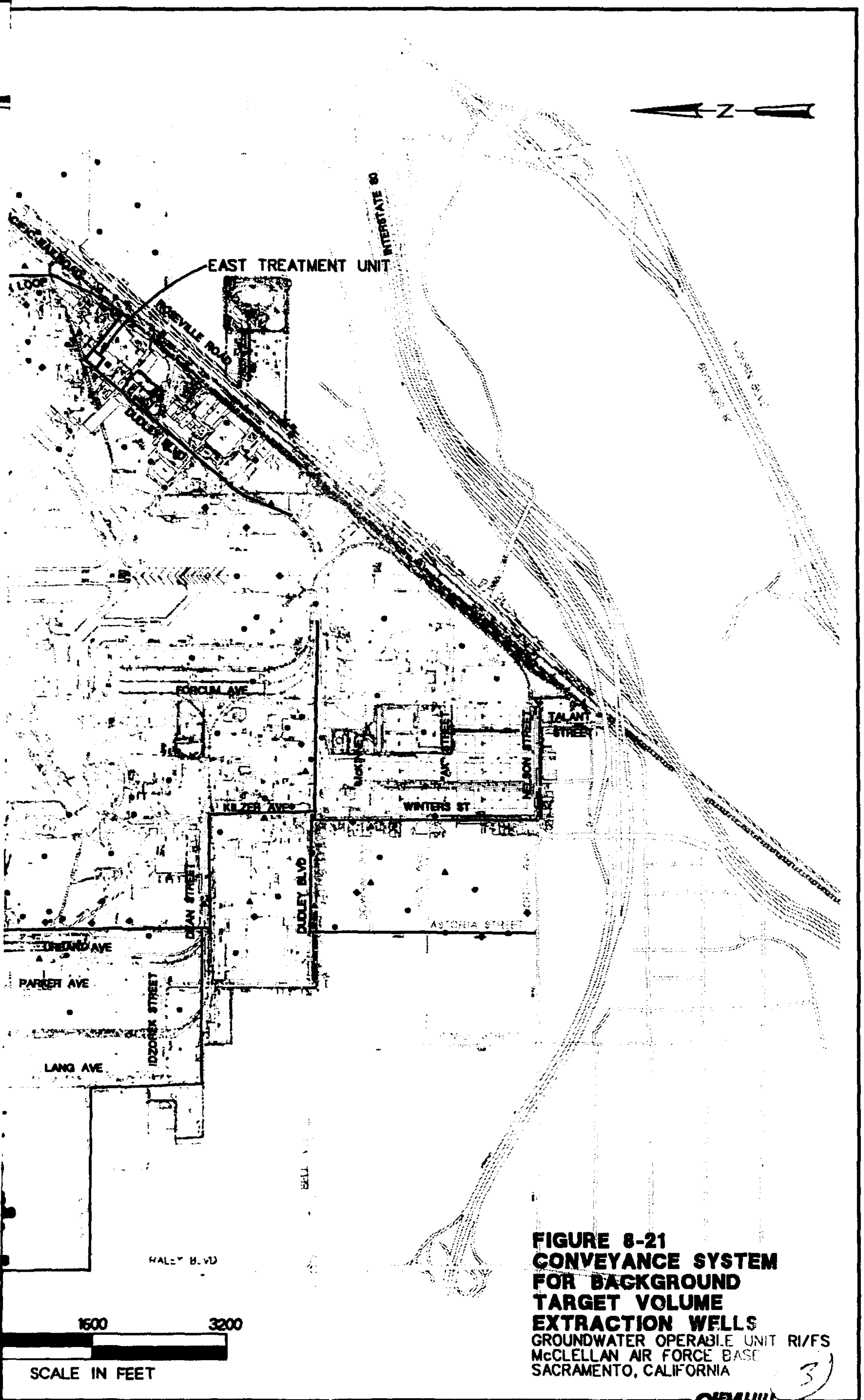


FIGURE 8-21
CONVEYANCE SYSTEM FOR BACKGROUND TARGET VOLUME EXTRACTION WELLS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Chapter 9
Groundwater Treatment Options

9.1 Introduction

Cost estimates for both grass roots new facilities and modifications to the existing GWTP are intended to be accurate to the order-of-magnitude, +50 percent and -30 percent level. Assumptions made in the development of the estimates are summarized in the following sections. The estimates produced are used for comparison among technologies during the option screening and alternative development phase of the FS.

Once the options are screened and the alternatives are assembled, budget level costs for specific treatment systems with fixed capacities are calculated and documented in Appendix R, Budget Level Cost Estimating. The results of the budget level comparison are presented in Chapter 13.

9.2 Standard Treatment Technologies

The following five groundwater treatment technologies were considered as the set of standard treatment technologies for the GW OU FS:

- Ultraviolet (UV) ozone advanced oxidation process (AOP)
- UV/hydrogen peroxide AOP
- Ozone/hydrogen peroxide AOP
- Air stripping
- Liquid-phase granular activated carbon (LGAC)

The air stripping technology releases a residual gas stream. To treat this residual gas stream, three offgas treatment technologies were considered in addition to the groundwater treatment technologies. The offgas treatment technologies are:

- Catalytic oxidation (CatOx)
- Thermal incineration
- Vapor-phase granular activated carbon (VGAC)

The groundwater and offgas treatment technologies are discussed in the following subsections. Figure 9-1 provides a schematic representation of each.

9.2.1 Water Treatment Technologies

UV/Ozone AOP

This technology treats groundwater by chemically oxidizing the VOCs present. Most reaction products are expected to be nonhazardous and to remain in the groundwater. Excess ozone gas does create a residual offgas stream, which may contain some VOCs. This offgas is decomposed in a catalytic decomposer, which removes any residual ozone and VOCs. Equipment required for this technology includes a reaction vessel or a number of series vessels, UV lamps and power sources, an ozone generation system, and the catalytic decomposer.

UV/Hydrogen Peroxide AOP

This technology treats the groundwater by chemically oxidizing the VOCs with hydrogen peroxide. The reaction is enhanced through the presence of UV light. It is similar to ozone/hydrogen peroxide AOP. The reaction takes place in a reaction vessel sized to give a specific reaction time. Equipment needed includes the reaction vessels with integral UV lamps, pumps, and hydrogen peroxide tankage and containment. Utilities needed include power to drive the UV lamps, hydrogen peroxide delivery, and storage and transfer facilities. This is a destructive process with minimal venting. Unlike ozone/hydrogen peroxide advanced oxidation, no gas stream is added to the reactor. Similarly, essentially all VOCs present are expected to be oxidized to nontoxic reaction products that pass from the system into the treated water.

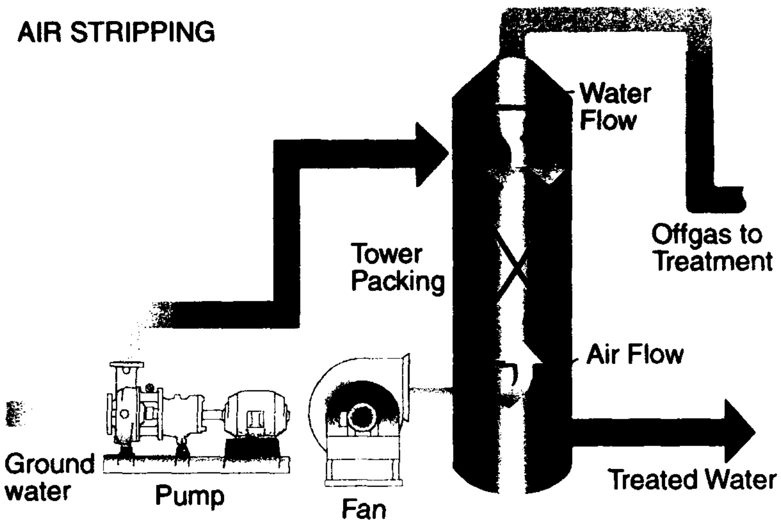
Ozone/Hydrogen Peroxide AOP

This technology treats the extracted groundwater by chemically oxidizing the VOCs to carbon dioxide, water, and dissolved hydrogen chloride. The ozone and hydrogen peroxide are contacted with the groundwater stream in a reactor vessel. Equipment required includes an ozone generator, pumps, hydrogen peroxide tankage and containment, and a large reaction vessel. Utilities required include power for generation of ozone, hydrogen peroxide delivery, and storage and transfer facilities. This process is a destructive process because the VOCs are reacted into non-toxic products that exit with the groundwater stream. Excess ozone is vented from the reactor through a catalytic vent control device, which decomposes any excess ozone to oxygen. Figure 9-1 shows a generic AOP to simplify the presentation with all three oxidizing agents used. Each of the technologies presented in these paragraphs would, in reality, only use two of the three agents shown in Figure 9-1. The catalytic ozone decomposer would only be used on processes that fed ozone to the reaction vessel.

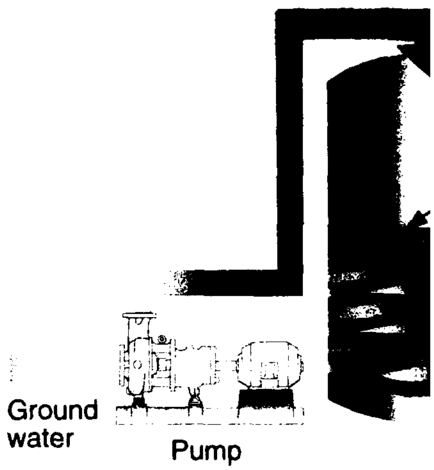
Air Stripping

Air stripping uses a tower to contact groundwater flowing downward with air flowing upward. Packing is used to break the groundwater stream into small droplets in the tower and enhance air-groundwater

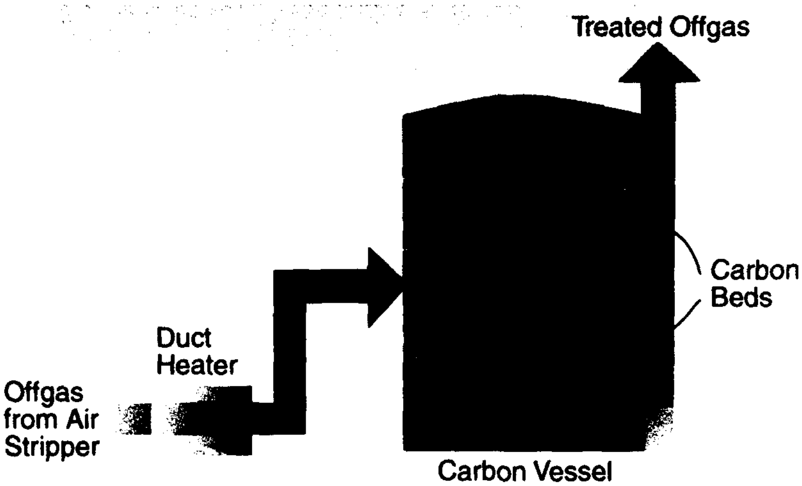
AIR STRIPPING



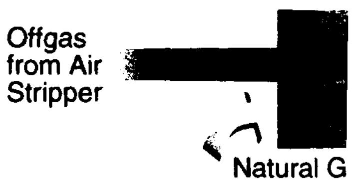
LIQUID-PHASE GRANULAR AC



VAPOR PHASE GRANULAR ACTIVATED CARBON



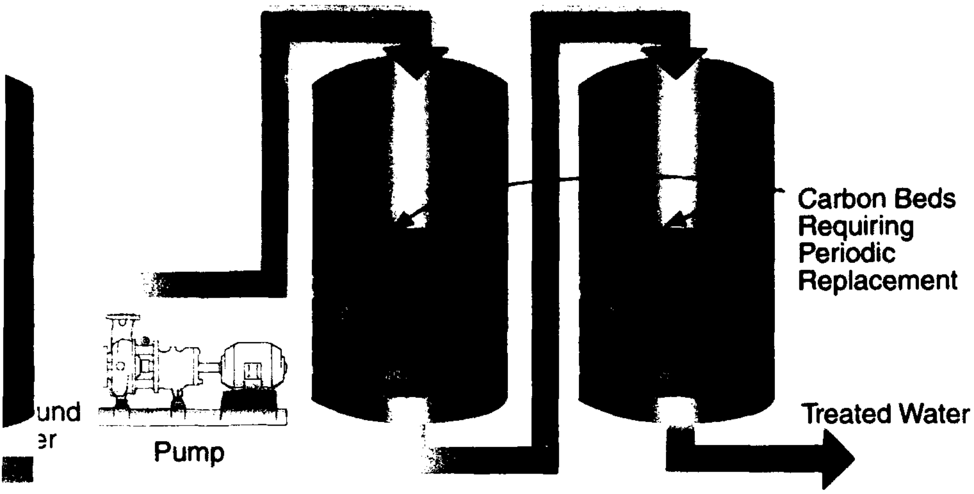
CATALYTIC OXIDATION



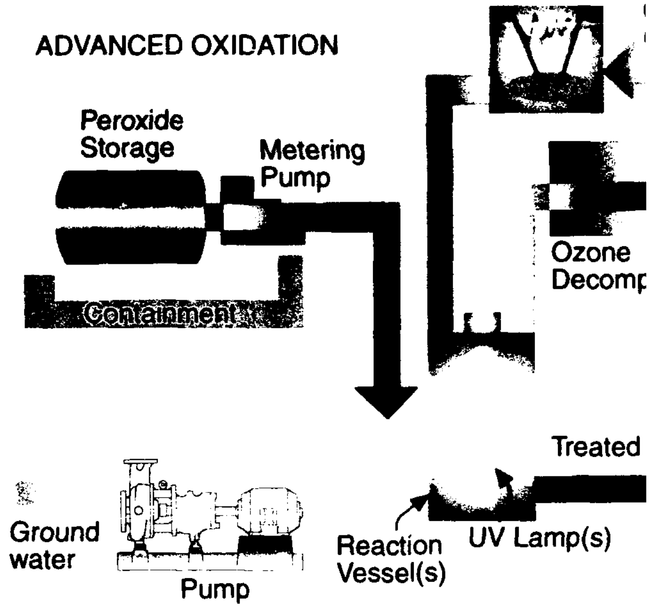
RDD1454_09

1

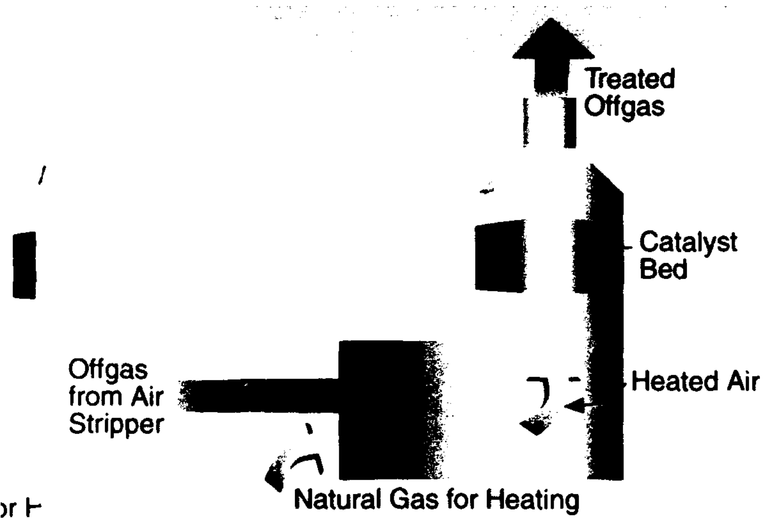
IQUID-PHASE GRANULAR ACTIVATED CARBON



ADVANCED OXIDATION



ATALYTIC OXIDATION



THERMAL INCINERATION

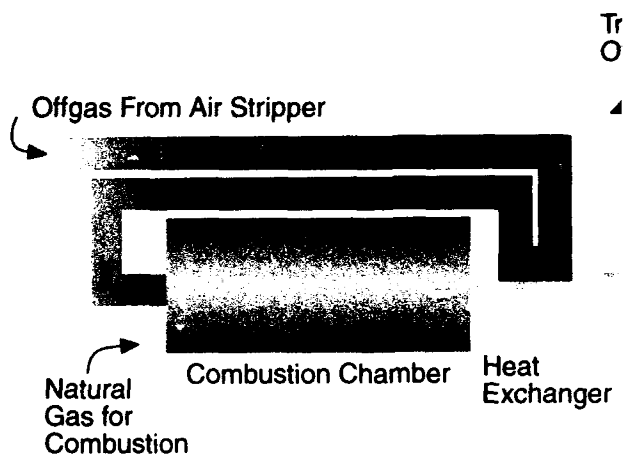


FIGURE 9-1
GROUNDWATE
TECHNOLOGIE
GROUNDWATER OPER
McCLELLAN AIR FORC
SACRAMENTO, CALIFO

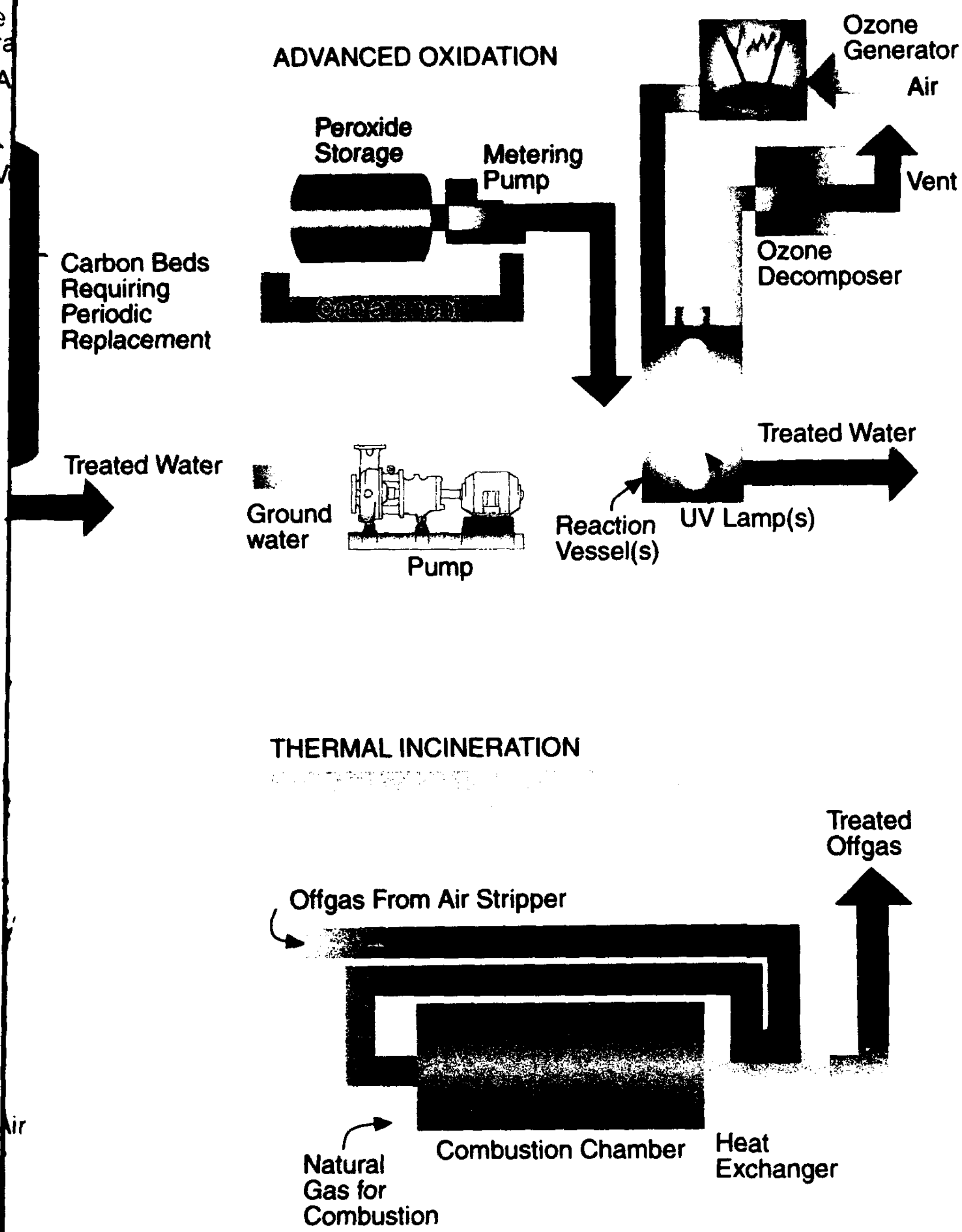


FIGURE 9-1
GROUNDWATER TREATMENT TECHNOLOGIES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

contact. As a result of this contact, VOCs transfer from the groundwater to the gas and exit the tower in an offgas stream. Air stripping equipment required includes the tower (approximately 40 feet tall) an air blower, and pumps. Utilities required include power to drive pumps and blowers to move the groundwater and air. Residuals generated include the offgas, which may require treatment before discharging to the atmosphere.

Liquid-Phase Activated Carbon

Carbon is used for groundwater treatment to remove a wide variety of chemicals, including VOCs. This technology works through adsorption of the contaminant chemical species onto the carbon. For most VOCs, a carbon bed will provide a high (greater than 95 percent) removal of compounds until it is saturated or loaded with contaminants. Typically, two carbon beds will be used in series. The first bed will be online until it is fully loaded, allowing the second bed to catch the breakthrough contaminants before final discharge. Once a bed is loaded, carbon vendors are employed to remove the spent carbon and refill the bed. The spent carbon is thermally regenerated at a vendor facility. Equipment required consists of aboveground skid-mounted tanks that contain the carbon beds and pumps. Utilities required include power to drive pumps. The only residual generated is the spent carbon, which is treated by a vendor.

9.2.2 Offgas Treatment Technologies

Catalytic Oxidation

This offgas treatment technology oxidizes VOCs in the air stripper offgas by heating the offgas and passing it through a catalyst bed, which enhances the oxidation of VOCs to nontoxic water vapor, carbon dioxide, and hydrochloric acid (HCl). HCl can be removed, if it is present in significant amounts, with a separate scrubber. Equipment required includes a packaged oxidizer system and stack, and utilities required include power for fans and natural gas to heat the air. If scrubbing is required, sodium hydroxide, storage, delivery, and distribution systems are required. Residuals include HCl, which is present in the offgas. Air stripper offgas streams usually do not contain HCl concentrations high enough to require treatment before discharge following a CatOx unit.

Thermal Incineration

This offgas treatment technology uses a heating source, typically natural gas, to heat the offgas to a point where the airborne contaminants will oxidize through combustion with atmospheric oxygen. The resulting postcombustion stream will contain carbon dioxide, carbon monoxide, HCl, and residual levels of sulfur and nitrogen oxides (SO_x and NO_x). HCl may require removal with a separate scrubber; although HCl emission rates are not anticipated to be significant for groundwater treatment operations in the GW OU FS. The equipment needed for this treatment technology includes a combustion chamber and a heat exchanger to preheat the feed gas with heated exhaust.

Vapor-Phase Granular Activated Carbon

Carbon is also used to treat air stripper offgas. The adsorption mechanism for airborne VOCs is similar to that described above. In gas-phase adsorption, water vapor in the gas stream adversely affects VOC adsorption. Duct heaters are used to raise the relative humidity of the offgas to enhance VOC adsorption and fiberglass vessels that house the carbon beds and a stack. Utilities required include power for fans to drive the offgas through the carbon bed and the heater. Residuals include the carbon, which is regenerated offsite.

9.3 Technology Screening Criteria

It was determined that certain treatment technologies could be eliminated from the evaluation process through a preliminary screening effort using three major criteria: effectiveness, robustness, and implementability. To objectively screen the technologies, each criterion was divided into measurable factors. The paragraphs below describe the measurable factors associated with the criteria.

9.3.1 Effectiveness

Three measurable factors were identified for this criterion: level of treatment for individual compounds, degree of treatment consistency, and residuals generated. Given that most standard technologies have the ability to remove compounds at a high removal efficiency and in a consistent manner, residual generation was in some cases seen to be a differentiating factor between technologies.

9.3.2 Robustness

Robustness was divided into four measurable factors: vendor availability, state of development, relative cost, and permitting issues.

9.3.3 Implementability

This criterion was divided into three measurable factors to assist in the screening process: the number of compounds treated, turndown capability, and relative response to upsets.

9.4 Technology Screening Results

9.4.1 Screening Methodology

The weighted sum method was used to screen the options. This method is a quantitative method for screening and ranking the remediation technologies. It provides a means of quantifying the important and relevant criteria to help evaluate cost-effective remediation technologies. This method involved the following four steps:

- Listing the important issues of each of the three screening criteria.
- Assigning weights which sum to 100 for each of the criteria in relation to its importance. For instance, the effectiveness of technology was considered more important than its robustness. Therefore, the former was given a weight of 40, and the latter was given a weight of 30.
- Scoring each issue using a scale of 0 to 5, against each criterion. The justification for the scoring was based on information compiled for each technology as summarized in Tables I-1 through I-8 in Appendix I.
- Multiplying the percent score of each criterion by the weight of the criterion, the option's overall weighted score was determined.

Table 9-1 summarizes the weighted score of each technology.

Table 9-1
Technology Scoring Summary

Technology	Weighted Score
UV/Ozone AOP	73
UV/Hydrogen Peroxide AOP	78
Ozone/Hydrogen Peroxide AOP	77
Air Stripping	84
LGAC	87
Catalytic Oxidation	81
Thermal Incineration	81
VGAC	82

9.4.2 Murder Board Summary

Using the weighted scoring evaluation of the eight standard treatment technologies, the feasibility of each was then determined at the Murder Board meeting in Sacramento, California. During this session, the eight available technologies were narrowed to six. UV/ozone AOP was determined to have too low of a weighted score as indicated in Table 9-1. Thermal Incineration, though having an above average score, was eliminated as a possible option because of negative public perception.

9.5 Existing Groundwater Treatment Plant

The existing GWTP treats groundwater extracted from OUs B, C, and D. It uses a combination of air stripping at elevated temperatures, secondary water treatment with LGAC, and thermal incineration and acid scrubbing of the incinerator offgas. Thermal incineration is similar to CatOx, except that higher temperatures are required to oxidize the VOCs without catalyst. Elevated temperature stripping is used to enhance the transfer of VOCs from the water to the air in the stripper. Heat is recovered from the incinerator offgas to raise the air stripper operating temperature. Utilities required include power, natural gas, and sodium hydroxide. Aqueous acid is also stored onsite and is used to control scale in the air stripper and heat exchangers. Residuals include the spent carbon and periodic carbon backwash water, which is discharged to Base treatment systems. Backwash is required to periodically clean solids from the LGAC beds. Appendix A contains an evaluation of this existing plant done in August 1993. The evaluation provides cost estimates for plant expansions to handle increasing groundwater flows.

There is also a second treatment plant in service for OU B flows that uses only LGAC.

9.5.1 Plant Configuration

The design capacity of the plant as originally installed was 1,000 gpm. Since operation began in the late 1980s, extracted flow rates were approximately 100 to 200 gpm. Since the required capacity of the plant was less than design, various equipment modifications have occurred over the years that have optimized the operation of the plant at the lower flow rate. The current GWTP flow scheme is illustrated in Figure 9-2.

9.5.2 Temporal Trends in Extracted Groundwater Concentration

Since the groundwater treatment plant began operation, extracted groundwater concentrations have significantly decreased. Figure 9-3 shows extracted groundwater concentration with time from 1987 to 1993. As is typical with many pump and treat type remediations, the groundwater concentration of VOCs starts high at approximately 50 ppm, drops rather rapidly in the first year of operation, then drops less rapidly to approach approximately 1 ppm in recent years.

9.5.3 Evaluation of Groundwater Treatment Plant with Screening Criteria

Evaluating the existing GWTP with the criteria of effectiveness, robustness, and implementability provides justification for continuing operation of the GWTP. The GWTP is effective in that it has a demonstrated performance history in treating extracted groundwater to the NPDES discharge requirements. Implementability is high since the facility exists, and its cost deserves consideration. At the time this document was

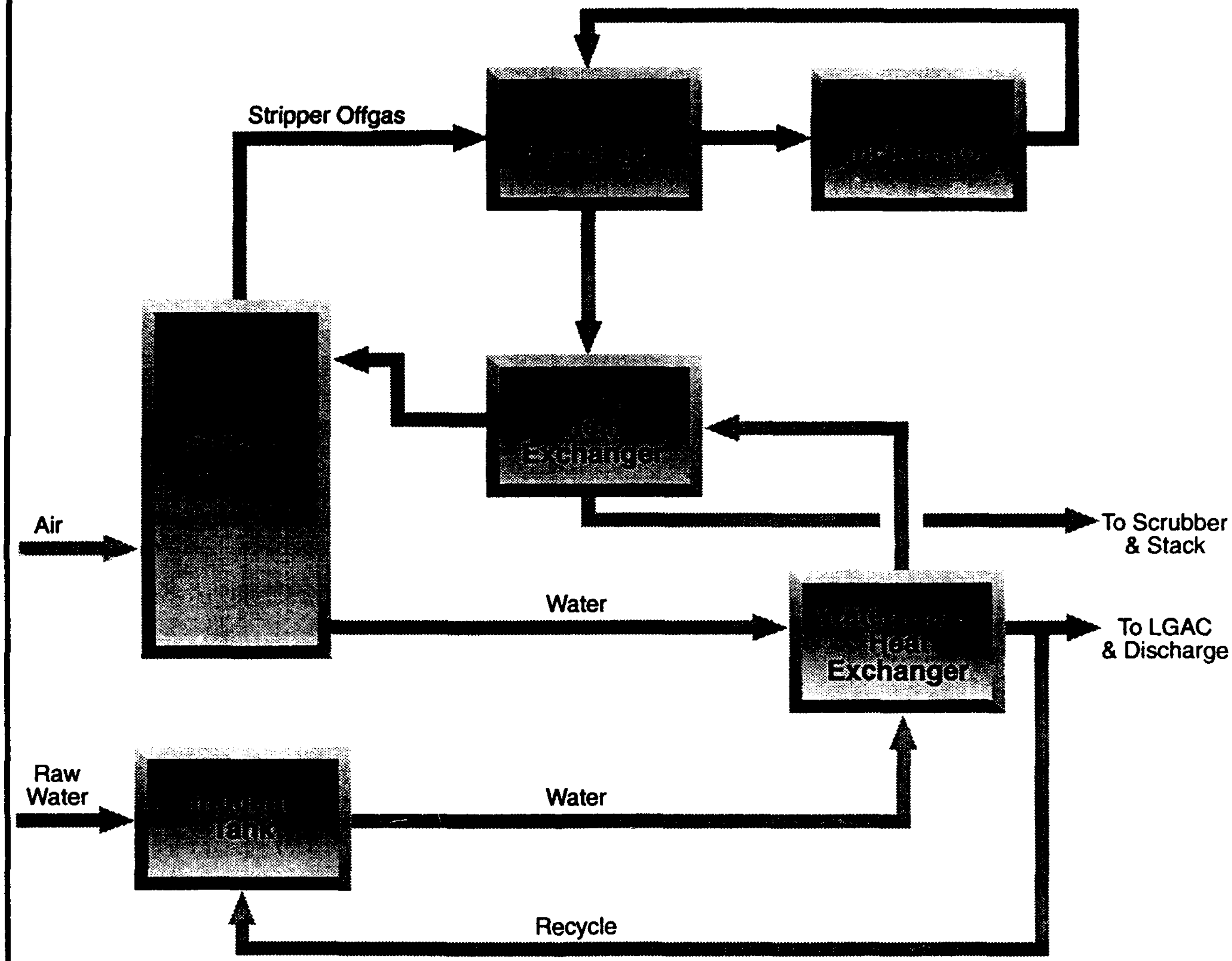
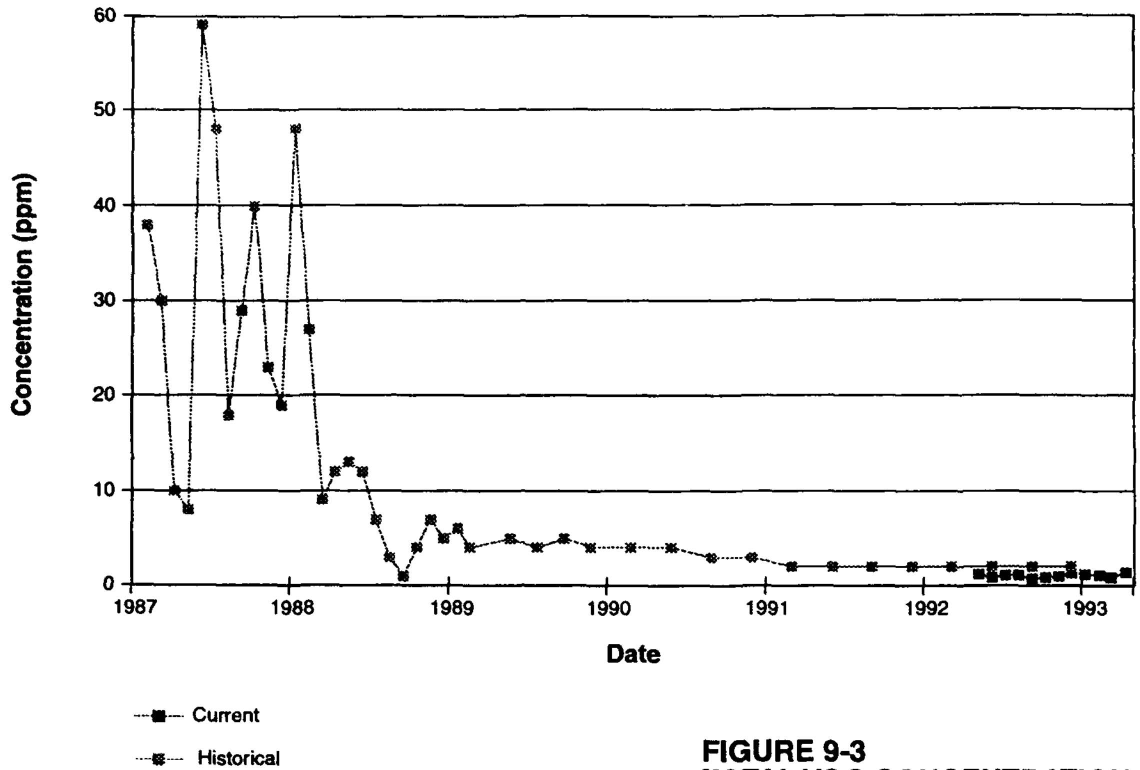


FIGURE 9-2
EXISTING GROUNDWATER TREATMENT PLANT FLOW DIAGRAM
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_10

CH2M HILL



RDD1454_185

FIGURE 9-3
TOTAL VOC CONCENTRATION
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

written, the GWTP annual O&M costs were approximately $1,000,000. Various future groundwater flow scenarios have been examined for altering the operation of the plant. Scenarios for the current throughput rate and higher rates that may require treatment in the future have been developed and are contained in Appendix A. Various options exist for decreasing the current operating cost of the plant, the most predominant opportunity being to modify the staffing level. These options and the capital cost avoided justify consideration of the existing GWTP as a treatment option along with the screened technologies resulting from the Murder Board.

9.5.4 Future Expansion of the GWTP and Associated Costs

Appendix A contains a detailed discussion of future flow scenarios and capital and O&M costs associated with plant expansion and operation. The initial design of the treatment plant was based on 1,000 gpm. According to influent concentration estimates of 1,2-DCA in future flow scenarios from OUs B,C, and D, it appears that efficient plant operation can be maintained up to approximately 700 gpm with little or no capital expenditure. Beyond 700 gpm, water temperatures and air flow rates in the stripper are estimated to vary to a point that 1,2-DCA begins to pass through in significant quantities. These increasing quantities then result in higher carbon usage and cause higher O&M costs. This contributes to carbon replacement costs. Capital improvements such as additional heat exchangers and carbon vessels are required at greater flows, resulting in capital cost for plant expansion. Order-of-magnitude cost estimates for the flow scenarios evaluated are shown in Table 9-2.

Table 9-2
Capital and O&M Costs Summary for Existing GWTP

Water Flow (gpm)	Capital Cost ($)	O&M Cost ($/yr)
330	0	716,000
1,000	198,000	1,138,000
2,400	2,187,000	1,967,000

These costs are estimated assuming that operational and maintenance labor costs are decreased by 15 percent in future operations, equating to approximately a new O&M labor cost of $470,000 per year. Carbon costs make up the majority of the remaining O&M costs, with power and incidentals making up a minor fraction. Capital costs are a result of one additional carbon vessel to handle the increased hydraulic throughput at 1,000 gpm. Additional carbon units, pumps, piping, stripper modifications, and heat exchangers are components that comprise the capital cost required to treat 2,400 gpm. This flow rate was chosen as the maximum hydraulic rate that could be treated in the existing tower.

9.6 Treatment Option Assembly and Cost Estimation

As a result of the Murder Board and technology screening phase of the feasibility study, a screened list of technologies was created. Because these technologies are all considered standard, the main differentiating criterion between the options would be cost. The technologies can be equally effective and equally robust and implementable if enough money is spent to make them work. On this basis, assembled options are compared with one another mainly on capital and O&M costs.

The paragraphs below describe how technologies were assembled into options. Capital and O&M cost estimation methods for each technology are discussed. The cost estimates for various technologies were combined into option cost estimates. These estimates were then adjusted to provide estimates of costs over a range of flow rates within each feasible target volume where they could be applied. This section describes the logic that grouped technologies into options.

9.6.1 Assembled Options

Some of the groundwater treatment technologies were combined with the offgas treatment technologies to create assembled options. The following are the most feasible treatment technologies and options:

- UV/Hydrogen Peroxide AOP
- Ozone/Hydrogen Peroxide AOP
- LGAC
- Air Stripping with CatOx Offgas Control
- Air Stripping with VGAC Offgas Control
- Air Stripping/CatOx with Ozone/Hydrogen Peroxide AOP Pretreatment
- Air Stripping/VGAC with Ozone/Hydrogen Peroxide AOP Pretreatment
- Air Stripping/CatOx with UV/Hydrogen Peroxide AOP Pretreatment
- Air Stripping/VGAC with UV/Hydrogen Peroxide AOP Pretreatment
- Air Stripping/CatOx with LGAC Post-Treatment
- Air Stripping/VGAC with LGAC Post-Treatment
- Existing GWTP (modified if necessary)

9.6.2 Design Basis

Five sets of estimates of flow and concentrations from the OUs at McClellan AFB were compiled to form the basis for comparing assembled options. A treatment performance requirement of removing acetone, methylethylketone, and methylisobutylketone to less than 1 mg/l and all other VOCs to less than 0.5 μg/l was used in developing the options. This is equivalent to the treatment requirements of the exiting GWTP and is considered a reasonable basis for comparing new options with the existing plant and with each other.

Table 9-3 shows the five flow and concentration sets used for evaluation. The five sets were chosen for the following reasons:

- Flows between hot spots and containment target volumes may be segregated. Developing cost of treatment for the individual and combined extracted flows will provide a basis for choosing if segregation or mixing is preferred.
- Flows will be split between the east and west sides of the Base into two treatment facilities, leading to the east versus west flow segregation in the scenarios.
- The concentrations of contaminants were not appreciably different between the four containment target zones;

therefore, one composite concentration set over a wide range of flows was evaluated.

Appendix M is a presentation of the basis for the influent concentration estimates.

9.6.3 UV/Hydrogen Peroxide AOP

UV/hydrogen peroxide oxidation capital costs were estimated based on vendor-provided capital cost estimates for the flow and concentration cases documented in Table 9-3. Installation costs of vendor-provided quotes were included as an allowance of 50 percent of the capital cost.

O&M costs were estimated based on vendor-provided estimates of power and hydrogen peroxide dosage requirements. Operator hours, analytical costs, and other allowances are based on project experience.

Table 9-3
Condensed Flow and Concentration Scenarios

	Design Conditions						
		Concentrations (μg/l)					
Flow	Flow Rate (gpm)	TCE	1,2-DCA	1,1-DCA	1,1,1-TCA	Acetone	MeCl
East Hot Spot	90	4,560	7	2	850	500	3
West Hot Spot	0 to 180	3,700	0.0	7	180	150	230
Containment Target Volumes including: • East Background • West Background • East MCLs • West MCLs	0 to 2,200	32	12	1	7	5	0
Combined East Side Hot Spot and Containment	390	1,070	11	1	195	120	0.7
Combined West Side Hot Spot and Containment	1,190	296	11	2	20	16	19

Note:
TCE = Trichloroethene
DCA = Dichloroethane
TCA = Trichloroethane
MeCl = Methylene chloride
MCLs = Maximum Contaminant Levels

9.6.4 Ozone/Hydrogen Peroxide AOP

Preliminary ozone/hydrogen peroxide oxidation equipment sizing was performed using in-house CH2M HILL worksheets that were based on known reaction rates of the contaminants of concern for various oxidant feed ratios. Two ozone/hydrogen peroxide oxidation designs were chosen: one which was smaller with less detention and reaction time to remove the pollutants to higher concentration levels than required for final discharge, and another design that treats the contaminants down to the 0.5 μg/l concentration required for discharge. The smaller design was combined with air stripping to achieve treatment to the required levels.

Capital costs for the ozone/hydrogen peroxide oxidation system were developed using spreadsheet algorithms to calculate installed cost of the system based on factors provided by literature and in-house CH2M HILL resources.

O&M costs were also estimated using spreadsheet algorithms based on factors for ozone/hydrogen peroxide systems provided by literature and in-house CH2M HILL resources.

9.6.5 Air Stripping

Preliminary air stripper sizing was performed using STRIPR, an in-house CH2M HILL program for the various flow and concentration scenarios. Two air stripper designs were chosen, one which used a low air flow to remove TCE, and one with a higher air flow to remove the 1,2-DCA to required discharge levels. Tower height was limited to 40 feet for aesthetic and air traffic reasons. A single tower was used for both the high and low air flow sizing within each scenario. For assembly into treatment options, the low air flow stripper size was combined with other technologies (AOP and LGAC) to achieve treatment to required levels, while the high air flow stripper size was designed to approximately meet the required treatment levels without additional water treatment. All stripper cases were combined with either CatOx or VGAC for offgas control.

Capital costs for air strippers were developed using spreadsheet algorithms that were calibrated based on vendor quotes. Installation costs were included as an allowance of 50 percent of the capital cost.

O&M costs were estimated by assigning operator labor hours, power requirements, and allowances for other items. McClellan AFB labor and analytical costs were assigned based on data from the existing ground-water treatment plant, assuming that these costs would remain constant for a similar technology.

9.6.6 Liquid-Phase Granular Activated Carbon

Preliminary sizing for two LGAC applications is provided: LGAC as a stand alone treatment system and LGAC as a post-treatment technology combined with air stripping.

Preliminary equipment sizing and costs for LGAC systems is based on vendor information for required empty bed contact times and skid-mounted system costs. A 20 percent installation factor is assumed to calculate installed system costs.

O&M costs are calculated based on Freundlich isotherm data for carbon usage and estimates of labor, analytical, and other O&M costs.

9.6.7 Catalytic Oxidation

Catalytic oxidation capital costs are estimated based on vendor-provided capital cost estimates for specific flow cases, corrected to the case-specific air flow using a correction factor.

O&M costs for operator labor are estimated based on project experience. Utility requirements are calculated for the specific cases using general vendor-supplied information.

9.6.8 Vapor-Phase Granular Activated Carbon

VGAC systems were sized assuming a superficial air velocity of 50 fpm or less through the carbon beds. On this basis, small single-bed, adsorbers were assumed up to 7 feet in diameter. For air flows requiring larger vessels, dual-bed vessels were assumed. The largest air flow was estimated to require three 12-foot-diameter dual-bed carbon vessels. The smallest air flow was estimated to require one single-bed 3-foot-diameter vessel. Capital costs of the VGAC vessels were estimated using algorithms to calculate fabricated fiberglass reinforced plastic (FRP) vessel cost for the given diameter and height and vendor information on carbon costs.

O&M costs include estimates of operating labor required and carbon usage based on the offgas flow and concentration for each case. Computer spreadsheets using Freundlich isotherms were used to estimate carbon bed life. Carbon replacement costs are based on offsite regeneration and are included in the O&M costs for VGAC.

9.6.9 Chlorination for Water Disinfection

For alternatives which use sale to water purveyors as an end use, disinfection of the treated groundwater is required before introduction into the water district's distribution network. Treatment facilities which use sodium hypochlorite disinfectant have been included in budget-level cost estimates for screened alternatives. These costs have not been included in the screening effort described in this chapter.

9.7 Treatment Option Evaluation

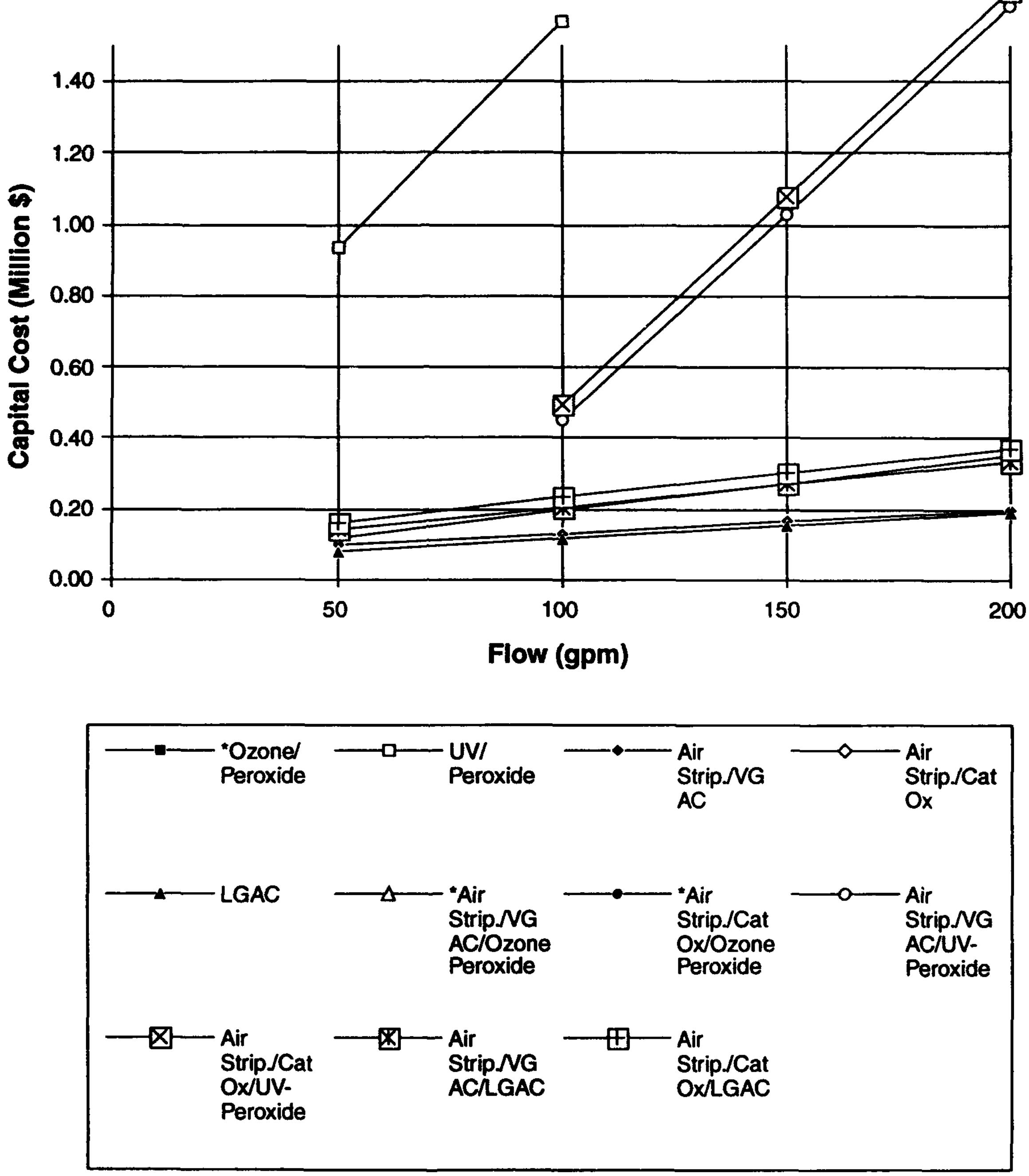
9.7.1 Cost Estimation Method

For each option, the five cost and flow scenarios are applied, and a plot of costs versus flow rate is developed. The cost analysis assumes a fixed concentration and a variable flow rate, as presented in Table 9-3. Plots are presented for capital costs and O&M costs. Estimates are based on prior efforts and vendor quotations. Under each of the scenarios, estimates for treatment systems at either one or two flow rates have been developed. Linear interpolation and some extrapolation is used to estimate treatment costs where two flow cases were evaluated. For scenarios with one flow case evaluation, similar slopes of cost versus flow from other curves are assigned.

9.7.2 Cost Plots

Figures 9-4 through 9-13 provide capital and O&M costs as a function of flow rate for five target volume cases. Linear interpolation with two points was used in developing the cost curves for the west hot spot and the containment target volumes, while the cost magnitude of the remaining curves was estimated using a single point coupled with a slope from one of the two target volumes mentioned. Because of similar flow rate ranges, the west hot spot slope of cost versus flow was used for the east hot spot, and the containment slope was used in the combined flow target volume plots.

Potential inaccuracies can result as the curves are extrapolated to the higher flow rates and as they approach zero flow. This inaccuracy may be more pronounced in lower flows on the plots developed using one cost estimate point (east hot spot, west combined, and east combined). Points have been removed from plots where linear interpolation at low flow rates produced negative or unreasonable costs.

