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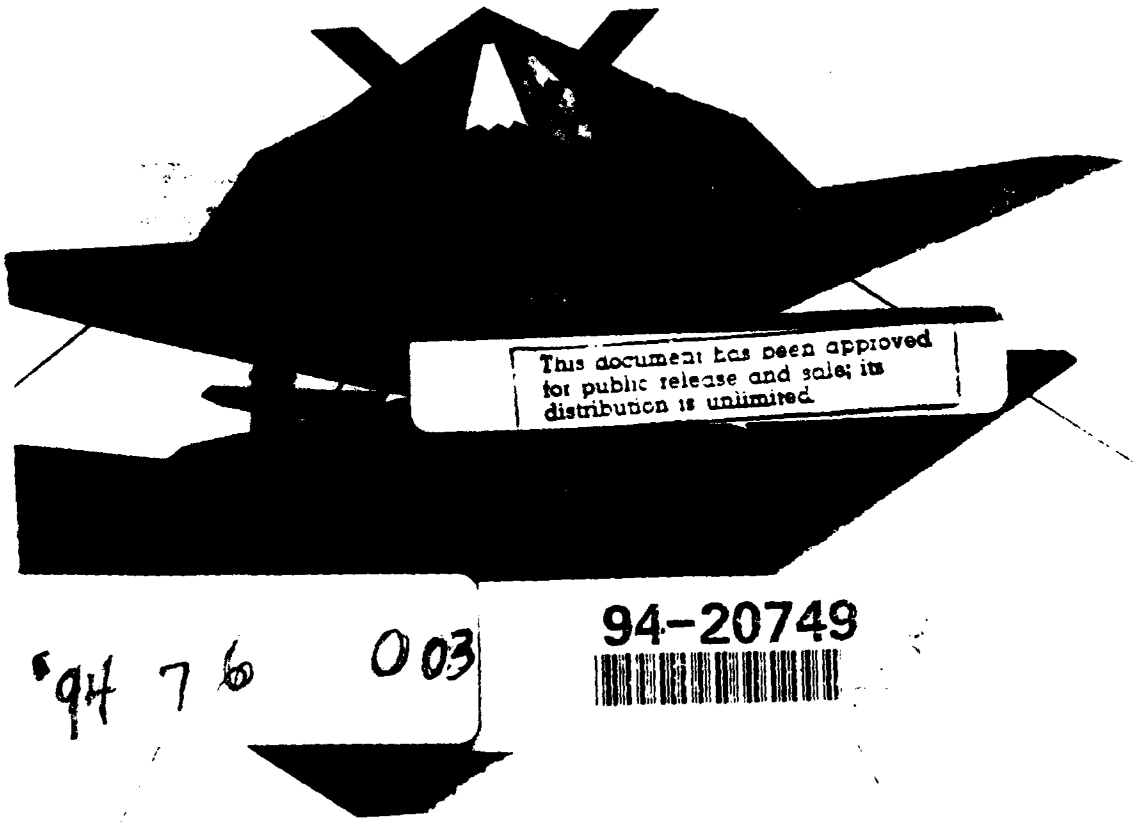
Basewide Groundwater Operable Unit

Groundwater Operable Unit Remedial Investigation/ Feasibility Study Report

Delivery Order 5066

Volume 3 of 3



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McCLELLAN AIR FORCE BASE, CALIFORNIA

JUN 23 1994

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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.

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

Attachment:
GW OU Final RI/FS

cc:
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Groundwater Operable Unit
Remedial Investigation/Feasibility Study Report

Volume 3 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**

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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.

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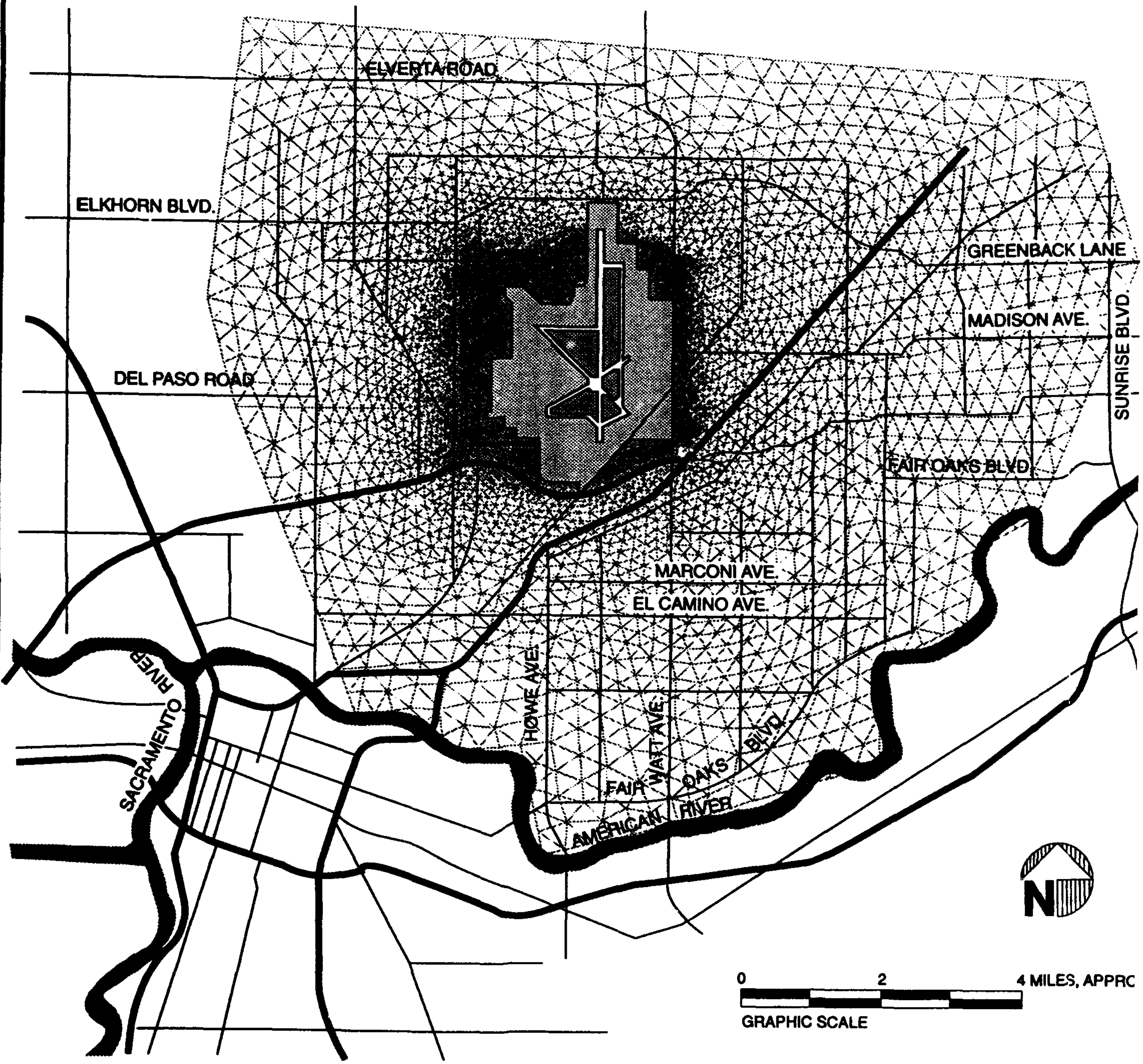

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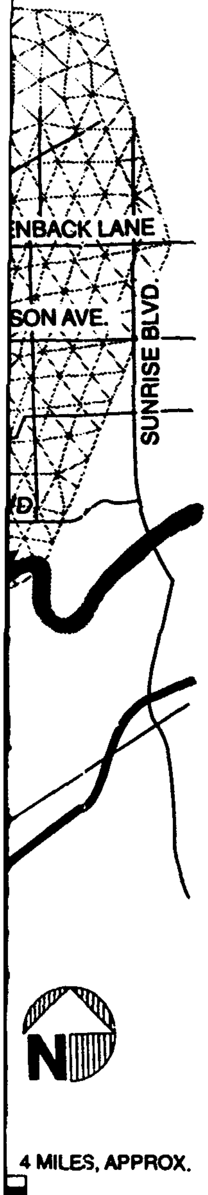