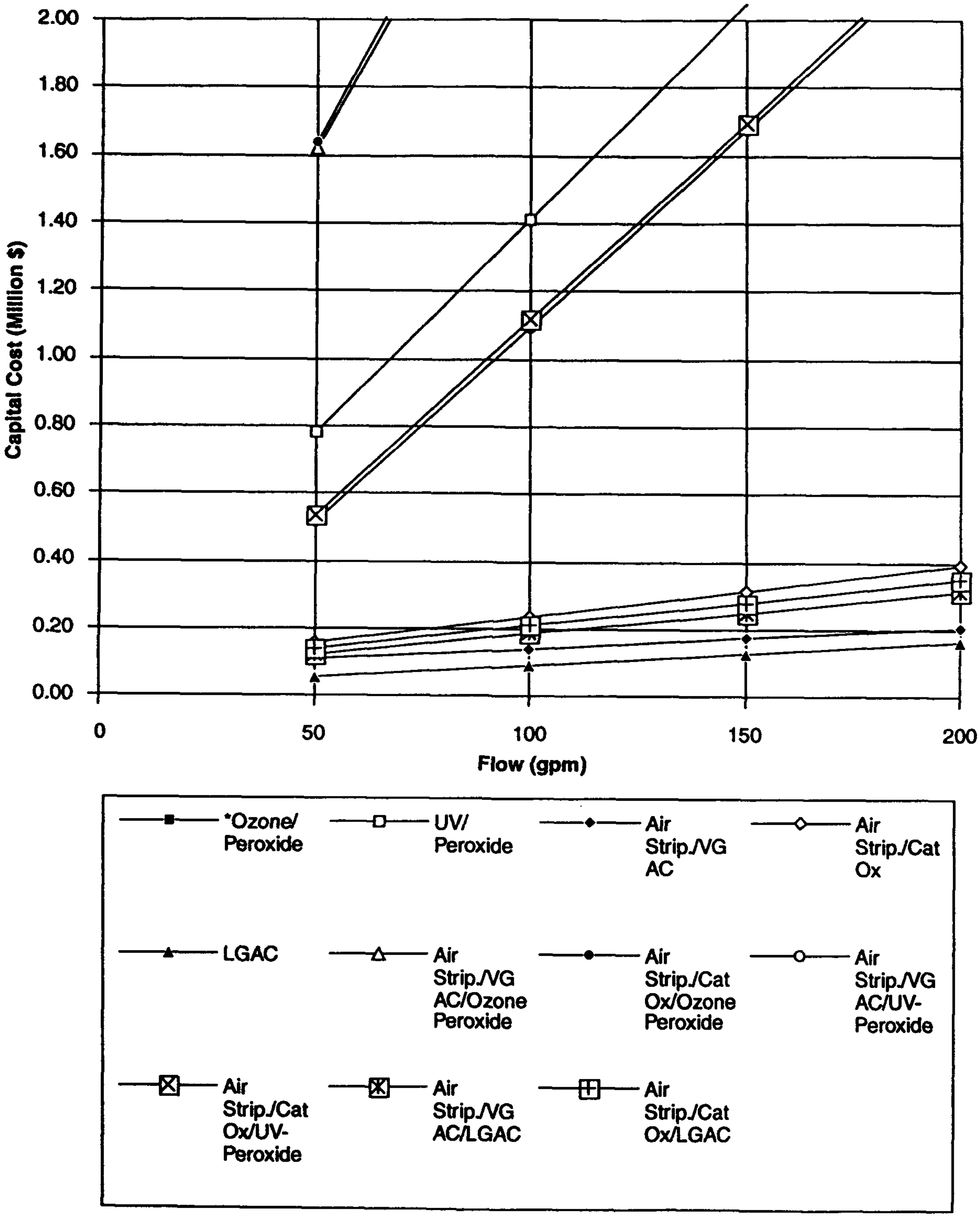


* Cost for this option(s) are greater than the scale of this plot.

RDD1454_30

FIGURE 9-4
EAST HOT SPOT
CAPITAL COSTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



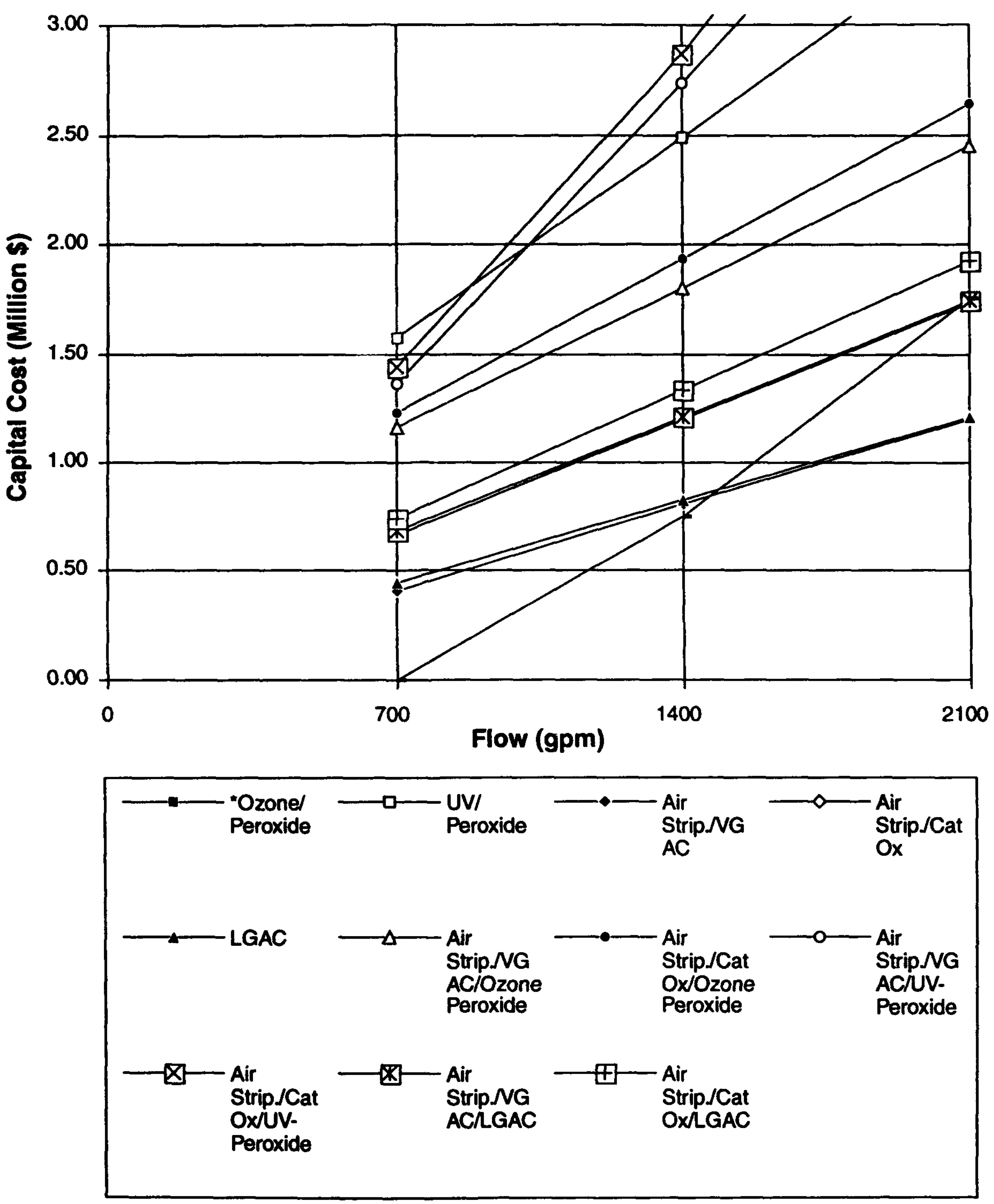
* Cost for this option(s) are greater than the scale of this plot

FIGURE 9-5
WEST HOT SPOT
CAPITAL COSTS

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_31

CH2M HILL

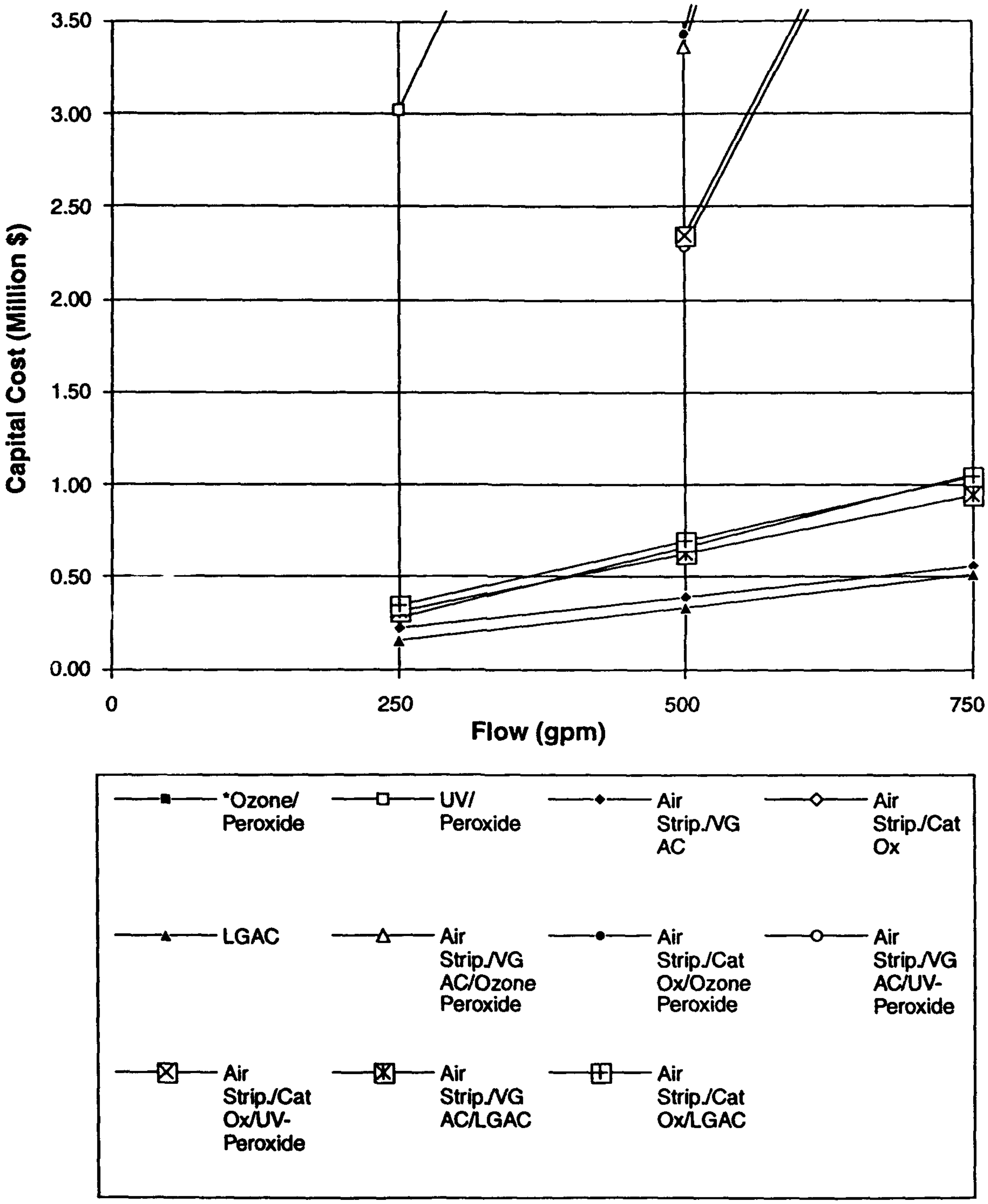


* Cost for this option(s) are greater than the scale of this plot

FIGURE 9-6
CONTAINMENT CAPITAL COSTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_32

CH2M HILL

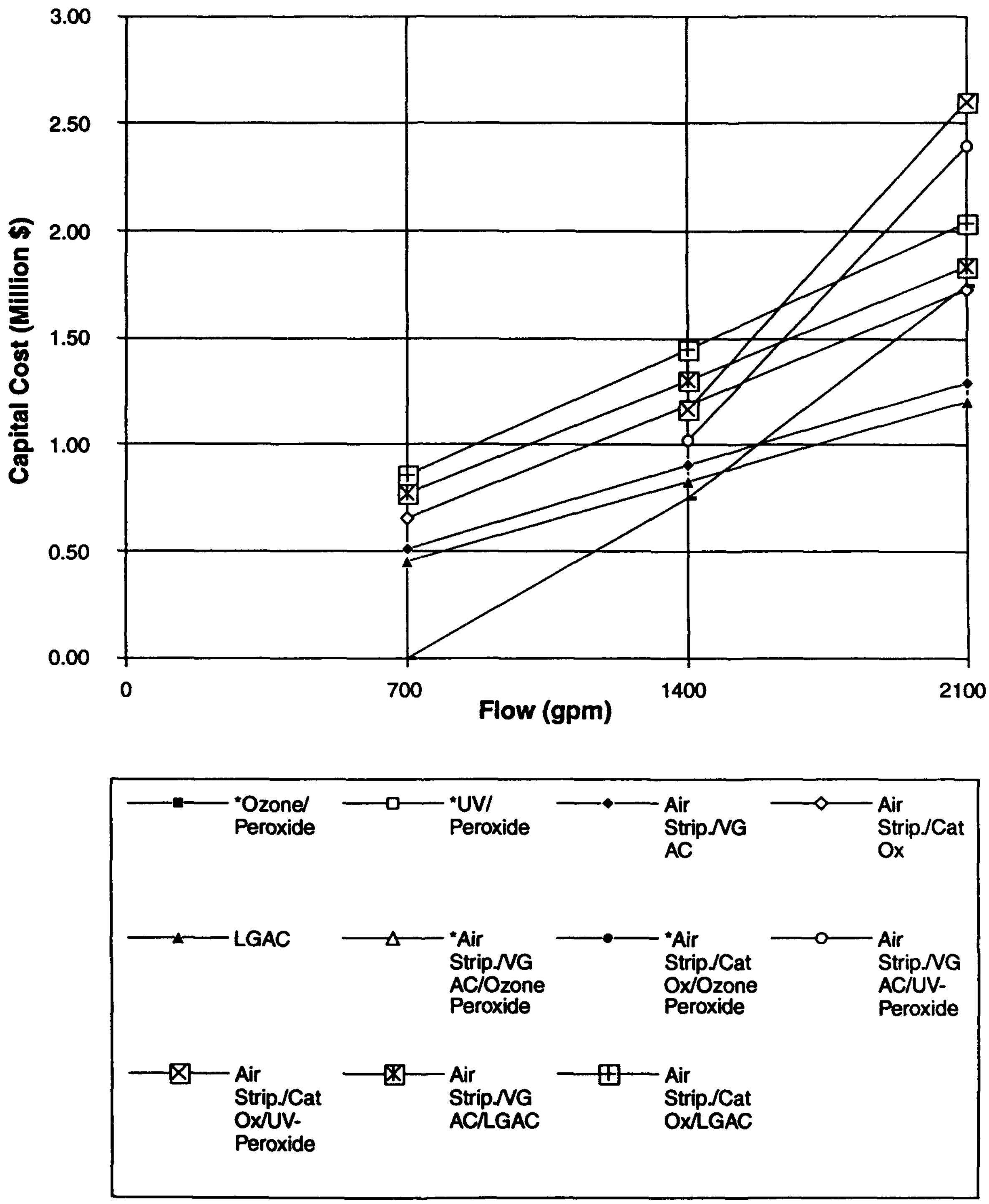


* Cost for this option(s) are greater than the scale of this plot

FIGURE 9-7
EAST COMBINED CAPITAL COSTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_34

CH2M HILL



* Cost for this option(s) are greater than the scale of this plot

FIGURE 9-8
WEST COMBINED CAPITAL COSTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_35

CH2M HILL

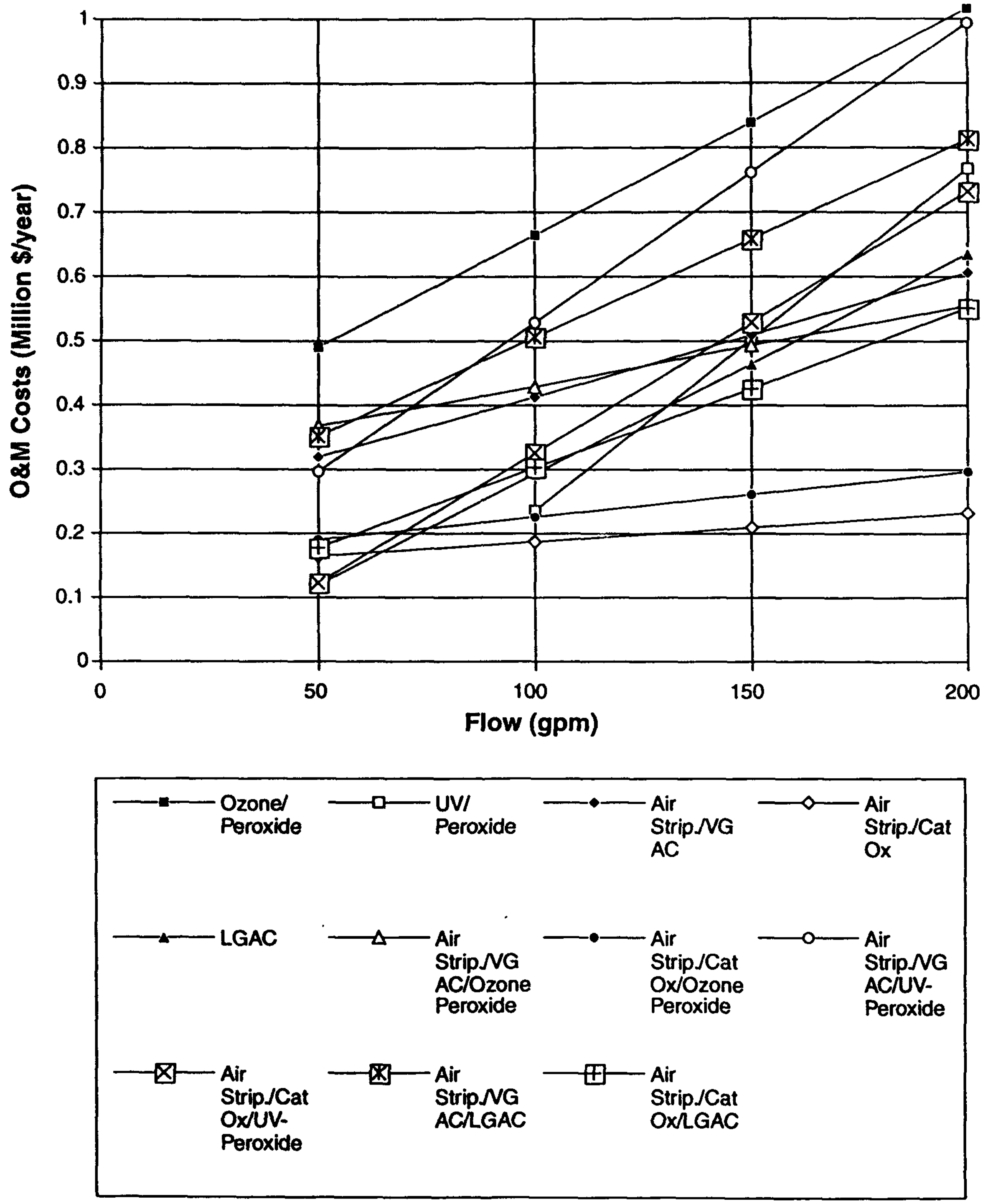


FIGURE 9-9
EAST HOT SPOT
O&M COSTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_36

CH2M HILL

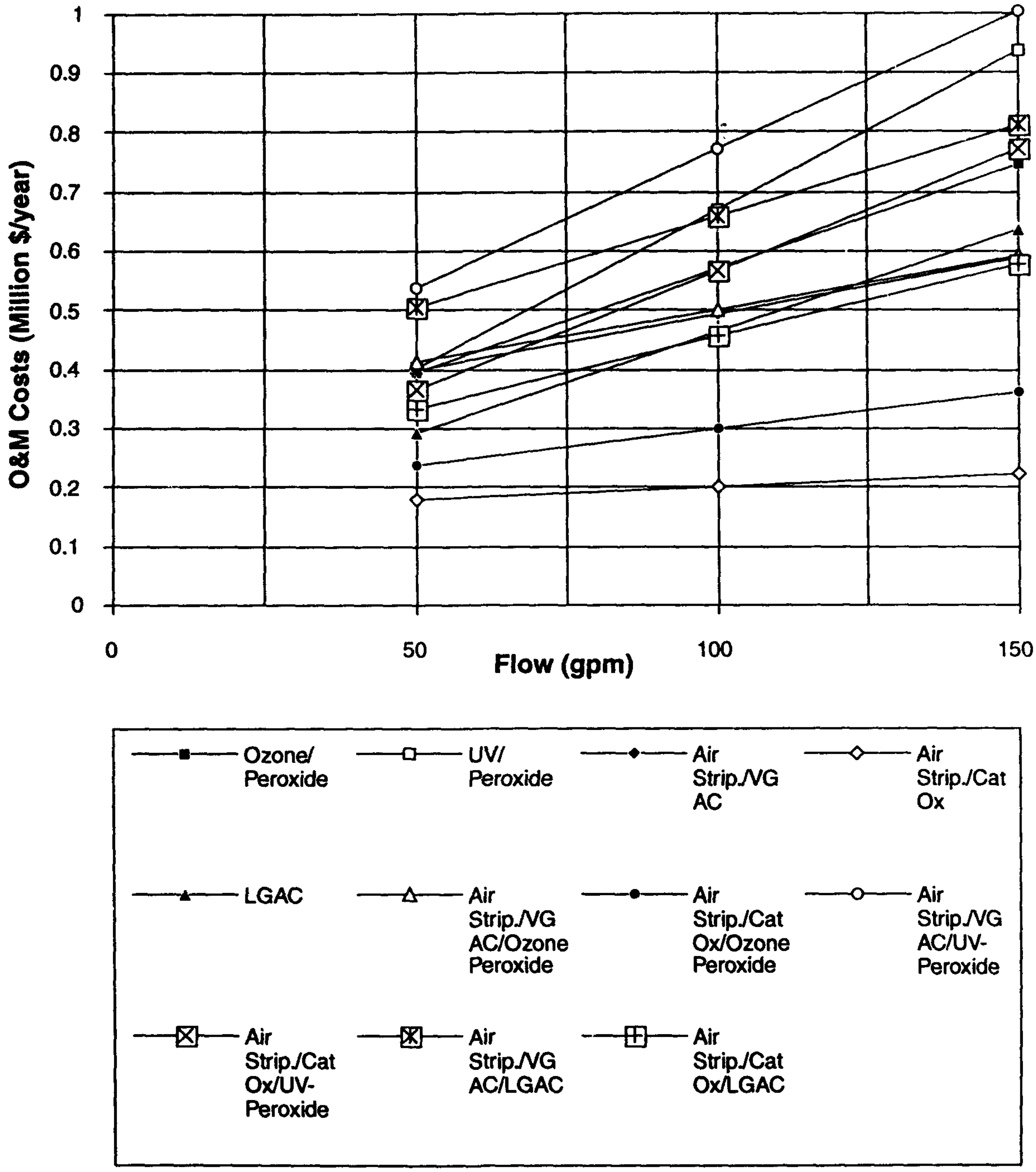


FIGURE 9-10
WEST HOT SPOT
O&M COSTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_37

CH2M HILL

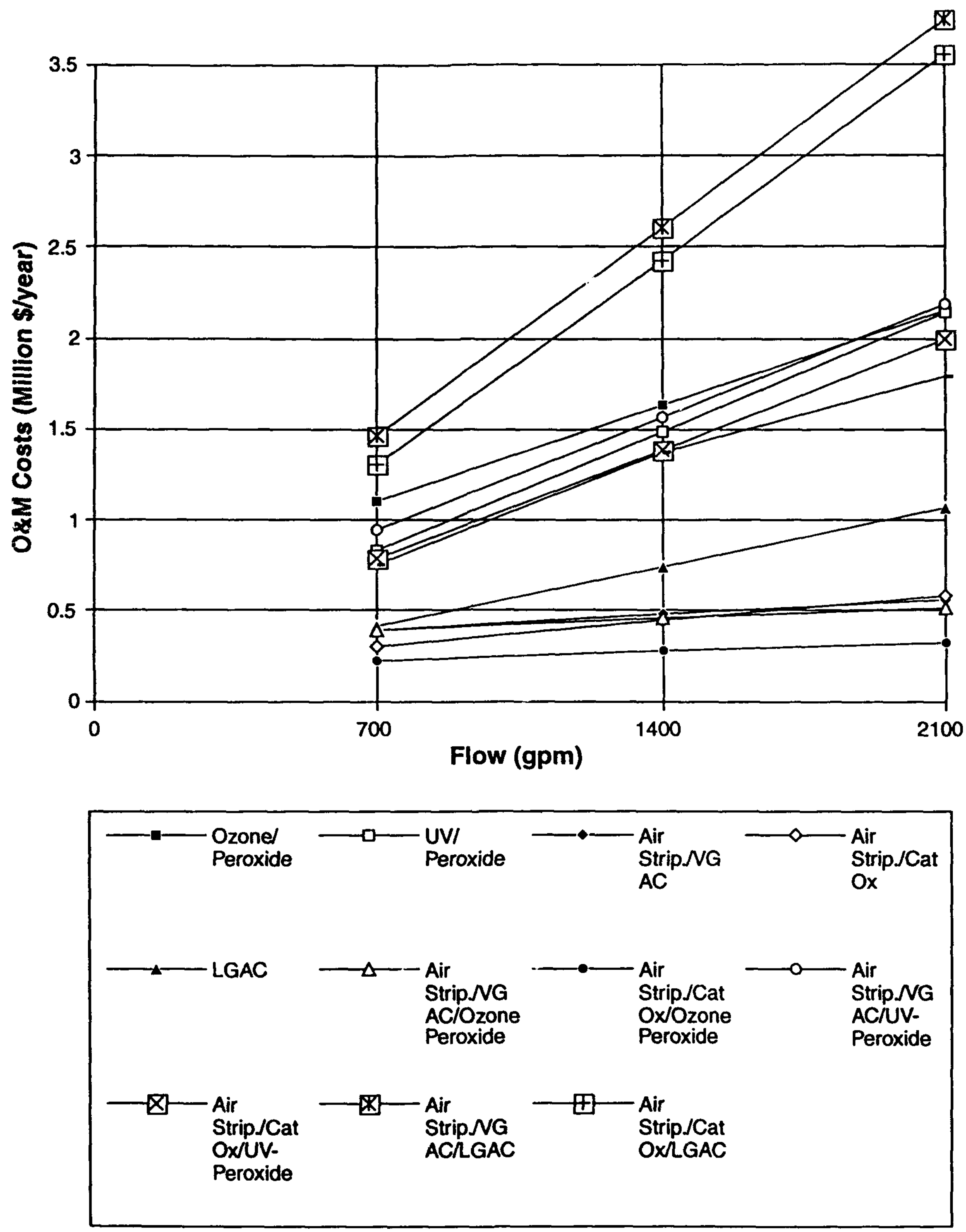


FIGURE 9-11
CONTAINMENT
O&M COSTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_38

CH2M HILL

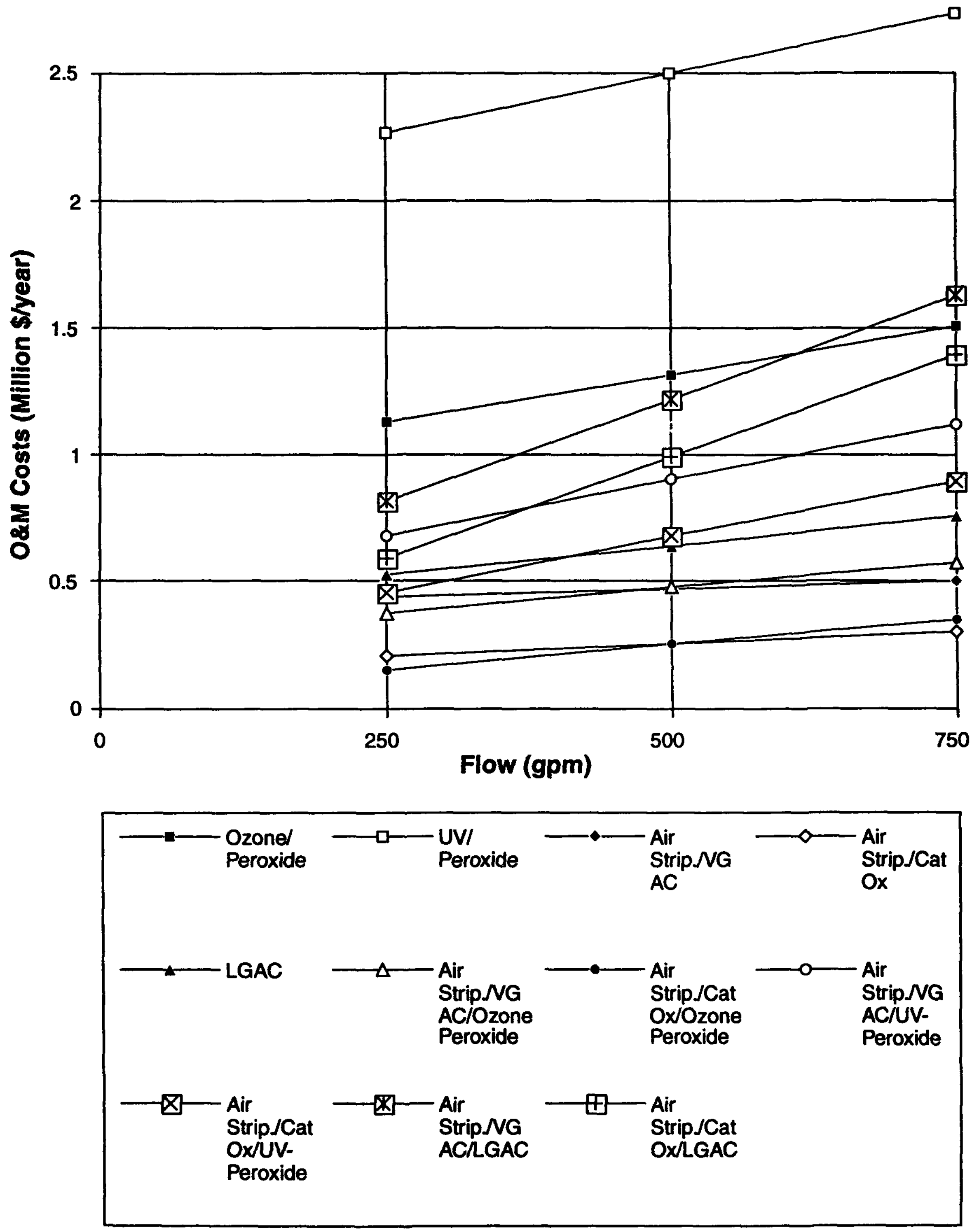
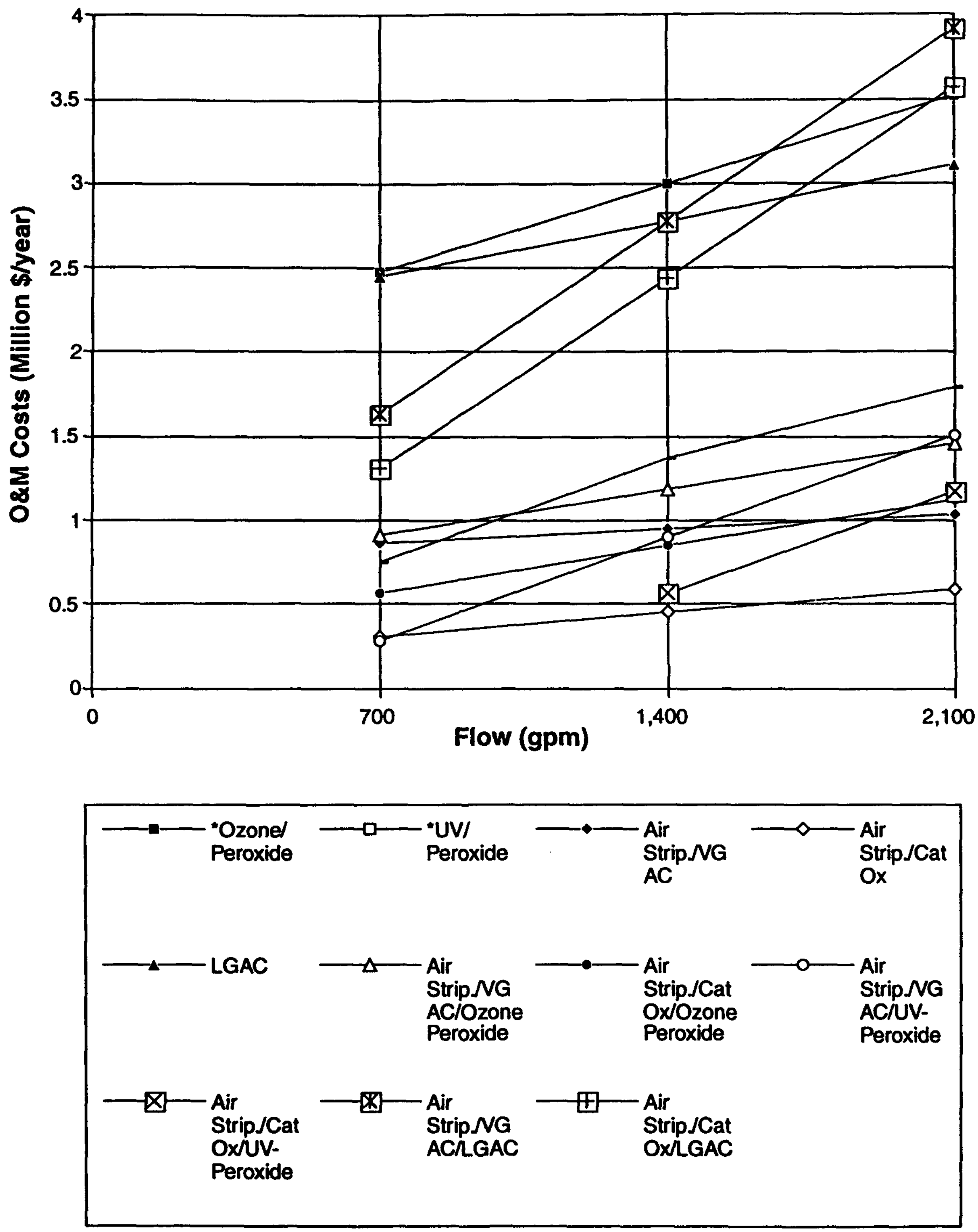


FIGURE 9-12
EAST COMBINED FLOW O&M COSTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_39

CH2M HILL



* Cost for this option(s) are greater than the scale of this plot

FIGURE 9-13
WEST COMBINED FLOW O&M COSTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_40

CH2M HILL

Chapter 10
Innovative Technologies

McCLELLAN AFB

10.1 Introduction

Innovative technologies are new and promising treatment technologies for cleaning up hazardous waste sites. By definition, they are relatively undeveloped and/or unproven compared to standard technologies, which are well-demonstrated to be effective for treating a given type of waste stream. Nevertheless, innovative technologies may offer potential benefits compared to standard technologies, such as faster, less expensive, or more acceptable treatment.

Chapters 8 through 13, excluding Chapter 10, describe the development, screening, and evaluation of remedial alternatives for groundwater at McClellan AFB, involving groundwater extraction, aboveground treatment, and end use of treated groundwater. The importance of in situ innovative treatment technologies is related to the limitations of the pump-and-treat approach. While pumping and treating is a critical component of groundwater remediation at the Base in that it prevents advancement of contaminant plumes while simultaneously removing contaminant mass from the subsurface, it is limited by the rate of diffusion of contaminants from relatively low permeability areas and the rate of dissolution of contaminants from the sorbed phase to the aqueous phase where they can be removed to the surface for treatment. In situ innovative technologies offer the potential for accelerating contaminant removal from the subsurface and/or contaminant transformation in the subsurface, and thereby reducing the overall remedial duration. Ex situ innovative technologies do not offer the potential for accelerating the cleanup or for providing higher treatment efficiencies (since proven, standard treatment technologies are available); however, they may provide less expensive or more acceptable methods for treating extracted groundwater or offgas resulting from aboveground or in situ treatment.

Figure 10-1 shows that the innovative technology evaluation, screening, and development task has followed a track parallel to the development of remedial groundwater alternatives for the Base. When sufficiently developed, innovative technologies will be incorporated into the Base groundwater cleanup program. But because of the unproven nature of innovative technologies, they require further testing at the bench-, pilot-, and/or field demonstration-scale before they can be fully evaluated to determine their feasibility and to develop design and operating criteria needed for full-scale implementation.

The major components of the innovative technologies task were:

- Site information review
- Technology information gathering and review
- Technology evaluation and screening
- Retained technologies development

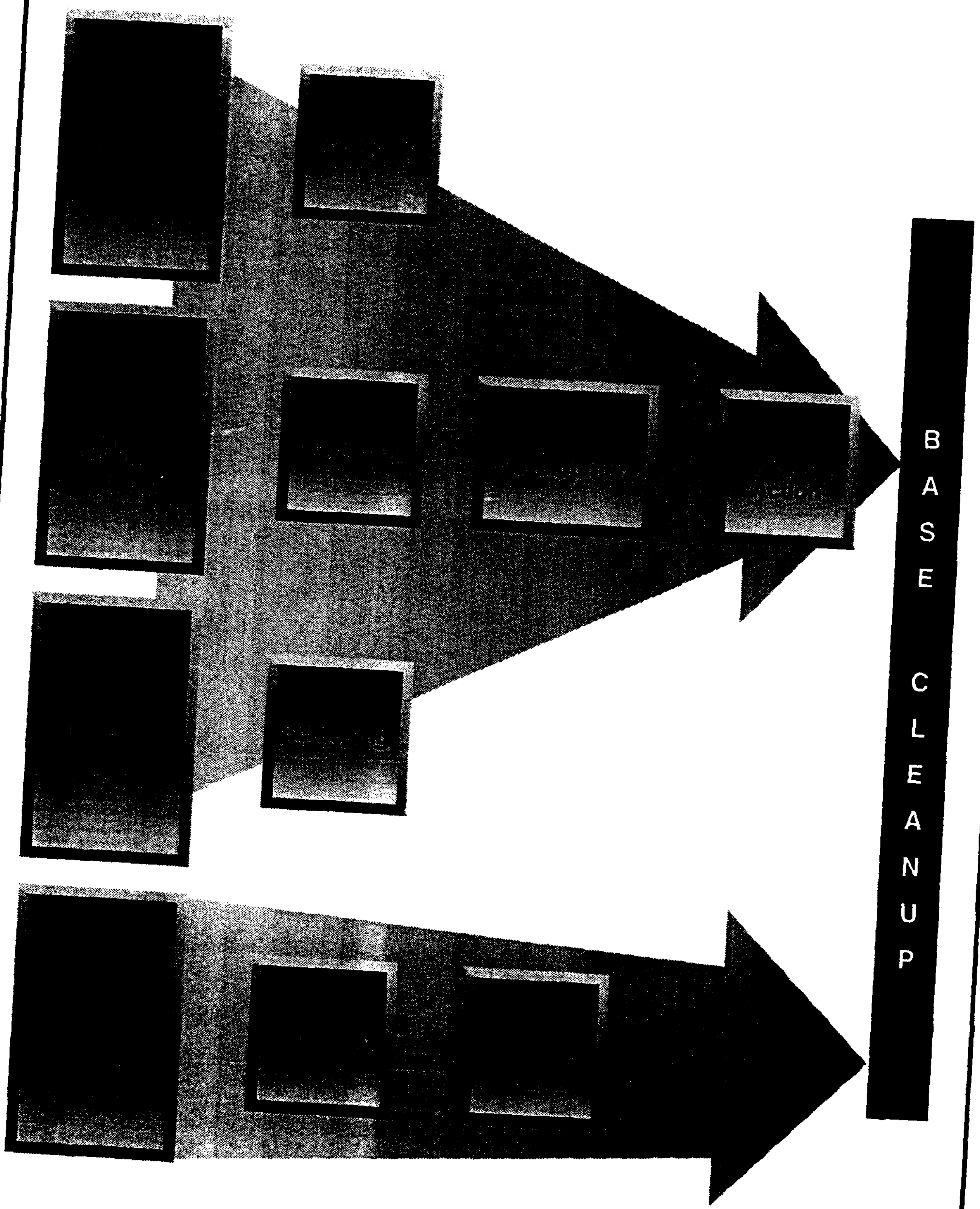


FIGURE 10-1
INNOVATIVE TECHNOLOGIES AND THE REMEDIAL ACTION
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_14

CH2M HILL

- Implementation plan development
- Feasibility study report preparation

The two predominant activities were the screening of technologies to identify the most promising innovative treatment technologies for remediating contaminated groundwater at the Base and development of implementation plans for the retained technologies. These two tasks are described further in the following subsections.

10.2 Innovative Technologies Screening

The overall goal of the innovative technologies screening activity was to develop a short list of the most promising innovative technologies for cleanup of contaminated groundwater at McClellan AFB. The procedures and results of the technologies screening activity are documented in more detail in Appendix L (Technical Memorandum L1).

The starting point was a list of the general site characteristics, including:

- Principal target contaminants—TCE and other chlorinated aliphatic hydrocarbons

- Target contaminant concentrations—500 to 25,000 μg/l in hot spots

- Target volumes for implementation of innovative technologies—hot spot areas in the A zone, areal extent roughly a few acres, thickness of contaminated zone roughly 10 to 30 feet

- Depth to groundwater—roughly 100 feet

- Transmissivities—roughly 10 to 2,000 ft^2/day

On the basis of these site characteristics, an initial list of potentially applicable innovative technologies was identified through literature and database reviews, vendor contacts, and consultation with internal and external experts. These technologies were then subjected to two levels of evaluation and screening to eliminate the less-promising technologies while retaining the technologies that are more appropriate for implementation at the Base. The primary screening criteria were potential effectiveness, development status, and relative cost. The secondary screening criteria were:

- Effectiveness
  - Achievable level of treatment
  - Treatment consistency
  - Advantages over standard technologies

- Robustness
  - Range of compounds treated
  - Turnup/turndown capability
  - Susceptibility to upsets

- Implementability
  - Vendor availability
  - State of development
  - Patent issues
  - Permitting issues

- Relative cost

Table 10-1 summarizes the results of the primary and secondary screening. Seven technologies were retained throughout the screening process, including four in situ treatment technologies (two biological and two physical/chemical), one ex situ groundwater treatment technology, and two offgas treatment technologies.

10.3 Implementation Plans

Implementation plans have been prepared for the seven innovative treatment technologies retained through the technology screening. The implementation plans are intended to provide a road map for evaluating, testing, and ultimately implementing innovative technologies at the Base. They are not intended to be work plans; work plan development would be the first step of subsequent technology evaluation projects.

10.3.1 General Implementation Issues

The general implementation philosophy for in situ innovative technologies is that they would initially be used to treat contaminant hot spots in the groundwater, where they could potentially provide the most benefit to the overall Base groundwater remediation. This means that they would initially be considered for implementation in areas of the A zone (which reportedly contains greater than 90 percent of the contaminant mass) with contaminant concentrations greater than at least 500 to 1,000 $\mu g/l$. The feasibility of implementing a given in situ innovative technology will be governed by site-specific conditions, and it is likely that the suitability of the various technologies will vary across the site. Consequently, implementation of multiple innovative technologies may well be appropriate. Figure 10-2 is a map of the Base indicating hot spot areas and locations where the different in situ innovative technologies may be appropriate. This is a preliminary map based on the current understanding of the groundwater, current technologies and the current remediation strategy. Additional locations or technologies may be identified in the future.

There are several engineering options for implementing in situ innovative technologies, including conventional vertical injection and extraction wells, horizontal injection and extraction wells, in situ recirculation units, and permeable reaction walls (Figure 10-3). These options have

Table 10-1
Innovative Technology Screening Summary

Initial List of Potentially Applicable Technologies	Technologies Retained From Primary Screening	Technologies Retained From Secondary Screening
In Situ Biological Treatment	**In Situ Treatment**	**In Situ Treatment**
Aerobic	Anaerobic Biotreatment	Anaerobic Biotreatment
Cometabolic	Cometabolic Biotreatment	Cometabolic Biotreatment
Anaerobic	Anaerobic/Aerobic Biotreatment	Air Sparging/Soil Vapor Extraction
Anaerobic/Aerobic	Air Sparging/Soil Vapor Extraction	Dual Phase Extraction
Enzyme Treatment	Steam Injection/Vapor Extraction	**Ex Situ Groundwater Treatment**
In Situ Physical/Chemical Treatment	Dual Phase Extraction	High Energy Electron Irradiation
Air Sparging/Soil Vapor Extraction	**Ex Situ Groundwater Treatment**	**Offgas Treatment**
Steam Injection/Vapor Extraction	Anaerobic Biotreatment	Cometabolic Biofiltration
Soil Heating/Vapor Extraction	Cometabolic Biotreatment	Resin Adsorption
Chemical Oxidation	Anaerobic/Aerobic Biotreatment	
Metal-Catalyzed Dehalogenation	Photolytic Oxidation	
Surfactant Flushing	High Energy Electron Irradiation	
Solvent Flushing	**Offgas Treatment**	
Dual Phase Extraction	Cometabolic Biofiltration	
Ex Situ Biological Groundwater Treatment	Resin Adsorption	
Aerobic	Photolytic Oxidation	
Cometabolic	High Energy Electron Irradiation	
Anaerobic	Flameless Thermal Oxidation	
Anaerobic/Aerobic		
Ex Situ Physical/Chemical Groundwater Treatment		
Evaporation/Catalytic Oxidation		
Chemical Oxidation		
Photolytic Oxidation		
High Energy Electron Irradiation		
Membrane Separation		
Photolytic Reduction		
Resin Adsorption		

Table 10-1
Innovative Technology Screening Summary

Initial List of Potentially Applicable Technologies	Technologies Retained From Primary Screening	Technologies Retained From Secondary Screening
Ex Situ Physical/Chemical Groundwater Treatment (continued)		
Surfactant Separation		
Wet Air Oxidation		
Supercritical Water Oxidation		
High Temp Steam Destruction		
Metal-Catalyzed Dehalogenation		
Offgas Treatment		
Photolytic Oxidation		
Membrane Separation		
Biofiltration/Aerobic		
Biofiltration/Cometabolic		
Resin Adsorption		
Scrubbing		
Photolytic Reduction		
High Energy Electron Irradiation		
Flameless Thermal Oxidation		

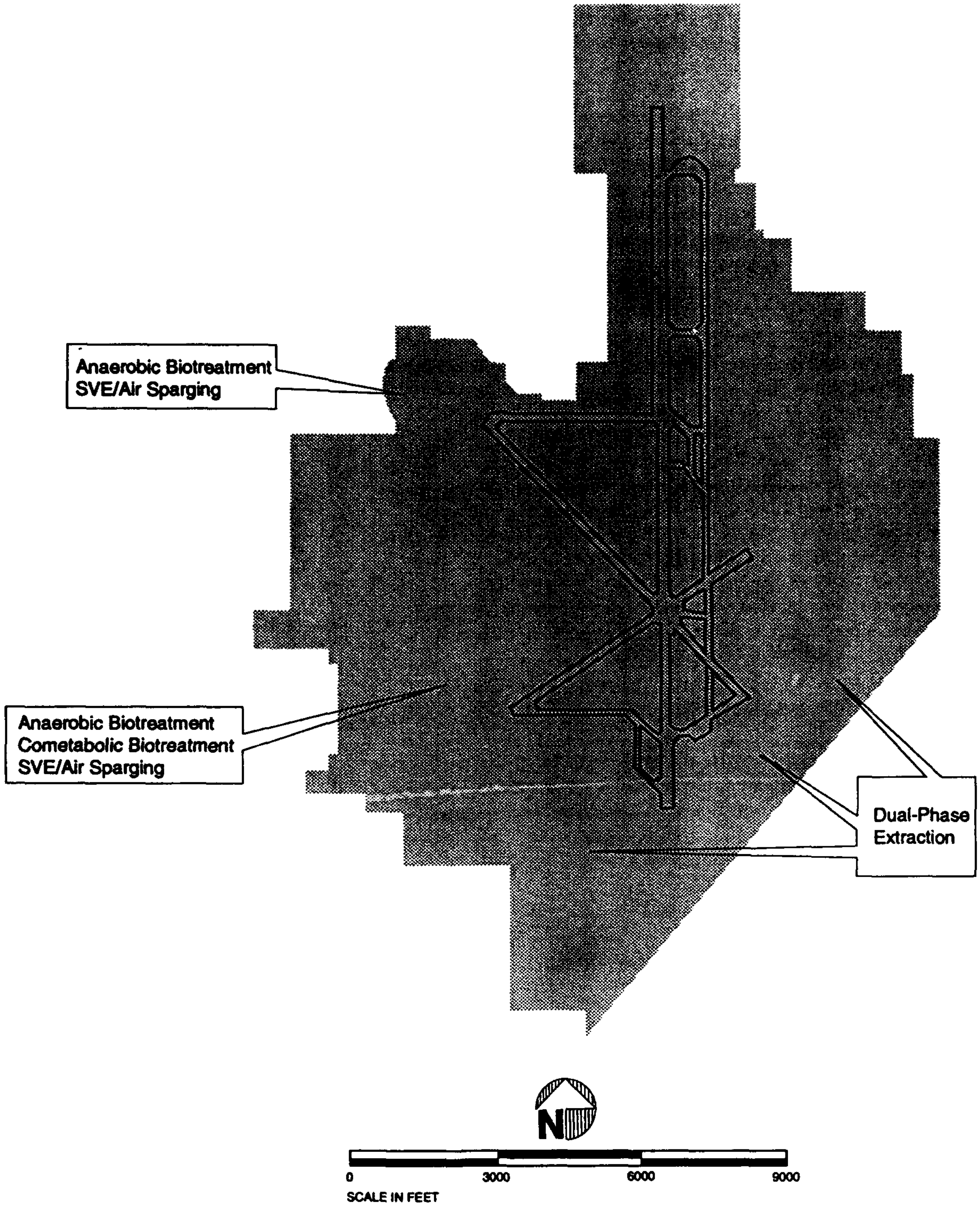


FIGURE 10-2
POTENTIAL INNOVATIVE TECHNOLOGY APPLICATION SITES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_22

CH2MHILL

characteristics that provide benefits under different site- and technology-specific conditions. The advantages and disadvantages of these implementation options are addressed in the appropriate technology implementation plans in Appendix L.

Evaluation of innovative technologies is necessarily an ongoing process. By definition, innovative technologies are relatively new and unproven. The development status and demonstration of innovative technologies will continue to advance, and new information will continue to become available. This information will need to be continually monitored. In addition to the technologies retained in the present screening, other technologies will undoubtedly be developed, which may be appropriate for groundwater remediation at the Base, so the continuing information review should not be limited to the retained technologies. Also, treatability testing at the bench-, pilot-, and/or field demonstration-scales will be necessary to fully assess technology feasibility for implementation at McClellan AFB.

Implementing an innovative technology at the Base will require an iterative evaluation/decision approach. Information on technology feasibility (effectiveness, robustness, implementability, cost) and design and operating parameters will become available from external sources (existing information and new information developed elsewhere) and from testing at the Base (bench-, pilot-, and field-demonstration testing). As each new bit of information is obtained, technology feasibility will need to be reevaluated and a decision made whether to proceed to the next step. Figure 10-4 is a flow diagram illustrating the general evaluation and decisionmaking process.

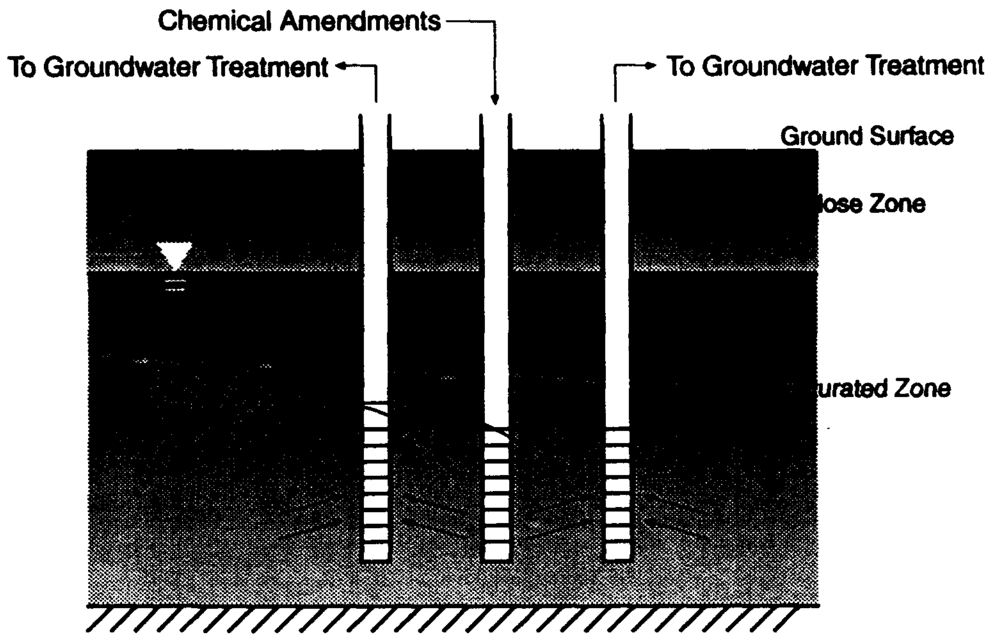
10.3.2 Implementation Plan Summaries

Individual implementation plans for the seven retained innovative technologies are included in Appendix L (Technical Memorandums L2 through L8). The implementation plans present the following information:

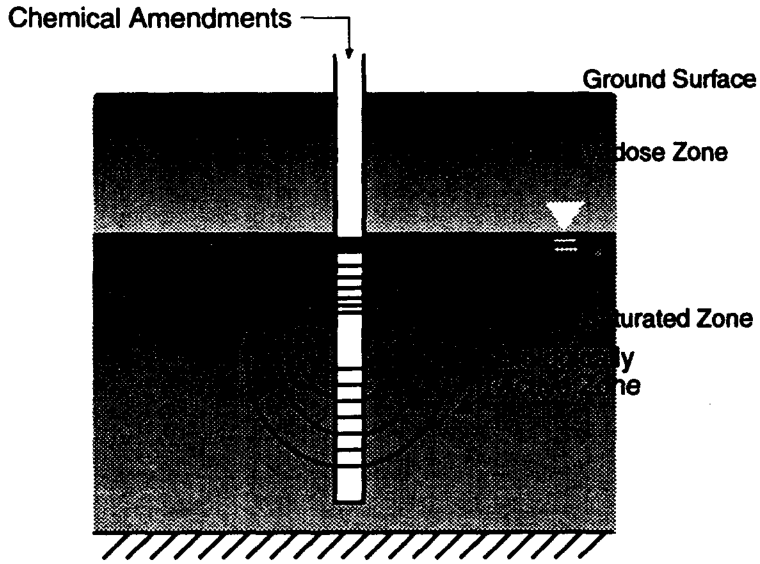
- Technology Overview
- Potential Benefits
- Locations for Implementation
- Implementation Approach
- Technology Limitations and Uncertainties
- Implementation Schedule
- Estimated Cost
- Works Cited

This information is briefly summarized in Tables 10-2 through 10-8. The schedule, cost information, and references are presented in the individual implementation plans (Appendix L).

VERTICAL INJECTION/EXTRACTION WELLS



IN SITU RECIRCULATION WELL



RDD1454_63

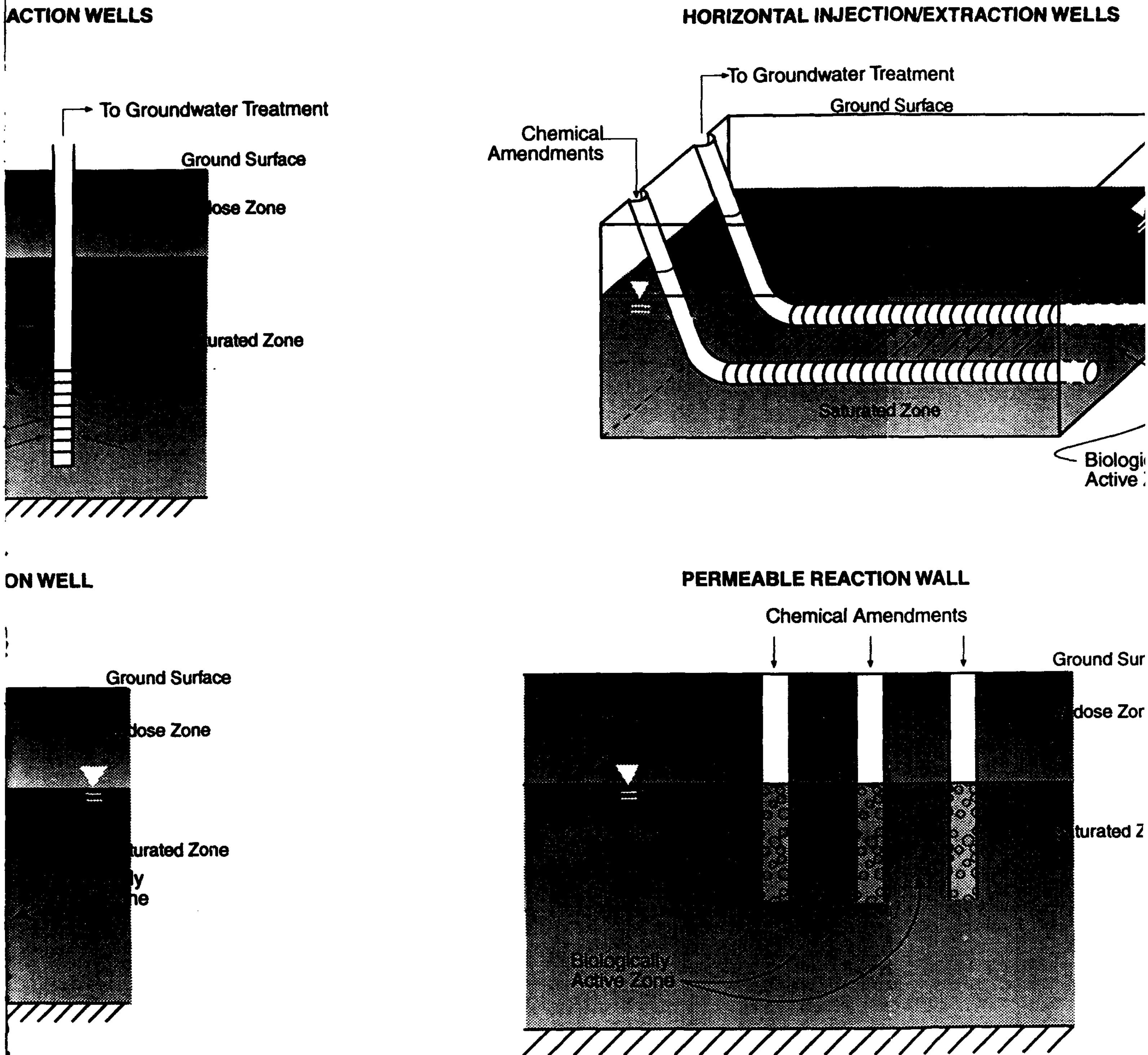


FIGURE 1
IN SITU B
CONFIGU
GROUNDWAT
McCLELLAN A
SACRAMENT

2

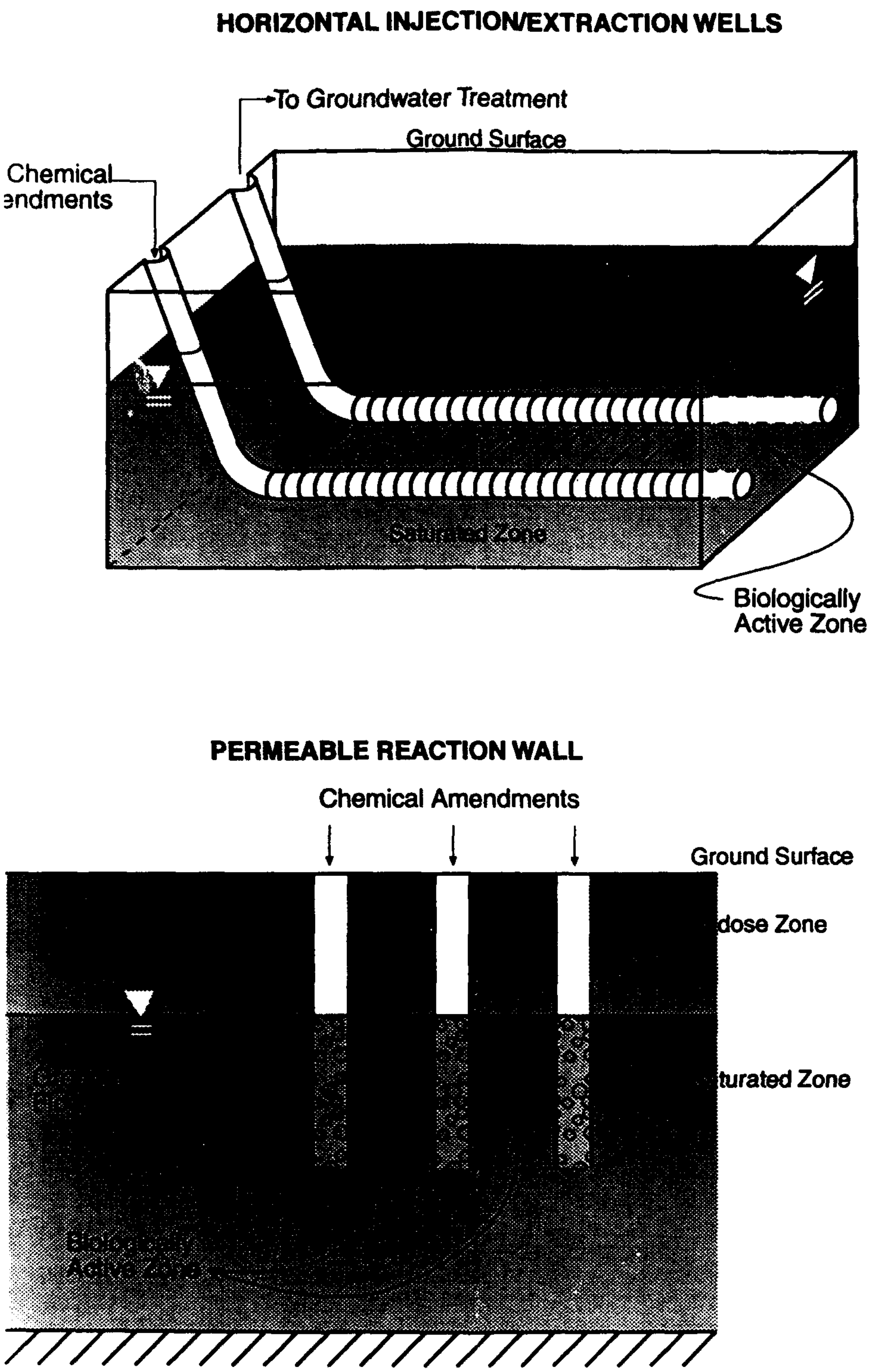
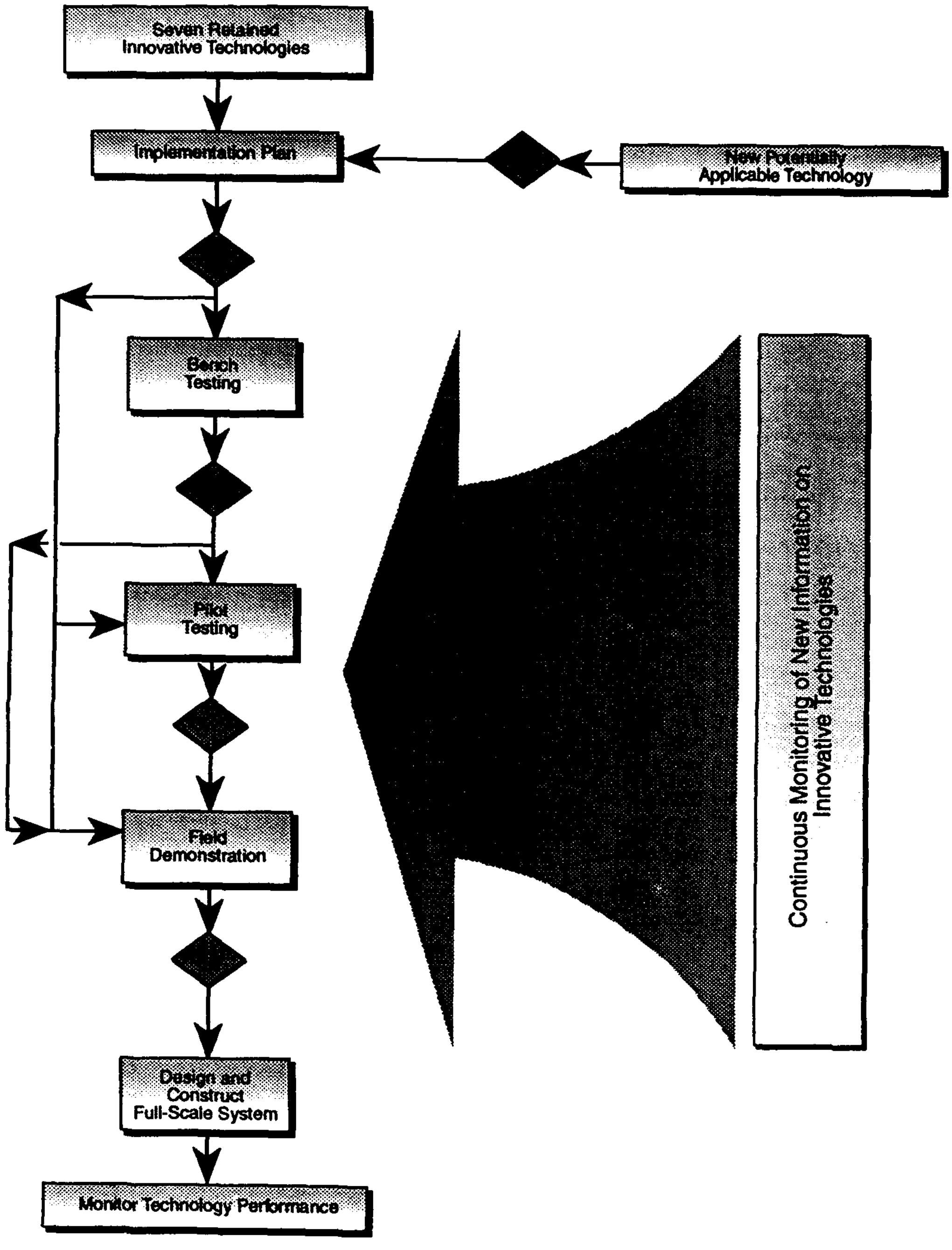


FIGURE 10-3
IN SITU BIOTREATMENT WELL CONFIGURATIONS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



Decide whether or not to proceed to next step

RDD1454_151

FIGURE 10-4
INNOVATIVE TECHNOLOGY IMPLEMENTATION DECISION DIAGRAM
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Table 10-2
In Situ Anaerobic Biotreatment
Implementation Plan Summary

Item	Description
Technology Description	In situ anaerobic biotreatment is the process of adding chemical amendments to groundwater to stimulate anaerobic biodegradation of contaminants. In situ anaerobic biotreatment can be used to degrade chlorinated organics in groundwater via reductive dehalogenation. To stimulate the reductive dehalogenation process, a readily degradable organic substrate (i.e., an electron donor, such as benzoate, acetate, formate, or lactate) is injected into the groundwater, along with inorganic nutrients (if necessary). Chlorinated aliphatic hydrocarbons (CAHs) are the principal contaminants in McClellan AFB groundwater, and those compounds are generally amenable to anaerobic breakdown. There are four basic configurations for implementing in situ anaerobic biotreatment: vertical injection and extraction wells, horizontal injection and extraction wells, in situ recirculation units, and permeable reaction walls.
Development Status	• Most research has been bench-scale testing at universities and by vendors • One full-scale application with promising results
Potential Advantages	• Destruction technology and treatment occurs in place • Potentially can accelerate groundwater cleanup • May treat high concentrations (tens of mg/l) and mixtures of contaminants • Virtually all chlorinated aliphatics present are amenable to anaerobic biodegradation • Complete degradation to nontoxic end products is possible • Many of the transformation products are biodegradable under aerobic conditions
Potential Disadvantages	• Anaerobic transformation of PCE, TCE, and DCE generates vinyl chloride, a highly toxic transformation product • Background electron acceptors, such as oxygen, nitrate, sulfate, and iron, must be depleted (requiring substrate addition) to allow reductive dehalogenation to proceed • An adequate anaerobic bacterial consortium might not exist in some areas and might be difficult to establish • Anaerobic conditions can cause water quality problems such as reduced iron and manganese, fermentation products, and sulfide which could potentially lead to the need for byproduct cleanup in the aquifer
Location of Implementation	• Hot spots in OUs C and D which have suitable permeabilities • Especially areas in OU D in which anaerobic biodegradation appears to be occurring naturally
Implementation Approach	• Conduct further site characterization at selected implementation location(s) • Conduct bench-scale microcosm studies to establish the presence of indigenous microorganisms and evaluate treatment potential • Perform hydrogeologic and contaminant transport modeling • Design, construct, and operate a pilot-scale system at the desired location to confirm in situ treatment performance • Evaluate cost benefit of implementing technology compared to pump-and-treat alone • If cost/benefit analysis is favorable, design a full-scale system based on the pilot testing results
Technology Limitations and Uncertainties	• The presence of the desired indigenous anaerobic microorganisms at locations of interest • The ability to establish and maintain appropriate treatment conditions in the subsurface • The extent to which the Base's heterogeneous subsurface will affect in situ treatment efficiency • Regulatory acceptance for substrate injection and groundwater reinjection • Achievable rates and levels of treatment

Table 10-3
In Situ Cometabolic Biotreatment
Implementation Plan Summary

Item	Description
Technology Description	In situ cometabolic biotreatment is the process of adding chemical amendments and oxygen to groundwater to stimulate aerobic cometabolism of chlorinated aliphatic hydrocarbons (CANS) and biodegradation of other contaminants. A primary organic substrate (e.g., methane, phenol, toluene) is injected into the groundwater to induce the production of nonspecific enzymes by a certain group of microorganisms. These enzymes fortuitously degrade CAHs, which are otherwise resistant to aerobic biodegradation. Aerobic cometabolism is effective at treating TCE, 1,2-DCE, and vinyl chloride, but not effective for PCE, carbon tetrachloride (CT), freons, 1,1-DCE, or 1,1,1-TCA. Most of these compounds are important groundwater contaminants at some locations of McClellan AFB. There are four basic configurations for implementing in situ cometabolic biotreatment: vertical injection and extraction wells, horizontal injection and extraction wells, in situ recirculation units, and permeable reaction walls.
Development Status	• Bench-scale testing at universities and by vendors has established treatability of CAHs • Pilot-scale field testing conducted at Moffett Naval Air Station has demonstrated ability to treat CAHs in groundwater
Potential Advantages	• Destruction technology and treatment occurs in place • Potentially can accelerate groundwater cleanup • May treat high concentrations (tens of mg/l) and mixtures of contaminants, including TCE and certain other chlorinated aliphatics • Complete degradation to nontoxic end-products is possible
Potential Disadvantages	• Does not effectively treat PCE, CT, 1,1,1-TCA, 1,1-DCE, or freons • Oxygenation of groundwater is additional expense • Subject to competitive inhibition and toxicity problems • Potential for biofouling and iron precipitation/plugging
Location of Implementation	• Hot spots in OU C that have suitable permeability (TCE is predominant contaminant in that area)
Implementation Approach	• Conduct further site characterization at selected implementation location(s) • Conduct bench-scale microcosm studies to establish the presence of indigenous microorganisms and evaluate treatment potential • Perform hydrogeologic and contaminant transport modeling • Design, construct, and operate a pilot-scale system at the desired location to confirm in situ treatment performance • Evaluate cost benefit of implementing technology compared to pump-and-treat alone • If cost-benefit analysis is favorable, design a full-scale system based on the pilot testing results.
Technology Limitations and Uncertainties	• The presence of the desired indigenous microorganisms at locations of interest • The ability to establish and maintain appropriate treatment conditions in the subsurface • The extent to which the Base's heterogenous subsurface will affect in situ treatment efficiency • Regulatory acceptance for substrate injection and groundwater reinjection • The ability to prevent offsite migration of injected substrate • Achievable rates and levels of treatment

Table 10-4 Dual-Phase Extraction Implementation Plan Summary	
Item	**Description**
Technology Description	Dual Phase Extraction (DPE) is a groundwater remediation technology that simultaneously extracts contaminants from the vadose, capillary fringe, and saturated zones. A DPE system consists of one or more wells screened over a depth approximately 5 to 10 feet above and 10 feet below the water table; an aboveground unit consisting of a high vacuum blower, an air/water separator, and piping connections to offgas and groundwater treatment systems; and, optionally, a system of passive or active air injection wells screened above the equilibrium water table established during operation. High vacuum conditions are essential for DPE to be most effective, and, therefore, fine-grained, low permeability sites where high vacuum can be maintained are most appropriate for application of the technology. The system extracts groundwater and soil vapors simultaneously through a central lift pipe or "straw." DPE enhances groundwater removal rates by increasing the hydraulic gradient toward an extraction well, increasing well yield and extraction of soluble contaminants. A dewatered zone is created in the vicinity of the well by the high vacuum in the zone of drawdown, and soil vapors are extracted from the vadose and dewatered zones.
Development Status	• Full-scale, single and multiple wellfield demonstrations have been performed at shallow applications (<30 feet) • Radian has conducted one deep pilot test (>90 feet) and will conduct pilot testing at McClellan AFB in the fall of 1993 • Skid-mounted systems are commercially available
Potential Advantages	• Potentially can accelerate groundwater cleanup • Enhances removal of contaminants and NAPLs in the capillary fringe • Effective in low permeability soils (e.g., clays, silts) • The high vacuum dewaters the vadose zone, exposing more unsaturated soil to vapor recovery • Groundwater extraction rates can be increased compared to conventional pump-and-treat • VOCs are transferred to the vapor phase in the straw, simplifying above-ground treatment
Potential Disadvantages	• Limited experience with deep water tables and multiple well applications may require additional testing and development work • Technology cost-effectiveness is reduced for sites with insufficiently low permeabilities or heterogeneities, which make it difficult to maintain high vacuum conditions • Patent fees are required for DPE • DPE requires aboveground water and vapor treatment
Location of Implementation	• Low permeability regions (silt and clay) are needed to maintain high vacuum • Hot spots in OUs A and B are potentially suitable locations
Implementation Approach	• Review the results of the DPE field demonstration project at McClellan AFB • If results are promising, determine whether additional pilot testing is needed and what refinements would be appropriate • If needed, conduct field-scale testing to obtain additional required information • Evaluate cost benefit of implementing DPE at the Base compared to conventional dual extraction • If cost/benefit analysis is favorable, design full-scale system based on pilot testing results
Technology Limitations and Uncertainties	• Effects of subsurface heterogeneities and moderate permeabilities on cost and effectiveness • Appropriate design and operating parameters for deep well systems • Achievable contaminant removal rates • The effect of repeated startup/shutdown periods on the movement of contaminants • Interactions of DPE wells in a multiple-well system

Table 10-5 **Soil Vapor Extraction/Sparging** **Implementation Plan Summary**	
Item	**Description**
Technology Description	Soil vapor extraction/sparging is an enhancement of conventional soil vapor extraction (SVE) for the removal of volatile contaminants from the saturated and unsaturated zones. Sparging involves injecting air into the saturated zone to mobilize VOCs dissolved in the groundwater and adsorbed to soil. Stripped contaminants are withdrawn from the subsurface through vapor extraction wells installed in the vadose zone. Air sparging may also enhance biodegradation of contaminants amenable to aerobic treatment through the increased supply of oxygen to the subsurface; and, conversely, may depress the biodegradation of compounds by anaerobic mechanisms. The most likely niche for SVE/sparging is at sites with contaminants and/or NAPLs concentrated in the smear zone and capillary fringe, particularly if the contaminants are aerobically biodegradable. Soil vapor extraction implemented without enhancements (i.e., air sparging or steam injection) is effective at removing contaminants from the vadose zone and can reportedly remove contaminants from the saturated zone. However, transport rates of dissolved contaminants in the aqueous phase to the air-water interface limit removal effectiveness. Sparging is intended to increase this rate of contaminant transport, especially in the smear zone/capillary fringe.
Development Status	• SVE/sparging has been used at full-scale to clean up more than 20 sites, including at least 10 sites contaminated with chlorinated VOCs • A few SVE/sparging applications have been at depths near 100 feet bgs • Technology vendors with full-scale SVE/sparging experience are available
Potential Advantages	• Potentially can accelerate groundwater cleanup • Can treat high concentrations of contaminants • Can enhance removal of contaminants from smear zone/capillary fringe • May promote treatment of aerobically biodegradable contaminants • VOCs removed in the vapor phase are generally less expensive to treat than in the liquid phase
Potential Disadvantages	• SVE/sparging may not effectively remove contaminants from groundwater because of air channeling • Anaerobic degradation of some chlorinated organics may be inhibited • Horizontal channeling can result in the uncontrolled migration of contaminants away from the treatment area
Location of Implementation	• SVE/sparging is most effective when focused on the smear zone/capillary fringe • Hot spots in OU C and OU D are potentially suitable locations
Implementation Approach	• Review information on SVE/sparging applications and Base subsurface characteristics • If conditions are appropriate for sparging, conduct pilot test at Site S, OU D, in conjunction with existing SVE demonstration • Evaluate cost benefit of implementing the technology compared to pump-and-treat alone • If cost/benefit analysis is favorable, design full-scale system based on pilot testing results
Technology Limitations and Uncertainties	• The effectiveness of contaminant removal from the saturated zone • The effects of subsurface heterogeneity on treatment performance and lateral migration of contaminants • The degree of air channeling and effects on treatment performance • The radius of influence of extraction and sparging wells and appropriate well spacing • The compatibility of subsurface conditions (permeability, contaminant distribution, heterogeneity) at target hot spot areas with SVE/sparging

Table 10-6 Electron Beam Ex Situ Groundwater Treatment Implementation Plan Summary	
Item	**Description**
Technology Description	Electron Beam (E-beam) treatment is an innovative advanced oxidation process that uses high energy electron irradiation of a thin aqueous stream to create highly reactive chemical species (e.g., aqueous electrons, H, and OH), which react with and transform organic contaminants. Organic contaminants are usually oxidized to carbon dioxide, water, and inorganic species; however, organic transformation products can also be formed.
Development Status	• Bench-scale treatment of chlorinated VOCs has been demonstrated for simple contaminant mixtures • A field demonstration project is planned for 1994 at DOE's Savannah River site • Vendors are developing mobile units • A full-scale (120 gpm) facility is in operation at municipal wastewater treatment plant in Florida (available for pilot testing)
Potential Advantages	• Destruction technology—capable of mineralizing contaminants if sufficiently high electron dose is applied • Any treatment residues remain in the single process effluent stream; no residual waste streams are produced • Technology expected to be robust in terms of ability to treat a range of flows and contaminant concentrations
Potential Disadvantages	• Limited effectiveness for chlorinated alkanes and ketones • Can form undesirable organic transformation products • Ability to treat complex mixture of contaminants unknown • Treatment efficiency is affected by water quality (i.e., alkalinity, dissolved solids, etc.)
Location of Implementation	• Treatment of extracted groundwater
Implementation Approach	• Existing bench-scale treatment data developed by vendors has been reviewed • Review any new data developed by vendors or other researchers, and review data from Savannah River site demonstration when available • Select technology vendor to conduct bench-scale testing using McClellan AFB groundwater samples to evaluate potential effectiveness for treatment of complex mixtures of chlorinated VOCs, and the effects of site groundwater chemistry • If bench testing yields promising results, conduct field pilot test when equipment becomes available • If treatment is acceptable, evaluate cost-effectiveness compared to standard groundwater treatment technologies • If cost/benefit analysis is favorable, work with vendor to design full-scale system
Technology Limitations and Uncertainties	• Ability to effectively treat complex mixture of contaminants • Ability to achieve treatment requirements at reasonable electron doses • Treatment costs compared to standard technologies • Effects of Base groundwater chemistry on treatment efficiency and dose requirements • Formation of transformation products • Technology scale-up issues and equipment availability and durability

Table 10-7
Cometabolic Biofiltration Offgas Treatment
Implementation Plan Summary

Item	Description
Technology Description	Biofiltration is a developing innovative technology for treating contaminated gases. In biofiltration, a contaminated gas stream is passed through a bed of biologically active media (e.g., peat, compost, soil, bark, plastic packing or foam, granular activated carbon) where contaminants are sorbed, dissolved, and biodegraded. Cometabolic biodegradation of chlorinated aliphatic hydrocarbons can be stimulated by adding a primary substrate such as methane, toluene, or phenol. Biofiltration is a generic term used to describe two separate but similar processes: (1) biofiltration using an organic-based media for adsorption and microbial support, and (2) biotrickling filtration, or bioscrubbing, using relatively inert packing for microbial support and cocurrent or countercurrent flow of water to exchange (scrub) gas-phase organics.
Development Status	• Full-scale units in use for odor control and treatment of certain municipal and industrial chemicals • Bench-scale research ongoing for treatment of chlorinated aliphatic hydrocarbons • A field pilot test is reportedly scheduled to be conducted by EG&G at McClellan AFB in the summer of 1994
Potential Advantages	• Possible cost savings when used in conjunction with vapor-phase carbon polishing (reduced carbon requirement) • Destruction technology – effects reduction in contaminant mass • Complete mineralization of TCE and certain other chlorinated aliphatics is possible • Public perception and air emissions advantages over thermal treatment methods
Potential Disadvantages	• Will not effectively treat PCE, carbon tetrachloride, freons, 1,1,1-TCA, or 1,1-DCE • Not robust – susceptible to upsets and inconsistent treatment performance • Probably would require polishing treatment (carbon) to achieve discharge requirements and consistent treatment • Ability to treat complex waste streams is unknown
Location of Implementation	• Treatment of air stripper offgas at groundwater treatment system • Treatment of soil venting process offgas at vadose zone/groundwater treatment system (SVE/sparging, SVE, dual phase extraction)
Implementation Approach	• Conduct an intensive information gathering effort, encompassing the several vendors and research groups active in biofiltration development • The relatively undeveloped status of the technology for treating chlorinated aliphatic hydrocarbons may suggest that testing be deferred while research progress is monitored • Review the results of any pilot testing in which biofiltration is used to treat gas streams contaminated with chlorinated aliphatic hydrocarbons, and continue to monitor the progress of the various research groups and vendors • Review the results of the scheduled field pilot test at McClellan AFB when available • If results are promising, evaluate the need for further testing and identify appropriate refinements • If necessary, select vendor system and conduct additional field pilot testing to obtain the needed information • If treatment is acceptable, evaluate the cost benefit of implementing biofiltration at the Base, either as a sole offgas treatment process or in combination with a polishing technology • If cost/benefit analysis is favorable, work with vendor to design full-scale system
Technology Limitations and Uncertainties	• Ability to treat complex mixtures of contaminants • Appropriate waste stream characteristics for technology implementation • Cost benefits achievable • Ability to sustain a consistent level of treatment • Polishing treatment requirements • Optimal design and operating parameters

Table 10-8 Resin Adsorption Offgas Treatment Implementation Plan Summary	
Item	**Description**
Technology Description	The resin adsorption technology employs polymeric resin adsorbents to remove VOCs from contaminated offgas. It is similar to vapor-phase carbon adsorption, but the resin reportedly has superior capacity and durability. The media can be regenerated in-place, through a large number of cycles, without significant loss of adsorption capacity. The contaminated gas stream passes through two resin-filled filter beds connected in series. When the capacity of the beds is reached, the air stream is switched to a second series of filters, and the loaded beds are desorbed by a combination of temperature, pressure, and an inert carrier gas (typically N_2). The contaminants are removed from the media and condensed; this liquid contaminant stream must be managed (treatment, disposal, reuse). The contaminated carrier gas stream is recirculated to the system influent.
Development Status	• Full-scale units are commercially available • Demonstrated for industrial applications • Some full-scale units in use • Field demonstrations for hazardous waste applications • Field pilot test ongoing at the McClellan AFB SVE demonstration project
Potential Advantages	• Potentially lower cost than standard treatment technologies • Regenerative system; reportedly little loss of capacity • Performance not significantly affected by high humidity gas streams
Potential Disadvantages	• Not a destruction technology, condensate must be managed • Poor removal of certain solvents (e.g., vinyl chloride, methylene chloride, ketones), similar to activated carbon • Effectiveness unproven for complex waste mixtures
Location of Implementation	• Treatment of air stripper offgas from a groundwater treatment system • Treatment of soil venting offgas at vadose zone/groundwater treatment system (SVE, sparging/SVE, dual phase extraction)

Implementation Approach	• Review PADRE performance results at McClellan AFB SVE field demonstration project
	• Review other demonstration project results
	• If current demonstration project does not meet objectives:
	  - Conduct bench testing for resin selection and adsorption capacity/desorption efficiency
	  - Conduct field pilot test to evaluate treatment efficiency and consistency, and to determine design and operating parameters
	• If treatment is acceptable, evaluate the cost benefit of implementing resin adsorption at the Base, either as a sole offgas treatment process or in combination with a polishing technology
	• If cost/benefit analysis is favorable, work with vendor to design full-scale system

Technology Limitations and Uncertainties	• Treatment performance achievable for complex mixture of contaminants • Adsorption capacity of poorly adsorbable contaminants • Ability to meet discharge requirements and need for polishing treatment • Management and final disposition of residual condensate stream • Cost compared to standard technologies • Desorption/regeneration efficiency and effect on adsorption capacity

Chapter 11
Water End-Use Options

Two end-use systems have been carried forward through a screening process that would provide a beneficial use for treated groundwater from McClellan AFB.

End-Use System 1 would convey the first 200 gpm of treated groundwater to McClellan AFB's existing greywater system. If greywater capacity beyond 200 gpm is developed in the future, it will be used; however, 200 gpm is the current estimated capacity. The remaining flow would be sold to neighboring water districts. In the event of maintenance requirements, the backup system would discharge the treated groundwater to Magpie Creek. The layout of End-Use System 1 is presented in Figure 11-1.

End-Use System 2 would also convey the first 200 gpm of treated groundwater to McClellan AFB's existing greywater system. The remaining flow would be injected into the groundwater at the northeast end of McClellan AFB or discharged to Magpie Creek, or both. Injection costs and capacity are estimated assuming the inorganic water qualities of the treated water will be similar to the aquifers where injection will take place. The proportion of treated water to be injected or discharged to Magpie Creek will be determined after pilot testing of injection. The layout of End-Use System 2 is presented in Figure 11-2.

The background information on McClellan AFB's existing end-use system, proposed treated groundwater quality, end-use screening criteria, an initial screening, a final screening, development of two recommended end-use systems, and order-of-magnitude capital and annual cost estimates are presented in Appendix Q, Evaluation of End-Use Alternatives.

11.1 Treated Groundwater Flows

The flow rates of the treated groundwater will vary depending on the extent of groundwater contaminant removal and the treatment plant locations. For this evaluation, four flow rate scenarios were developed:

- Scenario No. 1—Low flow at the east treatment unit of 400 gpm or 640 acre-feet per year
- Scenario No. 2—High flow at the east treatment unit of 720 gpm or 1,160 acre-feet per year
- Scenario No. 3—Low flow at the west treatment unit of 600 gpm or 960 acre-feet per year
- Scenario No. 4—High flow at the west treatment unit of 1,600 gpm or 2,560 acre-feet per year

11.2 End-Use Screening

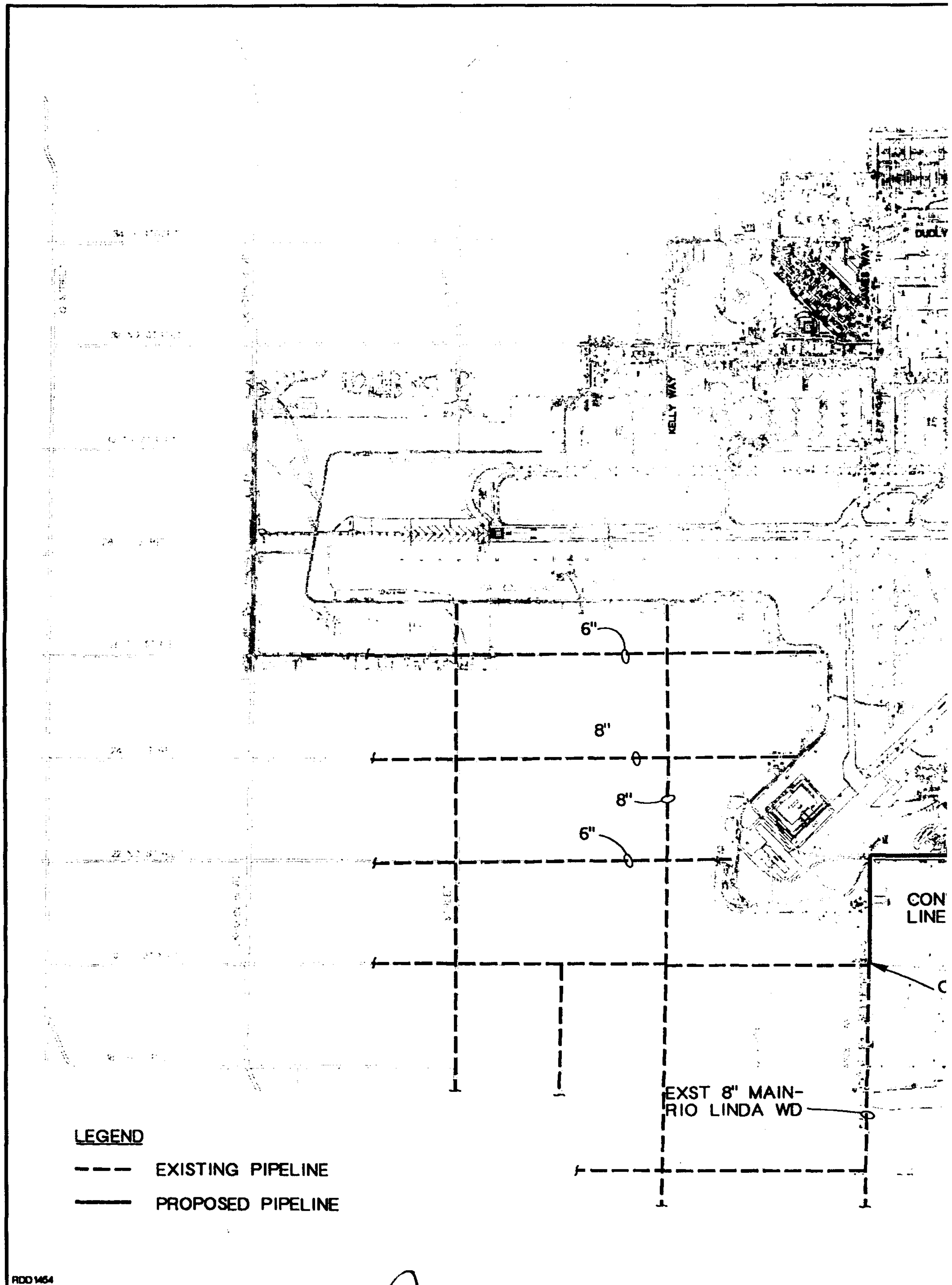
Eight end-use options were suggested by CH2M HILL, McClellan AFB, the regulatory agencies, or outside groups. Screening criteria were developed to limit the number of possible end uses for detailed evaluation. Table 11-1 presents the screening criteria and their measurable factors.

Table 11-1
End-Use Option Screening Criteria

Threshold Screening (Step 1)		**Additional Screening (Step 2)**	
Criteria	**Measurable Factor**	**Criteria**	**Measurable Factor**
Applicability	1. Meets the RWQCB definition of Beneficial Use 2. Located within a 5-mile radius of McClellan AFB	Effectiveness	1. Ability to handle 1,000 to 3,000 gpm flow variation 2. Ability to have minimum storage (i.e., 3,000 gpm at 3 days is 40 acre-feet) or no storage
		Robustness	1. Ability to take treated water year round 2. Ability to have a back-up system or hook into a backup system
		Implementability	1. Cost-effective in terms of capital and annual costs 2. Permitting issues are not limiting 3. Water quality desired is achievable by treatment systems being investigated 4. Ability to be constructed given physical and utility constraints

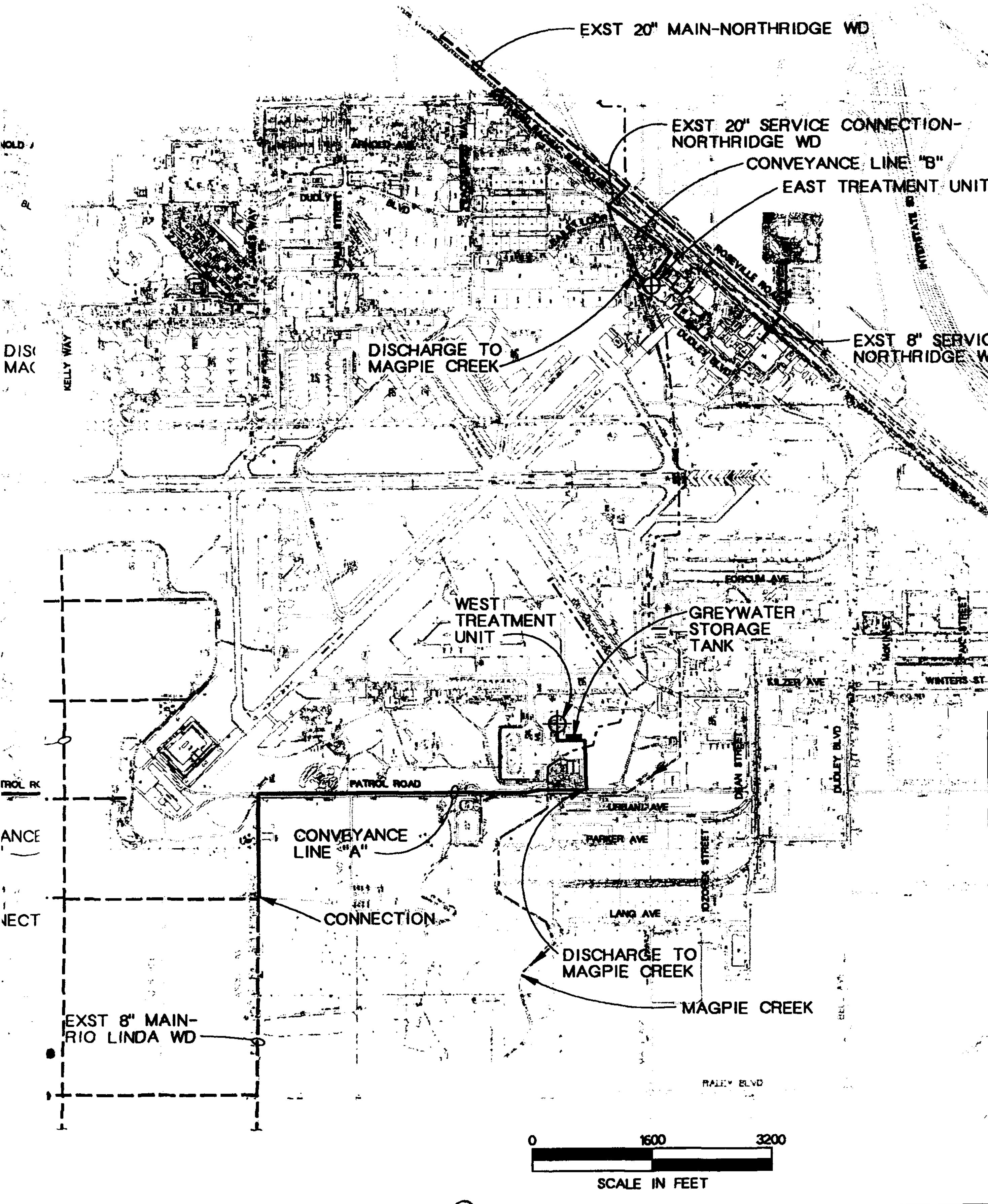
The screening process, which included the presentation of the screening criteria, discussion of possible end uses, and the implication of these end uses, involved two workshops. Initial screening took place at the August 10, 1993, Contaminated Groundwater Cleanup Workshop. The following end-use options were discussed:

- Onsite Groundwater Injection—Has potential; however, it may push contamination offsite into production wells, and it may split a contaminated plume. (Carried forward.)