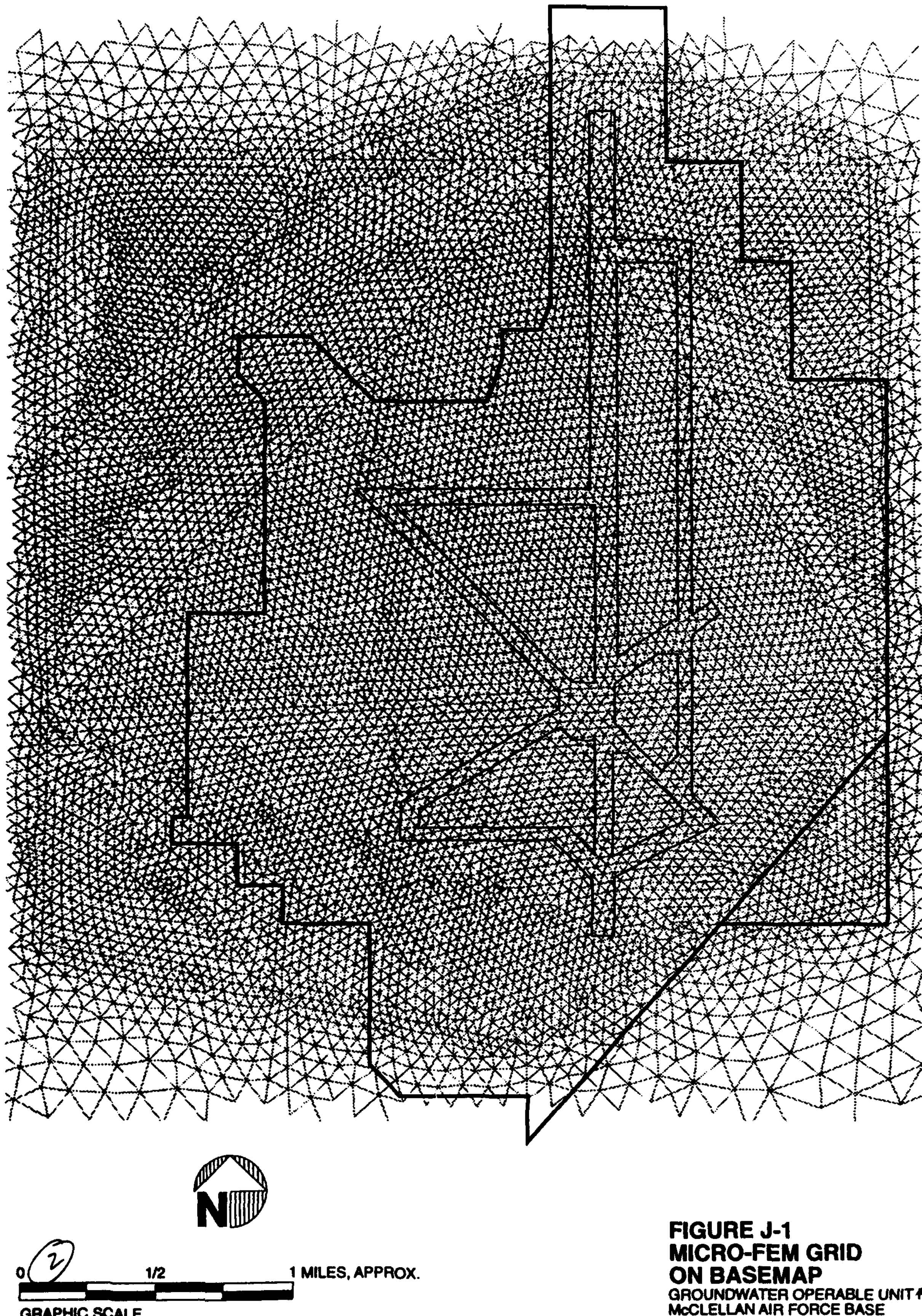


FIGURE J-1
MICRO-FEM GRID
ON BASEMAP
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

PREPARED FOR: McClellan Air Force Base

DATE: May 12, 1994

SUBJECT: Groundwater Model Development
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.GW

As a convenience to the reader, all oversize figures (11" x 17" or larger) have been located at the end of the appendix.

Introduction

This technical memorandum describes the construction, calibration, and application of the groundwater flow model developed to evaluate remedial action alternatives at McClellan Air Force Base (McClellan AFB). The objectives of the modeling effort and the uncertainties and limitations of using a numerical model to simulate a complex physical system are also discussed.

Modeling Objectives

A numerical groundwater flow model was developed as an analytical tool to assist in the development of extraction well networks to contain and remediate contaminated groundwater at McClellan AFB. The specific objectives of the modeling effort are as follows:

- Evaluate the total extraction rate required to contain various target volumes of contaminated groundwater
- Demonstrate that groundwater containment is a viable remedial alternative for contaminated groundwater at McClellan AFB
- Estimate the response of the groundwater system to potential remedial actions

Additional questions that were addressed during the course of the modeling effort include:

- The quantity of extracted groundwater requiring treatment
- The impact of end-use injection on the containment system

Numerical modeling was chosen as the appropriate tool for this task because it has the capability to represent multidimensional flow in a heterogeneous system with less conceptual idealization than is required by other analytical techniques. However, it was recognized from the outset that there will always be some uncertainty in the hydrogeologic understanding of the site and that the modeling analysis can only provide approximate answers to the items previously discussed. The process of developing a numerical model of a complex physical system requires that simplifying assumptions be made to reflect the uncertainties in the definition of 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. At McClellan AFB, the most significant uncertainties in the site characteristics used to construct the groundwater model include:

- 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

This technical memorandum provides a summary of the numerical modeling procedures and results as they pertain to the previously listed objectives.

Site Conceptual Model and Model Construction

The first step in the analytical process is to identify the essential features of the site hydrologic system that must be included in the conceptual model and to determine how the essential features can be represented in the numerical analysis. This procedure results in the development of a site conceptual model, which then forms the framework for construction of the numerical model. This section discusses the characteristics of the model code, essential quantitative aspects of the conceptual model that were included in the numerical model, and the procedures used to construct the numerical model. For further detail regarding the complete site conceptual model, refer to Chapter 4 of the RI/FS Report.

Groundwater Model Code Description and Selection

The groundwater flow model prepared for this project is a multilayer finite element model that can be run as a steady-state or transient system. The code for the model is Micro-Fem, an integrated groundwater modeling package developed in the Netherlands (Hemker, 1988). Micro-Fem runs on any PC with EGA or VGA graphics. The present version handles up to 16 aquifers and a maximum number of nodes between 1,000 and 4,000 on a PC with 590 Kb user-available RAM, depending on the number of layers in the simulated system. When extended memory is available on 80386- or 80486-based microcomputers, models up to 12,500 nodes (25,000 elements) can be designed. The package consists of several programs: two finite element mesh generators, a calculation module for steady-state flow and one for transient flow, a combined pre- and postprocessor called FeModel, a three-dimensional particle tracking program and some additional utilities. It is capable of modeling saturated, single-density groundwater flow in layered systems. Horizontal flow is considered in each layer, as is vertical flow between adjacent layers. A layered aquifer or different aquifers in a multiple-aquifer system can be modeled in this way.

The mesh generation routine is described in Lo, 1985. The band-width reduction technique is based on the approach of Gibbs et. al., 1976.

Programs called FemCalc (steady-state) and FemCat (transient) perform the calculations for solving the flow equations by means of a finite element technique with linear basis functions for the horizontal flow components and through a finite- difference scheme for the flow between adjacent layers. The system of equations is solved iteratively, using the method of successive over-relaxation (SOR) with automatic adjustment of the relaxation factor. The progress of calculations is shown on the screen by head improvements and residual water balance errors. The automatic stopping criterion can be overruled by the user.

The Micro-Fem model was chosen for use at McClellan AFB for several reasons outlined below:

- The finite element approach allowed the construction of a model grid that covered 100 square miles while maintaining node spacings as small as 75 feet in areas where groundwater extraction is simulated.

- Micro-Fem includes a three dimensional particle tracking utility that is ideal to evaluate capture in the stratified aquifer system at McClellan

- The graphical user interface allows rapid assignment of aquifer parameters to model nodes, and allows proofing of assigned values by graphical means

Finite Element Mesh Delineation and Boundary Conditions

Model Grid

The numerical model developed for McClellan AFB was developed in accordance with the site conceptual model discussed in Chapter 4 of the RI/FS report. The Micro-Fem groundwater model was constructed as a four-layer model using a computational finite element mesh of 11,510 nodes and 22,894 elements. Figure J-1 shows the general layout of the model grid which consists of a central area of extremely fine node spacing (75 ft) that transitions out to the model boundaries with constantly increasing node spacing. The total modeled area is approximately 100 mi^2, centered on McClellan AFB. The node spacing ranges from 75 to 2,000 feet, with smaller elements constructed in areas of observed contamination. High node density in areas of suspected and confirmed contamination allows improved definition o spatial hydraulic head distribution created by extraction well pumping. Along w improved definition in the hydraulic head field comes more reliable particle tracking analysis and better estimation of the extent of capture for a particular extraction wellfield.