RDD1454
GWOU/9-1.DGN (SUPERCEDED OLD 9-1.DGN)

1



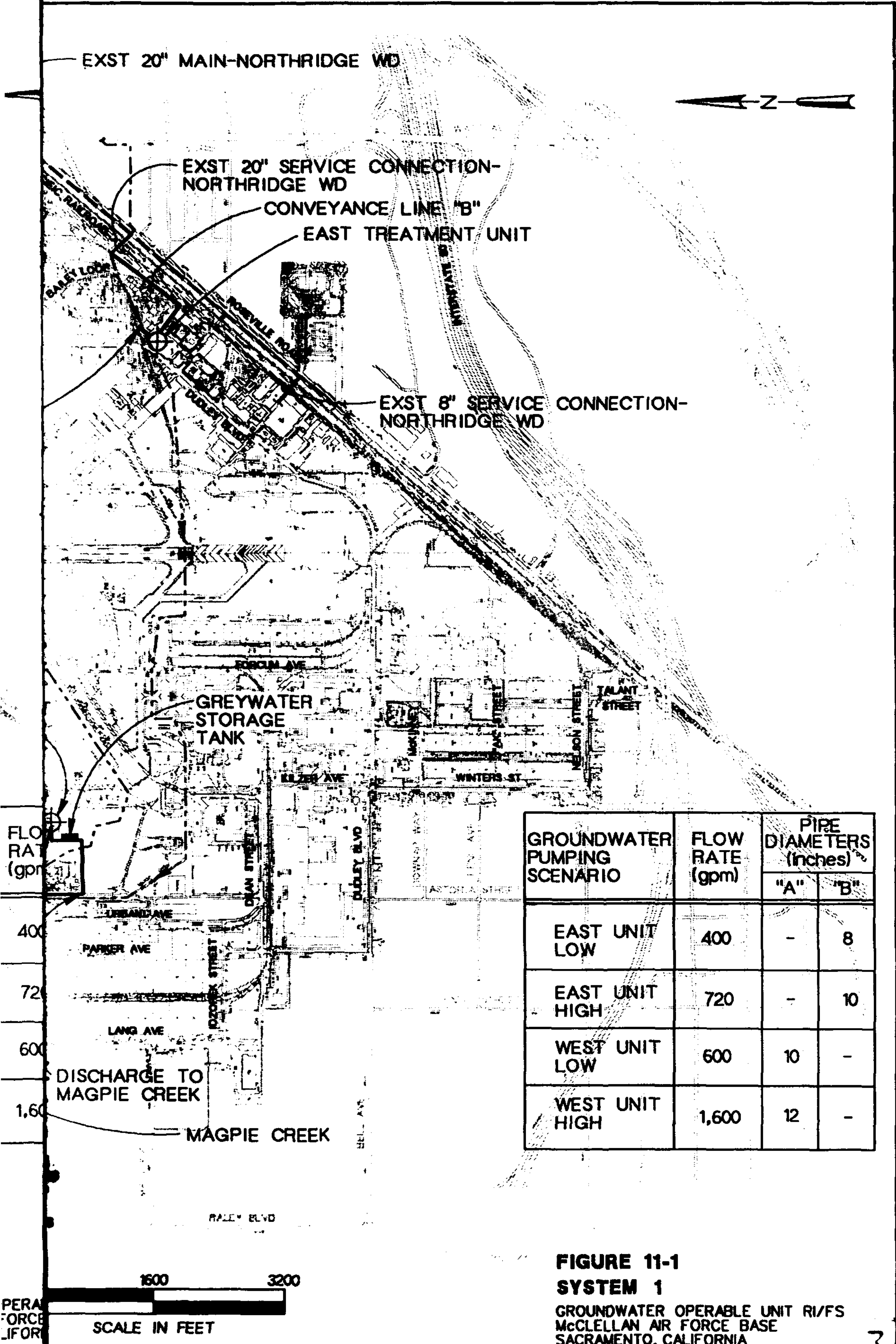
GROUNDWAT PUMPING SCENARIO
EAST UNI LOW
EAST UNI HIGH
WEST UNI LOW
WEST UNI HIGH

FIGURE

SYSTEM

GROUNDWAT
McCLELLAN
SACRAMENT

(2)

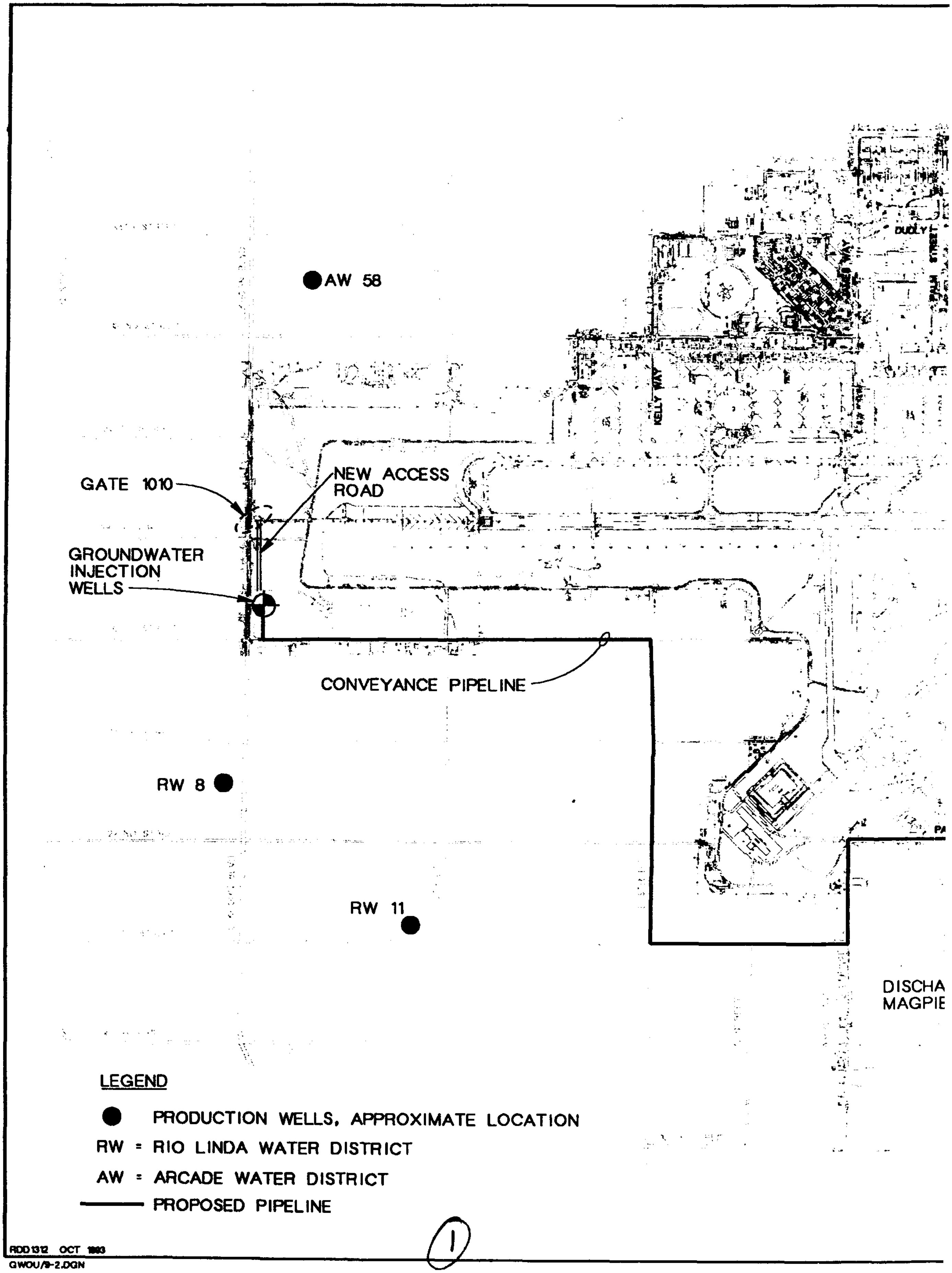


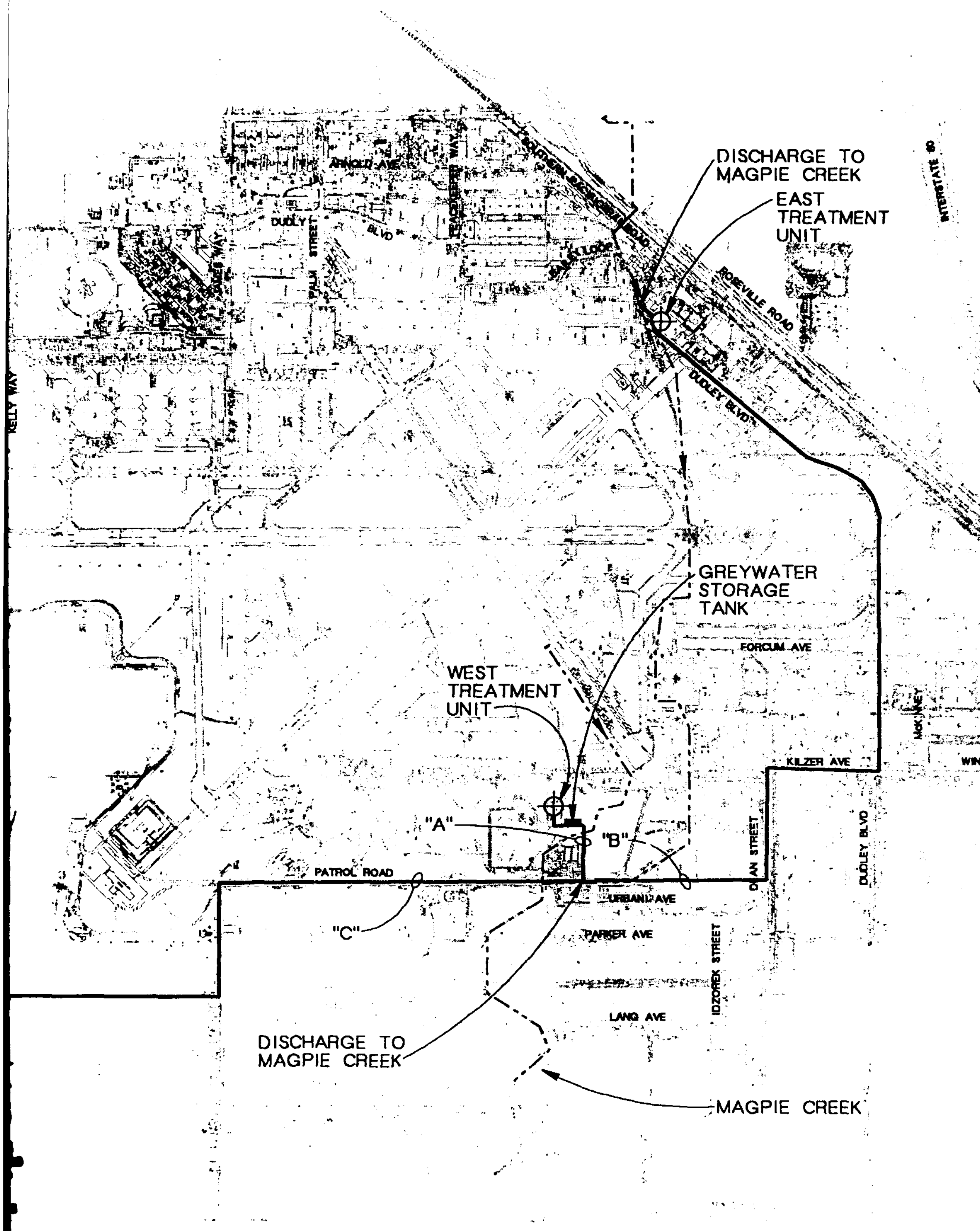
GROUNDWATER PUMPING SCENARIO	FLOW RATE (gpm)	PIPE DIAMETERS (inches)	
		"A"	"B"
EAST UNIT LOW	400	-	8
EAST UNIT HIGH	720	-	10
WEST UNIT LOW	600	10	-
WEST UNIT HIGH	1,600	12	-

FIGURE 11-1
SYSTEM 1

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL


AW 58
KELLY WAY
GATE 1010
NEW ACCESS ROAD
GROUNDWATER INJECTION WELLS
CONVEYANCE PIPELINE
RW 8
RW 11
DISCHA
MAGPIE
LEGEND
PRODUCTION WELLS, APPROXIMATE LOCATION
RW = RIO LINDA WATER DISTRICT
AW = ARCADE WATER DISTRICT
PROPOSED PIPELINE
RDD1312 OCT 1993
GWOU/9-2.DGN
1

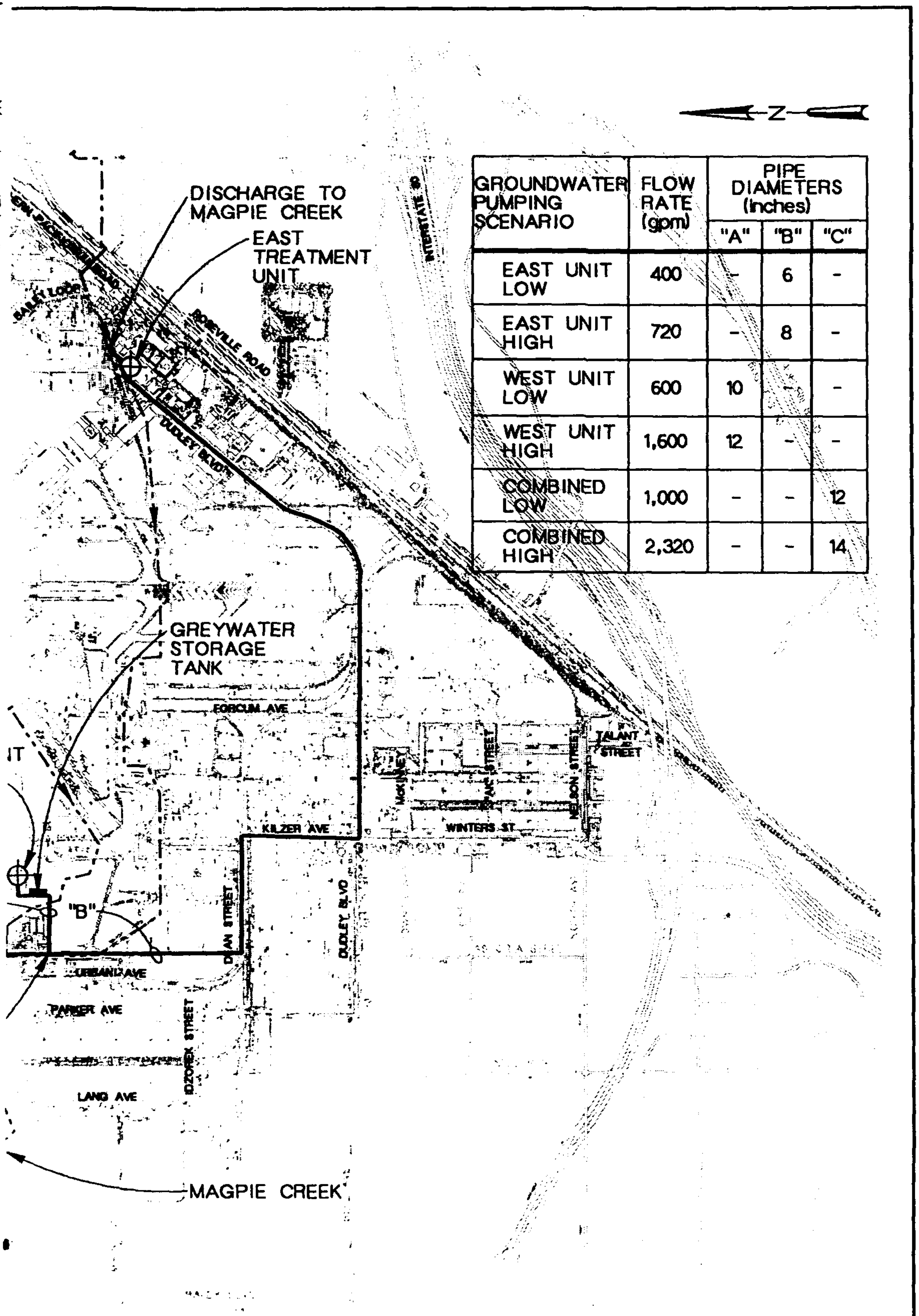


GROUNDWATER PUMPING SCENARIO	FL RA (g
EAST UNIT LOW	4
EAST UNIT HIGH	7
WEST UNIT LOW	6
WEST UNIT HIGH	1,(
COMBINED LOW	1,(
COMBINED HIGH	2,

FIGURE 11-
SYSTEM 2
GROUNDWATER
McCLELLAN AIR
SACRAMENTO, C

2

1



GROUNDWATER PUMPING SCENARIO	FLOW RATE (gpm)	PIPE DIAMETERS (inches)		
		"A"	"B"	"C"
EAST UNIT LOW	400	-	6	-
EAST UNIT HIGH	720	-	8	-
WEST UNIT LOW	600	10	-	-
WEST UNIT HIGH	1,600	12	-	-
COMBINED LOW	1,000	-	-	12
COMBINED HIGH	2,320	-	-	14

FIGURE 11-2

SYSTEM 2

GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

- Offsite Groundwater Injection—Would be hard for McClellan AFB to manage, and conveyance costs would be high. (Dropped.)

- Discharge to Magpie Creek—Has potential; however, it may create a riparian habitat that McClellan AFB would have to maintain after groundwater cleanup had ended. (Carried forward.)

- Recharge Basins—Probably not feasible due to a hardpan under most of McClellan AFB. (Dropped.)

- Discharge to Sacramento Regional Publicly Owned Treatment Works (POTW)—In the area around McClellan AFB, the existing sanitary sewerlines are near capacity, and this option would not present a beneficial use in the opinions of the attendees. (Dropped.)

- Discharge to Local Golf Courses—Perhaps feasible; however, it would be a seasonal usage with high summer demand and no winter demand. (Dropped.)

- Discharge to McClellan AFB Existing Greywater System—System has a limited capacity; however, McClellan AFB is interested in reusing as much water as possible. (Carried Forward.)

- Sell to Neighboring Water Utilities—Arcade, Rio Linda, Northridge, and Citizens Utilities are highly interested in purchasing the treated groundwater for domestic water supply provided that it meets safe drinking water quality standards. (Carried Forward.)

Final screening took place at the August 25, 1993, Alternatives Development Workshop. Participants included McClellan AFB, U.S. EPA, California DTSC, RWQCB, Clean Sites, neighboring water utilities, and CH2M HILL. This screening process resulted in the selection of End-Use Systems 1 and 2, as described at the beginning of this chapter.

11.3 End-Use System Components

Each end-use system has two common components—the existing McClellan AFB greywater system and discharge to Magpie Creek. In addition, there are the main components for each system. For End-Use System 1, the main component is selling to neighboring water utilities. For End-Use System 2, the main component is onsite groundwater injection. A description of these components is presented in the following section.

11.3.1 Existing Greywater System

McClellan AFB presently uses some water from the existing groundwater treatment unit in a greywater system. The greywater system consists of a 250,000-gallon storage tank, a pressurizing pump system near the existing groundwater treatment unit, and a network of piping to cooling towers and Don Julio Creek.

From discussions with McClellan AFB personnel, it has been determined that the greywater system could use approximately 200 gpm on a frequent basis. Only water from the west treatment unit site will be used for the greywater system, because of greywater connections already located at that site.

11.3.2 Discharge to Magpie Creek

The existing groundwater treatment plant discharges its water into Magpie Creek. Throughout much of McClellan AFB, Magpie Creek is a concrete-lined canal. Its existing design capacity is 700 cfs or approximately 314,000 gpm. For this study, it is assumed that Magpie Creek has available capacity to accommodate the four flow rate scenarios.

Continuous discharge to Magpie Creek may create additional riparian habitat that McClellan AFB may be responsible for after cleanup is completed; however, this potential requirement is not an ARAR. Discharge to Magpie Creek will be used as a backup discharge point during maintenance shutdown of the primary end-use component in both System 1 and System 2. It may be that discharge to Magpie Creek only happens once or twice per year.

System 2 would potentially use Magpie Creek for the entire flow if injection proves infeasible based on pilot testing. In addition, it will take several years to build all the extraction wells and pipelines, so Magpie Creek will remain the principal discharge point for the existing GWTP and for other extraction wells that are operated prior to the construction of the selected end use.

11.3.3 Sell to Neighboring Water Utilities

Selling the treated groundwater to neighboring water utilities is the main component of End-Use System 1. The purveyors that have expressed an interest in the treated groundwater and that have nearby facilities include Northridge Water District and Arcade Water District on the east, and Rio Linda Water District on the west.

Northridge Water District has two existing service connections in the vicinity of the proposed east treatment unit site. Arcade Water District has facilities further north of the east treatment unit site. Rio Linda Water District has facilities in the vicinity of the west treatment unit site. Proposed pipeline connections with Northridge Water District and Rio Linda Water District appear on Figure 11-1.

This analysis assumes that up to 650 gpm will be supplied to Northridge Water District and up to 1,600 gpm to Rio Linda Water District. No storage is required since the demand from both districts is much greater than the four flow rate scenarios.

While interest in obtaining the treated groundwater for a supplemental source of potable water is very high among the water districts there is one significant limitation concerning the DHS's philosophy. Currently, DHS states that if a contaminated groundwater source is extracted and treated from an area that has not traditionally been a source of potable water supply, the treated groundwater cannot be used for a potable water supply. If the contaminated groundwater is extracted and treated from an area that has traditionally been a source of potable water supply, the treated groundwater can be used as a potable water supply. The water utilities expressed an interest in pursuing this issue with DHS so that they could use McClellan AFB water as a source for domestic water supply.

11.3.4 Onsite Groundwater Injection

Injecting the treated groundwater onsite is the main component of End-Use System 2. Groundwater injection would involve pumping treated groundwater from both treatment units to injection wells at the north end of McClellan AFB. The north site was chosen because of its distance from any known groundwater contamination. For this end use, it has been assumed that water could be injected approximately 600 feet below ground surface.

The treated groundwater from the east and west treatment units would be injected into the wells. It has been assumed that a minimum of three and a maximum of four injection wells would be required to accommodate the four flow rate scenarios. One of the injection wells would be required as a standby well for maintenance purposes.

Neighboring water utilities are concerned about the uncertainties involved in groundwater injection. Some of the concern centers around the lack of knowledge of the effect of the injected water on the contaminant plumes. Such effects could include breaking the plume up, making the cleanup more difficult and possibly contaminating existing uncontaminated groundwater supplies. This issue is being evaluated as part of the RI/FS.

11.4 Facilities Required for the End-Use Systems

Facilities required for End-Use System 1, including connection to McClellan AFB existing greywater system, connection to neighboring water districts, and connection to Magpie Creek are presented in Table 11-2. The pump motor size is based on the maximum size required for a given groundwater pumping scenario. The layout of End-Use System 1 is shown in Figure 11-1.

Table 11-2 Facilities Required for End-Use System 1				
	Groundwater Pumping Scenario			
	East Treatment Unit		West Treatment Unit	
Facilities	Low Flow (400 gpm)	High Flow (720 gpm)	Low Flow (600 gpm)	High Flow (1,600 gpm)
1. Pipe Lengths (ft)				
6-inch-diameter	--	--	400	400
8-inch-diameter	1,800	--	--	--
10-inch-diameter	--	1,800	8,500	--
12-inch-diameter	--	--	--	8,500
2. Pump (hp)	25	40	50	110
3. Discharge Structure	1	1	1	1

Table 11-3 Facilities Required for End-Use System 2		
	Groundwater Pumping Scenario	
	Low Flow	High Flow
Facilities	400 gpm + 600 gpm = 1,000 gpm	720 gpm + 1,600 gpm = 2,320 gpm
1. Pipe Lengths (ft)		
6-inch-diameter	400	400
8-inch-diameter	11,800	--
10-inch-diameter	2,700	11,800
12-inch-diameter	18,000	2,700
14-inch-diameter	--	18,000
2. Pump (hp)	75	170
3. Discharge Structure	2	2
4. Injection Wells	3	4
5. Access Road (ft)	1,400	1,400

Facilities required for End-Use System 2, including connection to McClellan AFB existing greywater system, connection to injection wells, and connection to Magpie Creek are presented in Table 11-3. The pump motor size is based on the maximum size required for a given groundwater pumping scenario. The layout of End-Use System 2 is shown in Figure 11-2.

11.5 Estimated Capital and Annual Costs

Order-of-magnitude cost opinions were prepare[illegible]ch system in accordance with the guidelines of the American [illegible]ation of Cost Engineers. The assumptions and development of [illegible]se costs are presented in Appendix Q. It is normally expected that an estimate of this type would be accurate within +50 percent to -30 percent. It should be noted that these costs do not include any contingencies or allowances to account for permitting, engineering, services during construction, or changes in scope.

Capital costs for End-Use Systems 1 and 2 are presented in Table 11-4 for the four flow rate scenarios. Estimated capital costs for End-Use System 1 vary from approximately $626,000 (low flows) to $856,000 (high flows). Estimated capital costs for End-Use System 2 vary from approximately $2.3 million for the low flows to $2.7 million for the high flows. The east treatment unit portion of System 2 would not be constructed without the west treatment unit portion of System 2.

Table 11-4
Capital Costs for End-Use Systems 1 and 2

		Capital Cost Per Groundwater Pumping Scenario ($)			
		East Treatment Unit		West Treatment Unit	
System	Facilities	Low Flow (400 gpm)	High Flow (720 gpm)	Low Flow (600 gpm)	High Flow (1,600 gpm)
1	Pipeline	72,000	90,000	437,000	522,000
	Pumps	38,000	75,000	75,000	165,000
	Discharge Structure	2,000	2,000	2,000	2,000
	TOTAL	**112,000**	**167,000**	**514,000**	**689,000**
2	Pipeline	464,000	580,000	1,145,000	1,338,000
	Pumps	113,000	113,000	255,000	255,000
	Discharge Structure	4,000	4,000	4,000	4,000
	Injection Well	--	--	270,000	360,000
	Access Road	--	--	15,000	15,000
	TOTAL	**581,000**	**697,000**	**1,689,000**	**1,972,000**

Estimated annual costs for End-Use Systems 1 and 2 are presented in Table 11-5 for the four flow rate scenarios. Included in the annual costs are maintenance required on the physical appurtenances and energy costs associated with pumping. Labor to operate the systems and any labor, materials, and laboratory expenses associated with sampling procedures are not included.

Annual costs for End-Use System 1 vary from approximately $36,000 (low flows) to $82,000 (high flows). Annual costs for End-Use System 2 vary from approximately $98,000 (low flows) to $156,000 (high flows).

Table 11-5
Estimated Annual Costs for End-Use Systems 1 and 2

System	Facilities	Annual Cost Per Groundwater Pumping Scenario ($)			
		East Treatment Unit		West Treatment Unit	
		Low Flow (400 gpm)	High Flow (720 gpm)	Low Flow (600 gpm)	High Flow (1,600 gpm)
1	Pipeline	360	450	2,200	2,600
	Pumps	11,500	23,000	22,000	56,000
	Discharge Structure	200	200	200	200
	TOTAL	**12,060**	**23,650**	**24,400**	**58,800**
2	Pipeline	2,400	2,900	5,700	6,700
	Pumps	11,500	22,000	22,000	50,000
	Discharge Structure	400	400	400	400
	Injection Well	--	--	54,000	72,000
	Access Road	--	--	1,500	1,500
	TOTAL	**14,300**	**25,300**	**83,600**	**130,600**

Chapter 12
Assembly and Screening of Alternatives

This chapter contains the process of assembling alternatives from the individual components of the remedy (extraction, treatment, and end use) and the results of screening the alternatives. Six alternatives are carried to detailed evaluations and comparisons in Chapter 13.

12.1 Assembly of Alternatives

Alternatives are assembled by combining the components of the remedy. The number of potential alternatives is simply the product of the number of extraction options (3) times the number of treatment options (11) times the number of end uses (2), or 66 alternatives. Each alternative, if selected as the remedy, must function effectively given the uncertainties identified in Chapter 4. To properly evaluate the alternatives, they must be extended to include several "what if" scenarios for the uncertainties. For example, the alternative of controlling the MCL target volume, treating the water with an air stripper and vapor phase carbon, and delivering the water to the water utilities needs to be evaluated for a range of potential flows (due to the uncertainty of the extent of contamination), and a range of potential concentrations (due to the uncertainty of the distribution of the contaminants and the actual flows from the extraction system). Adding only these two uncertainties means the number of alternatives to be evaluated could be 66 times 3 flows/target volume times 3 concentrations per flow, or 594 alternatives. Given there are additional uncertainties to be evaluated and multiple evaluation criteria, there are potentially thousands of alternatives that require evaluation. A decision analysis model was constructed to assemble and evaluate the alternatives, select the dominant strategies, and perform sensitivity analyses on the strategies. Figure 12-1 shows the process of screening and assembling the alternatives. Appendix H contains the model's development and results.

The primary goal for the Groundwater OU remediation plan is to develop a strategy which selects an extraction network design, treatment technology, and effluent discharge system to successfully remediate the contaminated groundwater at McClellan AFB. The remediation plan should select the least-cost alternatives that remove mass and reduce contaminant concentrations in the target volume of groundwater to the required level. The plan must analyze the impacts of several important uncertainties and risks, including variability in flow and contaminant concentrations, potential impacts from air emissions during groundwater treatment, suitability of treated water for end uses, and changing the mission of McClellan AFB to dual use. The selected strategy must be flexible so that it can respond to the changing future conditions of these uncertainties and risks.

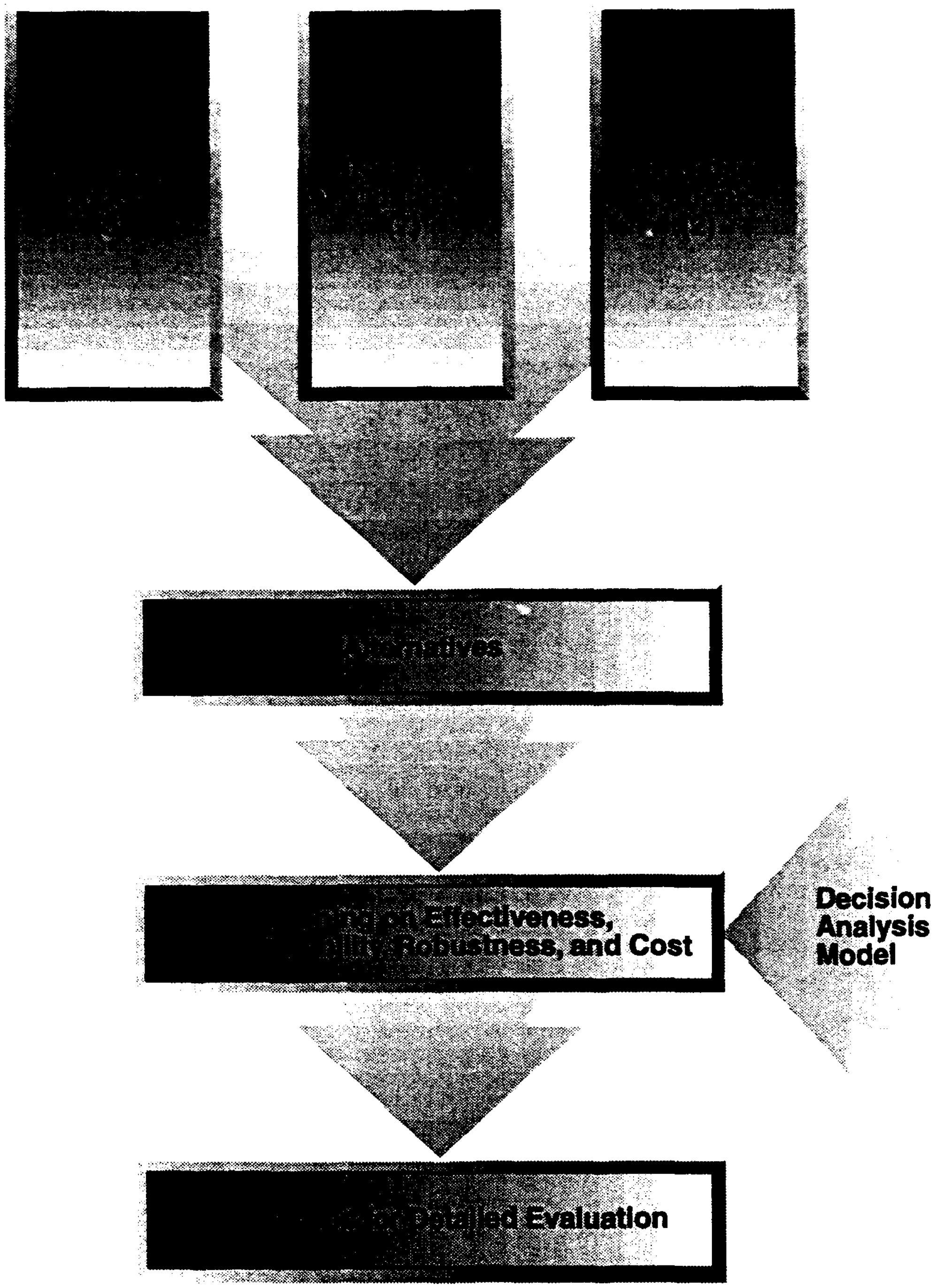


FIGURE 12-1
PROCESS FOR ASSEMBLING AND SCREENING ALTERNATIVES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_41

CH2M HILL

There are four main types of information used to select a remedial action alternative:

- Strategic options—the options, such as selecting an extraction network design, from which the decisionmaker may choose
- Uncertainties—the uncertain state of events, such as the actual flows from the different extraction network designs, which will be resolved in the future and will influence the consequences of selecting different strategic options
- Evaluation criteria—the criteria, such as selecting the least-cost solution, which the decisionmaker uses to evaluate the strategic options
- Assumptions—the rules that guide the structure of the decision, such as the requirement to select a treatment technology alternative before knowing what the future groundwater flow rates will be, and the values of certain variables, such as the probable range of flow rates for the extraction network design.

These four types of information are modeled in the decision analysis process, which is described in Appendix H. Two tools commonly used in decision analysis are influence diagrams and decision trees. Influence diagrams depict the relationships between decisions, uncertainties, and evaluation criteria. On the basis of this information, a decision tree is drawn that depicts the logical structure of the problem. This decision tree can be "solved" to yield an optimal strategy for accomplishing the objectives, taking into account the uncertainties involved. Drawing the influence diagram and decision tree and calculating all of the outcomes depicted by the decision tree were performed using the Decision Program Language (DPL) model developed by Applied Decision Analysis (ADA) in Menlo Park, California.

12.2 Screening of Alternatives

The screening of alternatives is performed by use of the decision analysis model and also by applying screening criteria to develop remedial alternatives. The screening criteria recommended by the NCP in Section 300.430(e)(7)(i-iii) are effectiveness, implementability, and cost. The McClellan program has added an additional criterion, robustness, to assess the alternatives' ability to function over the range of potential conditions, not just the conditions known today. Consideration of robustness is particularly important when selecting a remedy prior to full characterization of the extent of contamination or complete knowledge of the remedy's effectiveness. Even though this feasibility study supports an interim remedy, it is desirable that the interim remedy be capable of expanding to the full remedy once the extent of contamination is known. The extraction, treatment, and end-use options have been screened as separate components using these criteria; therefore, each component is acceptable on its own. However, it is necessary to pick the most cost-effective alternatives for the detailed evaluation. Applying the screening criteria to the assembled alternatives allows the selection of the most cost-effective alternatives, avoids the possibility of mismatched components, and recognizes the advantages of the synergy between some of the components.

12.2.1 Screening Criteria

The purpose of screening alternatives during the remedy selection process is to implement remedies that eliminate, reduce, or control risks to human health and the environment. Section 300.430(a)(iii)(A-F) of the NCP lists the expectations that EPA generally considers in developing appropriate remedial alternatives. These expectations apply to remedies selected for McClellan AFB and include:

(A) EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.

(B) EPA expects to use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.

(C) EPA expects to use a combination of methods, as appropriate, to achieve protection of human health and the environment. In appropriate site situations, treatment of the principal threats posed by a site, with priority placed on treating waste that is liquid, highly toxic, or highly mobile, will be combined with engineering controls (such as containment) and institutional controls, as appropriate, for treatment residuals and untreated waste.

(D) EPA expects to use institutional controls such as water use and deed restrictions to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants. Institutional controls may be used during the conduct of the RI/FS and implementation of the remedial action and, where necessary, as a component of the completed remedy. The use of institutional controls shall not substitute for active response measures (e.g., treatment and/or containment of source material, restoration of groundwaters to their beneficial uses) as the sole remedy unless such active measures are determined not to be practicable, based on the balancing of trade-offs among alternatives that is conducted during the selection of remedy.

(E) EPA expects to consider using innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies.

(F) EPA expects to return usable groundwaters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction.

The alternatives screening criteria for McClellan AFB's Groundwater OU RI/FS are presented as follows:

(1) *Effectiveness.* This criterion focuses on the degree to which an alternative reduces toxicity, mobility, or volume through treatment, minimizes residual risks and affords long-term protection, complies with ARARs, minimizes short-term impacts, and how quickly it achieves protection. Alternatives providing significantly less effectiveness than other, more promising alternatives may be eliminated. Alternatives that do not provide adequate protection of human health and the environment shall be eliminated from further consideration.

(2) *Implementability.* This criterion focuses on the technical feasibility and availability of the technologies each alternative would employ and the administrative feasibility of implementing the alternative. Alternatives that are technically or administratively infeasible or that would require equipment, specialists, or facilities that are not available within a reasonable period of time may be eliminated from further consideration.

(3) *Cost.* The cost of construction and any long-term costs to operate and maintain the alternatives shall be considered. Costs that are grossly excessive compared to the overall effectiveness of alternatives may be considered as one of several factors used to eliminate alternatives. Alternatives providing effectiveness and implementability similar to that of another alternative by employing a similar method of treatment or engineering control, but at greater cost, may be eliminated.

(4) *Robustness.* This criterion is a measure of an alternative's ability to not only function over the range of conditions known today, but also be implemented under unknown, yet probable, conditions in the future. An alternative that meets the other screening criteria as well as other alternatives, but is not as flexible under a probable range of uncertainties, can be eliminated from consideration.

12.2.2 Results of the Screening

The results from the decision analysis model (Appendix H) and the technology screening (Appendix I) were used to assemble, screen, and choose six alternatives that remove mass and reduce contaminant concentrations in a target volume of groundwater to the required level. The alternatives chosen are made up of extraction, treatment, and end-use systems. Various combinations of three target volumes, four treatment technologies, and two end-use systems differentiate the six alternatives as shown in Table 12-1.

Table 12-1
Alternatives for GW OU FS

Alternative	Extraction Target Volume	Extraction Flow Rate (gpm)		Treatment System[a]		End-Use System[b]
	Basewide	East	West	East	West	Basewide
1	MCL	460	630	AS/CatOx/ LGAC	GWTP	System 2
2	10^{-6} Cancer Risk	590	820	AS/CatOx/ LGAC	GWTP (w/expansion)	System 2
3	Back-ground	710	1,300	AS/CatOx/ LGAC	GWTP (w/expansion)	System 2
4	10^{-6} Cancer Risk	590	820	AS/VGAC/ LGAC	GWTP (w/expansion)	System 2
5	10^{-6} Cancer Risk	590	820	AS/CatOx/ LGAC	GWTP (w/expansion)	System 1
6	10^{-6} Cancer Risk	590	820	LGAC	GWTP (w/expansion)	System 2

[a]Treatment System Definitions: AS = Air Stripping; CatOx = Catalytic Oxidation Offgas Treatment; LGAC = Liquid-Phase Granular Activated Carbon; and VGAC = Vapor-Phase Granular Activated Carbon Offgas Treatment.
[b]End-Use System Definitions: System 1 = Water Utilities (primary); Greywater (secondary, west only); and Magpie Creek (backup). System 2 = Injection (primary); Greywater (secondary, west only); and Magpie Creek (backup and contingency).

McClellan AFB was divided into an "east" and a "west" side (with the runway representing the dividing line) for purposes of screening alternatives. This approach took into account the existing GWTP located on the west side of the Base. The basis for this approach was the cost of treating water on the east side of the Base (constructing and operating a new treatment plant) is less than conveying the water to the existing GWTP. The groundwater extracted from underneath OUs B, C, and D would be piped to the GWTP, while groundwater under OU A would be piped to a new plant constructed on the east side of the Base.

The decision analysis model considered four different cleanup strategies in screening remedial action alternatives. These cleanup strategies were reflected in each of the target volumes:

- Hot spots are delineated by a concentration of 500 $\mu g/l$ of TCE.
- MCL is delineated by a concentration of 5 $\mu g/l$ TCE. (The MCL target volume was determined largely by the extent of TCE in groundwater.)
- Health risk is delineated by a 1 x 10^{-6} increased lifetime cancer risk.
- Background is delineated by a concentration of 0.5 $\mu g/l$ of any of the chemicals of potential concern.

The hot spot target volume is not intended to specifically represent a remedial action objective, but was considered to evaluate the relationship between contaminant mass removal and cost. Isolation of the hot spot is integral to each groundwater containment option.

The results from the technology screening show that LGAC and air stripping would be the preferred groundwater treatment technologies for the east side of the Base. This is consistent with the decision analysis model results, which select LGAC as the most viable treatment technology in the remedial action strategy for the MCL, health risk, and background target volumes. Air stripping and LGAC are clearly superior to any of the advanced oxidation technologies based on cost, as can be seen from inspecting the cost curves for each technology in Appendix I. Because of the low net present cost of the current GWTP, the optimal strategy on the west side is to use the GWTP regardless of the target volume. The next best alternative is to use air stripping as a treatment technology on the west side.

Use of air stripping as a groundwater treatment technology would require an offgas treatment technology. Three offgas treatment technologies were evaluated in the technology screening: CatOx, thermal incineration, and VGAC. The technology screening did not show any of these three technologies to be clearly superior. However, thermal incineration and CatOx could have air quality impact and community acceptance problems. These were reflected in the decision analysis model uncertainty of "added permit complexity."

Two end-use systems for treated effluent were defined, as discussed in Chapter 11. The primary end uses were discharge to water utilities (System 1) or injection into groundwater (System 2). In general, decision analysis indicated that discharge to water utilities was preferred over injection in the remedial action strategies. If additional data show no difference in water quality between the treated water and injection aquifer, then injection would be preferred. The water quality from the potential remedial action treatment facilities can be estimated; however, water quality data are not available for the deeper aquifers where the water would be injected. The decision analysis model was used to calculate the value of additional data collection to resolve uncertainties in differences in water quality between treated effluent and injection aquifer. McClellan AFB is proceeding with obtaining water quality information in the zones where injection could take place.

The six alternatives were chosen to clearly differentiate the combination of extraction, treatment, and end-use options. By holding two of the components constant, testing of the possible values of the third component is straightforward.

Alternatives 1 through 3 list the same treatment and end-use systems, but are applied to different target volumes. Target volumes treated by Alternatives 1 through 3 are MCL, risk, and background, respectively. Comparison of these three alternatives will identify the different costs and benefits of the three potential target volumes.

Alternative 4 treats the same target volume and has the same end-use system as Alternative 2, but uses VGAC instead of CatOx in the treatment system. This is in case air emissions exceed permit requirements. Comparison of these two alternatives will identify the difference in costs and benefits of the two most viable offgas treatment options.

Alternative 5 treats the risk target volume, as does Alternative 2, but uses a different end-use system. Alternative 5 delivers the treated water to local utilities, while Alternative 2 injects treated water back into the aquifer. Comparison of these two alternatives will identify the differences in costs and benefits of the two most viable water end-use options.

Alternatives 2 and 6 treat the risk target volume and use the same end-use system, with the difference being in the treatment systems. Alternative 6, treatment only, consists of water polishing using LGAC treatment. Comparison of these two alternatives will identify the differences in costs and benefits of the two most viable treatment options.

A detailed evaluation of the six alternatives is presented in Chapter 13, Implementation Plans and Detailed Evaluation.

Chapter 13
Implementation Plans and Detailed Evaluation

Implementation plans for each of the six remedial action alternatives have been prepared and are summarized in this chapter. Each of the alternatives is evaluated against the evaluation criteria and compared to the other alternatives. The role of the detailed evaluation in the alternative selection process is illustrated in Figure 13-1. The preferred remedy is presented following the detailed evaluation.

The six alternatives which were selected allow comparison of each component as if it were part of a complete remedy. Alternatives 1, 2, and 3 each have different target volumes (MCLs, 10^{-6} cancer risk, and background, respectively), but consistent treatment and end-use options. This allows the comparison of the relative difference of the various target volumes under each of the evaluation criteria. Alternatives 2, 4, and 6 each have different treatment options, but consistent target volumes and end uses to allow the comparison of the three most promising treatment options. Alternatives 2 and 5 have different end-use options, but consistent target volumes and treatment options to allow the comparison of the two end-use options.

13.1 Implementation Plans

An implementation plan has been developed for each alternative. The objective of the plan is to provide a workable and efficient approach and schedule for implementing the remedial action.

The implementation plans for each alternative are illustrated in Figures 13-2 through 13-7. The central focus of the plan is the base map of McClellan AFB, which presents for each alternative the appropriate target volumes by zone, the proposed collection piping, end-use piping, and the proposed east treatment plant. Also presented for each alternative are illustrations depicting the current treatment processes used by the west treatment plant and those processes proposed for the east treatment plant; a table of statistics; and a table of the critical milestones for completion of the remedial action. The locations of the extraction and monitoring wells are presented in Appendix E and in Chapter 8.

The components of each alternative have been detailed in the previous chapters. The following discussion will focus on the scheduling and cost information developed for each alternative.

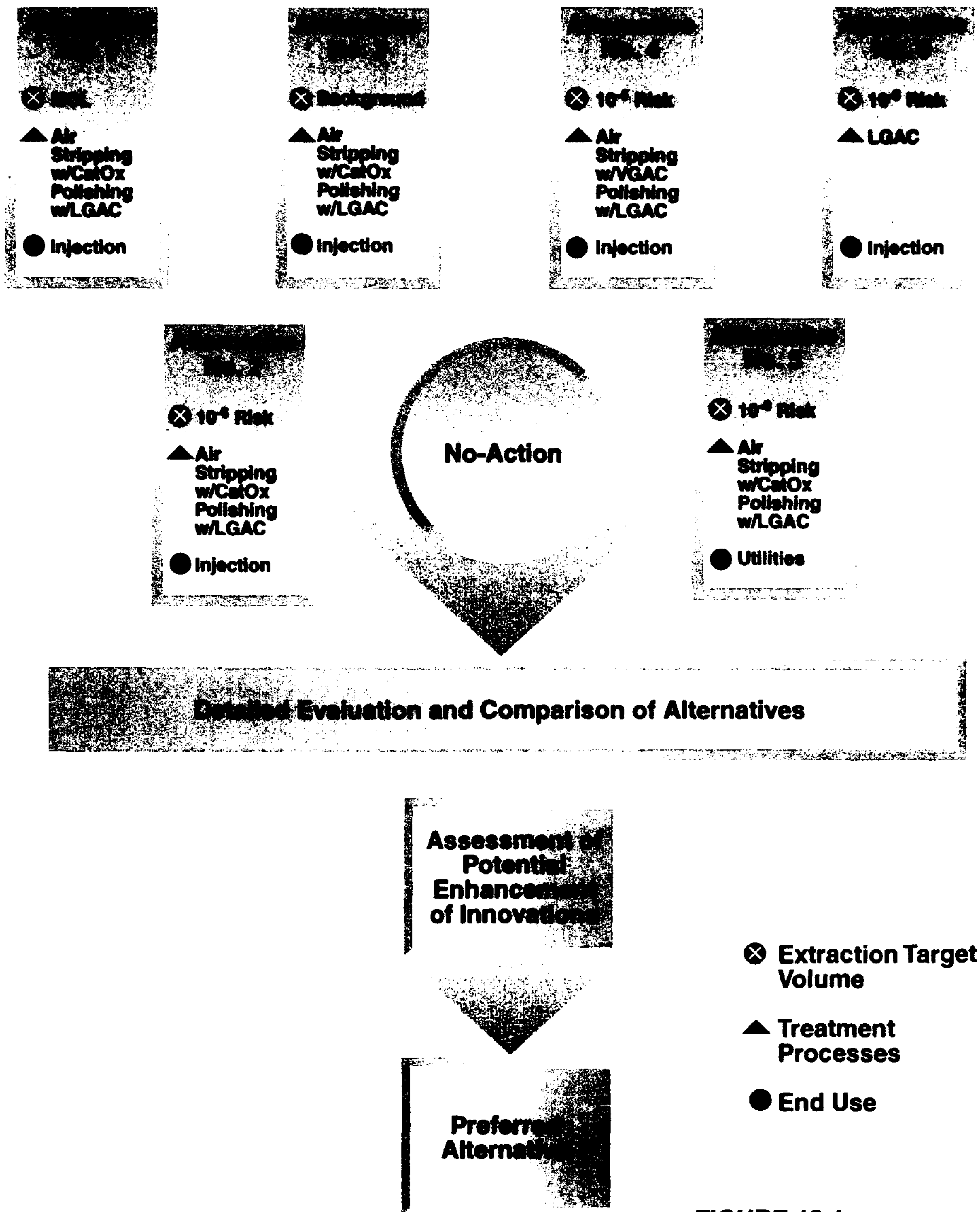
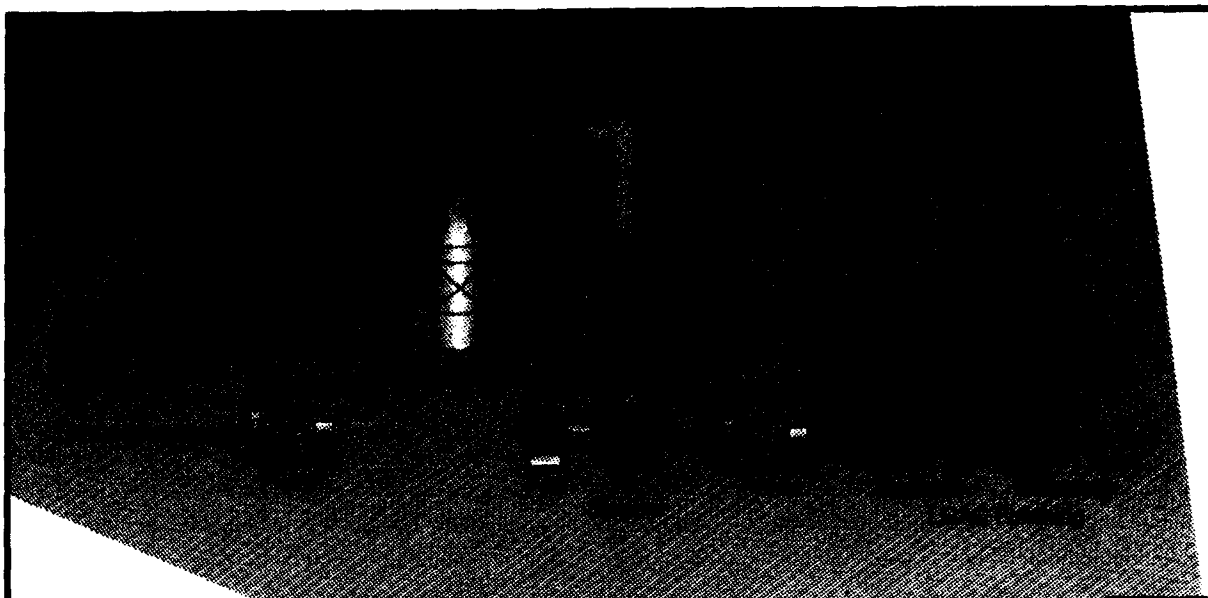
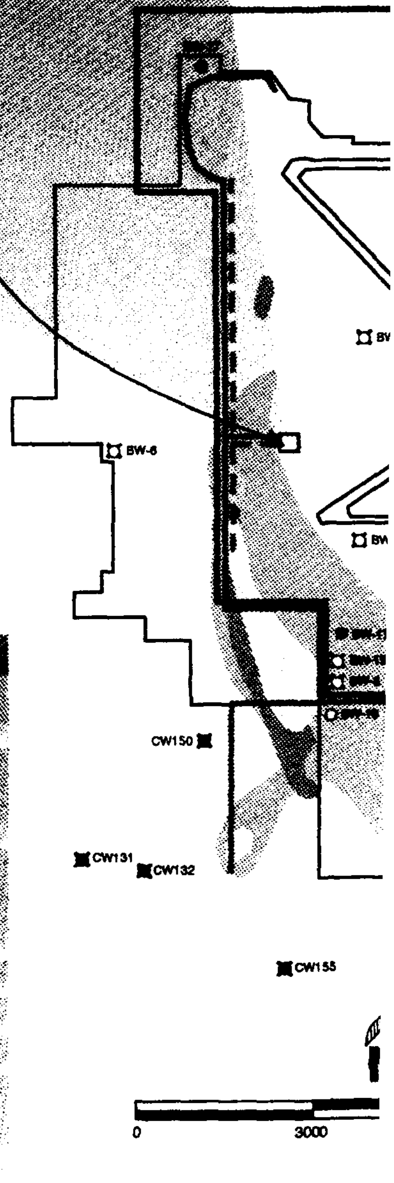


FIGURE 13-1
ALTERNATIVE SELECTION DECISION PROCESS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_13





STATISTICS

Target Volume: MCL			
Extraction System	A	B	C
Monitoring Wells			
OU A	25	10	3
OU B/C	23	9	6
OU D	1	0	0
Extraction Wells			
OU A	50	10	1
OU B/C	33	10	4
OU D	9	6	0

	Diameter	Length
Collection Piping	2" - 8"	90,100 ft

Treatment System	West	East
Capacity (gpm)	700	500
Influent Flow (gpm)	630	460
Performance	0.5 ppb for all organics	

End-Use System	West	East
To Utilities (gpm)	—	—
To Greywater (gpm)	200	—
To Magpie Creek (Emergency Only -gpm)	1000	500
To Injection (gpm)	630	460

	Diameter	Length
Piping	6" - 10"	10,700 ft

MILESTONES

	Early Date	Late Date
Monitoring Wells Completed		
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Apr. [illegible]
Extraction Wells Completed		
Oilbase	Jan. [illegible]	July [illegible]
Hot Spots	Apr. [illegible]	July [illegible]
Onbase	Sept. [illegible]	Apr. [illegible]
Collection Piping Functional	April [illegible]	Oct. [illegible]
Treatment Systems Functional	April [illegible]	Oct. [illegible]
End-Use Systems Functional	April [illegible]	Oct. [illegible]
Containment Achieved		
Offbase	Jan. [illegible]	July [illegible]
Onbase	Apr. [illegible]	Oct. [illegible]
Remedial Objectives Achieved	2110	

1

RDD1454_90

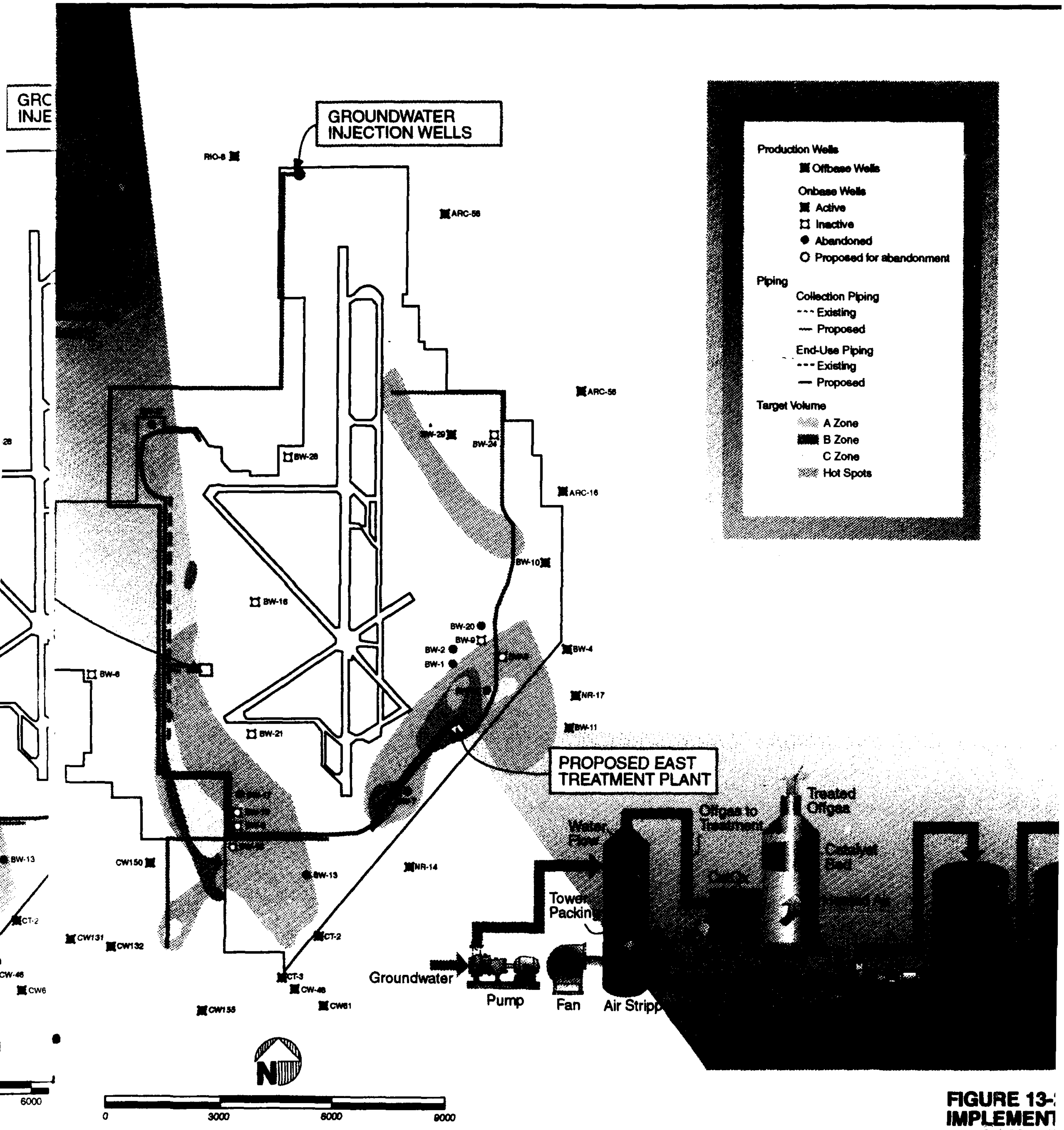


FIGURE 13-
IMPLEMENT
ALTERNATI
GROUNDWATER
McCLELLAN AIR
SACRAMENTO, C

2

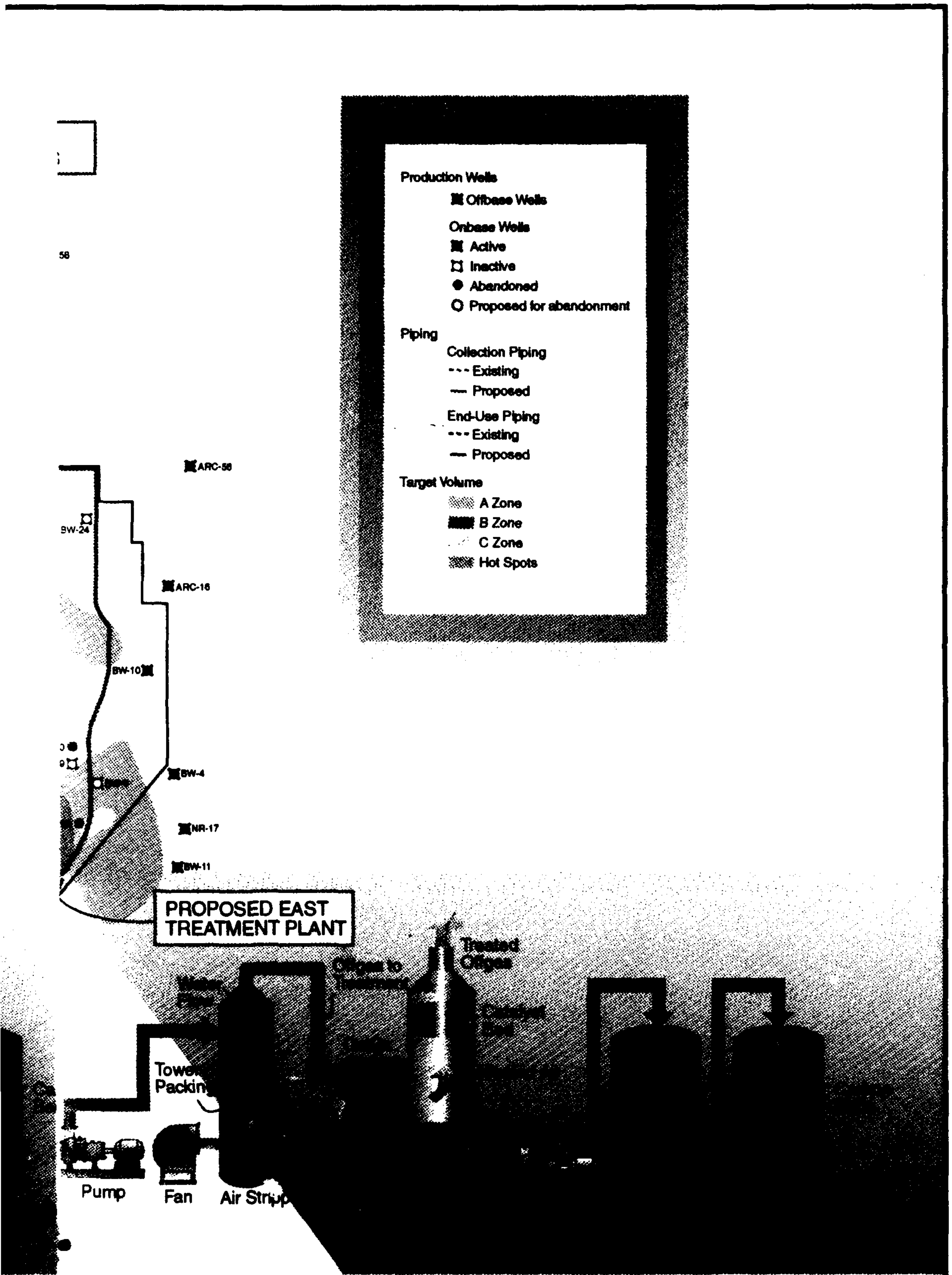
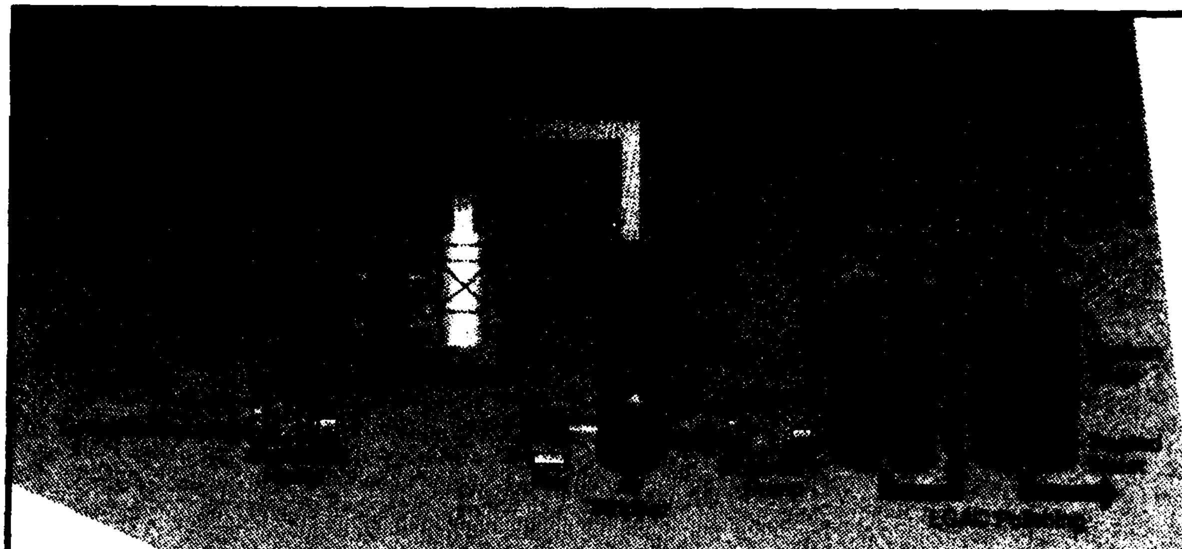


FIGURE 13-2
IMPLEMENTATION PLAN
ALTERNATIVE 1
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

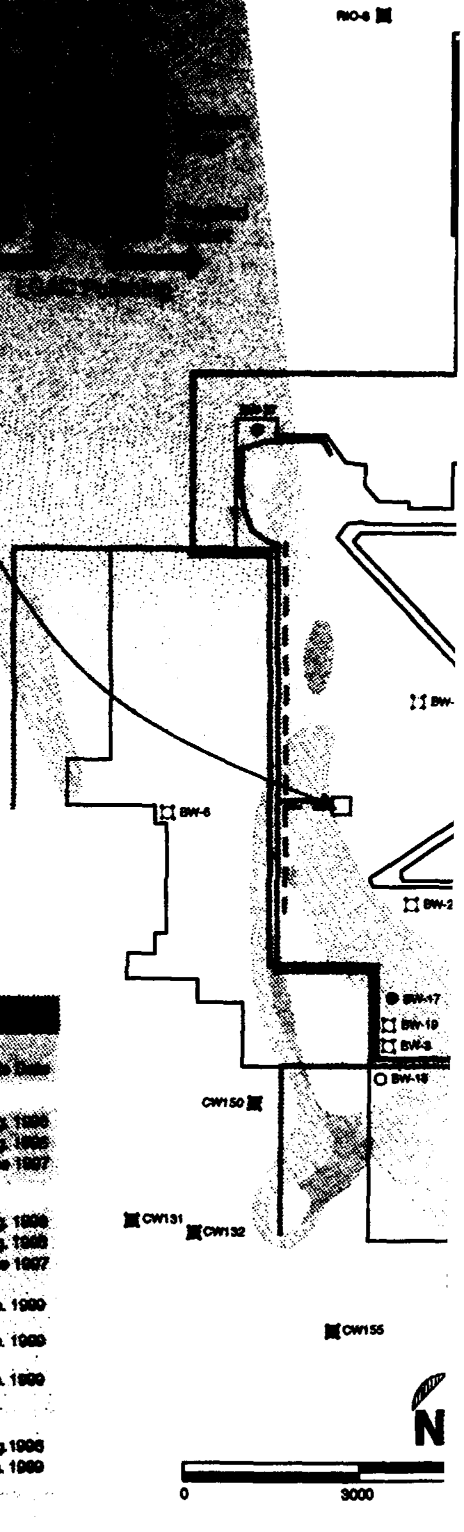
CH2M HILL



[illegible]			
[illegible]			
Extraction System	A	B	C
Monitoring Wells			
OU A	32	14	9
OU B/C	32	10	8
OU D	1	1	0
Extraction Wells			
OU A	55	11	4
OU B/C	40	12	5
OU D	11	7	0
	Diameter	**Length**	
Collection Piping	2" - 12"	102,300 ft	
Treatment System	**West**	**East**	
Capacity (gpm)	900	660	
Influent Flow (gpm)	820	590	
Performance	0.5 ppb for all organics		
End-Use System	**West**	**East**	
To Utilities (gpm)	—	—	
To Greywater (gpm)	200	—	
To Magpie Creek (Emergency Only -gpm)	1100	500	
To Injection (gpm)	820	590	
	Diameter	**Length**	
Piping	8" - 12"	10,700 ft	

MILESTONES

	Early Date	Late Date
Monitoring Wells Completed		
Offbase	Jan. 1996	Aug. 1996
Hot Spots	Jan. 1996	Aug. 1996
Onbase	Nov. 1996	June 1997
Extraction Wells Completed		
Offbase	Jan. 1996	Aug. 1996
Hot Spots	Jan. 1996	Aug. 1996
Onbase	Nov. 1996	June 1997
Collection Piping Functional	July 1998	Jan. 1999
Treatment Systems Functional	July 1998	Jan. 1999
End-Use Systems Functional	July 1998	Jan. 1999
Containment Achieved		
Offbase	Jan. 1996	Aug. 1996
Onbase	July 1998	Jan. 1999
Remedial Objectives Achieved	2160	



RDD1454_91

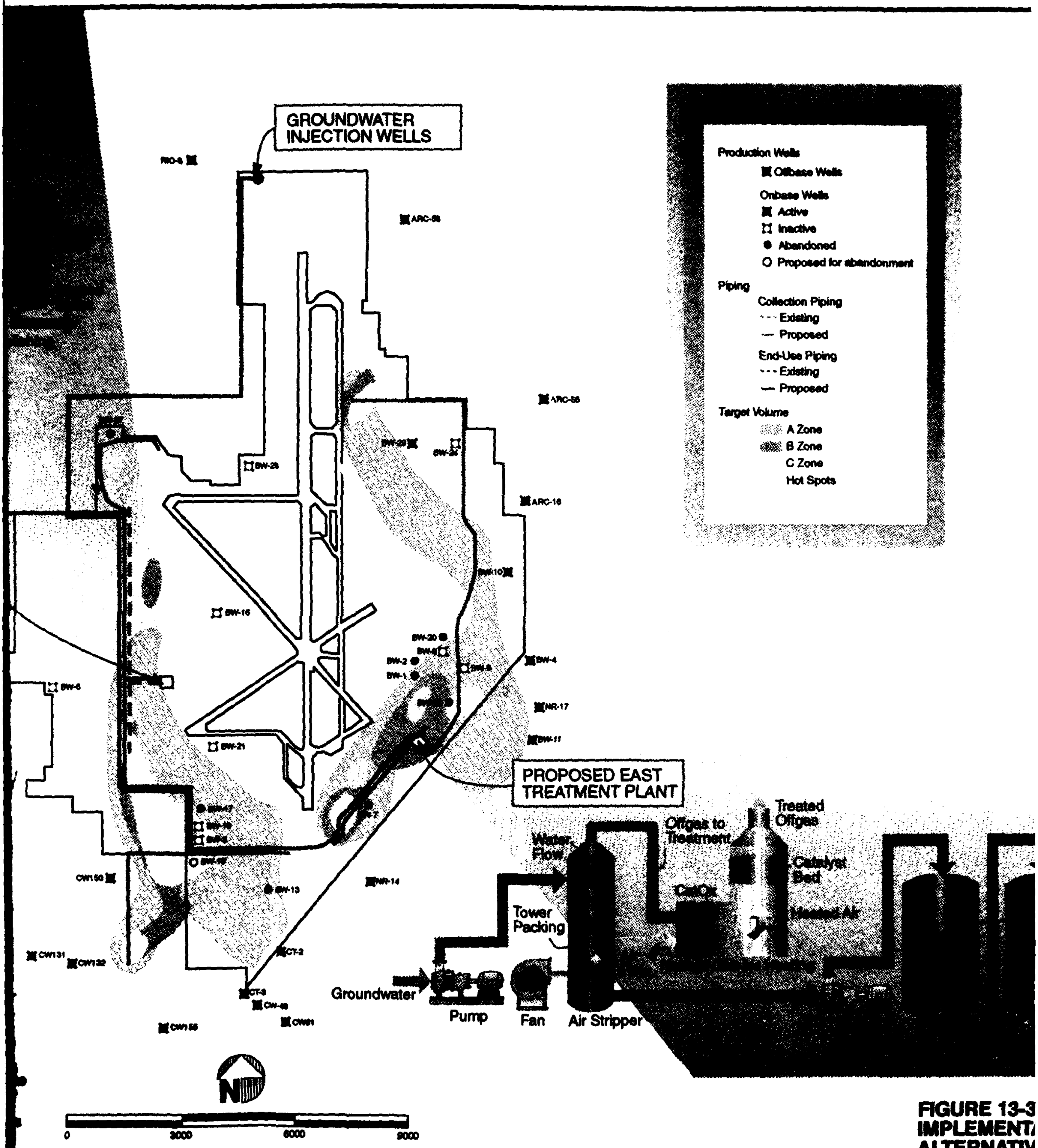


FIGURE 13-3
IMPLEMENTA
ALTERNATIV
GROUNDWATER O
McCLELLAN AIR F
SACRAMENTO, CA

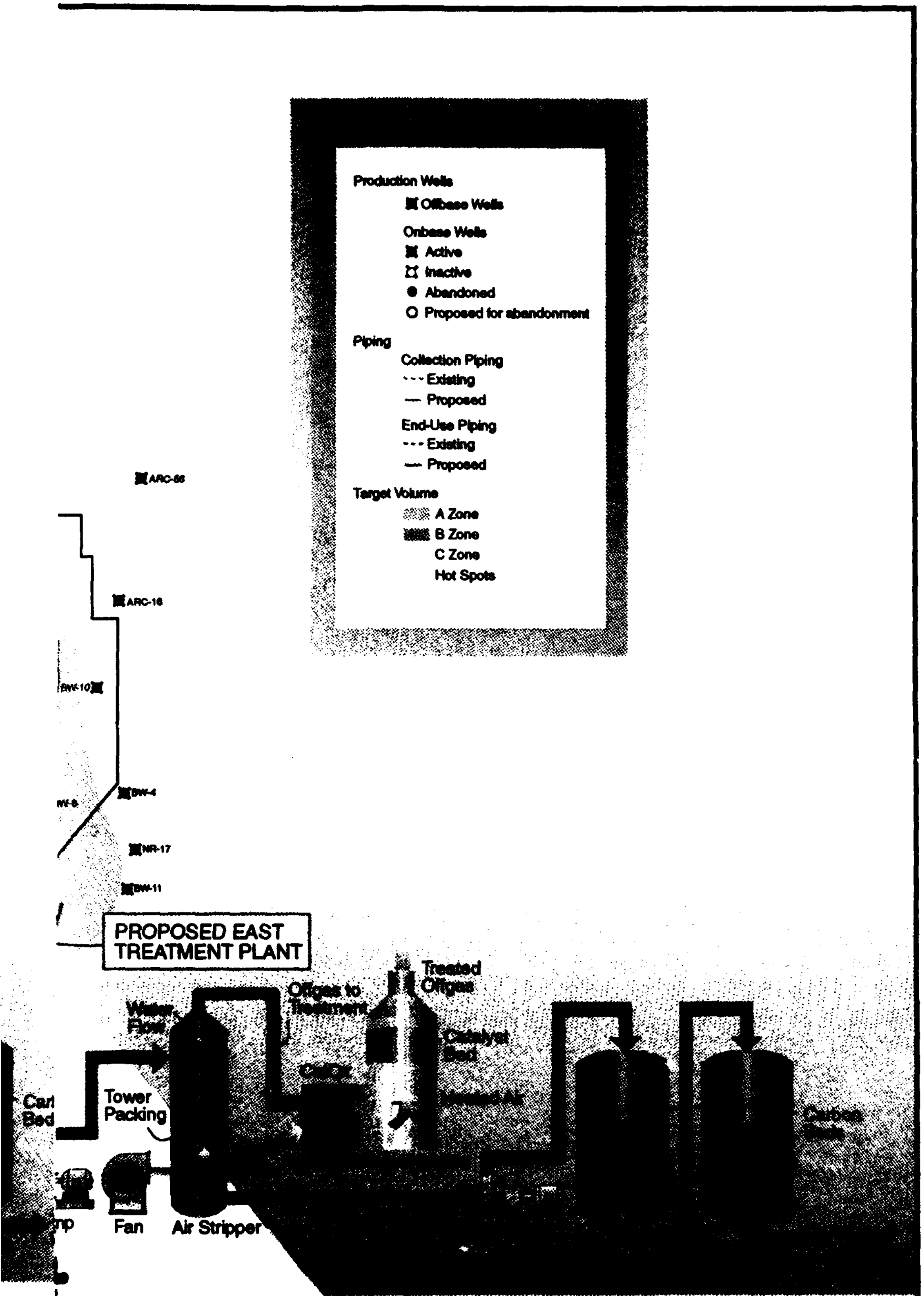
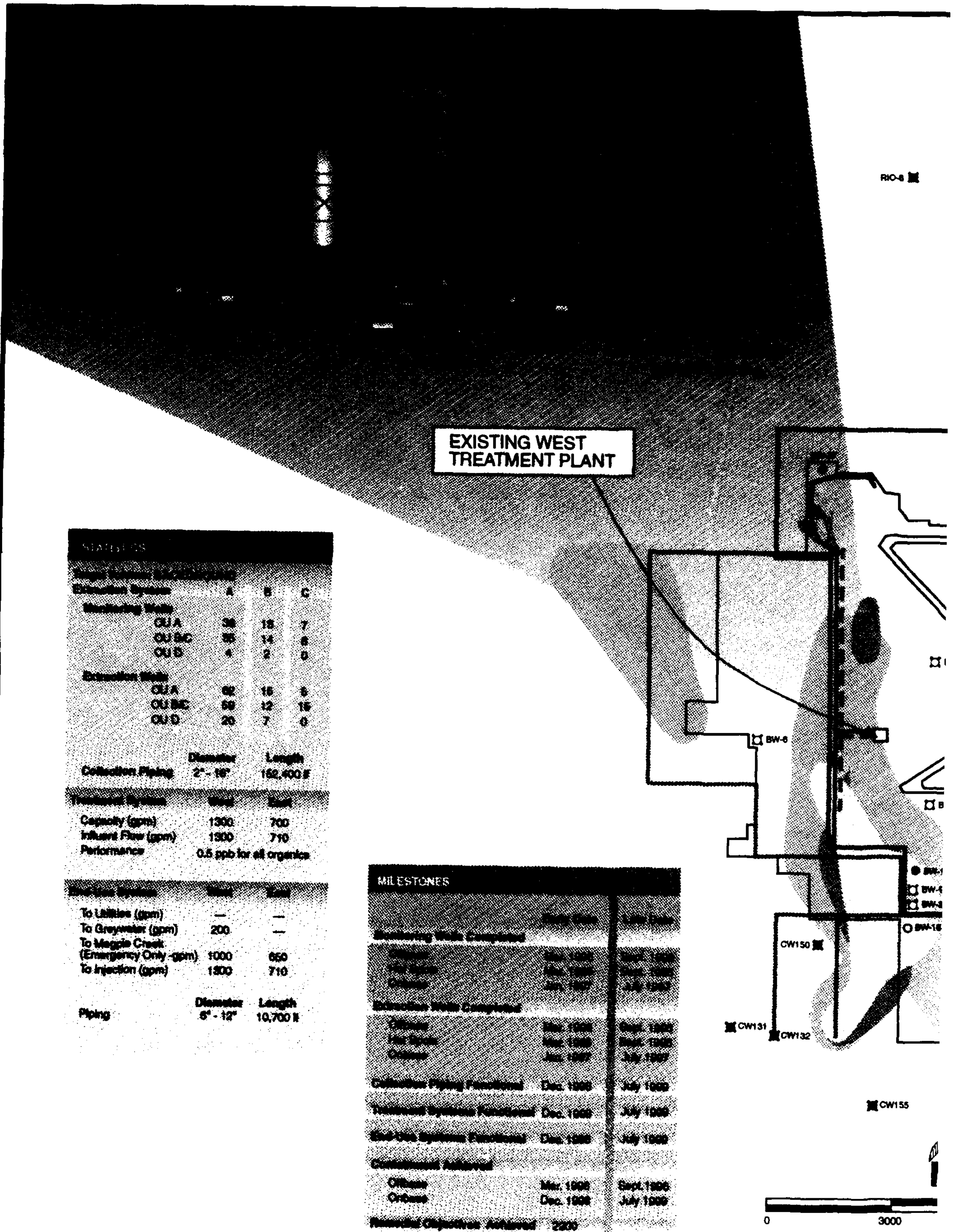


FIGURE 13-3
IMPLEMENTATION PLAN ALTERNATIVE 2
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



STATISTICS

[illegible]		A	B	C
Extraction System		A	B	C
Monitoring Wells				
	OU A	38	15	7
	OU B/C	55	14	8
	OU D	4	2	0
Extraction Wells				
	OU A	62	15	5
	OU B/C	59	12	15
	OU D	20	7	0

	Diameter	Length
Collection Piping	2" - 16"	152,400 ft

Treatment System	West	East
Capacity (gpm)	1300	700
Influent Flow (gpm)	1300	710
Performance	0.5 ppb for all organics	

End-Use System	West	East
To Utilities (gpm)	—	—
To Greywater (gpm)	200	—
To Magpie Creek (Emergency Only -gpm)	1000	650
To Injection (gpm)	1300	710

	Diameter	Length
Piping	6" - 12"	10,700 ft

MILESTONES

	Start Date	End Date
Monitoring Wells Completed		
Offbase	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
Onbase	[illegible]	[illegible]
Extraction Wells Completed		
Offbase	Mar. [illegible]	Sept. [illegible]
[illegible]	Mar. [illegible]	[illegible]
Onbase	Jan. 1997	July 1997
Collection Piping Functional	Dec. [illegible]	July [illegible]
Treatment Systems Functional	Dec. [illegible]	July [illegible]
End-Use Systems Functional	Dec. [illegible]	July [illegible]
Containment Achieved		
Offbase	Mar. [illegible]	Sept. [illegible]
Onbase	Dec. [illegible]	July [illegible]
Remedial Objectives Achieved	2200	

RDD1454_92

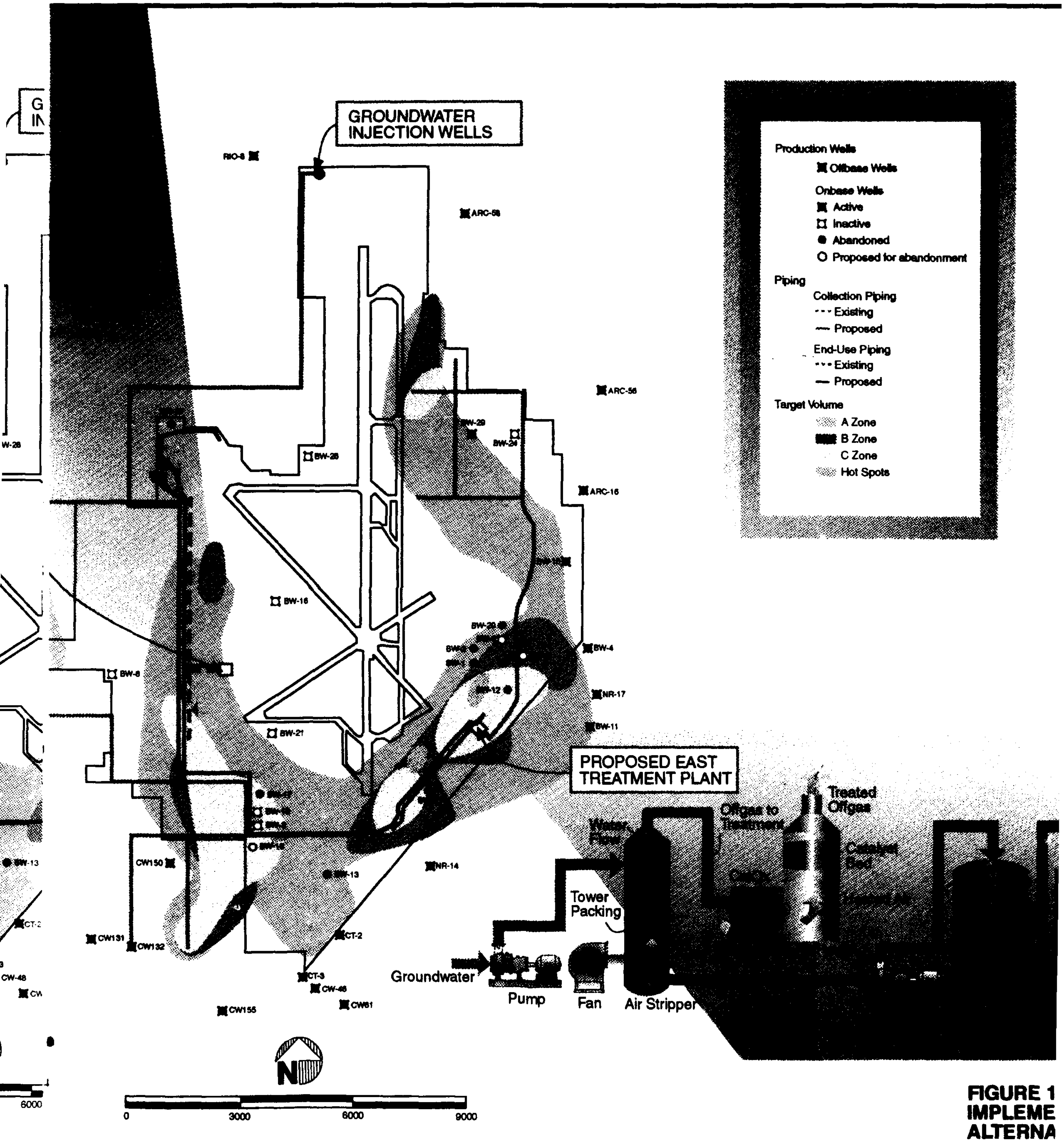


FIGURE 1
IMPLEME
ALTERNA
GROUNDWATI
McCLELLAN A
SACRAMENTC

2

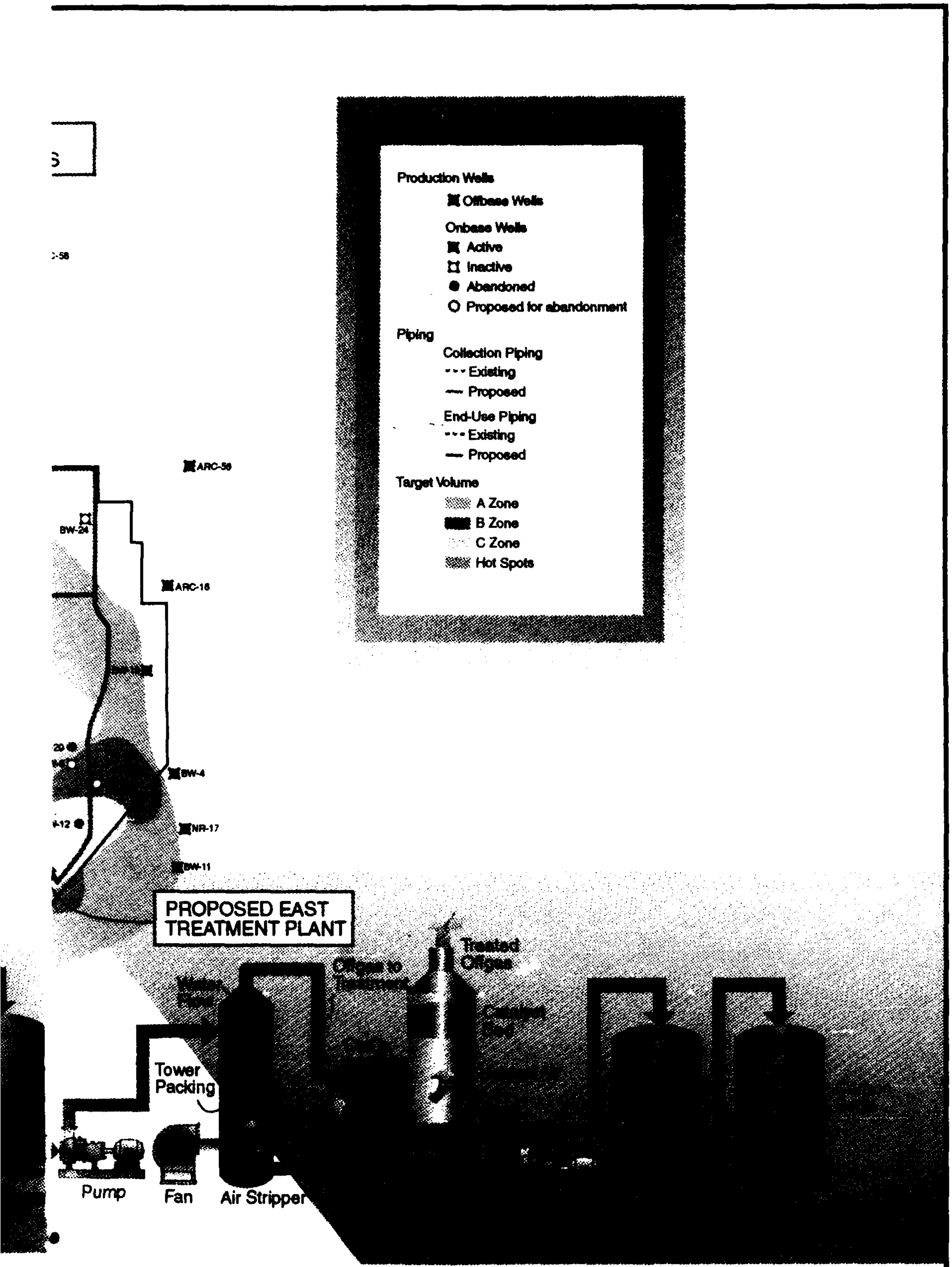
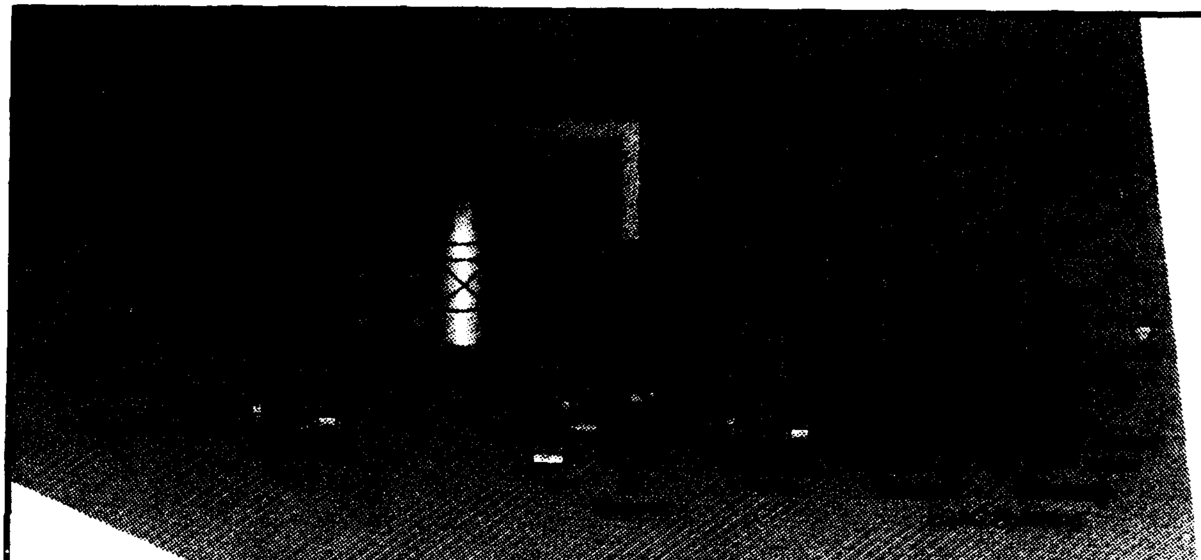
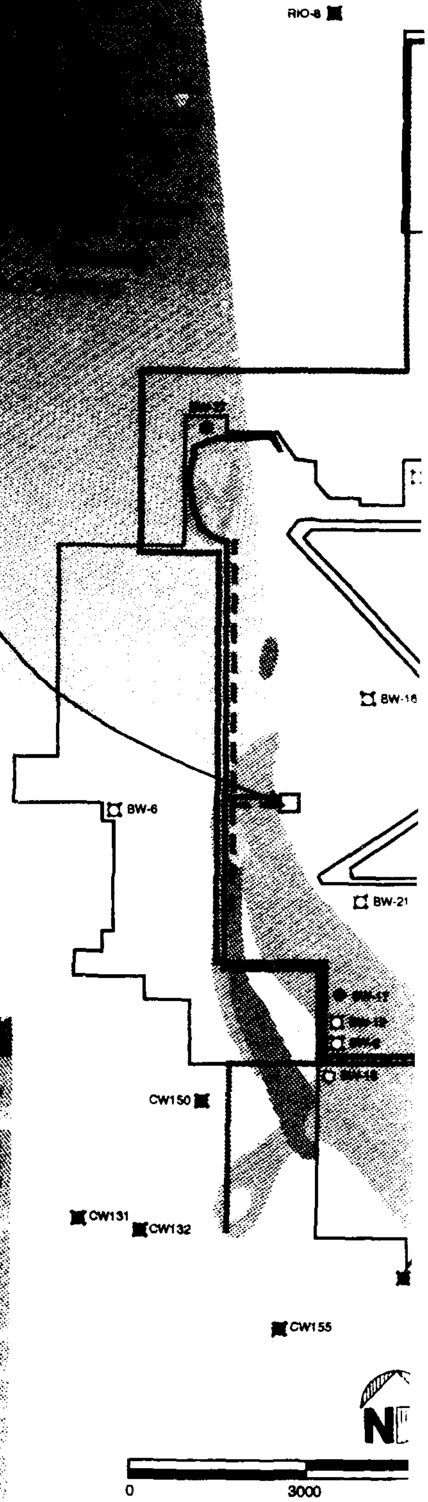


FIGURE 13-4
IMPLEMENTATION PLAN ALTERNATIVE 3
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL





STATISTICS

[illegible]		A	B	C
[illegible]				
[illegible]				
	OU A	32	14	9
	OU B/C	32	10	8
	OU D	1	1	0
[illegible]				
	OU A	55	11	4
	OU B/C	40	12	5
	OU D	11	7	0

	Diameter	Length
Collection Piping	2" - 12"	102,300 lf

[illegible]	[illegible]	[illegible]
Capacity (gpm)	900	660
Influent Flow (gpm)	820	590
Performance	0.5 ppb for all organics	

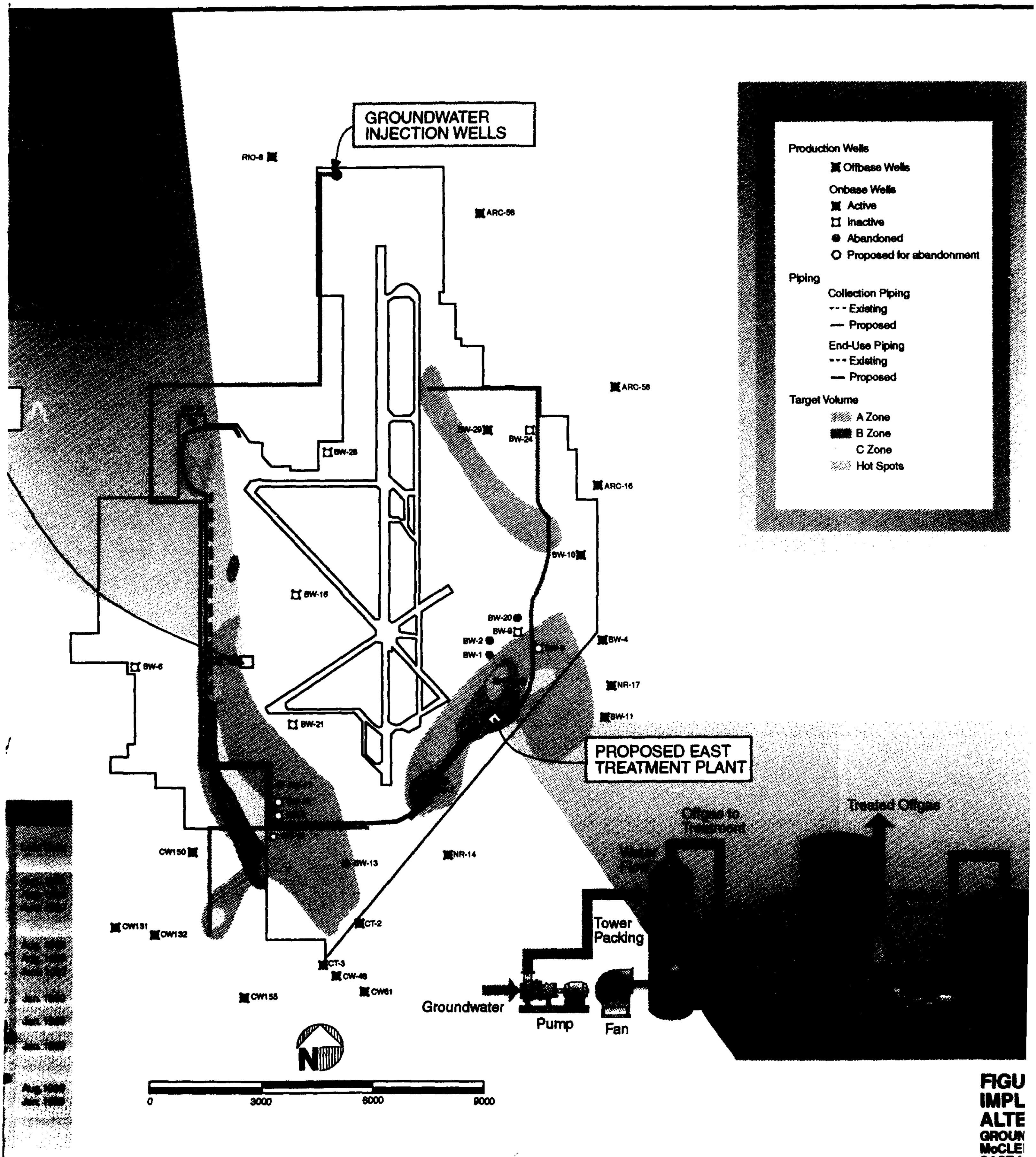
[illegible]	[illegible]	[illegible]
To Utilities (gpm)	—	—
To Greywater (gpm)	200	—
To Magpie Creek (Emergency Only -gpm)	1100	600
To Injection (gpm)	820	590

	Diameter	Length
Piping	6" - 12"	10,700 lf

MILESTONES

	[illegible]	[illegible]
[illegible]		
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]		
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]		
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	2160	

RDD1454_93



FIGU
IMPL
ALTE
GROUN
McCLE
SACRA

2

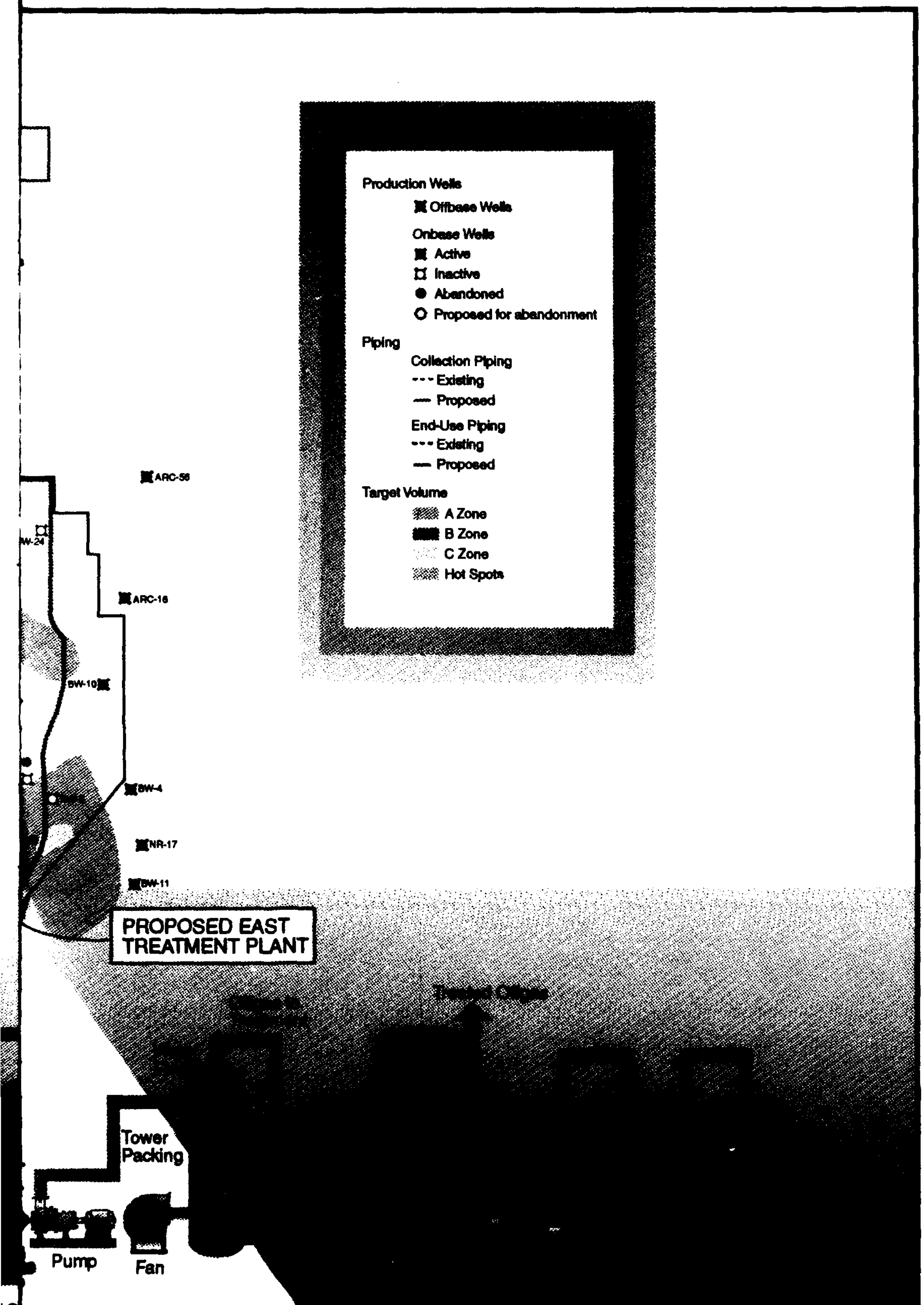
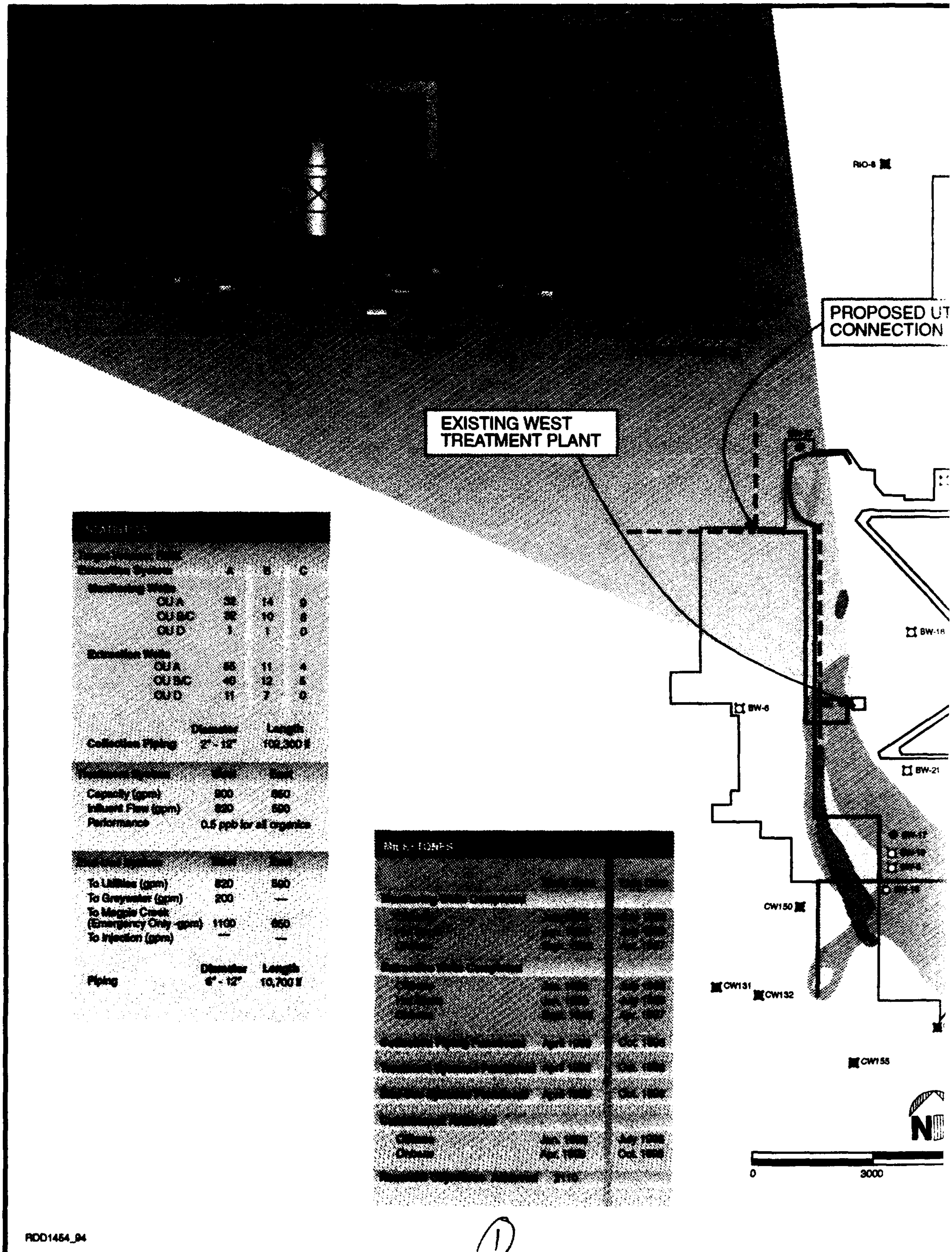