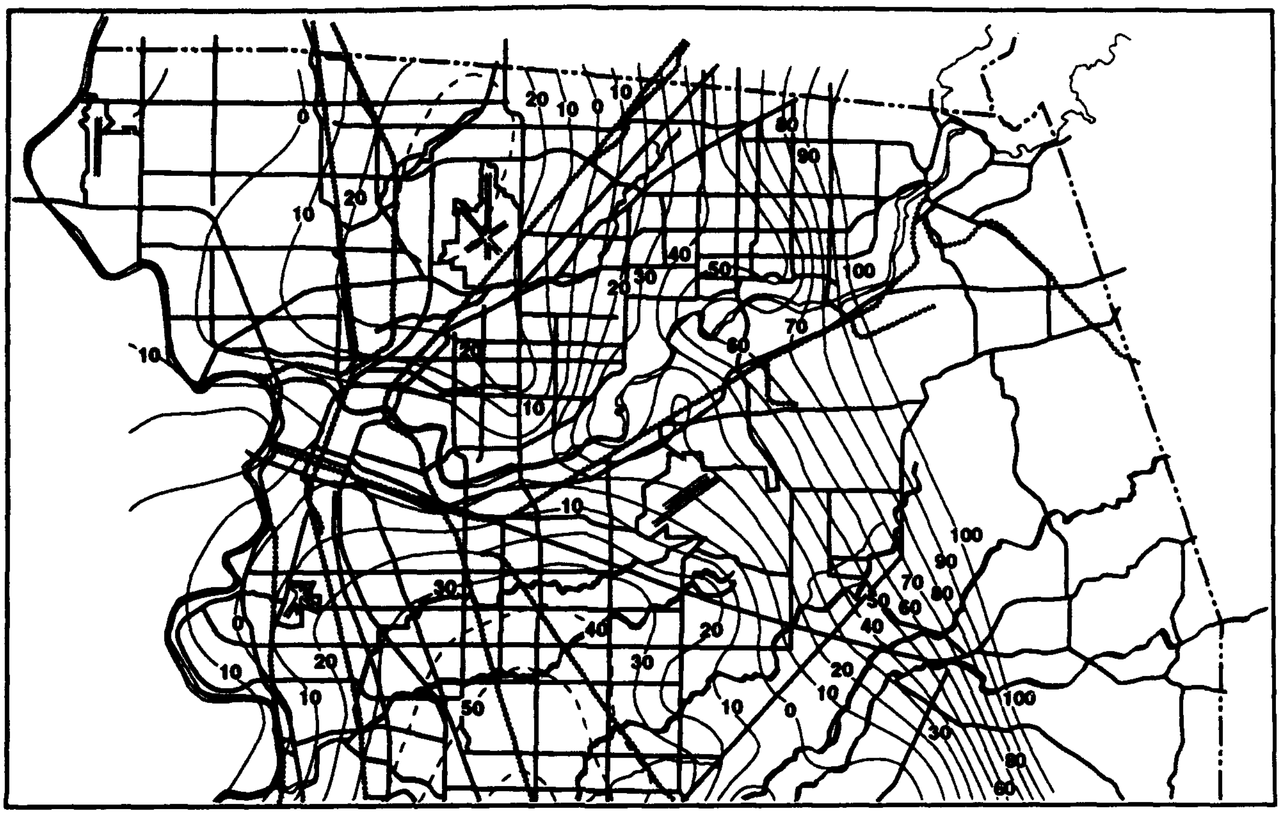
Boundary Conditions

Boundary conditions define the interactions between heads located within the modeled area and groundwater conditions outside the model area. The boundary condition on the lateral boundaries are fixed head boundaries in all four layers, assigned based on observed regional 1992 groundwater levels compiled by Sacramento County (Figure J-2). These boundary conditions account for the influence of regional groundwater conditions on the modeled area. The upper boundary is a prescribed flux boundary, with a specified recharge rate. At model nodes representing A-zone extraction wells, the recharge rate applied to the ground surface is subtracted from the extraction rate of the well. The lower boundary for this model is assigned as a no-flow boundary, corresponding to the base of the Mherten Formation which represents the base of the water bearing sediments in the lower Sacramento Valley.

Conceptual Model Description and Parameter Selection

The essential features of the hydrologic system at McClellan AFB included in the numerical model are:

- Monitoring Zone A
- Monitoring Zone B
- Monitoring Zone C
- The Regional Aquifer
- Base Extraction and Supply Wells
- Existing Base extraction wells



SOURCE: Sacramento County

This groundwater contour map is for general comparison only.
Specific information should be obtained by independent investigation.

FIGURE J-2
OBSERVED SPRING 1992 GROUNDWATER ELEVATIONS INTHE VICINITY OF McCLELLAN AIR FORCE BASE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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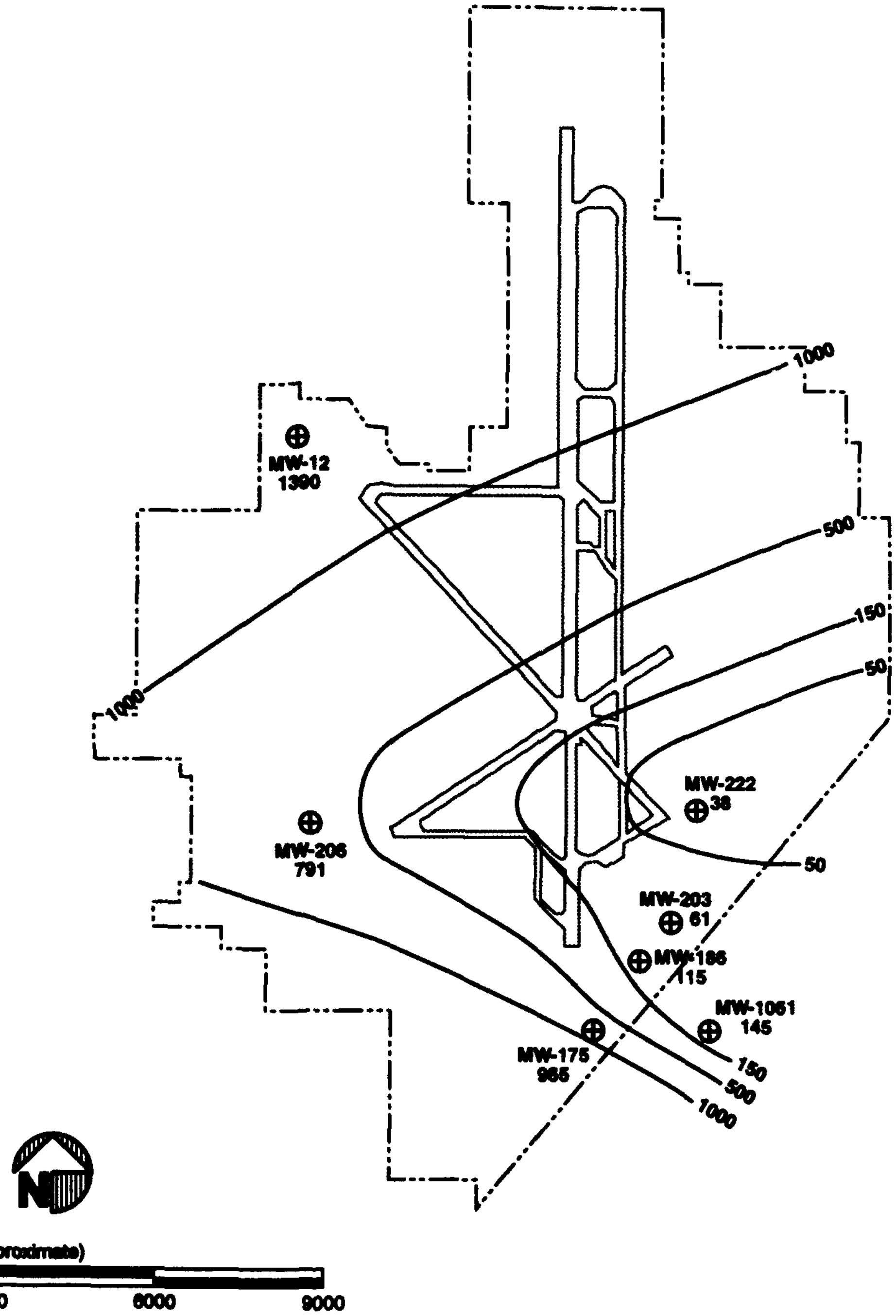
- Regional Groundwater Production
- Recharge of Precipitation to the Groundwater System

A description of how each of the conceptual model components was incorporated into the numerical groundwater model is provided below.

Monitoring Zone A

The A monitoring zone is defined in the numerical model to be consistent with the characteristics discussed in Chapter 4. The aquifer was simulated as an unconfined aquifer with the transmissivity distribution shown in Figure J-3. These values are based on the results of aquifer testing presented in the PGOURI and summarized in Tables J-1 and J-2. This transmissivity distribution was digitized as shown, gridded using the Golden Software SURFER computer program to create a 100 by 100 data field, and imported into Micro-Fem. The transmissivity value at each grid point was assigned to the nearest Micro-Fem node, and data values were averaged if more than one data point was assigned to an individual model node. A linear interpolation scheme included within Micro-Fem was then used to assign transmissivity values to any remaining model nodes without an associated transmissivity value. This gridding routine was only performed at locations on, and in the vicinity of McClellan AFB where transmissivity estimates were available from pumping tests. At areas distant from McClellan, an average transmissivity value for the zone was assumed to extend to the model boundaries. The vertical leakance between layers was assigned based on the local transmissivity estimate at each node and the layer thicknesses at that particular location. The layer thicknesses used in the simulations were calculated based on the structural contour maps for the base elevations for each zone presented in the PGOURI (Section 3, Figures 3-29 through 3-31).

The bottom elevation and groundwater levels in Monitoring Zone A are extremely critical to the development of the A-zone extraction well alternatives. This is due to the fact that portions of the A-zone west of the runway have a limited saturated thickness, and wells completed in the A-zone will produce little water. Containment of contaminated groundwater in these areas will require a greater density of extraction wells because of the limited pumping capacity of each individual well. The thickness of the A-zone was determined by subtracting the elevations of the base of the A-zone from the 1993 A-zone groundwater elevations (Figure 4-35). A more detailed mathematical description of the calculation of vertical leakance values is presented below.



LEGEND

⊕ Aquifer Tested Monitoring Well

791 Transmissivity Estimate From Aquifer Test (ft^2/day)

—— Transmissivity Contour (ft^2/day)

FIGURE J-3
TRANSMISSIVITY (FT^2/DAY) IN THE A ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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Table J-1
Summary of Single Well Aquifer Testing
McClellan AFB

		Transmissivity (gpd/ft)			Average Values	
Well ID	**OU**	**Papadopulos-Cooper Method**	**Jacob Method**	**Theis Recovery Method**	**T (gpd/ft)**	**K (ft/d)**
A Monitoring Zone						
MW-1061	A	1100	2500	5600	4100	34
MW-175	A	7220	12900	28100	20500	166
MW-186	A	900	600	1500	1100	10
MW-206	C	5900	16300	13600	15000	100
MW-203	A	500	6600	6600	6600	65
MW-222	A	300	300	100	200	2
B Monitoring Zone						
MW-1059	A	800	3800	4200	4000	53
MW-1062	A	4700	12500	12400	12400	170
MW-176	A	1000	7300	12800	12800	130
MW-179	A	5000	9600	5500	5500	100
MW-195	E	2100	10100	16900	16900	180
MW-198	A	2800	6900	15800	15800	217
MW-204	A	2500	20400	11700	11700	215
MW-207	C	1900	9500	7900	7900	129
MW-211	A	2800	11700	9500	9500	140
MW-223	A	1100	6300	11800	11800	120
MW-225	A	1700	10000	6700	6700	112
C Monitoring Zone						
MW-1060	A	1800	6200	4700	5500	73
MW-1063	A	4600	20400	18700	19600	262
MW-174	A	2400	7900	4000	6000	93
MW-177	A	7500	24000	20600	22300	300
MW-180	A	1800	5600	4000	4800	63
MW-187	A	14200	87000	32200	59600	770
MW-196	E	3200	14900	12400	13700	180
MW-199	A	16300	67500	58200	62900	823
MW-205	A	5700	1600	3500	2600	34
MW-208	C	3900	8000	N/C	8000	134

Notes:
N/C - Not Calculated
Source: Tables 3-3, 3-4, and 3-5 of the PGOURI (RADIAN, 1993)

Table J-2 Summary of Multiple Well Aquifer Testing						
			Transmissivity (gpd/ft)		Storage Coefficient	
OU	Contractor	Monitoring Zone	Range	Average	Range	Average
D	CH2M HILL	A	17,500 to 28,600	16,500	$9.0x10^{-4}$ to $8.2x10^{-3}$	N/A
D	CH2M HILL	B	2,300 to 19,300	8,800	$3x10^{-4}$ to $1.1x10^{-3}$	$8x10^{-4}$
D	McLaren	A/B	7,000 to 19,000	N/A	$5x10^{-4}$ to $9.1x10^{-3}$	N/A
C	Radian (1986)	A/B	7,700 to 8,600	8,000	$1.3x10^{-4}$ to $6.2x10^{-4}$	$3x10^{-4}$
C	Radian (1986)	C	7,600 to 15,000	12,000	$1.6x10^{-4}$ to $8.7x10^{-5}$	$1.6x10^{-4}$
C	Radian (1990)	A/B	5,700 to 6,900	6,300	$3.7x10^{-4}$ to $1.5x10^{-4}$	$2.6x10^{-4}$
C	Radian (1991)	C	4,150 to 5,100	4,600	$1x10^{-4}$ to $8x10^{-4}$	$4.5x10^{-4}$
C	Radian (1990)	B	9,700 to 10,100	9,900	$7.5x10^{-4}$ to $8.8x10^{-4}$	$8.1x10^{-4}$
C	Radian (1990)	C	10,800 to 12,100	11,000	$2.3x10^{-4}$ to $2.3x10^{-3}$	$1.3x10^{-3}$
C	EG&G Idaho	A	3,000 to 10,000	6,500	$5x10^{-4}$	$5x10^{-4}$

Note:
N/A = Information not available.

Sources:

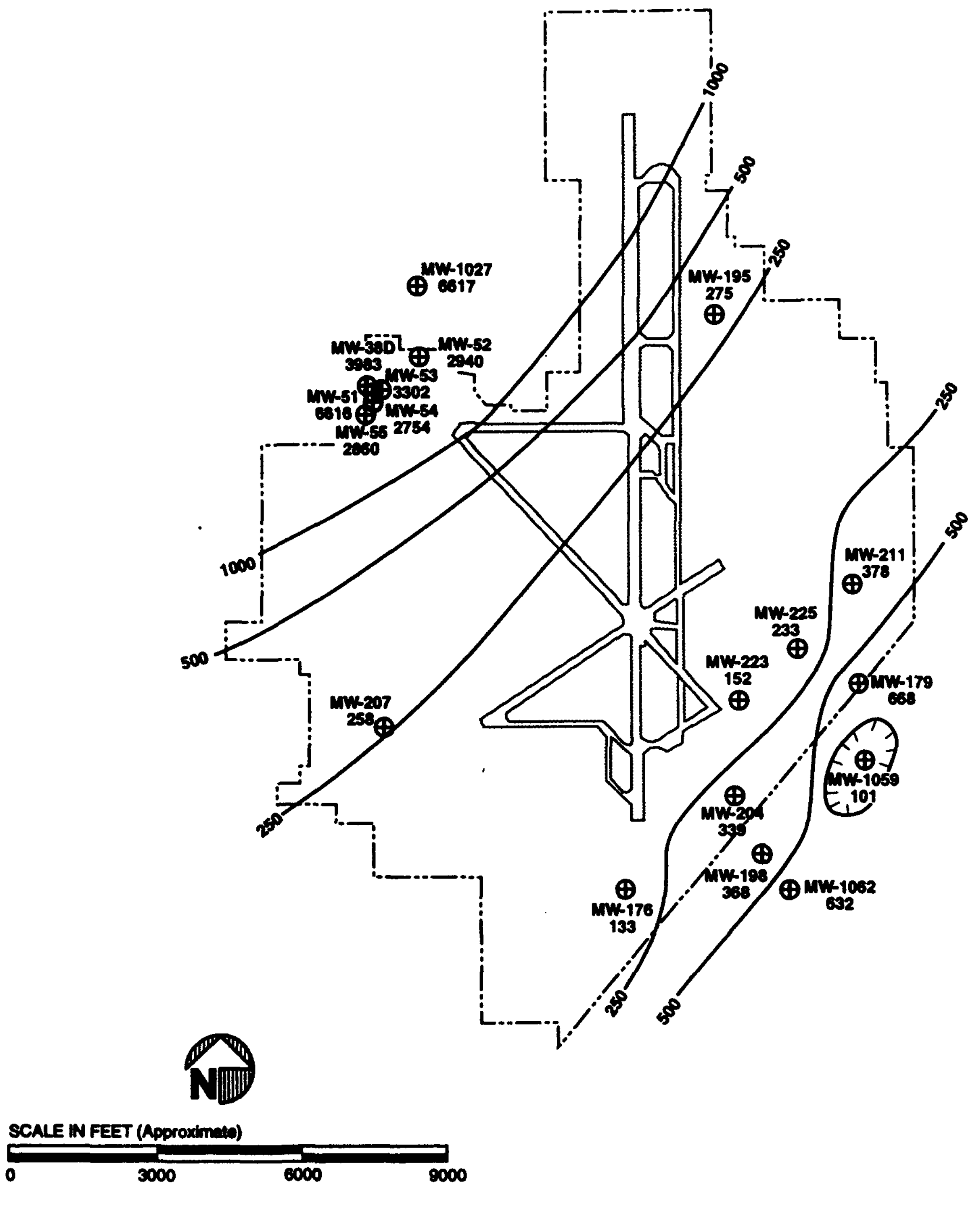
Transmissivity and Storage Coefficient Estimates: (Preliminary GW OU RI Table 3-9) Radian, 1992
CH2M HILL Aquifer Test Data and Interpretation: (CH2M HILL, 1984)
Radian Aquifer Test Data and Interpretation: (Preliminary GW OU RI-Appendix E, Radian, 1992)
EG&G and McLaren Aquifer Test Data Not Independently Evaluated

Monitoring Zone B

Monitoring zone B was simulated as a confined, leaky, aquifer. The transmissivity distribution used in the modeling simulations for monitoring zone B are presented in Figure J-4. The information contained on this figure was digitized, gridded, and assigned to model nodes using the methodology described above for the A-zone. Vertical leakance values were also determined in a similar manner. The thickness of the B-zone was calculated by subtracting the base elevation of the B-zone presented in the PGOURI (Section 3, Figure 3-30) from the base elevations of the A-zone presented in the same document.

Monitoring Zone C

Monitoring zone C was simulated as a confined, leaky, aquifer. The transmissivity distribution used in the modeling simulations for monitoring zone C are presented in Figure J-5. The information contained on this figure was digitized, gridded, and assigned to model nodes using the methodology described above for the A-zone. Vertical leakance values were also determined in a similar manner. The thickness of the C-zone was calculated by subtracting the base elevation of the C-zone presented in the PGOURI (Section 3, Figure 3-31) from the base elevations of the B-zone presented in the same document.