FIGURE 13-5
IMPLEMENTATION PLAN ALTERNATIVE 4
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



STATISTICS

[illegible]	A	B	C
[illegible]			
OU A	32	14	9
OU B/C	32	10	8
OU D	1	1	0
[illegible]			
OU A	65	11	4
OU B/C	40	12	5
OU D	11	7	0

	Diameter	Length
Collection Piping	2" - 12"	102,300 lf

[illegible]	[illegible]	[illegible]
Capacity (gpm)	900	650
Influent Flow (gpm)	820	590
Performance	0.5 ppb for all organics	

[illegible]	[illegible]	[illegible]
To Utilities (gpm)	820	590
To Greywater (gpm)	200	—
To Magpie Creek (Emergency Only -gpm)	1100	650
To Injection (gpm)	—	—

	Diameter	Length
Piping	6" - 12"	10,700 lf

MILESTONES

	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

RDD1454_94

1

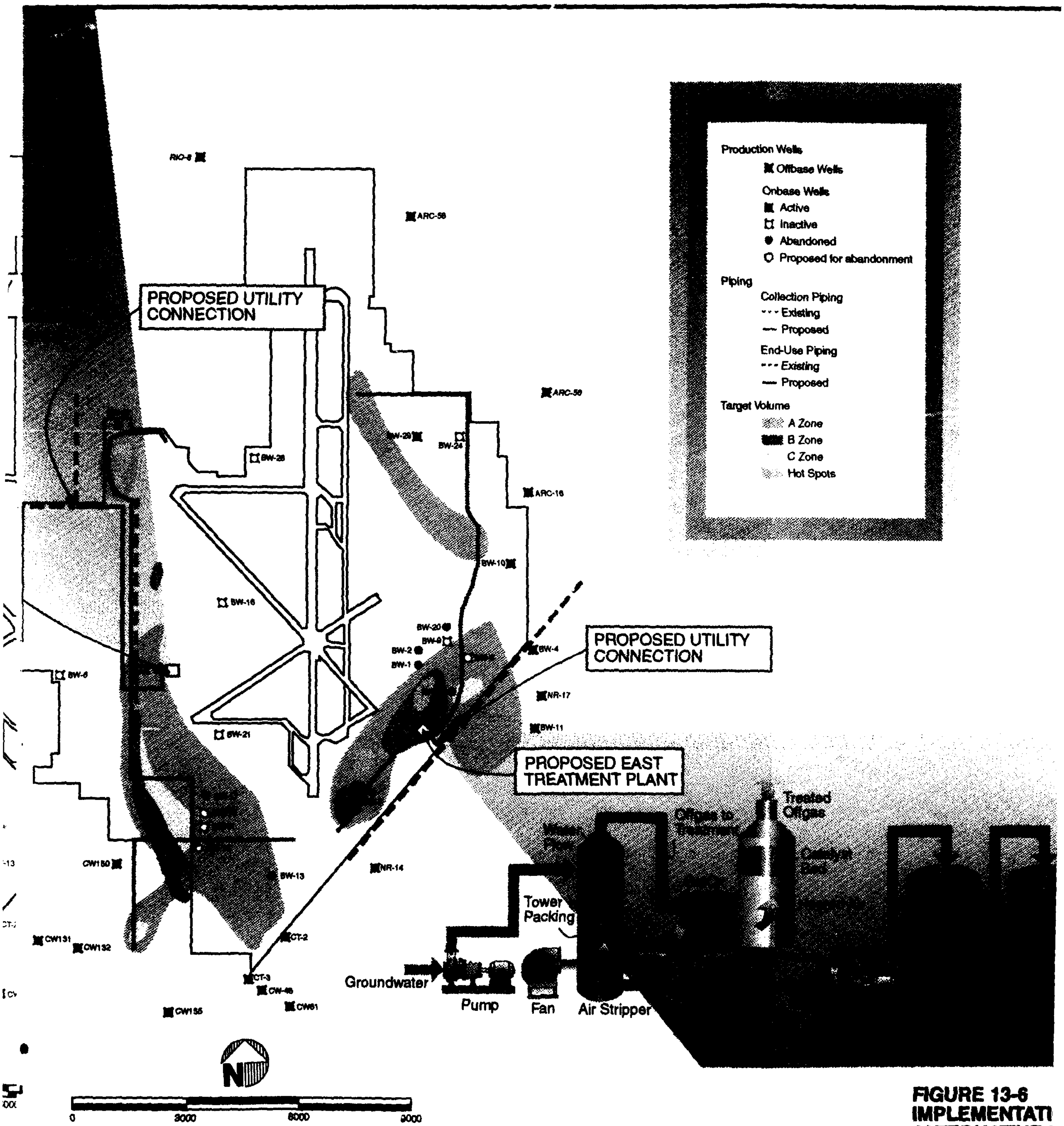


FIGURE 13-6
IMPLEMENTATI
ALTERNATIVE
GROUNDWATER OPER
McCLELLAN AIR FORC
SACRAMENTO, CALIFO

(2)

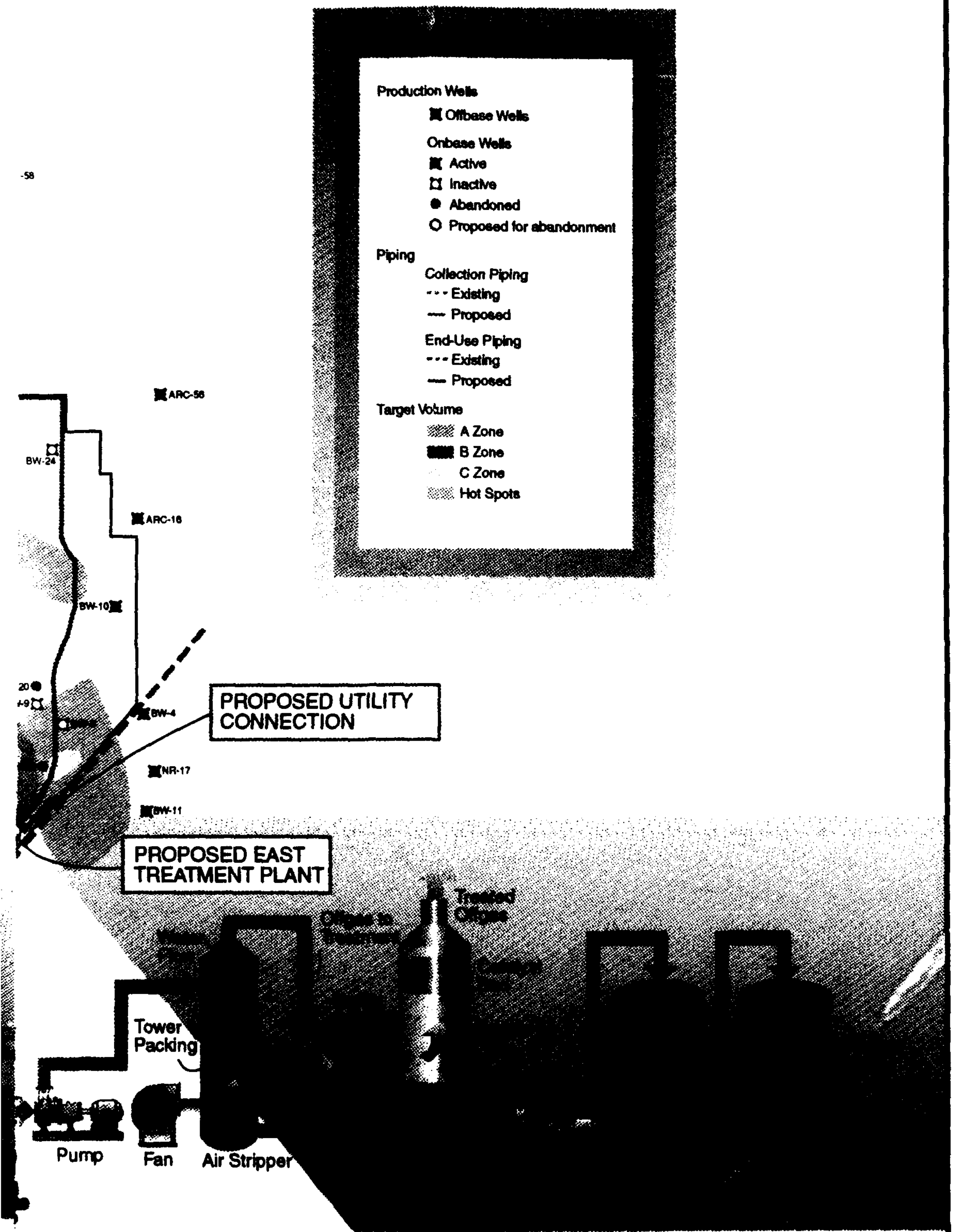
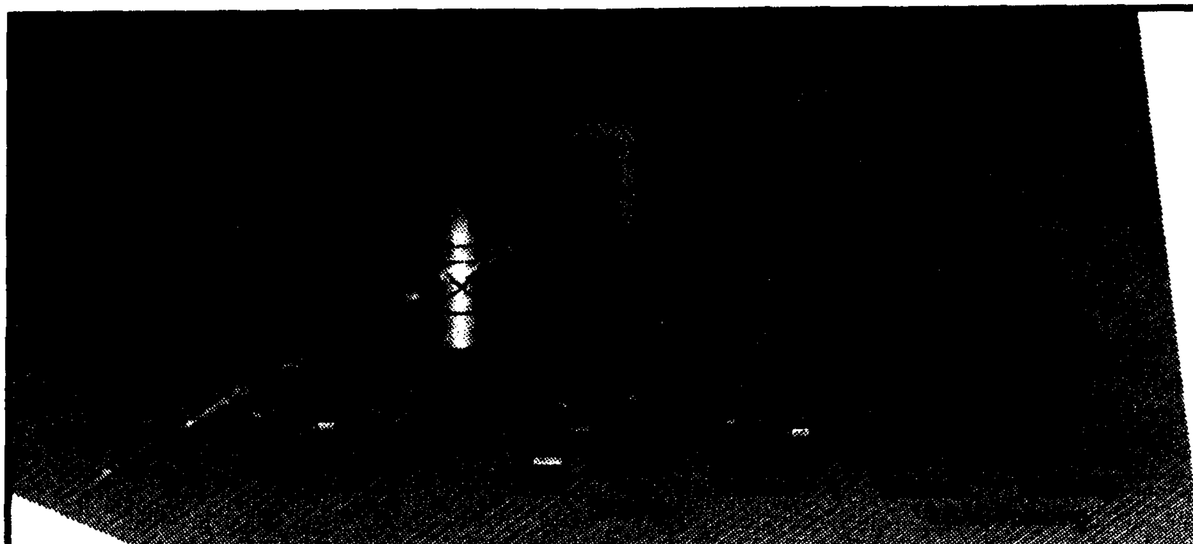
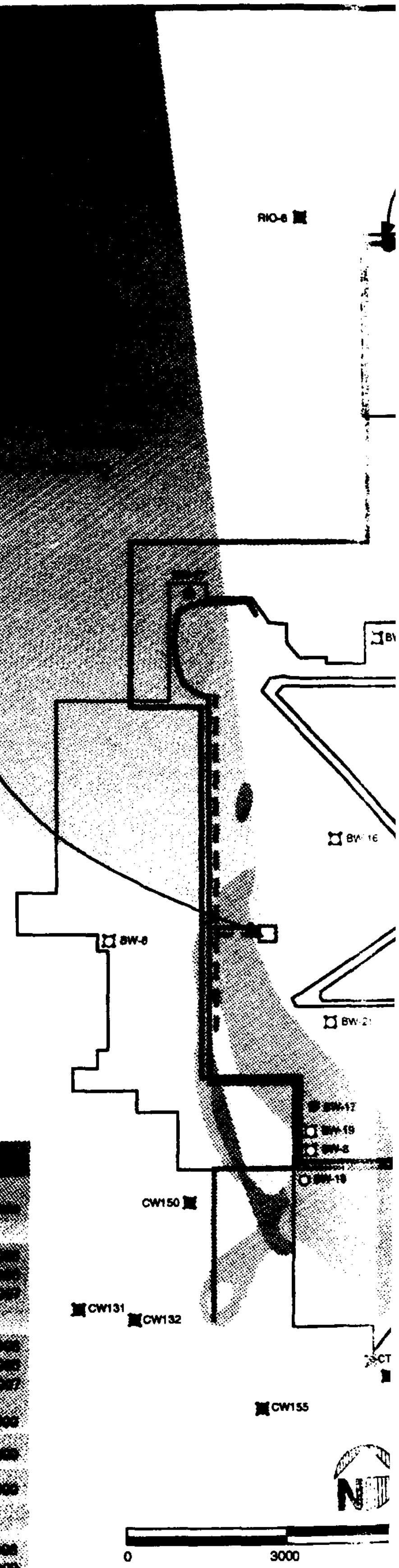


FIGURE 13-6
IMPLEMENTATION PLAN
ALTERNATIVE 5
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

3





[illegible]		A	B	C
[illegible]				
[illegible]	OU A	32	14	9
	OU B/C	32	10	8
	OU D	1	1	0
[illegible]				
	OU A	65	11	4
	OU B/C	40	12	5
	OU D	11	7	0

	Diameter	Length
Collection Piping	2" - 12"	102,300 ft

[illegible]	[illegible]	[illegible]
Capacity (gpm)	900	850
Influent Flow (gpm)	820	590
Performance	0.5 ppb for all organics	

[illegible]	[illegible]	[illegible]
To Utilities (gpm)	—	—
To Greywater (gpm)	200	—
To Magpie Creek (Emergency Only -gpm)	1000	600
To Injection (gpm)	820	590

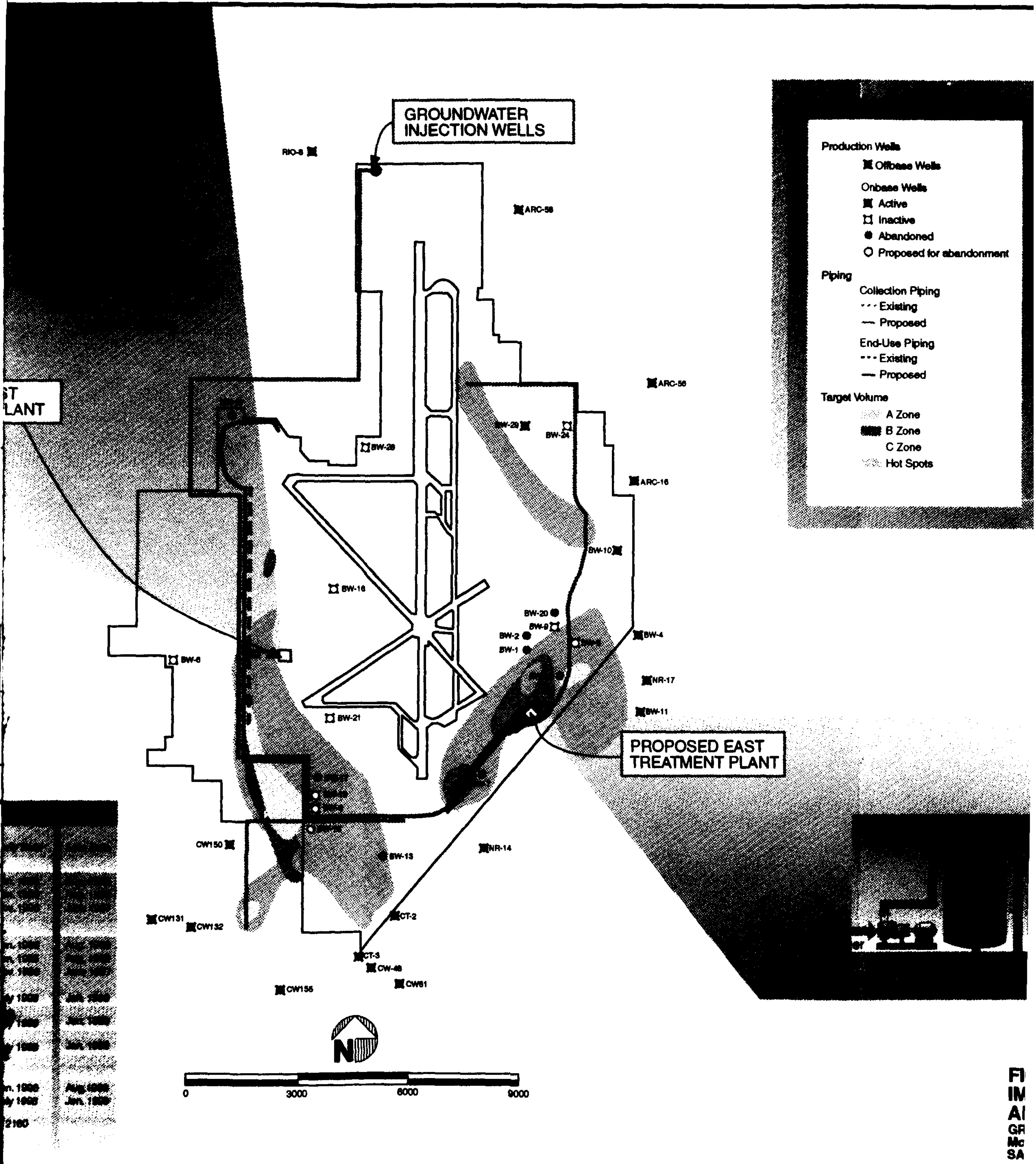
	Diameter	Length
Piping	6" - 12"	10,700 ft

MILESTONES

	[illegible]	[illegible]
[illegible]		
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]		
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	July [illegible]	Jan. [illegible]
[illegible]	July [illegible]	Jan. [illegible]
[illegible]	July [illegible]	Jan. [illegible]
[illegible]		
[illegible]	Jan. [illegible]	Aug. [illegible]
[illegible]	July [illegible]	Jan. [illegible]
[illegible]	2100	

RDD1454_95

1



FI
IM
AI
GR
Mc
SA

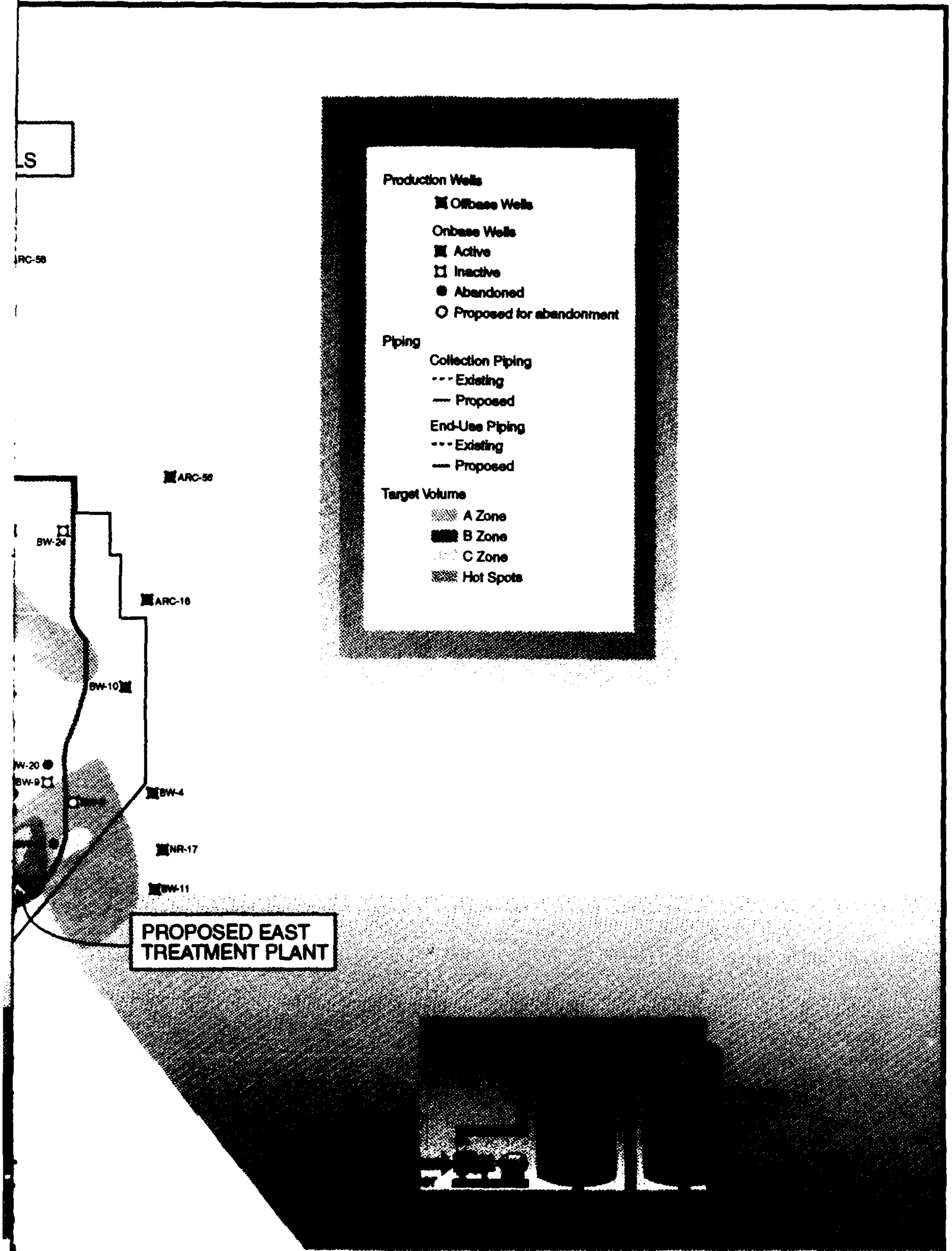


FIGURE 13-7
IMPLEMENTATION PLAN
ALTERNATIVE 6
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

13.1.1 Uncertainties and Priorities

The groundwater remedy can be divided into projects and prioritized by considering the relative, albeit qualitative, potential risk of several areas of uncertainty, and the appropriate sequencing of activities. A decision on the interim remedy is possible if the remedy addresses the uncertainties at the appropriate times and makes the proper adjustments. Following are the principle uncertainties identified by the RI/FS:

1. Extent of contamination. This can be subdivided into the following projects:

   a) Investigation of the deep plume (Monitoring Zones D and E) beneath OUs B and C

   b) Investigation of the extent of the plume moving offbase from OU B

   c) Investigation of the extent of the southern OU A plume

   d) Investigation of the extent of contamination east (offbase) of OU A

   e) Investigation of the extent of contamination in OUs G and H

   f) Investigation of the presence of groundwater contamination west of OU A, and also east of OU C (near the runway)

   g) Investigation of the presence of groundwater contamination at OUs E, F, G, and H

   h) Investigation of the low concentration plume west of OU C (offbase)

   i) Refinement of the OU D plume estimate

   Projects related to the extent of contamination can be simply defined as the work necessary to define the size of the interim remedy's target volume for containment.

2. Response of the groundwater system to the remedial action. This can be subdivided into the following projects:

   a) Obtainment of aquifer parameters from extraction wells using longer term aquifer tests (up to 72 hours)

   b) Investigation and testing of the effectiveness of horizontal wells in controlling the groundwater flow in areas subject to dewatering, and also as a replacement for the potential large number of vertical extraction wells

c) Design of the long-term data acquisition system to obtain faster results during the phased implementation of the remedy

d) Treatability studies of both standard technologies and innovative technologies

e) Investigation of the capacity to inject water as the end use

f) Testing of the ability to inject treated water in or near the hot spots while maintaining capture

The projects related to the response of the groundwater system can be simply defined as the work necessary to refine the conceptual design of the remedy so systems can be built at the appropriate capacity.

3. Flows and concentrations requiring treatment. This can be subdivided into the following projects:

a) Investigation of the background concentrations for metals in groundwater to determine if the metals present in unfiltered samples are a result of McClellan AFB's operations.

b) Determination of the metals concentrations in groundwater extracted over a long period of time to decide on the need for metals removal prior to injection, or other end uses. Even if the metals are naturally occurring, they may be at concentrations greater than the discharge limits for the end uses.

c) Improvement of the conceptual design of the remedy by adding information on the extent of contamination, the groundwater system response, and the flows and concentrations that need to be treated at defined points in the project.

There are numerous additional implementation details that will be resolved during the remedial design and remedial action. In several instances, contingency plans need to be put in place as an immediate part of the remedy (e.g., designing a wellhead treatment unit for City Wells 132 and 135 in case contamination reaches that area prior to containment of the plume moving south from OU B).

The interim remedial action alternatives can be considered to have baseline requirements that are common to each alternative, and specific requirements that are different for each alternative. The selected alternative will need to be capable of meeting both the baseline and specific requirements. An example of a baseline requirement is each alternative needs further definition of the extent of contamination. An example of a specific requirement is Alternative 1 must contain all groundwater with contaminant concentrations greater than MCLs. Contingency plans are typically baseline requirements, but could have small deviations by alternatives.

Following are the baseline requirements for each alternative:

- Determine the extent of contamination.
- Obtain aquifer parameters.
- Determine the effectiveness of horizontal wells.
- Design the long-term data acquisition system.
- Determine the capacity to inject water as the end use.
- Determine the ability to maintain containment of the hot spots while injecting treated groundwater to enhance flushing.
- Determine the background concentrations of metals.
- Determine the need for metals removal prior to use of the treated groundwater.
- Design contingency plans for the appropriate offbase wells (currently CW132 and CW155, but there could be additional wells threatened by OU A contamination).
- Properly decommission BW-18 and replace the water supply. Sufficient extraction capabilities will be constructed prior to the decommissioning of BW-18 to prevent offbase migration of contamination.
- Properly decommission other Base wells that may serve as conduits to contamination. This is an ongoing program.
- Continue operation of the Groundwater Treatment Plant.
- Contain the groundwater hot spots as they are defined by further investigation.
- Update the conceptual model at appropriate milestones.
- Continue to monitor water levels and water quality in the existing monitoring wells.
- Identify interim end uses for the water to allow extraction and treatment to begin independent of injection.

In assessing priorities, all the baseline requirements are of high priority because they are either predecessors to achieving containment, or predecessors to major design decisions, or activities that could alleviate imminent threats. In the case of the determination of the extent of contamination, there is a subset of priorities, with the highest priorities being:

- Deep plume beneath OUs B and C
- Plume moving south from OU B
- Southern OU A plume
- OU A plume offbase to the east
- OUs G and H plume

Following are the lower priorities for investigation of the extent of contamination:

- Investigation of the extent of contamination west of OU A and east of OU C in the runway area
- Investigation of the presence of groundwater contamination at OUs E, F, G, and H
- Investigation of the low concentration plume west of OU C (offbase)
- Refinement of the OU D plume estimate

Priorities for Containment

The remedy must be implemented in a phased approach because of the need to resolve uncertainties, the magnitude of the potential remedy, and resource constraints. The priorities for containment, and the basis for the priority, are discussed in the following paragraphs.

High priority containment projects include:

- OU A offbase to the east
- OU A southern plume offbase
- OU B offbase plume
- OU B/C deep plume (considerable investigation is needed prior to containment)
- Hot spots in OU A (two hot spots), OU B (two hot spots), and OU C (one hot spot known today)

The OU A and B offbase plumes are high priorities because they are potential threats to offbase water users. The deep plume beneath OUs B and C is a high priority because the contamination is in the more permeable materials subject to pumpage by water users. The hot spots are a high priority because the isolation of the vast majority of contaminant mass can be achieved by containment of the hot spots.

Lower priority containment projects include:

- OU A onbase contamination
- OU B/C onbase contamination
- Low concentration area west of OU C
- OU D expansion (if necessary)
- OUs E, F, G, and H onbase contamination

The onbase contamination is a lower priority because the threat to the public does not exist. The offbase contamination west of OU C is a lower priority because the Air Force has replaced individual water wells with potable supply, thereby removing the threat to the public. In addition, the concentrations are low and much farther from water supply wells than the OU B plume.

13.1.2 Scheduling

The schedule for each alternative was developed based on the following factors:

- Prioritizing of the implementation steps
- Sequence of activities to complete the remedial action program and estimated duration of each activity
- Assumed method of project delivery
- Uncertainties/contingency plans

Detailed schedules for each alternative are presented in Appendix S.

The sequence of major tasks is presented in Figure 13-8, located in a pocket at the end of this chapter.

Project Delivery

Several different project delivery approaches are possible for implementing the selected alternatives. The selected delivery approach will ultimately depend on availability of funding and personnel. For example, funding constraints may limit the number of activities that are conducted in parallel, extending the project schedule. A formal Project Delivery Analysis that determines the optimal delivery system by accounting for possible funding/resource constraints should be performed prior to project execution. Delivery of the project was based on the following assumptions:

- Master planning of the Basewide Groundwater remedial action and investigations will be conducted at the outset of the project. The interim remedy will be implemented in three phases. The first phase will focus on reducing uncertainties and beginning containment on the high priority areas. The second phase will reduce remaining uncertainties (mostly extent of contamination), complete containment of the high priority areas, and begin containment of lower priority areas. The third phase will complete containment of the target volume.

  The development and testing of innovative technologies will occur continuously during the project, and they will be integrated at the appropriate points. Similarly, the construction of collection and treatment systems will start when they are sufficiently defined. To accommodate this approach, a Groundwater OU Work Plan will be developed prior to Phase 1. It will include the overall plan for the

Groundwater OU and the details of the Phase 1 activities including the Sampling and Analysis Plan (SAP). Following interpretation of Phase 1 results, a Phase 1 report will be prepared as well as the Phase 2 Work Plan and SAP. Following Phase 2, a Phase 2 report and Phase 3 Work Plan and SAP will be prepared. Pertinent design details will be included in the work plans.

- Basic ordering agreements will be negotiated with subcontractors for the installation of the monitoring and extraction wells. Task orders will be issued as well locations are identified and funded.

- Additional subcontractors will be solicited for the laboratory analysis and sampling teams.

- One turnkey contractor will be solicited and contracted by the Base to both design and construct the treatment plants, end-use piping, and collection piping.

- Installation of the monitoring and extraction wells will be implemented in each OU in the order of the previously listed priorities.

- Installation of the offbase wells will include individual wellhead treatment systems that will operate until the long-term treatment/end-use/collection systems are complete.

- Mapping of the existing utilities will be conducted in parallel with the well installation.

- Design and construction of the collection piping, end-use piping, and treatment systems will be conducted in parallel with each other. Design phase will initiate at the completion of the final layout of onbase wells.

- Testing of innovative technologies will be conducted in parallel with the implementation of the remedial action.

- Pilot-scale testing of innovative technologies will not be implemented in hot spot areas until the hot spot is contained.

- Innovative technologies will be incorporated into the remedial action when adequate data collected from bench- and pilot-scale tests have proven their performance and cost-effectiveness.

Sequence of Tasks

A specific detailed sequence of tasks was established to more accurately determine the schedule and costs of implementing each alternative. Activities such as document review by McClellan AFB and agencies, acquisition of permits and access agreements, preparation for fieldwork, and validation of data were detailed as well as the activities required to design and construct the facilities.

A project management tool, Microsoft Project, was used to develop the schedules for each alternative. The sequence of activities and estimated duration were developed by design engineers for input into the program. The sequencing was based on the following assumptions:

- The Groundwater OU Work Plan will include the SAP for the next phase of fieldwork. The SAP will include a Health and Safety Plan (HASP) and Quality Assurance Project Plan (QAPP) addendum (if necessary). Sampling of the Basewide monitoring and extraction wells will be discussed. It is assumed that a full review of this document will be conducted by the agencies.

- Completion of the monitoring and extraction wells for each OU includes the following: (1) final layout; (2) permit acquisition and contractor selection; (3) drilling, sampling, and aquifer testing; (4) laboratory analysis; and (5) data interpretation and validation.

- Monthly monitoring reports will be generated and submitted to McClellan AFB and the agencies for review. These reports will summarize the field activities, including the essential monitoring and aquifer test data and interpretations as to whether the data are consistent with the McClellan AFB conceptual model. The schedule assumes that if the monitoring and extraction well program is operating within the bounds of the overall strategy, then no other intermediate reports will be submitted to the agencies until the monitoring and extraction well systems are complete.

- Preliminary and final design packages of the collection, treatment, and end-use systems will consist of plans, specifications, design analysis report, and a cost analysis. It is assumed that only McClellan AFB will review these documents; copies will be provided to the agencies for their information.

- Use of innovative technologies assumes the need to conduct a bench-scale test, followed by a pilot-scale test, followed by the implementation of the full-scale project.

Uncertainties/Contingency Plans in Scheduling

Uncertainties in site conditions could affect the performance of remedial action for the Groundwater OU. Therefore, the implementation plans need to be flexible to respond to data and site conditions different from those considered in evolution and development of the remedial action alternatives. Contingency plans have been incorporated to account for these uncertainties:

- **Extent of Contamination**—Additional monitoring and extraction wells would be required if the extent of contamination is greater than anticipated.

- **Hydrological Response to System**—Additional extraction wells would be required if flows from the extraction system were less than anticipated. Impacts to the implementation schedule may be as above.

- **Treatment Plant Performance (Capacity and Effectiveness)**—Additional time has been allocated in the implementation plan for revising the treatment plant process train if the plant does not perform as expected or the flow and quality of the influent is not consistent with the design parameters.

The implementation schedules presented in Figures 13-2 through 13-7 include two dates: earliest completion and latest completion. The earliest completion date assumes that the remedial action was implemented without the need for contingency plans. The latest completion date assumes that data inconsistent with the conceptual model were encountered during the project and that full implementation of the contingency plans was required.

13.1.3 Cost Estimating

Cost estimates for each alternative are summarized in Tables 13-1. The detailed estimates are located in Appendix R. The budget-level estimates were developed based on capital and operation and maintenance costs. These costs were further analyzed using the measures of present worth, total cash outlay, and total Base costs.

Capital costs include both construction and engineering. Construction costs were based on either vendors' quotes or recent bids for similar projects. Engineering costs were developed based on the level of effort required to complete each of the specified tasks.

Table 13-1
Capital Cost Summary

Task	Capital Cost ($)					
	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**Alternative 6**
Master Plan/Work Plan of Remedial Action	643,594	643,594	643,594	643,594	643,594	643,594
Utility Mapping	491,272	540,161	728,568	540,161	540,161	540,161
Onbase/Offbase Production Wells (Contingency Planning)	56,512	56,512	56,512	56,512	56,512	56,512
Extraction System						
Subcontractor Procurement	119,637	119,637	119,637	119,637	119,637	119,637
Phase 1 – Well Installation	3,618,118	4,125,140	4,892,015	4,125,140	4,125,140	4,125,140
Phase 2 – Well Installation	3,955,553	4,563,213	5,318,892	4,563,213	4,563,213	4,563,213
Phase 3 – Well Installation	6,558,357	7,476,231	9,475,633	7,476,231	7,476,231	7,476,231
Treatment/End – Use/Collection Systems						
Western Area						
Collection Piping	1,939,744	2,743,220	4,616,279	2,743,220	2,743,220	2,743,220
Treatment Plant	404,316	965,619	2,424,283	837,940	883,596	883,596
End-Use Piping	1,185,432	1,234,392	1,334,892	1,176,635	1,288,703	1,234,392
Eastern Area						
Collection Piping	2,362,418	2,124,278	2,616,081	2,124,278	2,124,278	2,124,278
Treatment Plant	936,555	1,312,635	1,751,835	915,069	[illegible],635	709,851
End-Use Piping	558,960	627,185	725,465	627,185	[illegible],578	627,185
Injection Site Construction	463,050	689,850	916,650	689,850	[illegible]000	689,850
Total	23,293,518	27,221,668	35,620,337	26,638,666	26,696,499	26,536,860

RDD10013AB6.WP5

13.2 Detailed Analysis of Alternatives

13.2.1 Overview

Each of the six alternatives was evaluated against 11 criteria. The first nine of these criteria match those recommended by the EPA in guidance documentation for conducting RI/FS work. Two additional criteria, impact of uncertainties and cost-effectiveness, have been added to complete the evaluation process.

13.2.2 Description

The evaluation criteria are grouped such that two are threshold criteria, which any alternative must meet; five are comparison criteria, which allow comparison of the alternatives against each other; and two are other criteria, which may not come into play in this RI/FS report, but require attention and consideration later in the Groundwater OU remedial effort.

The following threshold criteria are used in this document:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs

The following comparison criteria are used:

- Long-Term Effectiveness and Permanence
- Reduction in Toxicity, Mobility, and Volume through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

The following criteria will not be addressed in this document and will require further examination following agency and public comment periods on the RI/FS document:

- State Acceptance
- Community Acceptance

These criteria form the minimum criteria recommended by the EPA.

For this site, the following two additional criteria have been identified and have relevant bearing on the evaluation of the alternatives:

- Cost-Effectiveness
- Response of Alternatives to Uncertainties

13.2.3 Overall Protection of Human Health and the Environment

The No-Action Alternative would not provide adequate protection to human health and the environment. While there are no significant risks to human health or the environment under current conditions, groundwater contaminants within OUs A, B, and C are not contained and have the potential to migrate offbase and impact offbase municipal or supply wells.

Alternatives 1 through 6 provide equivalent protection of human health and the environment. Each alternative contains contaminated groundwater and prevents future migration offbase. Figure 13-9 is a comparison of the average risk of contracting cancer for American adults, the risk of contracting cancer as a result of Sacramento's current air quality, and the risks from consumption of the groundwater after the remedial action is in place (residual risk). As shown in Figure 13-9, each target volume is associated with some residual level of increased cancer risk. However, these risks fall within the 10^{-6} to 10^{-4} range that remedial actions are expected to achieve under the NCP.

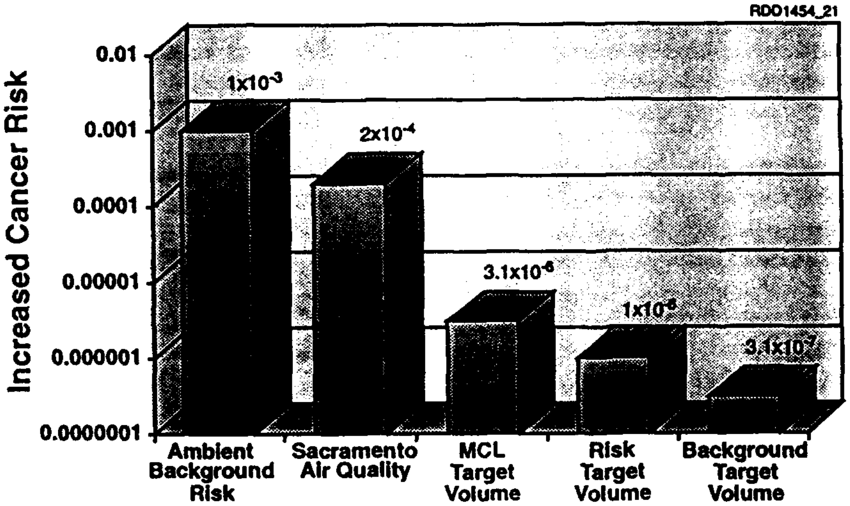


FIGURE 13-9
COMPARISON OF RESIDUAL RISKS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

13.2.4 Compliance with ARARs

The No-Action Alternative is not adequate to meet ARARs or to fully remove the possibility of future exposure to the public water supplies. Concentrations of groundwater contaminants exceed allowable levels under state and federal requirements. The OU D capture zone is adequate for the contamination within the OU D hot spot, but the OU B/C plume and the OU A plume are not fully contained by the existing systems.

Table 13-2 summarizes how Alternatives 1 through 6 comply with the ARARs. All of the alternatives meet MCLs under the Safe Drinking Water Act and meet target cancer risk levels under the NCP. Treated water would achieve discharge requirements under the Clean Water Act and California's Inland Surface Water Plan requirements.

Table 13-2
Compliance with ARARs

Alternative	No Action	1	2	3	4	5	6
Meets Safe Drinking Water Act Criteria (MCLs)		✓	✓	✓	✓	✓	✓
Meets SWRCB Resolution 9249 (TBC)-Background Remedial Goal				✓			
Meets Target Risk Level Remedial Goals per NCP		✓	✓	✓	✓	✓	✓
Meets CWA Discharge Requirements	Not applicable	✓	✓	✓	✓	✓	✓
Meets SWRCB Inland Surface Waters Plan Requirements	Not applicable	✓	✓	✓	✓	✓	✓
Meets SMAQMD Rule 202, New Source Review-Without Base Action to Offset NO_x or ROG	Not applicable						✓
Potentially Meets TBACT	Not applicable	✓	✓	✓	✓	✓	✓
Meets RCRA Requirements		✓	✓	✓	✓	✓	✓
Meets SWRCB Resolution 6816-Nondegradation Policy		✓	✓	✓		✓	✓

Alternatives 1, 2, 3, and 5 would use air stripping with CatOx for offgas control from air stripping towers. These alternatives are subject to ARARs limiting acceptable NO_x discharges and requiring best available control technology (BACT) for offgas control on new emission sources. Currently, McClellan AFB is not permitted to discharge additional amounts of NO_x. These alternatives potentially would not meet Sacramento Municipal Air Quality Management District (SMAQMD) rules for new source review. To operate the equipment identified in these alternatives, it will be necessary for McClellan AFB to offset NO_x emissions from other sources within the Base.

Alternative 4 would use vapor phase carbon for offgas control in the east side plant. This option is expected to allow slight VOC emissions into the air, but will not create NO_x or SO_x. This technology has been considered BACT. Removal efficiencies are expected to be in the range of 95 to 99 percent for most compounds in stripper offgas. Methylene chloride and vinyl chloride, which have relatively limited extent in groundwater, would not be efficiently controlled by vapor phase carbon. Generally, offgas concentrations would be low or nondetect, with occasional transient peaks. A risk assessment would be required to evaluate if the emissions from these concentrations would require Best Available Control Technology-Toxics (T-BACT) under SMAQMD requirements.

The existing GWTP is currently operating under the substantive requirements of permits for water and air discharge. These permits were initially given based on water flow rates of 1,000 gpm. Alternatives 2 and 3 require expansion of the existing GWTP to greater than 1,000 gpm. Compliance with ARARs would be readily achievable for Alternatives 2 and 3.

The California DHS–Office of Drinking Water opposes the sale of the treated groundwater to the utilities on the basis of policy. This weighs against sale of the water to the utilities and makes injection more favorable.

13.2.5 Long-Term Effectiveness and Permanence

This criterion is applicable to all alternatives. It is applied to each alternative in terms of the risk remaining at the site after the response objectives have been met; that is, after concentrations of contaminants in the target volumes have been reduced to the target concentrations (MCL, background, or 10^{-6} cancer risk). The primary focus of this evaluation is the extent and effectiveness of controls that may be required at the conclusion of remedial activities.

The No-Action Alternative is not effective in the long-term since containment of hot spots in OUs A, B, and C is not achieved, and contamination may migrate offsite from these areas.

Alternative 1 contains and treats contaminants in the MCL target volume. Alternatives 2, 4, 5, and 6 contain and treat concentrations in the 10^{-6} cancer risk target volume, while Alternative 3 contains and treats concentrations in the background concentration target volume. The magnitude of the residual risk resulting after the response objectives are met for each of these target volumes is shown in Figure 13-9.

Following the remedial action, all alternatives are expected to be effectively equivalent in their adequacy and reliability of controls.

13.2.6 Reduction in Toxicity, Mobility, and Volume through Treatment

This comparison criterion is applicable to all alternatives. It focuses mainly on the treatment system, identifying the fate of extracted contaminants, and secondarily on the mass of contaminants that are destroyed from the site.

Alternatives 1, 4, and 6 allow the direct comparison of the three treatment options, air stripping with catalytic oxidation as the offgas treatment, air stripping with vapor-phase carbon as the offgas treatment, and liquid-phase granular activated carbon (LGAC) which does not produce an offgas.

Because spent carbon is commonly regenerated by desorbing the contaminants and oxidizing the resulting airborne gaseous compounds (possibly by thermal or catalytic oxidation processes), there is not a significant difference in the ultimate destruction of the contaminants; the difference is where it occurs. In the case of Alternative 1, the destruction of the contaminants takes place in the catalytic oxidation unit (east-side plant) or thermal oxidation unit (eastern GWTP) at McClellan AFB. In the cases of Alternatives 4 and 6, the destruction of the contaminants takes place at the carbon regeneration facility, which could potentially be outside California. Given the ultimate destruction of the contaminants is similar for the three treatment options, the alternatives are considered equivalent with respect to reduction of toxicity and mobility by treatment.

The amount of the contaminants removed from the groundwater can be quantified in three different ways: toxicity, mass, and volume. The following paragraphs describe each of these amounts.

The target volumes reflect a level of residual risk that would remain in the ground following the remedial activities. Therefore, the reduction in risk or toxicity of the individual alternatives can be reasonably represented by comparing the resulting risk value with existing risks. Risks vary at different areas of groundwater contamination; however, the current worst-case risk magnitude is approximately 10^{-2}. This value is location-specific and assumes that a human ingests water from one of the hot spots at McClellan AFB. In comparison, the other risk values associated with remediated target volumes assume a human ingests that water, cleaned to whatever the target value is (MCL, 10^{-6} cancer risk, or background (<0.5 ppb).

As can be seen from Figure 13-10, removal of risk for any of the target volumes is essentially 100 percent, ranging from greater than 99.99 percent to a low of about 99.97 percent. While these figures are subject to uncertainty in the accuracy of the risk calculations, they are essentially equal in magnitude. Therefore, there is little differentiation between alternatives on the basis of reduction of toxicity.

Contaminant mass removal is represented between target volumes in Figure 13-11. This figure shows mass of TCE contained within concentration isopleths representative of the three target volumes. As shown, the overall mass does not vary significantly between target volumes; therefore, there is no advantage to one alternative over another when judged by this factor.

Figure 13-12 illustrates the large volume of contaminated area and depth involved at McClellan AFB. The MCL target volume encompasses approximately 1.25 billion cubic feet, or 46 million cubic yards. In comparing this volume to other target volumes, an increase by a factor of approximately 50 percent occurs between the MCL and 10^{-6} cancer risk volume, and a factor of approximately three between the MCL and background volumes. While judging alternatives on the basis of this factor weighs in favor of the target volume which affects the largest volume of soil and water, it cannot be weighed highly in comparison with risk-based criteria because there is little incremental benefit in treating higher volumes for that reason alone.