LEGEND

⊕	Aquifer Tested Monitoring Well
133	Transmissivity Estimate from Aquifer Test (ft^2/day)
—	Transmissivity Contours (ft^2/day)

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FIGURE J-4
TRANSMISSIVITY (FT^2/DAY) IN THE B ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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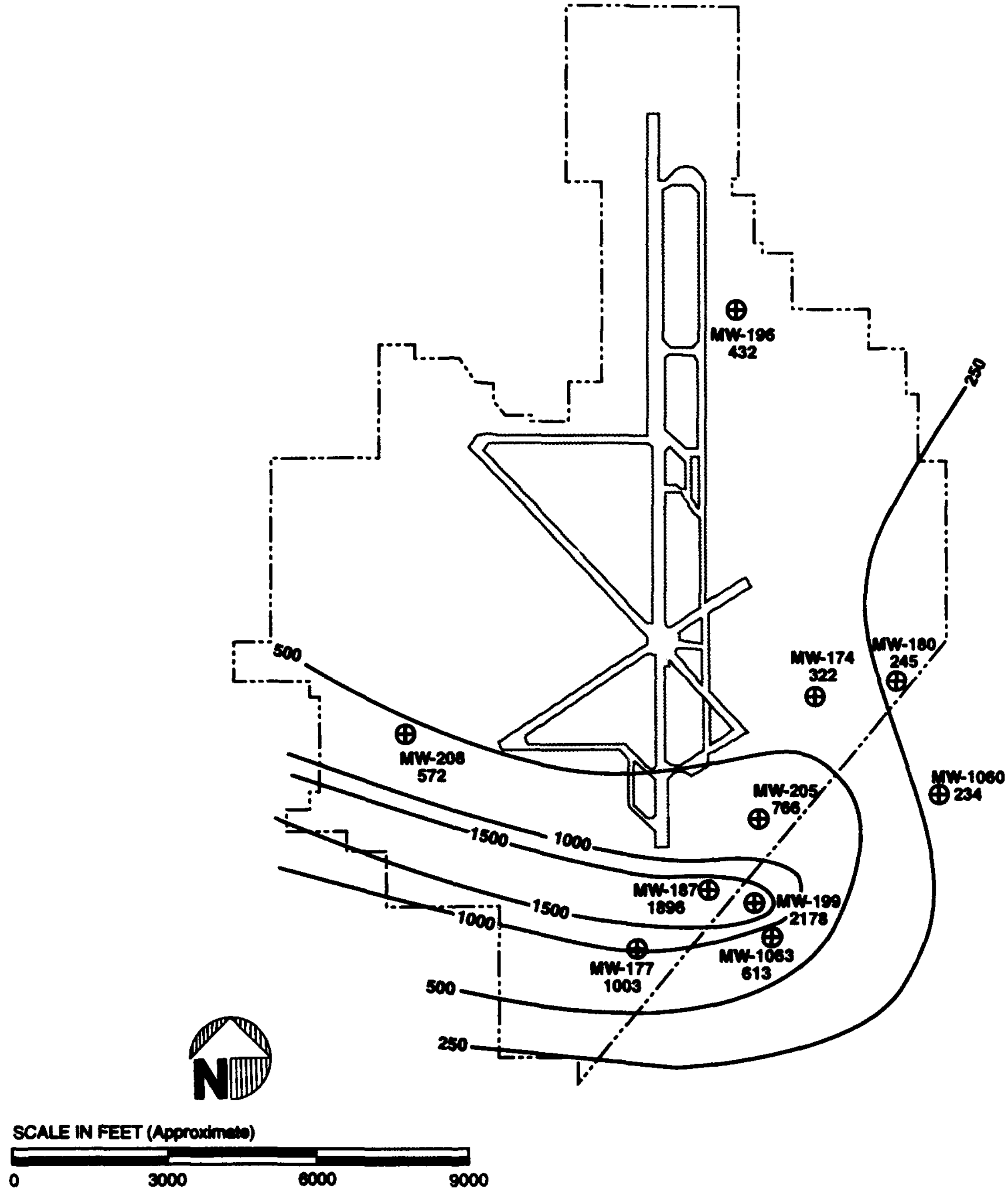

LEGEND

⊕ Aquifer Tested Monitoring Well

572 Transmissivity Estimate From Aquifer Test (ft^2/day)

Transmissivity Contour (ft^2/day)

FIGURE J-5
TRANSMISSIVITY DISTRIBUTION IN THE C ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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Regional Aquifer

The regional aquifer was modeled as a confined, leaky aquifer system. The main source of information regarding the aquifer properties of the regional aquifer was the regional groundwater model developed for this area by S.S. Papadopolus in 1987. AFORTRAN computer program was developed to read the Papadopulos model input files and extract the hydraulic parameters needed for Micro-Fem. The regional aquifer, as defined here, represents the entire aquifer thickness in the Sacramento area from the water table to the base of the water bearing aquifer (defined as the base of the Mherten formation). The upper three layers of the groundwater model (the A,B, and C Monitoring Zones) do extend to the model boundaries, but their low transmissivities are overwhelmed by the transmissivity of the regional aquifer, and they do not significantly impact groundwater flow. The vertical leakance between the C-zone and the regional aquifer was calculated using a method identical to that described above. Due to the great thickness of the regional aquifer compared to monitoring zone C, the hydraulic conductivity of the regional aquifer dominated this leakance calculation. The assumed hydraulic conductivity distribution of the regional aquifer is presented in Figure J-6. The assumed thickness distribution of the regional aquifer was also obtained from the Papadopulos model.

Vertical Leakance

The conceptual model of groundwater flow includes leakage upward and downward. This was incorporated by specifying a leakage term between layers. Value of this parameter is a function of the conductance of each layer, which is a function of average vertical hydraulic conductivity between layers and the thickness of the layers.

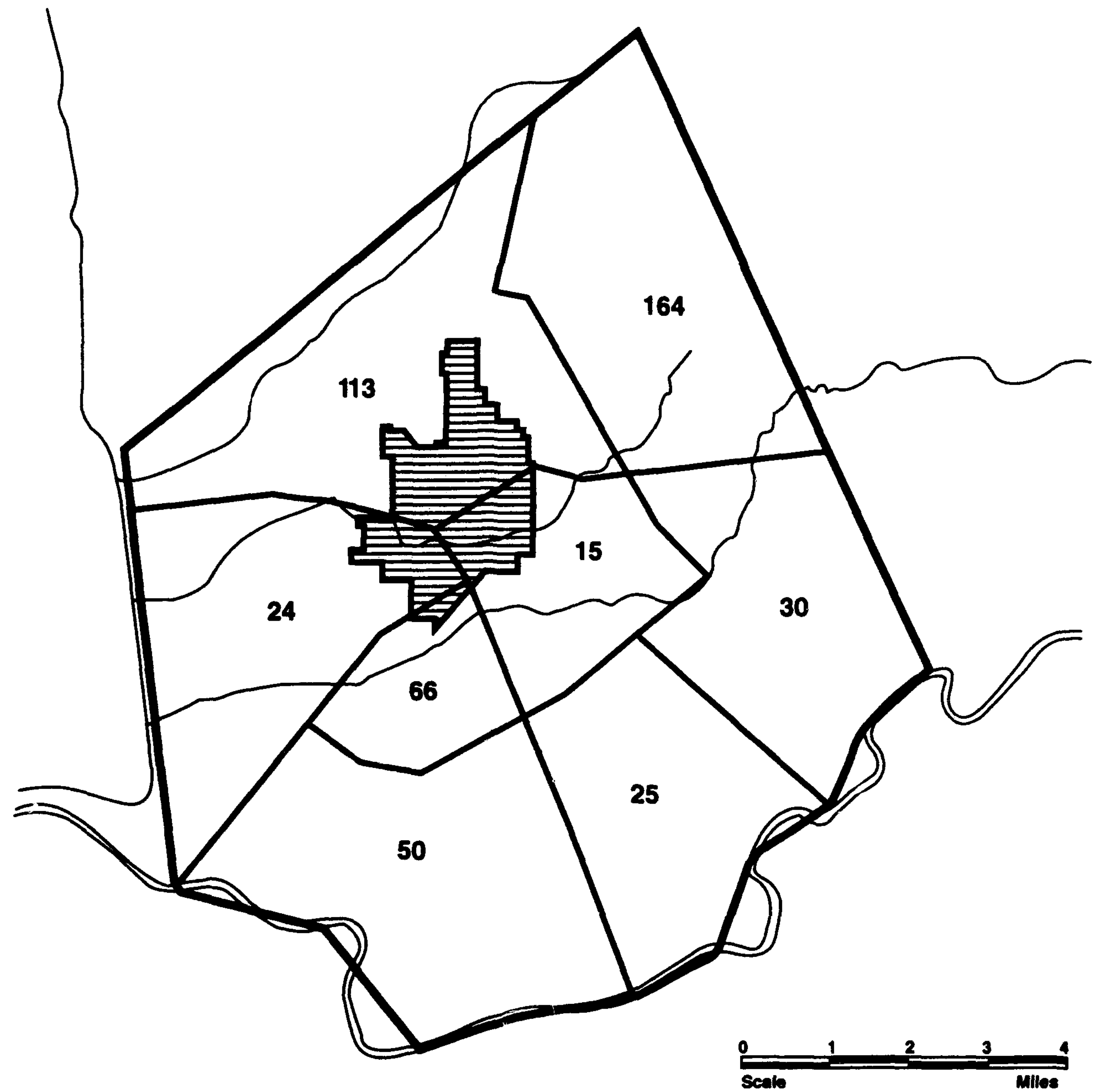
The vertical leakance was computed with the help of the MicroFem computing capabilities using the following equation:

$$VC = 1/(d_1/k_{v1}+d_2/k_{v2}) \tag{1}$$

where:

VC	=	the vertical conductance between Layer 1 and Layer 2
d_1	=	the thickness of Layer 1
k_{v1}	=	the vertical hydraulic conductivity of Layer 1
d_2	=	the thickness of Layer 2
k_{v2}	=	the vertical hydraulic conductivity of Layer 2

The value of the vertical hydraulic conductivity (k_v) was assumed to be 10 percent of horizontal hydraulic conductivity to satisfy an anisotropy ratio of 1 to 10.



EXPLANATION

Model Boundary

30 Model Subdomain
(Number indicates hydraulic conductivity in feet per day)

Source: Papadopulos, 1987

FIGURE J-6
HYDRAULIC CONDUCTIVITY DISTRIBUTION IN THE REGIONAL AQUIFER
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_708

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Regional Production Wells

The regional groundwater production data were included in the calibrated S.S. Papadopolus model and these were directly imported into the Micro-Fem model. Comparison of the distribution of regional groundwater production included in the Papadopuos model with the information presented in Appendix N indicate that all of the major pumping wells in the vicinity of the Base were incorporated in the Papadopulos data set (See Appendix N for the locations of these pumping centers).

Base Extraction and Supply Wells

Base well pumping for BW-10, BW-18, and BW-29 was included in the groundwater model based on average annual pumping rates for 1992 obtained from the Metcalf & Eddy Quarterly Monitoring Reports. The assumed pumping rates for the operating Base wells was 270 gpm, 975 gpm, and 375 gpm for Base wells BW-10, BW-18, and BW-29 respectively. Existing Base extraction well pumping was also included in the model, using average pumping rates for 1992, based on Radian Quarterly Production Well Data for McClellan AFB. Table J-3 presents the assumed average pumping rates for the Base extraction wells at McClellan.

Table J-3
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 C	B	25.4
EW-141	OU C	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

Recharge of Precipitation

The actual recharge of precipitation to the groundwater system varies spatially based on land use, drainage patterns, and urbanization. The initial assumption used in the groundwater model was a uniform distribution of recharge of 2.5 inches per year. This values represents approximately 15 percent of the annual rainfall at McClellan AFB. This values was adjusted by +/- 25 percent to improve the accuracy of the calibration.

Calibration and Sensitivity Analysis

Model calibration is an interactive process in which certain model parameters are adjusted to produce predicted groundwater elevations that closely match observed conditions. Usually, the parameters adjusted are those that have not been accurately measured in the field and that can have a strong influence on the simulation results. The objective of the calibration process was to achieve a run that produced simulated water levels that closely matched the calibration head target. The results of the calibration process for the McClellan model suggest that minor adjustments of the recharge rate were sufficient to achieve agreement between the simulated heads in the upper three aquifers at the site and the observed water levels in site monitoring wells. Slightly higher recharge rates (up to 25%) were necessary in the northern portions of the Base and slightly lower values (up to 25%) were necessary in the southern portions of the Base. Calibration was quite accurate in the central portions of the Base using the initially assigned value. These results are consistent with the presence of open space in the northern portions of the Base allowing recharge, and the relatively heavy urbanization in the southern portions of the Base preventing it. It is acknowledged that this is not a unique solution to matching observed water levels, and that other parameters could be adjusted to obtain similar results. Regional aquifer parameters were obtained from a previously calibrated numerical model, so they were not considered a calibration parameter.

Water Level Calibration

The following criteria were used for calibration:

- The model should yield the same water level distribution configuration observed at the site.
- The model should accurately predict the cone of depression at known pumping well locations
- The model should accurately predict the overall gradient within the model domain.

Calibration Summary

This section summarizes the results of the calibration process for the groundwater model used to evaluate remedial options at McClellan AFB. All of the methods used to quantify the state of calibration of the model rely on some form of comparison between simulated groundwater levels and the water levels measured in monitoring wells in January 1993. The data set used for these comparisons is the water levels measured in 194 monitoring wells across the site; 97 A-zone wells, 63 B-Zone wells, and 34 C-zone wells. Wells with screens in the transition between zones were assigned to the higher aquifer for the purposes of data comparison. Extraction wells were omitted from this comparison as the well efficiency of each extraction well will influence the measured groundwater levels in the well, while the simulated water levels reflect an assumed 100 percent well efficiency.

Table J-4 presents the simulated and actual water level for all of the calibration wells at the site, along with the magnitude of the residuals. The average residual between the simulated and actual water levels is 1.2 feet. Figure J-7 presents this same information in graphical form. An perfect match between simulated and observed values would generate a line with a slope of 1.0 as indicated on the figure. The best fit line through the data set is also presented on this figure for comparison. This comparison indicates that in the lowest water level ranges (i.e., the southern part of the Base), the model predicts slightly higher water levels than those observed. In the higher water level ranges (the northern portions of the Base) the model predicts slightly lower water levels than those observed.

Another way of quantifying the error between the simulated and observed water levels is through the used of a histogram analysis of the water level residuals. The results of this analysis are summarized in Figure J-8 and Table J-5. This evaluation indicates that at 78 percent of the wells, simulated water levels are within two feet of actuals, and in 98 percent of the wells, simulated water levels are within four feet of the observed. The final three wells have simulated water levels that are within four to six feet of the observed.

A final presentation method of the state of calibration is to compare the simulated groundwater contours with the measured water levels. Figures J-9 through J-11 show these comparisons for the A-zone, B-zone, and C-zone, respectively. The same trends described above can be seen on these figures. Predicted water levels on the south end of the base are slightly high, and predicted water levels on the north end are slightly low. However, the overall accuracy of the simulated water levels, and groundwater flow directions, are more than adequate to meet the objectives of this groundwater modeling effort.

Table J-4 Simulated versus Observed Water Levels - Revised Calibration McClellan AFB Groundwater Model				
Zone	Well	Observed Water Level	Simulated Water Level	Observed less Simulated
A	MW-10	-38.59	-36.7	-1.89
A	MW-1002	-36.75	-35.3	-1.45
A	MW-1004	-36.23	-35	-1.23
A	MW-1005	-36.05	-34.6	-1.45
A	MW-1009	-35.25	-34.5	-0.75
A	MW-1014	-40.29	-40.1	-0.19
A	MW-1015	-46.04	-42.8	-3.24
A	MW-1016	-44.26	-44.5	0.24
A	MW-1020	-45.21	-43.2	-2.01
A	MW-1021	-46.87	-47.5	0.63
A	MW-1026	-35.08	-35	-0.08
A	MW-1044	-46.29	-46.3	0.01
A	MW-1054	-46.49	-44.4	-2.09
A	MW-1064	-35.77	-34.1	-1.67
A	MW-1069	-46.44	-42.8	-3.64
A	MW-107	-36.09	-35.3	-0.79
A	MW-11	-37.78	-36.1	-1.68
A	MW-110	-37.06	-34.9	-2.16
A	MW-111	-37.35	-35	-2.35
A	MW-115	-39.35	-37.2	-2.15
A	MW-12	-38.06	-36.5	-1.56
A	MW-123	-42.22	-40.7	-1.52
A	MW-128	-38.15	-38.3	0.15
A	MW-129	-38.48	-38.3	-0.18
A	MW-131	-39.18	-39.3	0.12
A	MW-135	-41.81	-40.1	-1.71
A	MW-139	-40.13	-40.1	-0.03
A	MW-14	-38.41	-36.7	-1.71
A	MW-145	-44.12	-43	-1.12
A	MW-15	-38.2	-36.5	-1.7
A	MW-150	-46.21	-45.5	-0.71
A	MW-153	-44.15	-47.2	3.05
A	MW-155	-44.86	-45.1	0.24
A	MW-157	-43.55	-46.6	3.05
A	MW-158	-43.64	-45.9	2.26

Table J-4 Simulated versus Observed Water Levels - Revised Calibration McClellan AFB Groundwater Model				
Zone	Well	Observed Water Level	Simulated Water Level	Observed less Simulated
A	MW-159	-43.01	-44.1	1.09
A	MW-160	-35.12	-35.7	0.58
A	MW-164	-42.36	-41.8	-0.56
A	MW-169	-31.97	-33.4	1.43
A	MW-172	-33.5	-34.5	1
A	MW-175	-41.1	-40.7	-0.4
A	MW-182	-40.34	-39.5	-0.84
A	MW-185	-33.17	-34.3	1.13
A	MW-186	-38.03	-38.1	0.07
A	MW-188	-36.57	-35.9	-0.67
A	MW-191	-42.62	-42.5	-0.12
A	MW-197	-36.3	-36.7	0.4
A	MW-200	-44.21	-46.7	2.49
A	MW-202	-33.53	-34.3	0.77
A	MW-203	-36.35	-36.5	0.15
A	MW-206	-38.17	-38.5	0.33
A	MW-209	-36.3	-36.7	0.4
A	MW-212	-31.64	-33.7	2.06
A	MW-214	-41.05	-41.2	0.15
A	MW-217	-45.46	-47.5	2.04
A	MW-21D	-37.47	-37	-0.47
A	MW-222	-34.71	-35.5	0.79
A	MW-224	-33.02	-33.9	0.88
A	MW-226	-32.21	-33.4	1.19
A	MW-228	-32.34	-34.1	1.76
A	MW-235	-43.23	-45.2	1.97
A	MW-236	-43.5	-45.4	1.9
A	MW-25D	-40.03	-40	-0.03
A	MW-28D	-34.22	-35.9	1.68
A	MW-33S	-38.04	-38	-0.04
A	MW-41S	-43.27	-46.4	3.13
A	MW-44S	-36.73	-36.2	-0.53
A	MW-60	-37.57	-36.5	-1.07
A	MW-61	-39.61	-39	-0.61
A	MW-62	-36.37	-36.2	-0.17