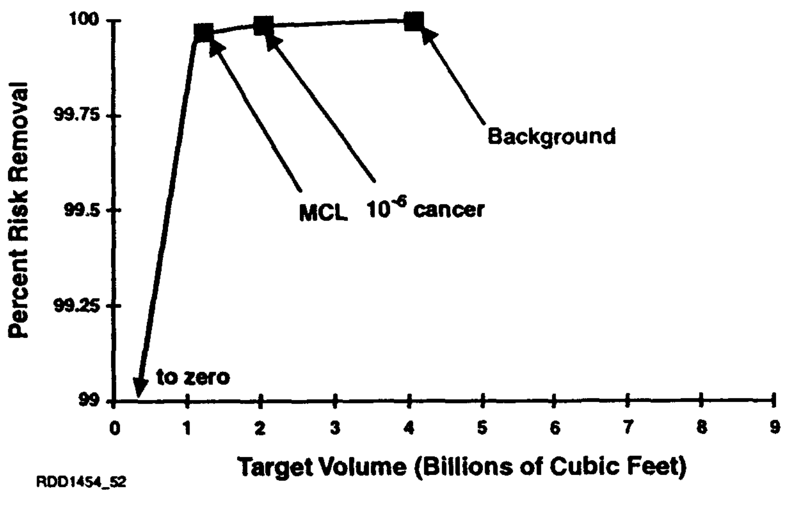


FIGURE 13-10
COMPARISON OF REDUCTION IN RISK ACROSS TARGET VOLUMES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

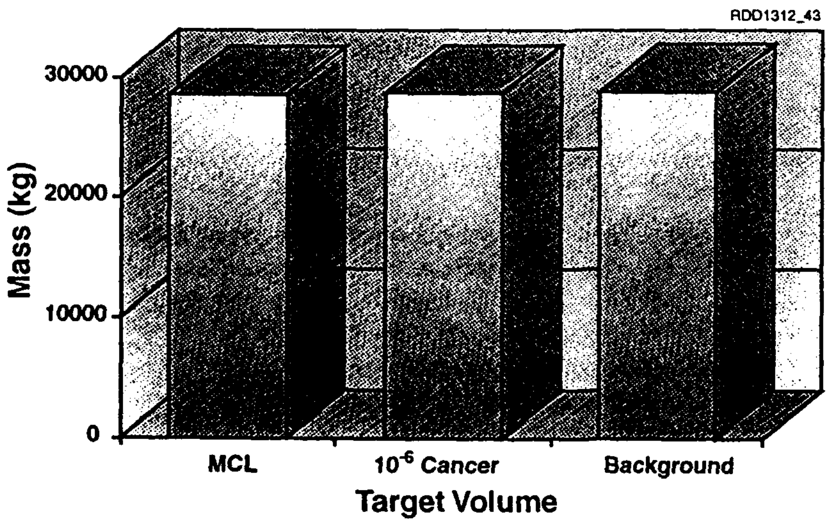


FIGURE 13-11
COMPARISON OF MASS OF TCE ACROSS TARGET VOLUMES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

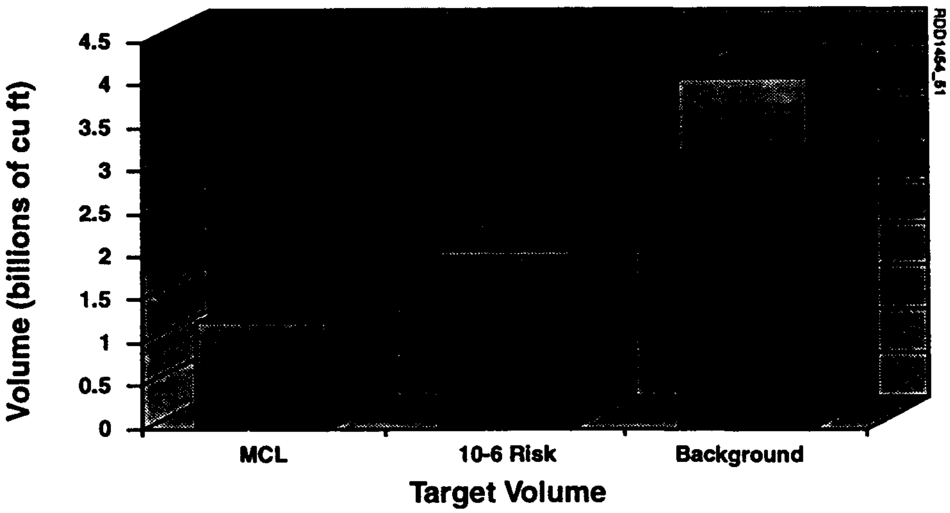


FIGURE 13-12
COMPARISON OF REDUCTION IN CONTAMINATED VOLUME ACROSS TARGET VOLUMES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Figure 13-11 shows that all alternatives achieve essentially 100 percent of toxicity reduction. In addition, the increase in volume between the MCL and background target volumes appears significant, which will require higher capital and O&M spending. When comparing this significant volume increase with the incremental gain in risk or toxicity reduction, it can be seen that the gain is small. This phenomenon suggests that the optimum alternative should include the MCL target volume to achieve toxicity reduction essentially equivalent to the other target volumes while treating one-half to one-third of the volume.

Mobility of the groundwater contamination is arrested with any of the alternatives. For each extraction system design, groundwater containment has been the objective. Therefore, with any of the target volumes within the alternatives, mobility of contaminants will be arrested, and each alternative cannot be differentiated from another on this basis.

13.2.7 Short-Term Effectiveness

This comparison criterion is applicable to all alternatives. Under it, alternatives will be evaluated with respect to effects on human health and the environment during the construction and operation phases of the remedial action, until the remedial response objectives are met.

The No-Action Alternative is acceptable in that the operation of the existing groundwater treatment plant does not pose a threat to workers, the community, or the environment. As a Basewide Groundwater OU remedial action, it is unacceptable because it does not address various source or uncontained contaminated areas and effectively would require an infinite time to clean up these areas.

As discussed in Appendix C, workers involved with construction of facilities required to implement any of the remedial action alternatives would not be exposed to any greater risks than normally encountered during construction activities. Construction activities would not be expected to expose the public to increased risks.

Short-term health risks during implementation could be associated with emissions of acid and oxidant gases from CatOx offgas treatment. Mitigation of these impacts could involve selection of a remedial action alternative that does not involve the use of CatOx, installing emission controls for acid and oxidant gases, or siting the facility so that air quality impacts fall on uninhabited locations.

The time to reach the response objective is variable with each target volume and is primarily a function of water flow rate, and initial and final contaminant concentration. Initial concentration and response objective (final concentration) vary with the target volumes and the specific location within a target volume. Figure 13-13 shows an estimate of the time required to reach the target concentration, and the effect of initial concentration and final concentrations by target volume for TCE.

Figure 13-13 has been developed assuming that the NAPLs are isolated within the target volume. It can be seen that times to clean up increase as initial concentrations increase, indicating that the hot spot areas will take longer than containment areas. On the other dimension, it can be seen that cleanup times will be longer if the final concentration is lower, as is the case with the background target volume versus the 10^{-6} cancer risk, versus the MCL. Judging each alternative under this evaluation factor, it appears advantageous to choose alternatives on the basis of MCL target volumes to minimize cleanup time. If the DNAPLs were not isolated, the remediation time could be hundreds of years.

With respect to the short-term effectiveness criterion, the alternatives based on the MCL target volume will reach the remediation goals first, and given the MCLs are protective of public health and compliant with ARARs, the alternatives based on the MCL target volume would be preferred.

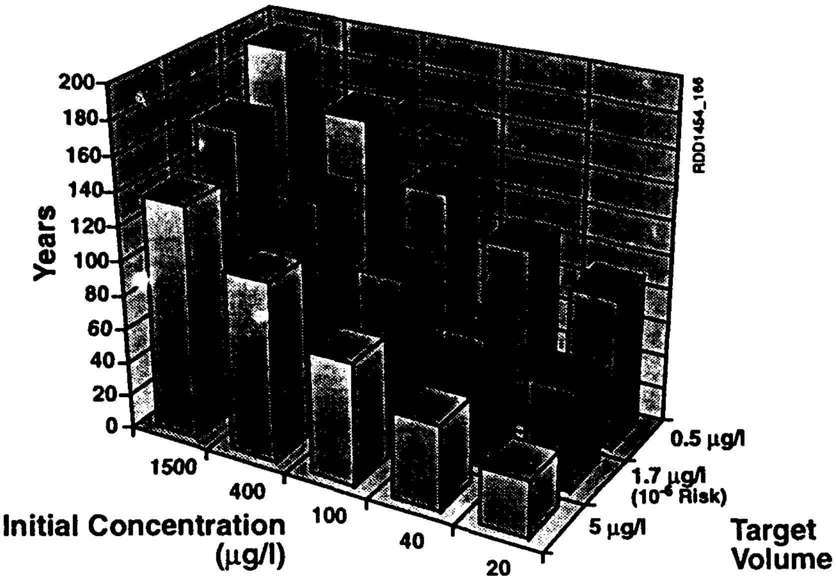


FIGURE 13-13
ESTIMATED TIMES TO CLEANUP
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

13.2.8 Implementability

This comparison criterion is applicable to all alternatives. It is used to compare alternatives on the basis of technical and administrative feasibility and availability of materials and services required for implementation. In addition, since innovative technology implementation and future source controls will be active at McClellan AFB, this criterion addresses the ease of implementing these future remedial activities.

Alternatives 1 through 6 are similar in their technical and administrative feasibility. All standard treatment technologies identified for the alternatives are proven in applications at similar hazardous waste sites. Engineering principles and calculations can be applied to design and specify the types of equipment in the options chosen with relatively high accuracy. Regulatory agencies and end users are familiar with components of the water treatment processes, providing high institutional and administrative feasibility. In addition, numerous vendors are available for each component, providing excellent availability of most services and materials.

The injection of treated water in or near the hot spots may pose implementation difficulties. Modeling indicates injection could shorten the time per pore volume removed, which in turn could shorten the remedy. However, maintaining containment of the hot spots with injection is more difficult than without, and the enhanced flushing will probably occur in the higher permeability zones, which are the easier zones to clean up. Pilot testing of injection improvements in hot spot remediation is necessary prior to implementing it as part of the remedy.

As discussed previously in the implementation plans, each alternative is flexible in incorporating innovative technologies into the remedial action. While minor differences exist, the six alternatives identified do not differ significantly in facilitating the implementation of innovative technologies.

Table 13-3 summarizes the implementability of each alternative and compares them to the No-Action Alternative.

13.2.9 Cost

This comparison criterion is applicable to all alternatives. It is used to compare alternatives on the basis of capital costs, both direct and indirect, as well as O&M costs. In addition, consideration is given to the time value of money in analyzing and comparing alternatives.

Table 13-3
Implementability

Factor	Alternatives						
	No Action	1	2	3	4	5	6
Technically Feasible (Many similar installations)	Not applicable	✓	✓	✓	✓	✓	✓
Vendors, Installation Contractors, and Operations Resources Locally Available	Not applicable	✓	✓	✓	✓	✓	✓
Compatible with Innovative Technologies through Sequencing/Phasing	Not applicable	✓	✓	✓	✓	✓	✓
Does Not Require Air Discharge Permit	Not applicable						✓
NO_x, ROG Emissions May Require Offsets from Other Base Source Reductions	Not applicable	✓	✓	✓	✓	✓	

Evaluation Factors

This criterion is divided into four factors:

- Capital cost
- O&M cost
- Total cash outlay
- Cost after 11 years of project life

Comparison of Alternatives

The No-Action Alternative has cost associated with operation and maintenance of the existing extraction, treatment, and end-use systems. On the basis of the budget information, a cost of $1 million per year will be assigned to this alternative for O&M costs associated with wellfield and GWTP operation. For comparison purposes, a project life of 30 years will also be assumed for the No-Action Alternative.

Table 13-1 summarizes the budget-level costs for each of the alternatives. Note that in this table, the GWTP was used to treat the westside flow from the plant. In alternatives where treatment of greater than 700 gpm was necessary for the west side, capital improvements for the GWTP were accounted for in the treatment capital cost amounts. In addition, the O&M costs of the GWTP were calculated assuming operations labor on the order of three to four full-time equivalent employees to make O&M estimates for the GWTP comparable with O&M estimates for other technologies.

The information contained in the tables above is further evaluated in Table 13-4, which compares total capital and O&M costs, net present value, total cash outlay, and costs after 11 years of operation, assuming a discount of 5 percent and a project life of 20 years. The cost after 11 years of operation is important because the Air Force DERA funding will pay for operations for the first 10 years of the remedy, but McClellan AFB will need to pay for operations past 10 years. The costs do not include injection of treated groundwater in or near the hot spots. The estimated capital cost of adding this injection is $1.1 million.

Table 13-4
Cost Summary Table
McClellan AFB Groundwater Operable Unit RI/FS

	Alternative ($)					
Cost Indicator	**1**	**2**	**3**	**4**	**5**	**6**
Capital Cost	23,293,518	27,221,668	35,620,337	26,638,666	26,696,499	26,536,860
O&M Cost–1st 5 years	2,208,000	2,610,000	3,335,000	2,553,000	2,912,000	2,553,000
O&M Cost–years 6 through 19	2,845,000	3,558,000	3,993,000	3,656,000	3,977,000	4,699,000
Net Present Cost[a]	54,900,000	66,100,000	81,000,000	66,000,000	70,100,000	74,000,000
Total Cash Outlay[a]	74,200,000	90,100,000	108,200,000	90,600,000	96,900,000	105,100,000
Cash Outlay after 11 years[a]	22,800,000	28,500,000	31,900,000	29,200,000	31,800,000	37,600,000

[a]Assumptions:
Interest Rate = 0.05
Analysis Period = 20 years

13.2.10 State Acceptance

State acceptance is determined after review of the Draft RI/FS Report and by the signing of the IROD.

13.2.11 Community Acceptance

Community acceptance is also determined after public review of this document. This will be accomplished through formal draft reviews, and public feedback will be included in the Response Summary in the IROD.

13.2.12 Impact of Uncertainties

The impact of uncertainties has been addressed in previous chapters on decision analysis and treatment costs. In the evolution of this document, most of the cost information available at the time of writing those chapters was accurate within an order-of-magnitude range (+50 percent to 30 percent). The structure of this RI/FS is such that information was valuable in leading to screening alternatives down to the six that are the subject of the detailed evaluation in this chapter. At this point, more accurate estimates have been assembled for each of the six alternatives. As discussed in Chapter 4, these uncertainties will be addressed through identification of the uncertainties, definition of the bounds of each, and identifying the potential impact.

Impact of Changes in Future Hydrogeologic Conditions

The magnitude of the changes in future hydrogeologic conditions ranges from continued decline in water levels to rising water levels. The probability of changes in water consumption and management near McClellan AFB causing water levels to rise is low, and if it occurred, it would affect the alternatives equally. Design of the remedial action probably does not need to include contingency measures for the possibility of rising water levels caused by changes in groundwater consumption or management because the probability is low and the change would be gradual (years) rather than instantaneous. A second possibility for changing water levels is the implementation of SVE in the vadose zone. Application of a vacuum above the water table can cause a proportional rise in the water table. The duration of an SVE remedy would be short compared to the groundwater remedy, and typically, the yield of the extraction field is not limited by the well construction, so the design of the groundwater remedy does not need to be altered to accommodate this possibility.

The potential future conditions that can affect the groundwater remedy are the declining water levels. Areas of Monitoring Zone A, east of the runway, have an extremely limited saturated thickness from which to extract contaminated groundwater. This situation severely limits the quantity of groundwater that can be pumped from a single extraction well and results in a large number of wells being required to contain the target volumes in that area. The fact that regional groundwater levels are declining in the vicinity of the Base suggests that this situation will likely become worse in the future, with some portions of the A-zone completely dewatering in 15 to 20 years.

Different strategies can be used to address this situation in different portions of the A-zone east of the runway. These strategies are briefly outlined below.

In areas where both the A zone and B zone are contaminated, contamination can be withdrawn from B-zone wells as extraction in the A zone becomes impractical because of declining water levels. The remaining A-zone extraction wells can then be converted or replaced with SVE wells or dual-phase extraction wells.

In areas where the contaminated A zone overlies uncontaminated B zone, the situation is more complex. Extraction would be limited to the A zone because extracting from the B zone could draw contamination downward into clean areas of the aquifer. The first step in these areas will be to install additional monitoring wells screened between the base of the A zone and the base of the B zone or perform vertical profiling using in situ (HydroPunch) techniques. The current monitoring network consists of wells that are predominantly screened at the base of their target monitoring zone. This results in target volumes that are defined based on water quality in the lower portions of each unit. In reality, in areas where the A zone is significantly contaminated, it is likely that the upper portions of the B zone are also contaminated. Information collected from these new proposed monitoring wells will help resolve this issue. If the upper portions of the B zone are indeed contaminated, the A-zone extraction wells will have a screened interval that extends downward into the upper B zone to take advantage of the greater saturated thickness. In areas where the upper B zone is not contaminated, A-zone extraction will be converted or replaced with SVE wells or dual-phase extraction wells as groundwater extraction becomes impractical.

One other strategy that may be applicable for the A zone east of the runway is to install a number of horizontal wells. One horizontal well with a 500-foot screen length could contain and extract contaminated groundwater in an area roughly 600 feet long by 250 to 300 feet wide. The performance of these wells will depend on the actual hydraulic conductivity distribution that exists in the vicinity of each horizontal well. The main benefit of this type of well installation is that the number of wells required may be reduced significantly, and the associated collection pipeline costs could also be reduced. CH2M HILL has contacted drilling companies that perform this type of drilling, and additional information on the horizontal drilling process is included in Appendix P. A single horizontal well should be installed, and the capture provided should be measured prior to design to avoid significant differences in design flow assumptions.

The basic implementation strategy for the remedy is to install the extraction system and measure the flows and concentrations prior to installation of the collection pipelines, treatment plant, and end-use system. This strategy does not directly measure the impact of the long-term decline in water levels on the remedial action; therefore, the design will need appropriate contingencies to address lower flows and a thicker vadose zone.

Each of the alternatives' extraction and end-use systems are affected equally. The alternatives with the treatment systems that best accommodate turndown in flow will be superior if water levels decline; however, the potential decrease in flow is small so the ranking of the alternatives does not change.

Impact of Changes in the Extent of Contamination

The uncertainties with respect to the extent of the contamination affect both the extent of the hot spots and the overall extent of the contamination above the selected cleanup goal.

Changes in the extent of the hot spots, as compared to the current estimate, is likely because new hot spots may be identified, and the estimate of the bounds of the hot spots may change, during the collection of additional information. The change may increase or decrease the hot spot volumes and flows, principally affecting the treatment plant. If the hot spot volume or flow is greater than expected the contaminant mass, loading to the treatment plant will increase and possibly the influent concentrations as well. If the hot spot volume or flow is less than expected then the contaminant mass loading to the treatment plant will decrease and possibly the concentrations also. This issue is potentially a shorter term issue because the strategy for the hot spots is to isolate them from the plumes so they are not continuing sources and apply innovative in situ technologies to reduce the contaminant mass within them. If the innovative in situ technologies are effective, the impact of a difference in the hot spot extent is potentially minimal.

The alternatives are based on the interpretation of the available groundwater data. Target volumes have been identified for the various plumes and remediation goals. Each target volume has areas where the boundary may be extended or reduced based on the results of additional information collected during the implementation of the remedy. The range estimated for the changes in the target volumes are 80 percent, 120 percent, and 150 percent of the current estimate. The decision analysis model used this range in screening the alternatives so the likelihood of one alternative being significantly less effective at the different target volumes is low. In addition, the likelihood of the target volumes being larger than estimated is lower for the MCL target volume and the 10^{-6} risk target volume than for the background target volume. This is caused by the monitoring network, which has the greatest well density near the source areas and the lowest density in the fringes of the plumes.

In the case of changes in the extent of the hot spots or changes in the extent of the target volumes, the implementation strategy planned by McClellan AFB can overcome the potential impacts. The potential outcomes of this uncertainty do not affect any one alternative more severely than another.

Changing Concentrations with Time. As discussed in Chapter 9, groundwater concentrations typically will decrease with time as the contamination is flushed from the subsurface pore volume. There is some uncertainty as to how this temporal trend will occur. Figure 9-3 shows total VOC concentrations in groundwater from the existing OU D and OU B/C extraction systems decreasing by approximately a 50:1 ratio after 5 years of operation. Furthermore, the initial concentration fell by a 10:1 ratio after only 2 years of operation. This trend to decrease concentration is dependent on the characteristics of the aquifer, the pumping rate, and geologic conditions. Given uncertainties associated with the subsurface environment, the future concentration trend of extracted groundwater VOC concentrations is also relatively uncertain.

Total VOC concentration will most probably decrease as treatment progresses. The uncertainty is the temporal trend in the way they will decrease and the trend of concentrations of specific contaminants. To develop the impact of these uncertainties on the alternatives proposed, the following two cases will be assumed:

- Case 1—Total VOC concentrations drop to 10 percent of the estimated influent concentrations used to develop the alternatives.
- Case 2—Concentration of "bad actors," or compounds which raise special considerations in selecting the alternatives, increase.

Case 1—VOC Concentrations Drop to 10 Percent of Initial Estimates

In Case 1, the alternatives in the west side plant are not expected to be significantly affected by a drop in concentrations. Required capital and O&M costs are anticipated to remain essentially constant.

For Alternatives 1, 2, 3, and 5, air stripping followed by LGAC polishing is used for water treatment on the east side. The carbon polishing costs are not estimated to be *significantly impacted by a drop in influent* concentration; therefore, these four alternatives will be impacted the same by this uncertainty.

For these alternatives, an air stripper has been sized to remove all contaminants present to less than 0.5 μg/l. Given the estimated inlet concentrations, this relates to required removal efficiencies of approximately 99.95 percent for TCE in the air stripper. If the inlet concentration drops to 10 percent of the design value, the required removal efficiency drops to 99.5 percent. Under these conditions, the air flow to the stripper can decrease to approximately 25 percent of the design value.

This decrease in airflow results in a minor O&M cost savings for decreased power consumption in the air blower. Design must take this range of airflow into consideration when specifying equipment to allow one fan to function over a range of flow rates, but capital cost is not significantly impacted.

The reduction in airflow can result in a natural gas consumption savings in the catalytic incinerator by approximately 75 percent. However, not all catalytic incinerators will be capable of handling a decrease in flow rate to 25 percent of the design value. In fact, fluidized bed oxidizers will not be capable of handling that range of turndown and would not allow any O&M savings to occur. For fixed bed oxidizers, this range of airflows could be accommodated if the system was designed with the airflow range as a criterion.

For Alternative 4, the same fan power costs could be realized. Offgas treatment using VGAC can easily take advantage of the decreased airflow and organic loading. These units, which are conceptualized in the cost estimates as rental vessels, can be replaced with smaller vessels and will use less carbon if the influent concentration drops. The offgas treatment rental cost is anticipated to drop by approximately 60 percent if the influent concentration drops to one-tenth of the initial design value. Because of these factors, Alternative 4 is affected more positively than Alternative 1 by this uncertainty.

For Alternative 6, LGAC replacement costs would decrease to approximately one-tenth of the initial design value, providing significant O&M savings. Capital equipment would not require any changes. This alternative is affected more positively than any of the others by this uncertainty.

Case 2 – "Bad Actors" Concentration Rise

Of the significant contaminants found at McClellan AFB and included in the design basis for equipment sizing and cost estimation, vinyl chloride and methylene chloride deserve special consideration. These two compounds can be stripped fairly readily at the estimated influent concentrations. Drops in concentration of either do not affect alternative costs. However, if concentrations of either rise in the future operation of the extraction system, they deserve concern under Alternative 4.

Alternatives 1, 2, 3, and 5 use CatOx and are estimated to be effective at destroying these compounds under a wide range of concentrations, as is the west side GWTP.

Alternative 4, which uses VGAC as offgas treatment for the east side plant, is relatively ineffective on these two compounds. VGAC has been sized to remove all compounds that are more adsorbable than methylene chloride and vinyl chloride. It is estimated that the concentration of these compounds is low in stripper offgas because of their initial low concentration in the influent groundwater from the east side. These low concentrations, which are not treated by carbon, are estimated to be permittable. If concentrations in the influent water of these compounds rise, concentrations in the carbon treated offgas will also rise. This uncertainty in the magnitude of the offgas concentration is fairly minor because there is a relatively low probability that these concentrations will rise. However, Alternative 4 is weighed less attractive if impacted by this uncertainty because of potential air permitting difficulties.

Permitting Uncertainty

There are two points of uncertainty with the air permitting effort for the east side treatment plant. One is NO_x emissions; the other is VOCs. The potential uncertainties associated with permitting the sale of treated groundwater to the utilities have been resolved by California DHS-ODW stating their policy on the issue. Sale of treated groundwater to the utilities will not be allowed under DHS-OWD policy.

NO_x Emissions. With Alternatives 1, 2, 3, and 5, CatOx is proposed. This technology will create NO_x. Rough estimates indicate that Alternatives 1, 2, and 5 will generate about 12 tons per year of NO_x, Alternative 3 about 20 tons per year. Currently, the Base can offset NO_x emissions by reducing levels of NO_x from other sources at the Base or by purchasing offsets to allow increased emissions. These levels are seen as significant. The OU D Site S catalytic oxidizer for SVE offgas currently produces on the order of 2 tons of NO_x per year. This amount was permitted through reduction of other permitted sources at McClellan AFB. Comparing the magnitude of the values indicates that the east side emissions would be significant and may not be able to be compensated through other Base NO_x reductions.

While this indicates a disadvantage for these alternatives, the impact may not be as severe as indicated. Preliminary sizing of air strippers used a set of design criteria that did not include minimizing air flow, or NO_x emissions. Future design activities could potentially decrease these NO_x levels to as little as 25 percent of the anticipated emissions, bringing them into a range where they may be more easily permitted.

This uncertainty affects Alternatives 1, 2, 3, and 5 to increase the capital cost and lower the O&M cost. Higher capital costs would result from designing the strippers to remove the same amount of contaminants using a lower airflow, potentially requiring a second tower. Downsizing of the offgas treatment systems would counteract this somewhat. O&M costs are estimated to decrease slightly because of lower air blower flow requirements.

With Alternatives 4 and 6, no NO_x is produced. These alternatives are not affected by this uncertainty.

VOC Emissions. With Alternatives 1, 2, 3, and 5, CatOx is used as offgas control. This technology is estimated to be effective at destroying all organics present at 95 percent or greater DRE.

With Alternative 4, VGAC is used as the offgas control device. VGAC is not effective on vinyl chloride or methylene chloride. It has been estimated that the low levels of these compounds in the east side influent water are not high enough to constitute a health risk and result in a permittable offgas stream. The actual permitting process will require dispersion modeling and risk assessments that will more accurately indicate the magnitude of the concern. These results are uncertain at this time and weigh against Alternative 4.

Alternative 6 does not have air emissions and is not impacted by this uncertainty.

Innovative Technologies

Application of innovative technologies is a prime target of the McClellan AFB remedial effort. In the application of these technologies, there is a given amount of uncertainty. The prime motive behind innovative technologies is to minimize the cost of the remedial action. This can occur in two ways: a more cost-effective treatment technology can be installed as part of a pump and treat system (ex situ technologies) or a source area or hot spot cleanup can be accelerated with an in situ technology. The effect of in situ technologies reduces the time of the overall remediation and avoids costs. Uncertainty exists associated with the performance of any innovative technology. There is uncertainty in the technologies ability to perform in an effective, robust, cost-effective manner or be implementable at the site. While implementation plans have been developed that will provide testing and staged implementation to minimize the uncertainty, there is still a relatively large amount of uncertainty as to any technologies performance.

Providing bounds for the uncertainties is difficult. The selection of promising technologies and methods of implementing one or more to minimize uncertainty in an optimum manner has been a task of this RI/FS. The uncertainty of successful implementation has been minimized. The uncertainty of the performance of any one innovative technology is not quantified here and is recognized as a variable which can be reduced through proper implementation.

Impacts can only be positive, since in all alternatives there will be a standard technology that will be capable of treating the extracted groundwater. The uncertainty impacts the remedial action by either having no effect, or by lowering costs or reducing the remedy time. Either of these positive effects are beneficial to McClellan AFB.

13.3 Conclusions

This section presents the recommended target volume, treatment option, and end use to address contaminated groundwater at McClellan AFB.

13.3.1 Target Volume

The recommended target volume was selected by comparing Alternatives 1, 2, and 3, where the treatment and end uses were held constant and the three target volumes were used. This comparison resulted in the selection of the 10^{-6} cancer risk as the preferred target volume. The 10^{-6} target volume provides greater protection than the MCL target volume at a slightly higher cost. The background target volume was not selected because the large increase in project cost is not warranted by the slightly greater level of protection to the public. Included in all the alternatives was the isolation and remediation of the hot spots.

13.3.2 Treatment and End Use

During the evaluation and screening of the components of the alternatives, treatment and end use were addressed separately. Once the alternatives were assembled the interfaces between treatment and end use added. Alternatives 2, 4, and 6 have different treatment options, but constant target volumes and end uses. Of these, Alternatives 4 and 6 have almost identical capital cost, and Alternative 2 is only 3 percent more. Net present value indicates the difference between Alternatives 2, 4, and 6 are more pronounced.

The economics of these alternatives are so similar that their response to the outcome of the areas of uncertainty is critical to the decision. Of particular uncertainty are the long-term influent concentrations. In the case of the permitting for NO_x emissions, Alternative 2 is affected, but Alternatives 4 and 6 are not because they would not produce NO_x. The cost of dealing with the NO_x issue is highly variable, but in all instances it is substantial. The first possibility is to perform a Basewide NO_x inventory to determine if the Base already has capacity for an additional NO_x source of approximately 12 tons per year. If they do not have capacity, then they could offset the additional source by reducing their current emissions. The last choice would be to purchase NO_x credits from another party.

There is a possibility of reducing the NO_x emissions through an alternative stripping tower design, but any savings in the handling of the NO_x emissions would be offset by increased capital cost.

The potential changes in influent concentration could make a substantial difference in the economics. If the eastern influent concentrations decrease similarly to the existing GWTP, Alternatives 4 and 6 have lower operational costs, with Alternative 6 having the least operational cost. Conversely, if new hot spots are identified, similar to Site 24 in OU A, the impact on the cost of Alternative 6 could be a substantial increase in carbon cost.

Alternative 4 contains the preferred treatment train because its cost is less sensitive to higher influent concentrations, it would not require the cost of dealing with NO_x emissions, nor would it produce NO_x emissions.

Alternatives 2 and 5 contain the two different end-use options and are consistent in the target volume and basic treatment train. On the basis of capital cost, Alternative 5 is slightly lower, but the net present value of Alternative 2 is lower. This is due to a higher O&M cost of Alternative 5 because of the requirement of chlorine contact prior to discharge to the water utilities. The recommended end use for the project is to inject the treated groundwater. This end-use option has a lower net present value than discharge to the water utilities, along with the fact that the current DHS-ODW policy forbids the potential sale of treated contaminated groundwater to the local utilities.

Two possibilities could make the injection option less favorable. First is the possibility that the deeper aquifer water quality is better than the treated water, in which case the antidegradation policies of the RWQCB would not allow the injection to take place without treatment. Second is the possibility that the injection would be more difficult and require a greater power cost and labor cost, or possibly more wells. This cannot be resolved until an injection test well is installed. Both of these outcomes would make polishing and discharge to the water utilities less expensive than injection.

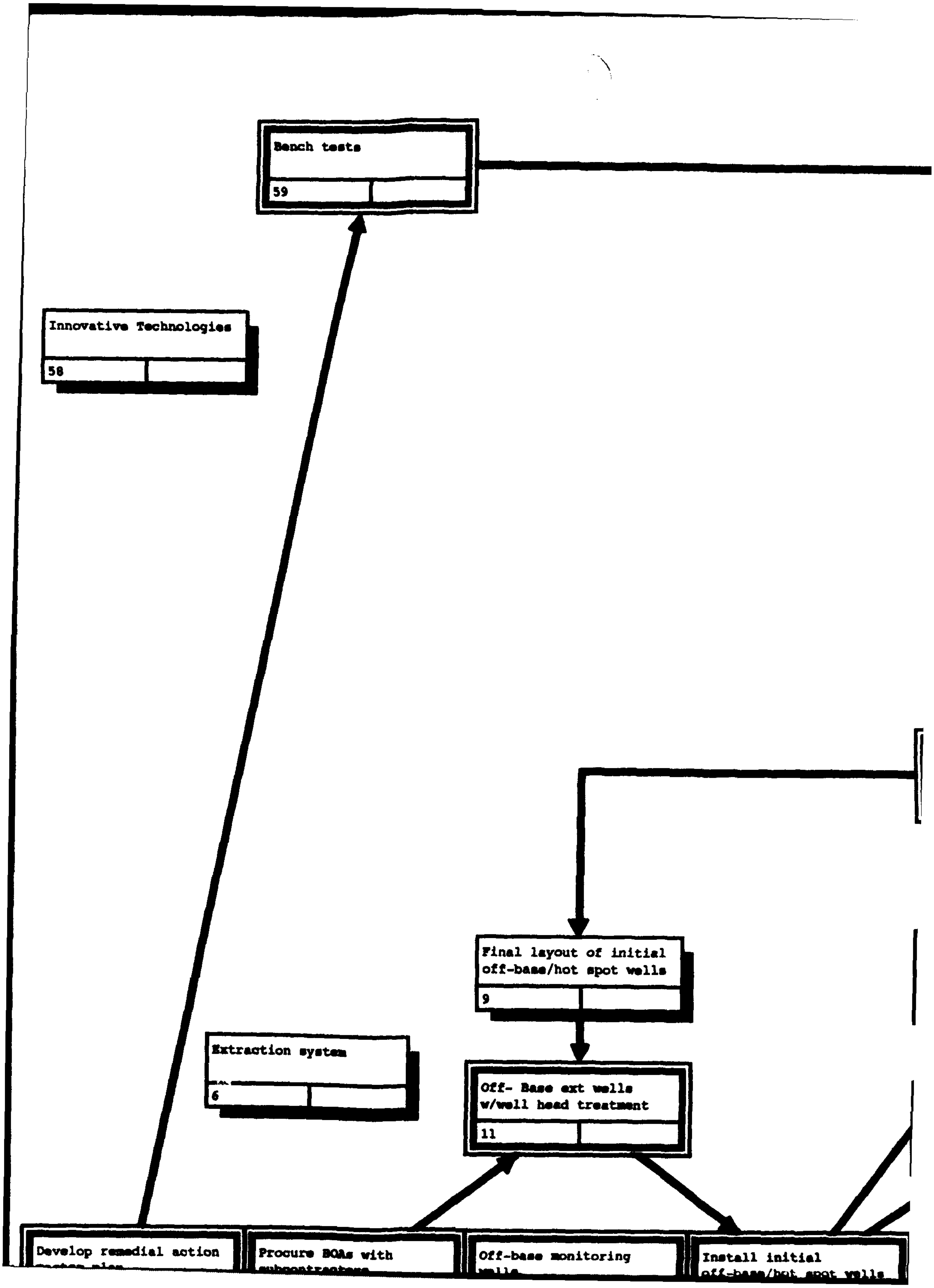
13.3.3 Preferred Remedy

The preferred remedy for the Groundwater OU is control of the 10^{-6} risk target volume, treatment of the extracted groundwater using an air-stripper with VGAC on the offgas followed by polishing the water with LGAC, and injection of the treated water. The hot spots within the groundwater plumes will be hydraulically isolated to remove the DNAPLs as a continuous source to the less concentrated areas. Innovative technologies that will be applied to the hot spots include high-vacuum, dual-phase extraction, in situ anaerobic biological treatment, in situ cometabolic (aerobic) biological treatment, and SVE. The innovative technologies will be tested to measure their effectiveness and cost prior to implementation. The remedy includes all the baseline requirements listed in Section 13.1.1.

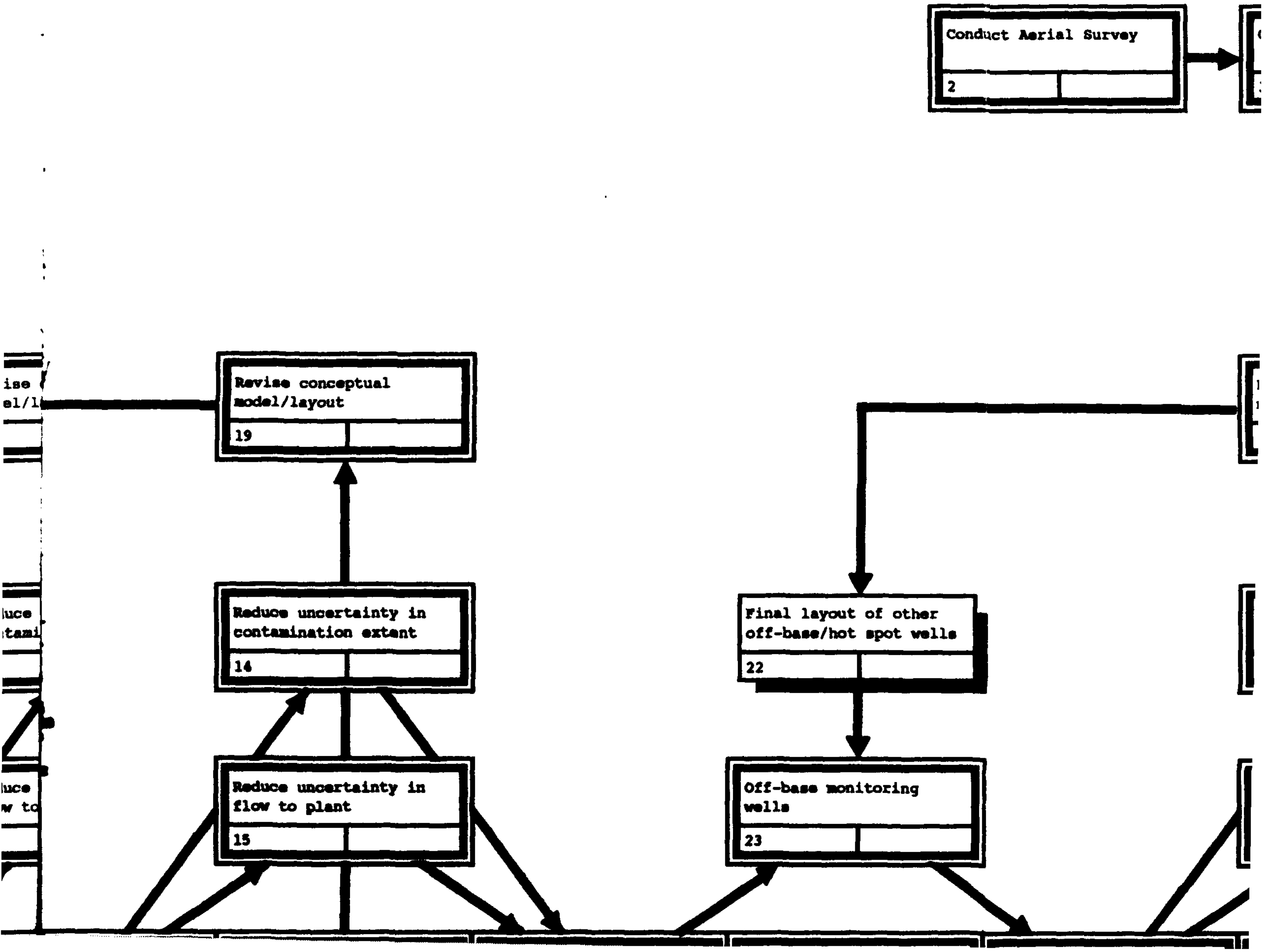
McClellan AFB is currently pilot testing the high-vacuum, dual-phase extraction process at OU A. The two in situ biological processes will receive a high priority for evaluation and testing because of their potential to destroy contaminants in situ. The SVE/sparging process will be tested in conjunction with the ongoing SVE pilot test at OU D.

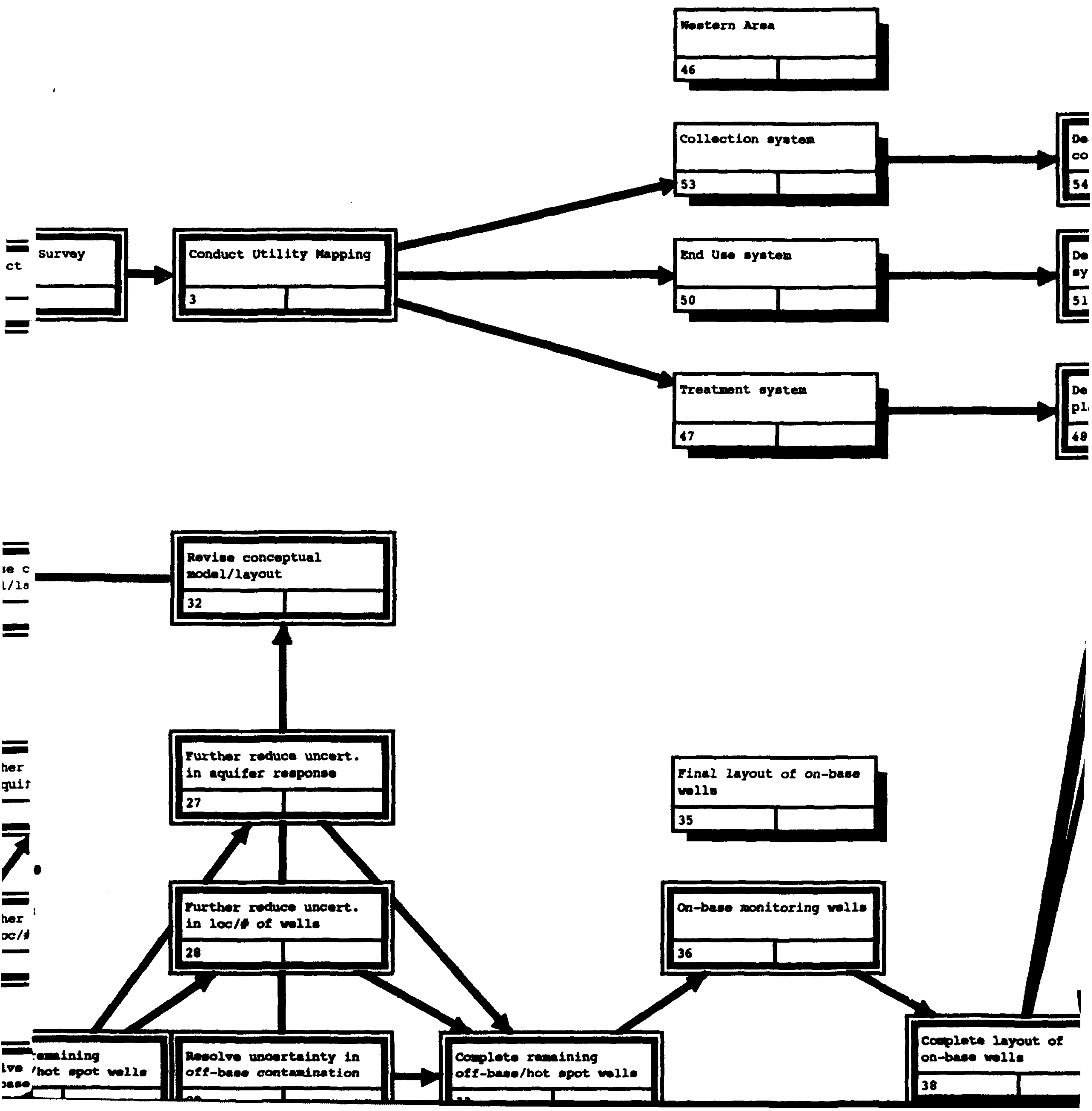
Innovatives technologies that will be pursued for the improvement of the selected treatment train are resin adsorption and biofiltration to replace the VGAC or reduce the treatment burden and cost. These technologies will be tested at McClellan AFB on the existing groundwater treatment plant. E-beam destruction of VOCs in water will not be pursued further until the testing at Savannah River is completed and evaluated.

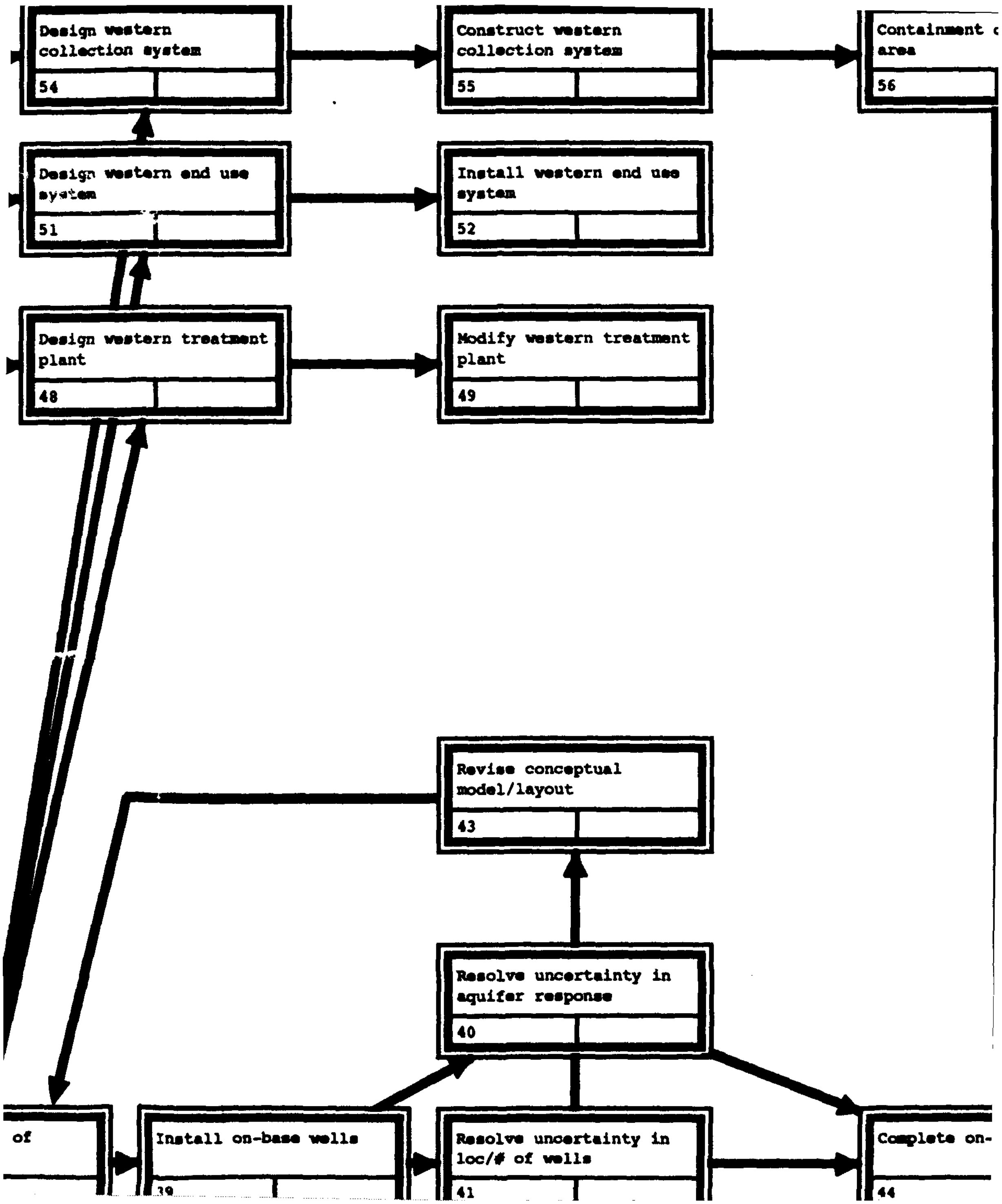
Contingency measures to be included in the remedy are potential metals removal prior to water end use, potential onbase reuse of a portion of the water, and wellhead treatment on offbase supply wells. The contingency measures will only be implemented if necessary.