Table J-4 Simulated versus Observed Water Levels - Revised Calibration McClellan AFB Groundwater Model				
Zone	Well	Observed Water Level	Simulated Water Level	Observed less Simulated
A	MW-65	-42.89	-44	1.11
A	MW-7	-44.74	-45.1	0.36
A	MW-72	-38.62	-36.5	-2.12
A	MW-75	-38.13	-38	-0.13
A	MW-88	-36.97	-36	-0.97
A	MW-89	-37.86	-36.5	-1.36
A	MW-90	-37.67	-36.4	-1.27
A	MW-91	-37.37	-36.2	-1.17
A	MW-92	-37.12	-36	-1.12
A	MW-1000	-45.28	-43.2	-2.08
A	MW-1003	-36.24	-35	-1.24
A	MW-1010	-35.69	-34.2	-1.49
A	MW-1034	-40.41	-36	-4.41
A	MW-1042	-36.01	-33.9	-2.11
A	MW-108	-36.41	-35.4	-1.01
A	MW-113	-37.91	-35.1	-2.81
A	MW-124	-42.09	-42	-0.09
A	MW-126	-41.77	-41.8	0.03
A	MW-38D	-38.14	-36.1	-2.04
A	MW-52	-37.16	-35.6	-1.56
A	MW-53	-38.71	-36	-2.71
A	MW-54	-38.07	-36.9	-1.17
A	MW-55	-38.95	-36.6	-2.35
A	MW-57	-38.23	-36.5	-1.73
A	MW-70	-37.63	-36	-1.63
A	MW-74	-37.57	-36	-1.57
A	MW-76	-37.2	-36.1	-1.1
B	MW-1001	-35.74	-34.9	-0.84
B	MW-1022	-50.89	-51.2	0.31
B	MW-1027	-35.47	-35.3	-0.17
B	MW-1028	-34.95	-35.3	0.35
B	MW-1038	-38.06	-38.1	0.04
B	MW-104	-35.96	-35	-0.96
B	MW-1045	-47.4	-46.7	-0.7
B	MW-105	-35.55	-35.5	-0.05

Table J-4 Simulated versus Observed Water Levels - Revised Calibration McClellan AFB Groundwater Model				
Zone	Well	Observed Water Level	Simulated Water Level	Observed less Simulated
B	MW-1050	-46.52	-42.7	-3.82
B	MW-1055	-46.8	-45	-1.8
B	MW-1059	-34	-35.2	1.2
B	MW-1062	-37.82	-37.9	0.08
B	MW-1065	-31.92	-34.7	2.78
B	MW-1066	-31.9	-34.7	2.8
B	MW-1068	-31.93	-34.7	2.77
B	MW-109	-36.6	-35.5	-1.1
B	MW-112	-37.66	-35.2	-2.46
B	MW-118	-42.52	-42.2	-0.32
B	MW-130	-39.91	-41.8	1.89
B	MW-134	-41.35	-40.7	-0.65
B	MW-142	-40.39	-40.8	0.41
B	MW-143	-39.09	-39.2	0.11
B	MW-146	-44.23	-43	-1.23
B	MW-151	-47.03	-45.9	-1.13
B	MW-156	-46.11	-46.3	0.19
B	MW-165	-42.55	-42.2	-0.35
B	MW-173	-34.28	-35.9	1.62
B	MW-176	-41.35	-41.3	-0.05
B	MW-179	-32.56	-35.2	2.64
B	MW-183	-40.66	-39.6	-1.06
B	MW-189	-36.68	-36	-0.68
B	MW-18D	-34.36	-35.6	1.24
B	MW-192	-43.13	-42.7	-0.43
B	MW-195	-32.93	-35	2.07
B	MW-198	-37.95	-37.8	-0.15
B	MW-19D	-36.73	-36	-0.73
B	MW-201	-46.21	-47.2	0.99
B	MW-204	-37.43	-37.5	0.07
B	MW-207	-39.05	-39.1	0.05
B	MW-20D	-37.49	-36.9	-0.59
B	MW-211	-31.96	-35.3	3.34
B	MW-213	-31.68	-34.8	3.12
B	MW-215	-40.95	-41.2	0.25

Table J-4 Simulated versus Observed Water Levels - Revised Calibration McClellan AFB Groundwater Model				
Zone	**Well**	**Observed Water Level**	**Simulated Water Level**	**Observed less Simulated**
B	MW-218	-47.3	-47.5	0.2
B	MW-220	-41.05	-40.4	-0.65
B	MW-223	-35.13	-36.3	1.17
B	MW-225	-33.48	-35.5	2.02
B	MW-227	-32.14	-35.6	3.46
B	MW-229	-33.53	-35.6	2.07
B	MW-22D	-38.6	-39.6	1
B	MW-23D	-48.45	-47.9	-0.55
B	MW-24D	-43.81	-42	-1.81
B	MW-26D	-38.57	-39	0.43
B	MW-27D	-35.28	-36.7	1.42
B	MW-29D	-33.11	-35.5	2.39
B	MW-51	-37.26	-36.7	-0.56
B	MW-58	-36.8	-35.9	-0.9
B	MW-59	-37.02	-36.3	-0.72
B	MW-63	-46.11	-46	-0.11
B	MW-64	-47.7	-47.6	-0.1
B	MW-66	-50.88	-49.6	-1.28
B	MW-71	-34.23	-35.8	1.57
B	MW-69	-38.67	-38.6	-0.07
C	MW-1046	-48.62	-49.7	1.08
C	MW-1051	-46.71	-42.7	-4.01
C	MW-1056	-47.84	-44.6	-3.24
C	MW-1060	-34.22	-36.7	2.48
C	MW-1063	-37.97	-38.8	0.83
C	MW-119	-41.78	-42.3	0.52
C	MW-122	-41.65	-42.3	0.65
C	MW-125	-40.5	-41.3	0.8
C	MW-127	-41.54	-41.8	0.26
C	MW-132	-47.25	-46.7	-0.55
C	MW-133	-41.4	-40.4	-1
C	MW-136	-39.88	-39.6	-0.28
C	MW-138	-39.36	-39.2	-0.16
C	MW-147	-44.21	-42.5	-1.71
C	MW-152	-48.64	-46.2	-2.44

Table J-4 Simulated versus Observed Water Levels - Revised Calibration McClellan AFB Groundwater Model				
Zone	**Well**	**Observed Water Level**	**Simulated Water Level**	**Observed less Simulated**
C	MW-154	-47.1	-47.8	0.7
C	MW-161	-36.05	-37.5	1.45
C	MW-166	-42.02	-42.3	0.28
C	MW-171	-32.17	-36.9	4.73
C	MW-174	-34.41	-36.9	2.49
C	MW-177	-41.23	-41.3	0.07
C	MW-180	-33.11	-36.2	3.09
C	MW-181	-40.18	-40.3	0.12
C	MW-184	-40.35	-39.7	-0.65
C	MW-187	-39.1	-39.5	0.4
C	MW-190	-36.76	-36.2	-0.56
C	MW-193	-42.23	-42.8	0.57
C	MW-199	-37.99	-38.5	0.51
C	MW-205	-37.56	-38.2	0.64
C	MW-208	-39.29	-38.6	-0.69
C	MW-216	-40.67	-40.9	0.23
C	MW-219	-48.93	-50.7	1.77
C	MW-221	-41.57	-40.7	-0.87
C	MW-148	-41.97	-42.5	0.53