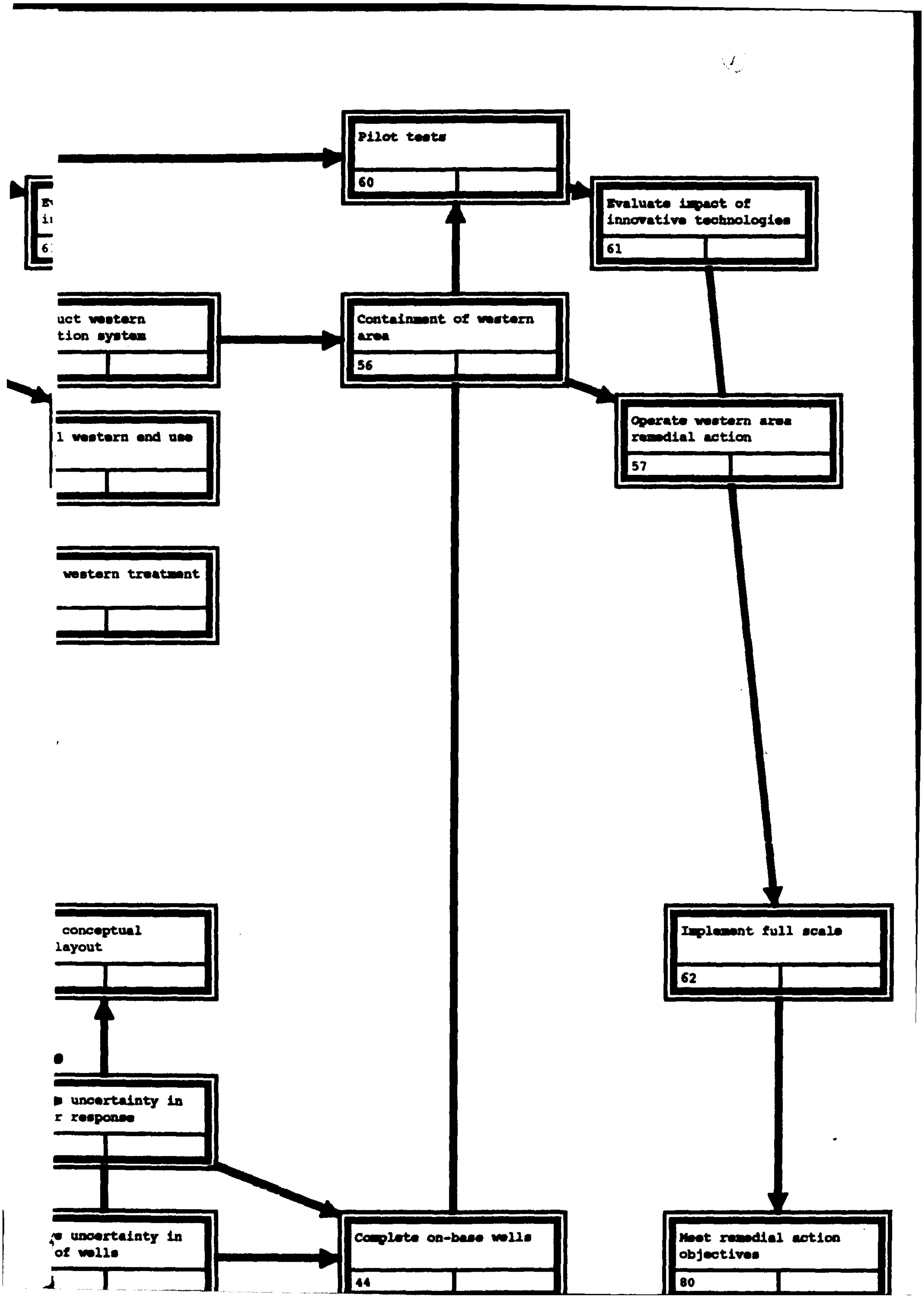
Bench tests
59
Innovative Technologies
58
Final layout of initial off-base/hot spot wells
9
Extraction system
6
Off- Base ext wells w/well head treatment
11
Develop remedial action
Procure BOAs with
Off-base monitoring
Install initial


Conduct Aerial Survey
2
Revise conceptual model/layout
19
Reduce uncertainty in contamination extent
14
Reduce uncertainty in flow to plant
15
Final layout of other off-base/hot spot wells
22
Off-base monitoring wells
23

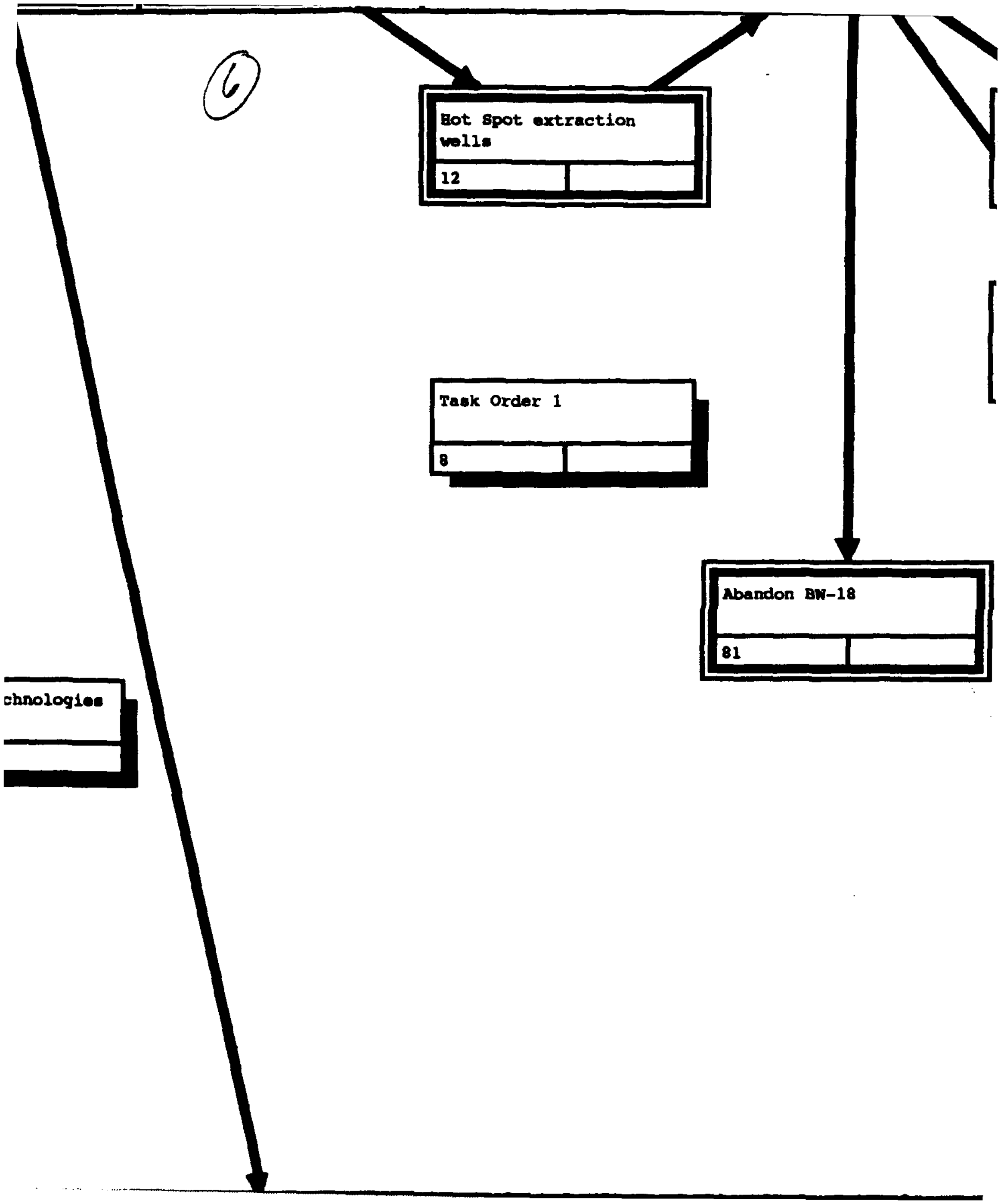

Western Area
46
Collection system
53
End Use system
50
Treatment system
47
Survey
Conduct Utility Mapping
3
Revise conceptual model/layout
32
Further reduce uncert. in aquifer response
27
Further reduce uncert. in loc/# of wells
28
Final layout of on-base wells
35
On-base monitoring wells
36
Resolve uncertainty in off-base contamination
Complete remaining off-base/hot spot wells
Complete layout of on-base wells
38



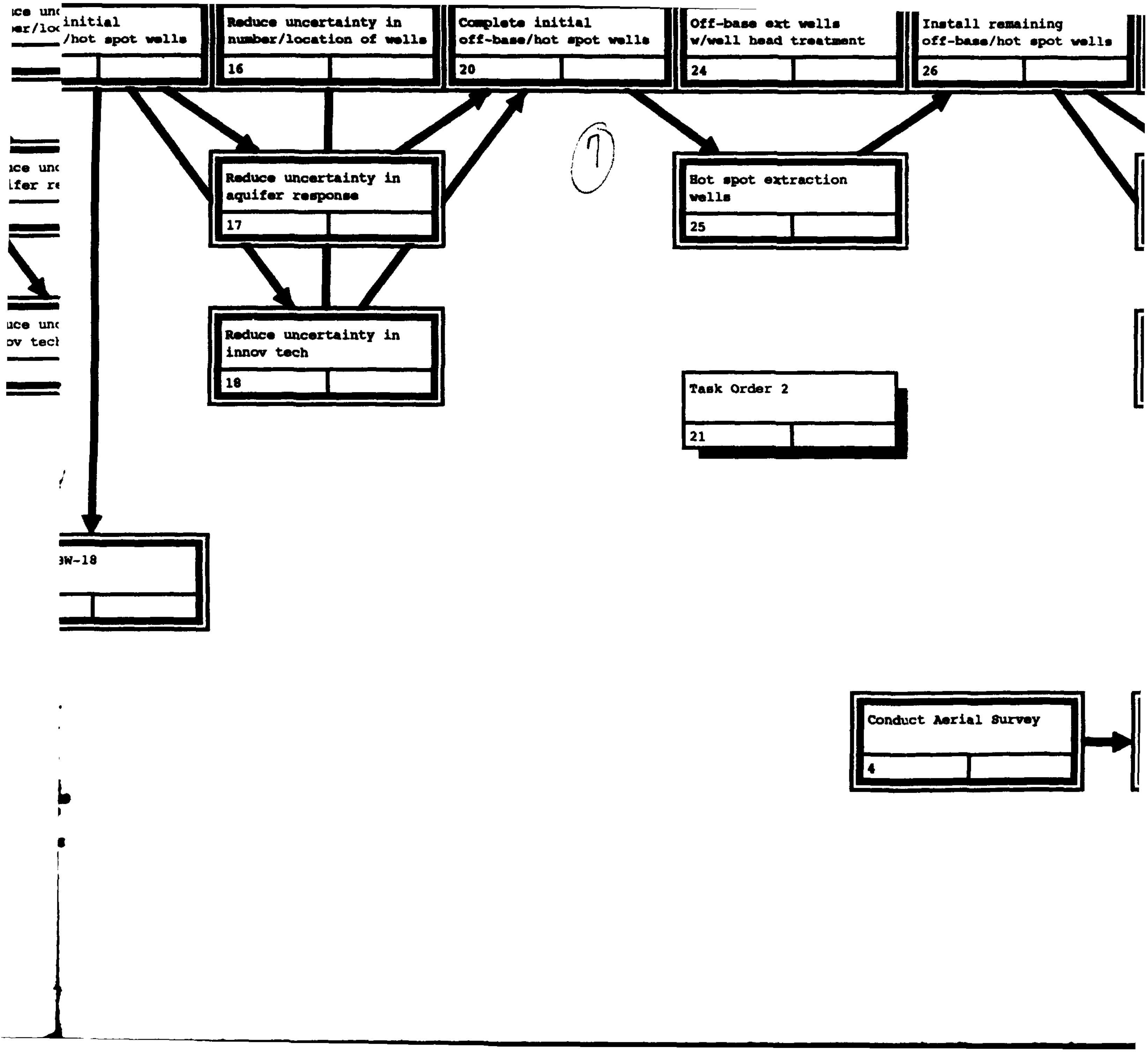
Design western collection system
54
Construct western collection system
55
Containment
area
56
Design western end use system
51
Install western end use system
52
Design western treatment plant
48
Modify western treatment plant
49
Revise conceptual model/layout
43
Resolve uncertainty in aquifer response
40
of
Install on-base wells
39
Resolve uncertainty in loc/# of wells
41
Complete on-
44



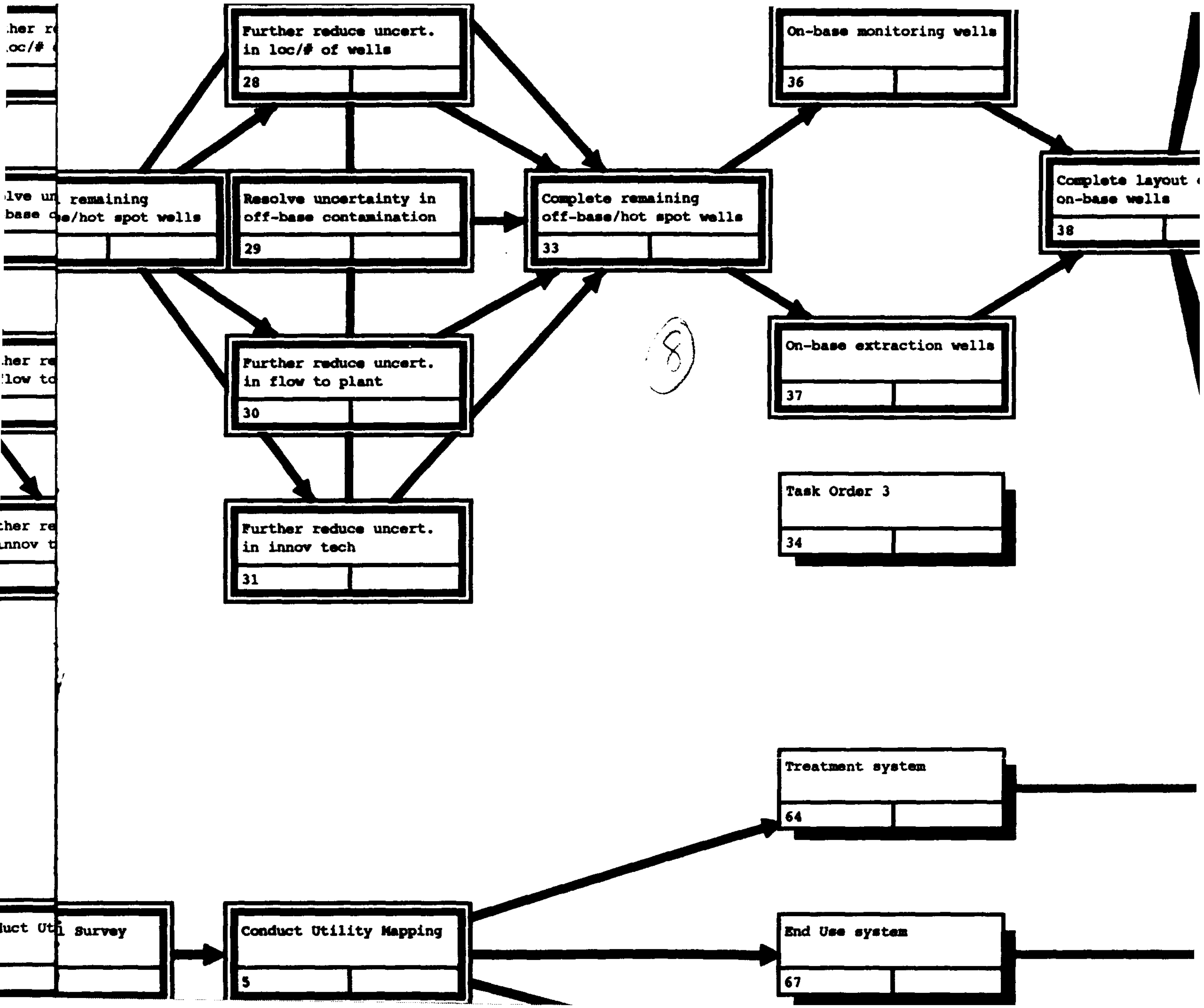
Pilot tests
60
Evaluate impact of innovative technologies
61
uct western
tion system
Containment of western area
56
l western end use
Operate western area remedial action
57
western treatment
conceptual
layout
Implement full scale
62
uncertainty in
r response
uncertainty in
of wells
Complete on-base wells
44
Meet remedial action objectives
80

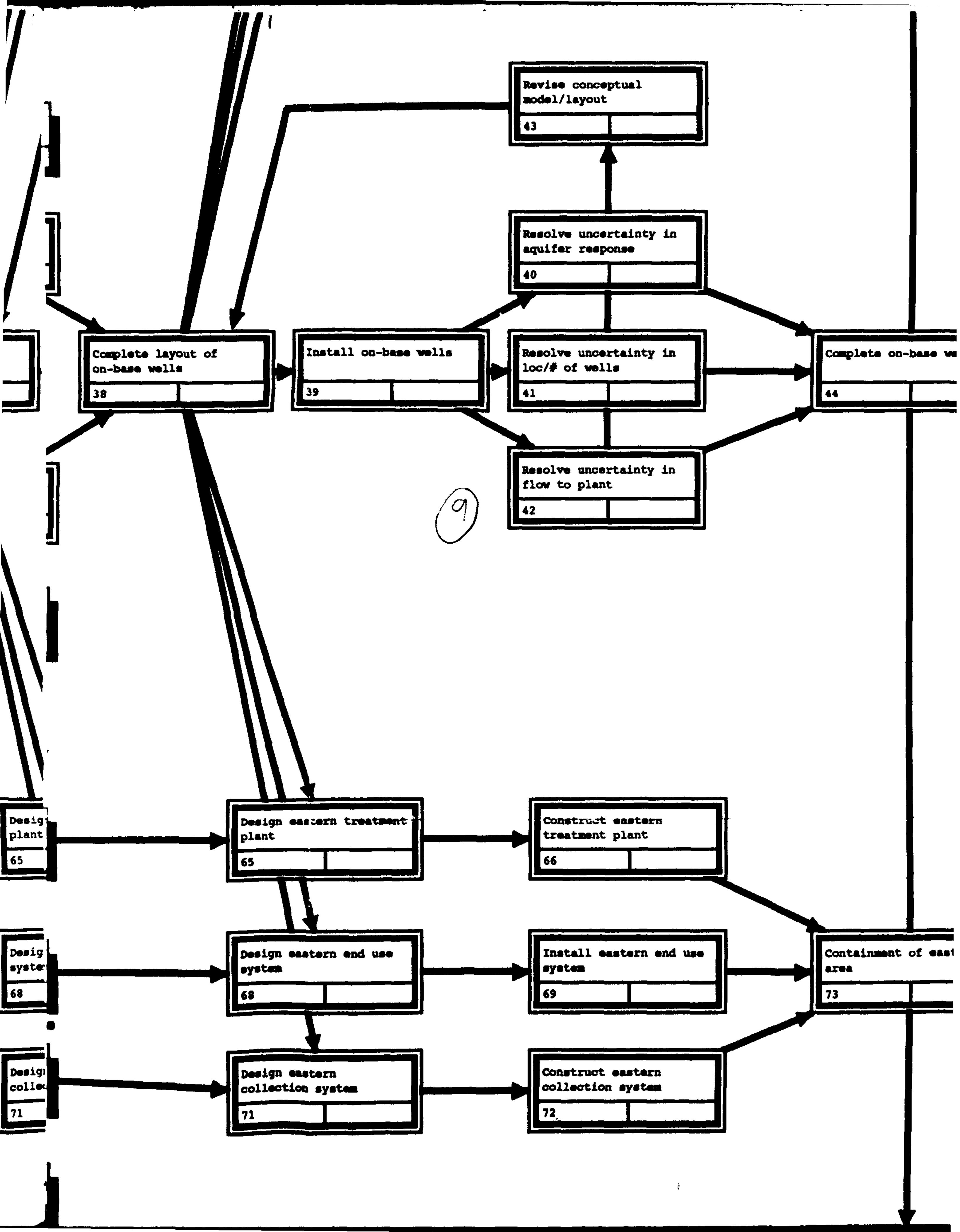


Hot Spot extraction wells
12
Task Order 1
8
Abandon BW-18
81
chnologies

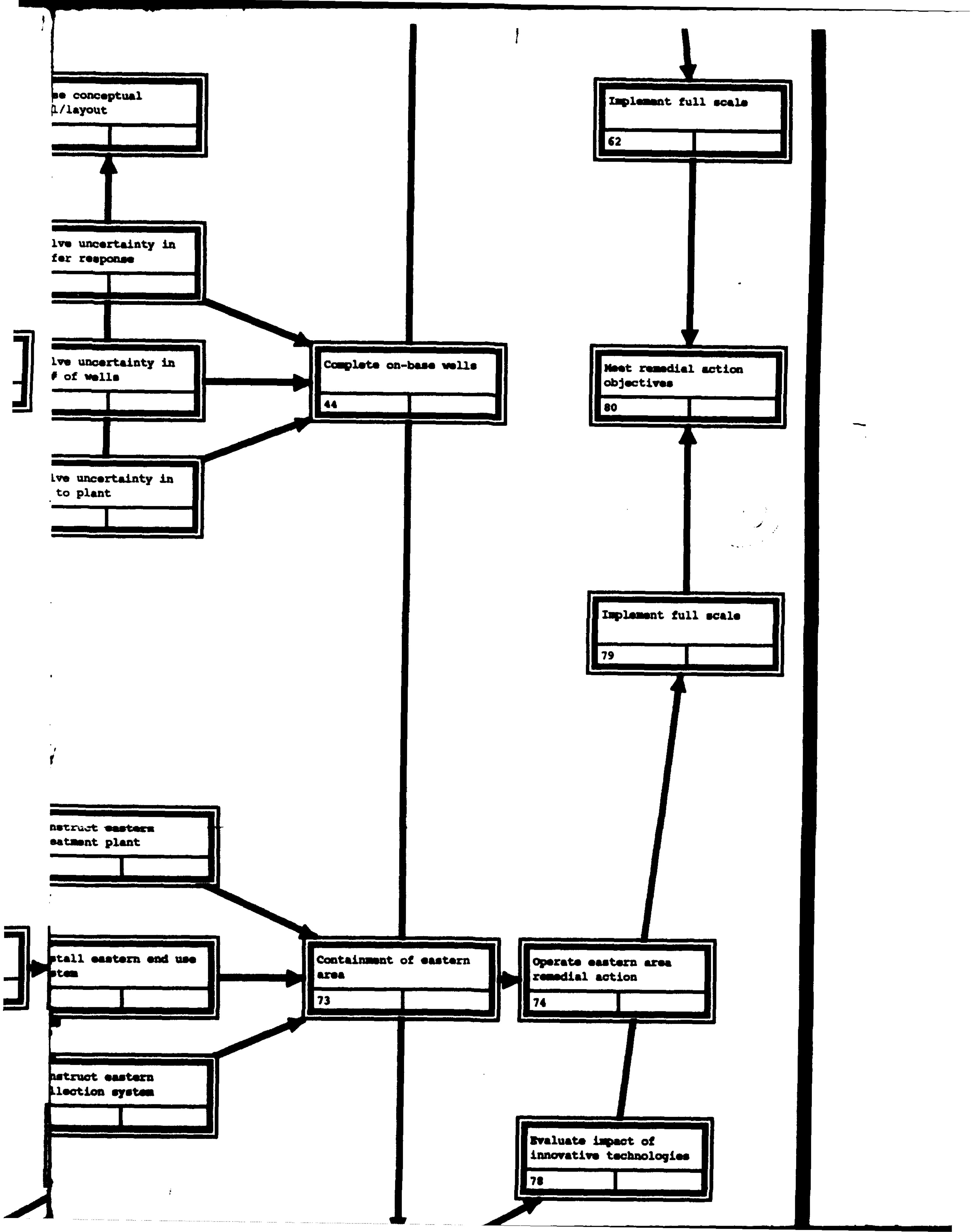


initial
/hot spot wells
Reduce uncertainty in number/location of wells
16
Complete initial off-base/hot spot wells
20
Off-base ext wells w/well head treatment
24
Install remaining off-base/hot spot wells
26
Reduce uncertainty in aquifer response
17
7
Hot spot extraction wells
25
Reduce uncertainty in innov tech
18
Task Order 2
21
Conduct Aerial Survey
4

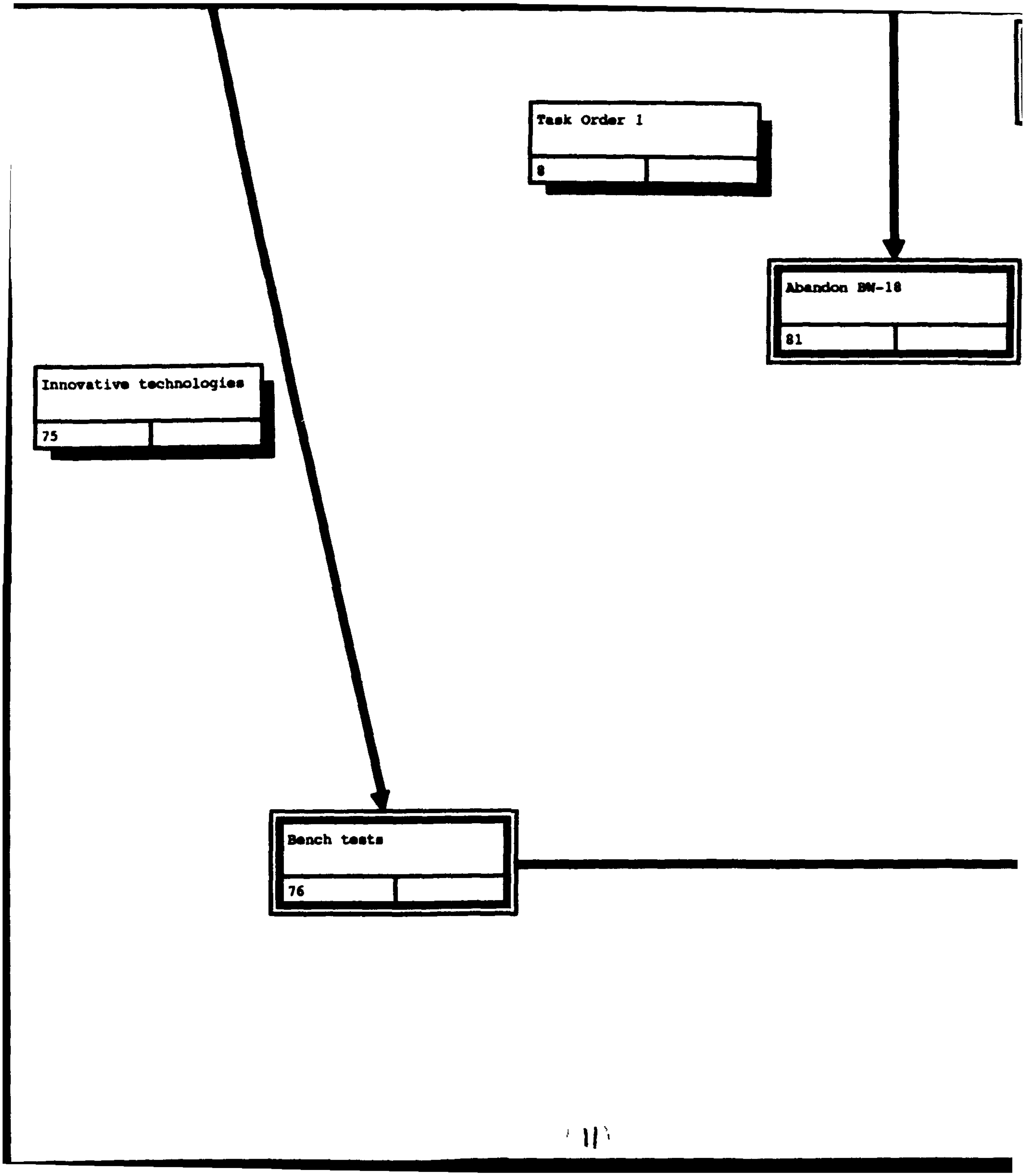

Further reduce uncert. in loc/# of wells
28
On-base monitoring wells
36
remaining e/hot spot wells
Resolve uncertainty in off-base contamination
29
Complete remaining off-base/hot spot wells
33
Complete layout on-base wells
38
Further reduce uncert. in flow to plant
30
On-base extraction wells
37
Task Order 3
34
Further reduce uncert. in innov tech
31
Treatment system
64
Survey
Conduct Utility Mapping
5
End Use system
67

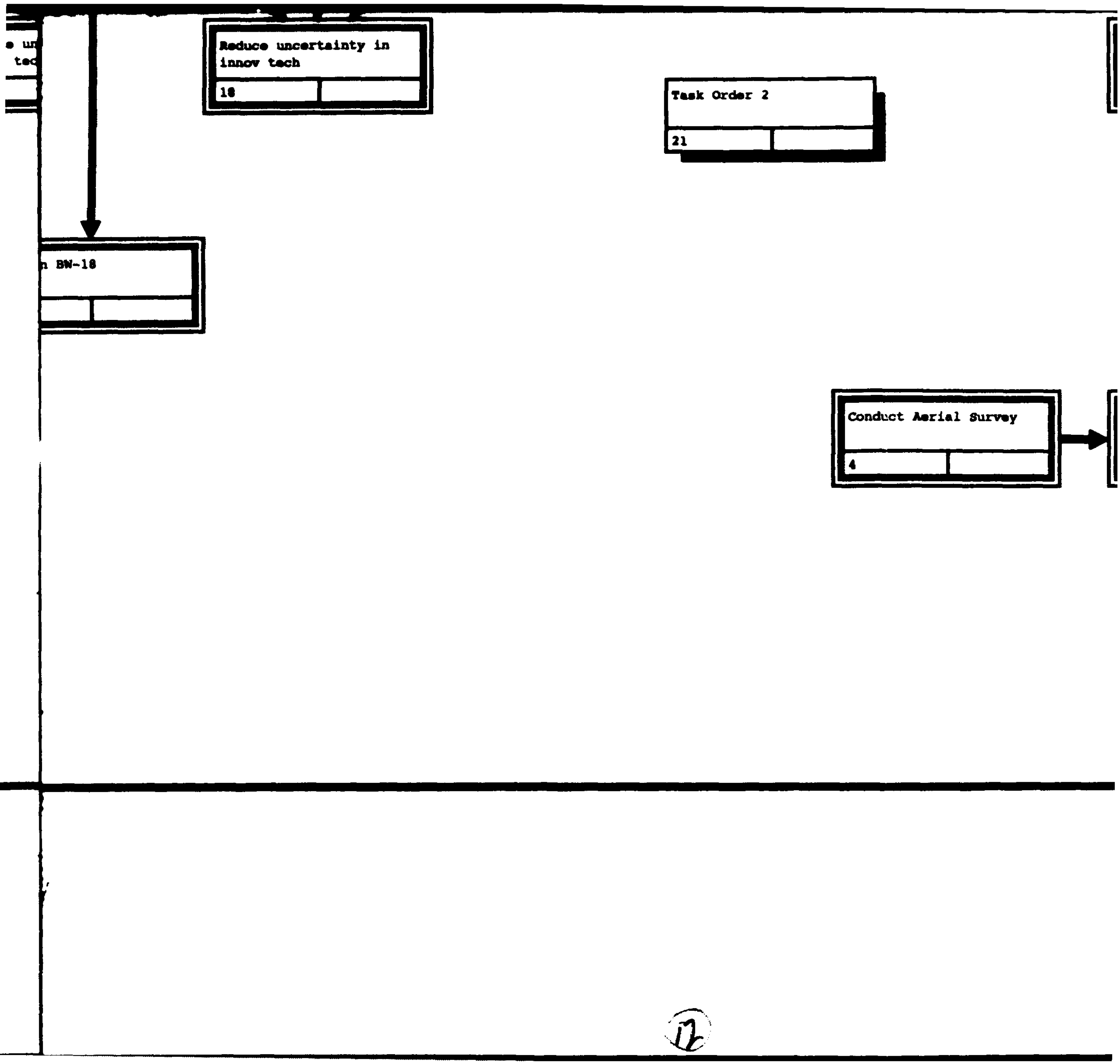


Revise conceptual model/layout
43
Resolve uncertainty in aquifer response
40
Complete layout of on-base wells
38
Install on-base wells
39
Resolve uncertainty in loc/# of wells
41
Complete on-base w
44
Resolve uncertainty in flow to plant
42
9
Design eastern treatment plant
65
Construct eastern treatment plant
66
Design eastern end use system
68
Install eastern end use system
69
Containment of east area
73
Design eastern collection system
71
Construct eastern collection system
72

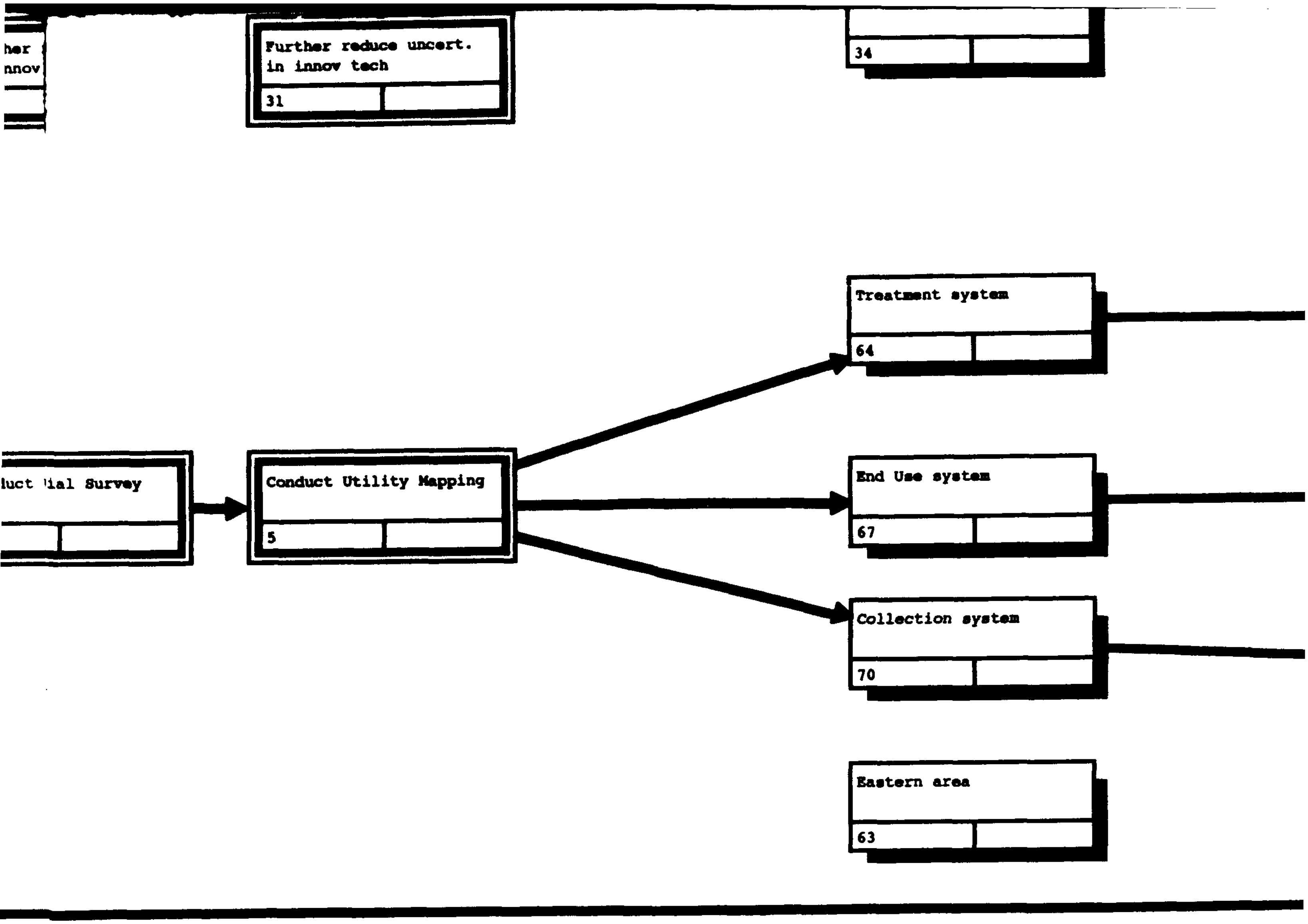


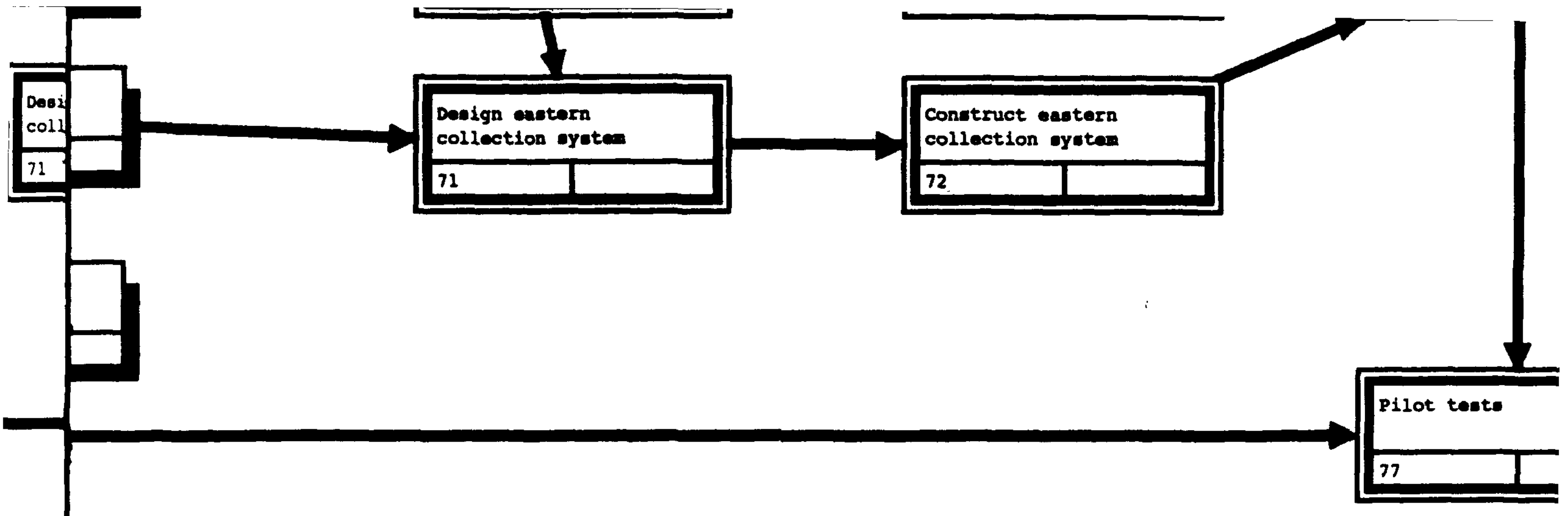
se conceptual
l/layout
Implement full scale
62
lve uncertainty in
fer response
lve uncertainty in
# of wells
Complete on-base wells
44
Meet remedial action objectives
80
lve uncertainty in
to plant
Implement full scale
79
nstruct eastern
eatment plant
stall eastern end use
stem
Containment of eastern area
73
Operate eastern area remedial action
74
nstruct eastern
llection system
Evaluate impact of innovative technologies
78


Task Order 1
8
Abandon BW-18
81
Innovative technologies
75
Bench tests
76



Reduce uncertainty in innov tech
18
Task Order 2
21
n BW-18
Conduct Aerial Survey
4


Further reduce uncert. in innov tech
31
34
Treatment system
64
Conduct Utility Mapping
5
End Use system
67
Collection system
70
Eastern area
63



FIGU
IMPL
SEQU
GROUN
McCLEL
SACRAM

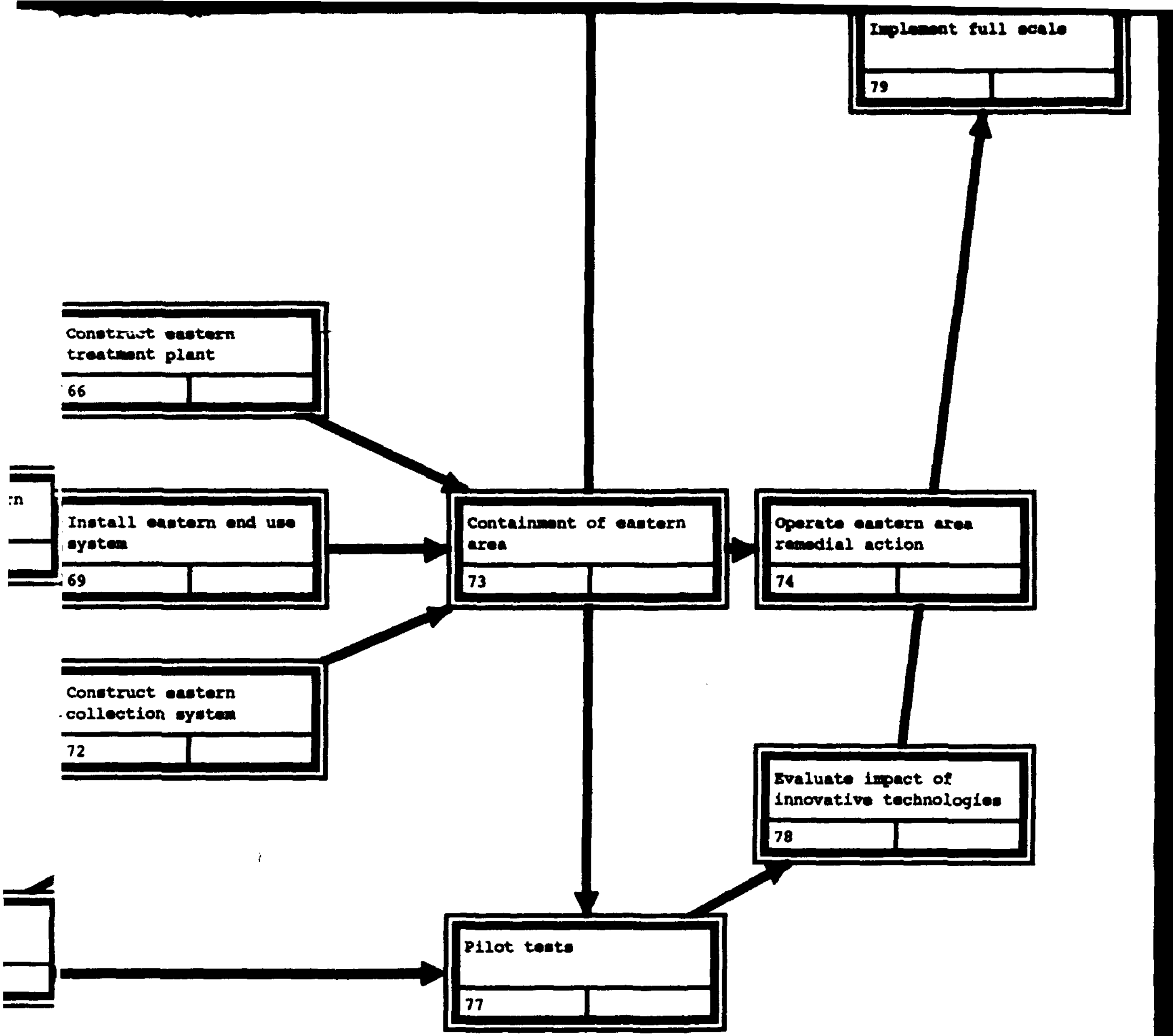


FIGURE 13-8
IMPLEMENTATION PLANS/ SEQUENCE OF MAJOR TASKS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Chapter 14
Works Cited

Agency for Toxic Substances and Disease Registry. 1993. *Public Health Assessment for McClellan Air Force Base, Sacramento, Sacramento County, CA*, CERCLIS No. CA4570024337.

California Air Resources Board. 1984. *California Surface Wind Climatology.*

California Department of Water Resources. 1974. "Evaluation of Groundwater Resources." *Sacramento County Bulletin 118-3.*

California Department of Water Resources. 1978. "Evaluation of Groundwater Resources of Sacramento Valley." *Sacramento County Bulletin 118-6.*

CH2M HILL. 1981. Installation Restoration Program Records Search. Prepared for McClellan AFB, Sacramento, California.

CH2M HILL. 1984. *Site Characterization Study, Area D.* Prepared for McClellan AFB, Sacramento, California.

CH2M HILL. 1992a. *Work Plan: Soil Vapor Extraction Treatability Investigation, Site S, Operable Unit D.* Prepared for McClellan AFB, Sacramento, California.

CH2M HILL. 1992b. *Sampling and Analysis Plan Operable Unit D Field Investigation.* Prepared for McClellan AFB, Sacramento, California.

CH2M HILL. 1992c. *Operable Unit D Remedial Investigation Report.* Prepared for McClellan AFB, Sacramento, California.

CH2M HILL. 1993a. *Work Plan: Steam Injection/Vacuum Extraction Treatability Investigation, Site 22, Operable Unit C1.* Prepared for McClellan AFB, Sacramento, California.

CH2M HILL. 1993b. *Operable Unit C Preliminary Assessment.* Prepared for McClellan AFB, Sacramento, California.

Clark, C. S., C. R. Meyer, P. S. Gartside, V. A. Majeti. B. Specker, W. F. Balistreri, and V. J. Elia. 1982. An Environmental Health Survey of Drinking Water Contamination from a Pesticide Waste Dump in Hardeman County, Tennessee. *Arch. Environ. Health.* 37:9-18.

Cohen, R. M., and J. W. Mercer. 1993. *DNAPL Site Evaluation. C. K. Smoley.*

EG&G Idaho. 1988. Informal Report: McClellan Air Force Base Industrial Wastewater Collection System Characterization Report. Prepared for McClellan AFB, Sacramento, California.

Engineering Science. 1983. *Final Report, Installation Restoration Program, Phase II-Confirmation*. Prepared for U.S. Air Force Occupational and Environmental Health Laboratory, Brooks AFB, Texas.

Fogelman, Ronald P. 1979. *Chemical Quality of Ground Water in the Eastern Sacramento Valley, California*. U.S. Geological Survey. Water-Resources Investigations 78-124. Prepared in cooperation with the California Department of Water Resources. June.

Freeze, R.A., and Cherry, J.A., 1979. *Groundwater*. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Graf, Charles. 1991. *Behavior of Organic Contaminants in the Subsurface, Lecture Notes, Arizona Department of Environmental Quality*. September.

International Institute for Land Reclamation and Improvement (ILRI). 1973. Drainage Principles and Applications.

Jacobs Engineering Group. 1992. *Remedial Investigation Sampling and Analysis Plan for Operable Unit A*. Prepared for McClellan AFB, Sacramento, California.

Jacobs Engineering Group. 1992. *Sampling and Analysis Plan for Operable Unit C1*. Prepared for McClellan AFB, Sacramento, California.

Kahrl, W. L., Project Director and Editor. 1978. The California Water Atlas.

Kruseman, G.P., and de Riddler, N.A. 1991. Analysis and Evaluation of Pumping Test Data. International Institute for Land Reclamation and Improvement, the Netherlands.

Ludorff & Scalmanini. 1983. *Base Wells Sealing Report*. Prepared for McClellan AFB, Sacramento, California.

McClaren Environmental Engineering. 1986. *Basewide Report on Contamination*. Prepared for McClellan AFB, Sacramento, California.

McClaren Environmental Engineering. 1986. Technical Memorandum for the Shallow Investigation Program in Areas A, B, C, and Other Sites. Parts I-III. Prepared for McClellan AFB, Sacramento, California.

McClellan Air Force Base. 1993. Management Action Plan.

National Oceanic and Atmospheric Administration. 1989. Climatological Data Summary for California. Vol. 93, No. 13

National Research Council. 1980. *Drinking Water and Health*. Volume 3. National Academy Press, Washington, D.C.

Norris, R. M. 1990. *Geology of California*, Second Edition.

Pauls, C.F. and J.R. Doane. 1973. *Comprehensive Summary of Magpie Creek, McClellan Air Force Base, California.* USAF Environmental Health Laboratory.

Radian Corporation. 1984. Inventory of private wells offbase.

Radian Corporation. 1986-current. Installation Restoration Program Sampling and Analysis Program: Technical Reports. Prepared for McClellan AFB, Sacramento, California.

Radian Corporation. 1989. *Engineering Evaluation/Cost Analysis-Environmental Assessment.* Prepared for McClellan AFB, Sacramento, California.

Radian Corporation. 1990. *Preliminary Groundwater Operable Unit Remedial Investigation (Hydrogeologic Assessment) Sampling and Analysis Plan.* February.

Radian Corporation. 1991. *Comprehensive CERCLA Work Plan.*

Radian Corporation. 1991. *Installation Restoration Program (IRP), McClellan Air Force Base Comprehensive CERCLA Work Plan.* July.

Radian Corporation. 1991. Preliminary Groundwater Operable Unit Remedial Investigation Technical Report. Prepared for McClellan AFB, Sacramento, California.

Radian Coporation. 1991. Operable Unit B Remedial Investigation. Prepared for McClellan AFB, Sacramento, California. Draft expected June 1994.

Radian Corporation. 1992. *Preliminary Groundwater Operable Unit Remedial Investigation, Final.* September.

Radian Corporation. 1992. *Operable Unit A Remedial Investigation Sampling and Analysis Plan.* September.

Radian Corporation. 1992. *Installation Restoration Program (IRP) Stage 7, Preliminary Groundwater Operable Unit Remedial Investigation.* September.

Radian Corporation. 1993. *Operable Unit B1 Remedial Investigation/Feasibility Study.* Prepared for McClellan AFB, Sacramento, California. Draft. March 3.

Radian Corporation. 1993. Operable Unit C Remedial Investigation/Feasibility Study Sampling and Analysis Plan, Draft. Prepared for McClellan AFB, Sacramento, California.

Radian Corporation. 1994. Working Copy Basewide RI/FS Quality Assurance Project Plan (QAPP) Update. May.

Sacramento County. 1985. Census Tracts.

State of California, Department of Water Resources in cooperation with the U.S. Geological Survey. 1978. *Evaluation of Ground Water Resources: Sacramento Valley*. Bulletin 118-6. August.

State of California, Department of Water Resources in cooperation with County of Sacramento. 1974. *Evaluation of Ground Water Resources: Sacramento County*. Bulletin 118-3. July.

Shy, C. M. 1985. "Chemical Contamination of Water Supplies." *Environmental Health Perspect*. 62:399-406.

University of California, Berkeley, Division of Agricultural Sciences. Undated. *Average Daily Air Temperature and Precipitation in California*.

U.S. Environmental Protection Agency. 1989. *Risk Assessment Guidance for Superfund. Human Health Evaluation Manual Part A, Final*. OSWER Directive 9285.701A. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Washington, DC.

U.S. Environmental Protection Agency. 1990. National Contingency Plan. *Federal Register*. 55:8665-8865. March 8.

U.S. Environmental Protection Agency. 1990. *Subsurface Contamination Reference Guide*. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/2-90/011. October.

U.S. Environmental Protection Agency. 1991. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. Memorandum from Don R. Clay, April 22, 1991. Office of Solid Waste and Emergency Response. OSWER Directive 9355.0-30.

U.S. Environmental Protection Agency, Region IX. 1993. Preliminary Ecological Survey, Draft. Prepared for McClellan AFB, Sacramento, California.

Upton, A. C., T. Kneip, P. Toniolo. 1989. Public health aspects of toxic chemical disposal sites. *Ann. Rev. Public Health*. 10:1-25.

Williamson, J. S. 1981. "Epidemiologic Studies on Cancer and Organic Compounds in U.S. Drinking Water." *Sci. Tot. Environ.* 18:187-203.