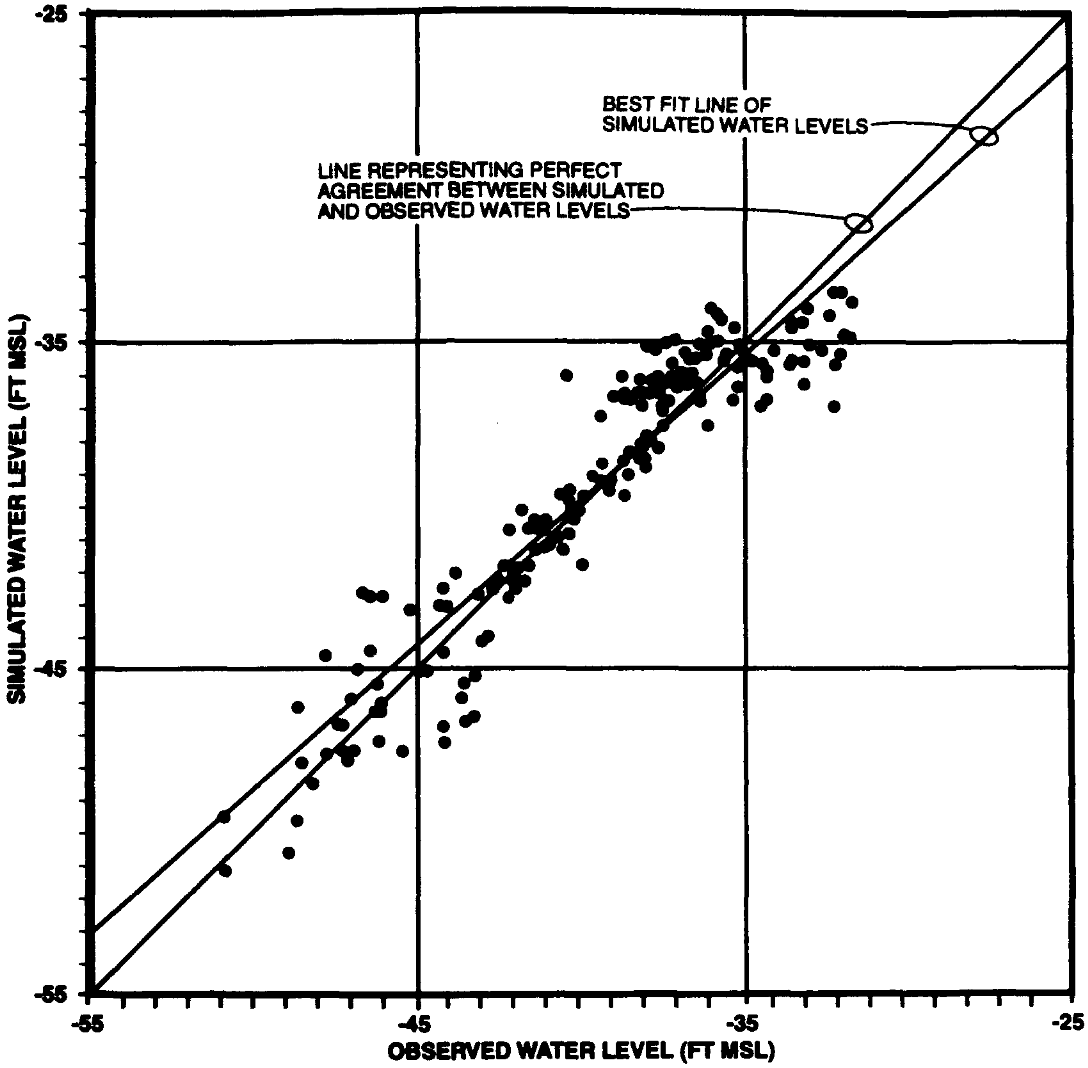


FIGURE J-7
SIMULATED VS. OBSERVED
GROUNDWATER ELEVATIONS
McCLELLAN AFB GROUNDWATER MODEL
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_706

CH2MHILL

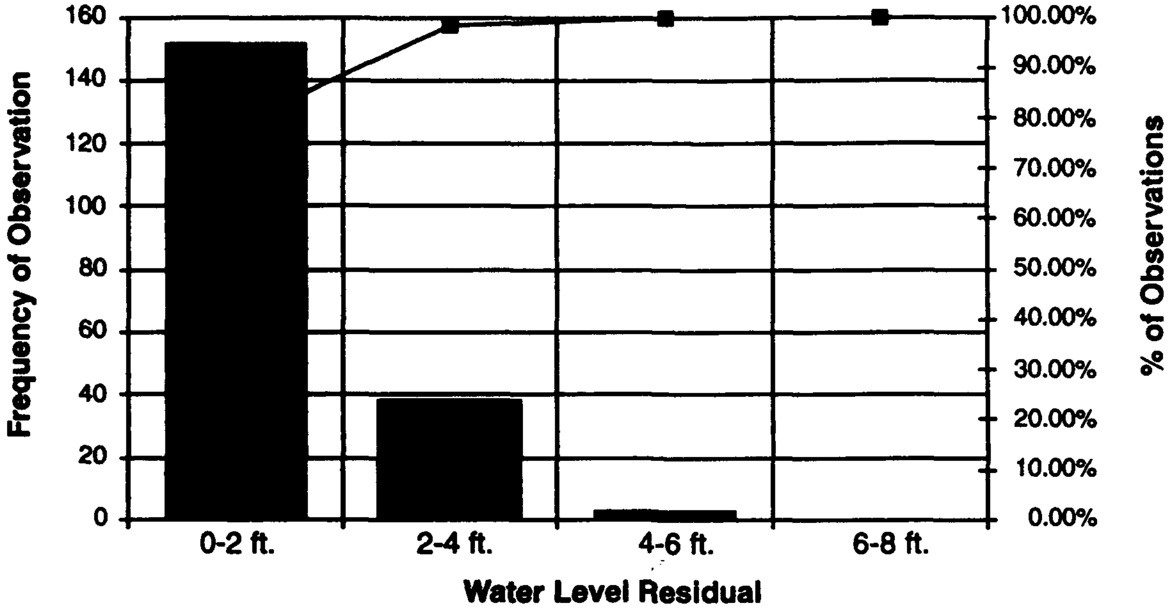
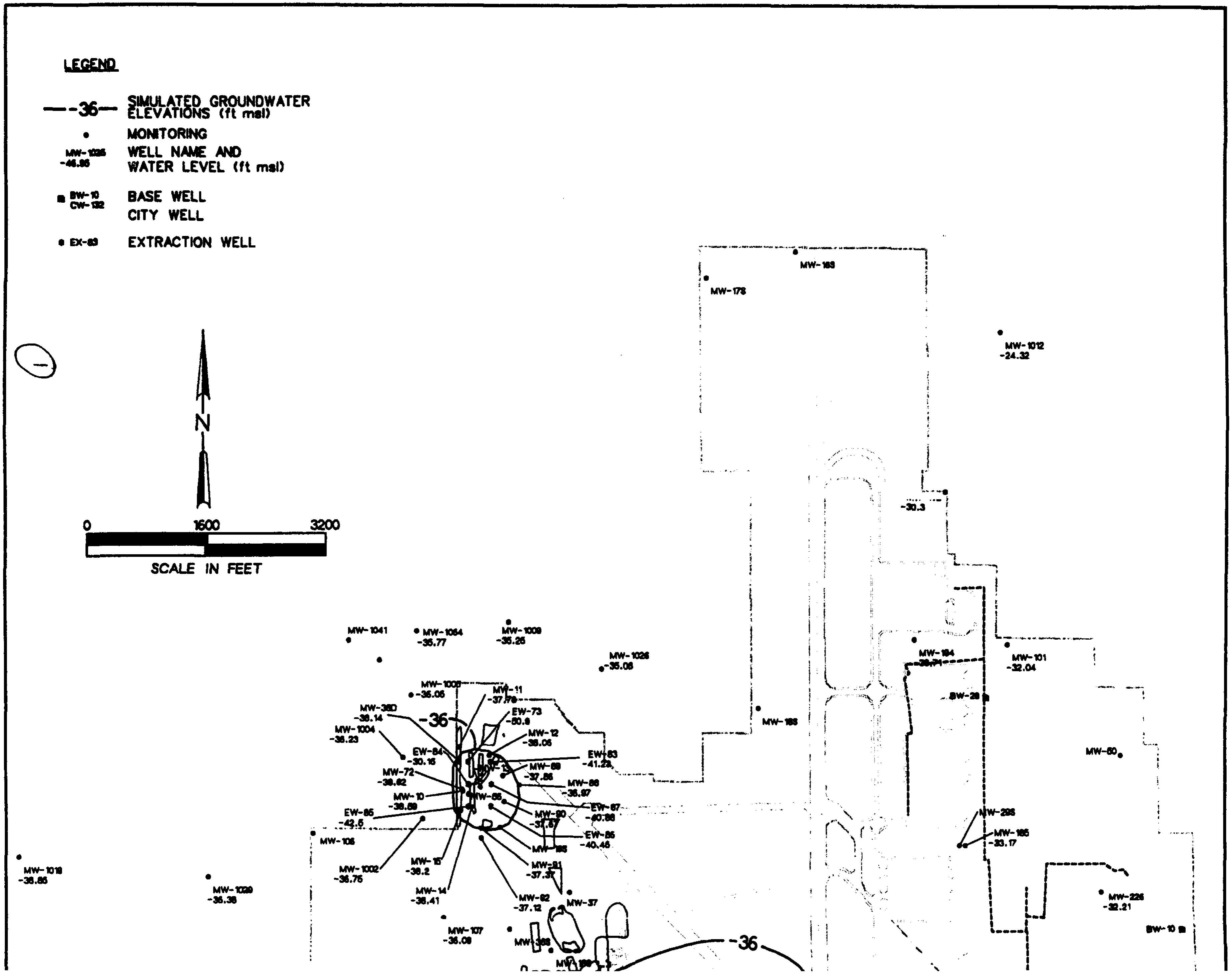


FIGURE J-8
HISTOGRAM OF WATER LEVEL RESIDUALS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1464_709

CH2M HILL


LEGEND
-36 SIMULATED GROUNDWATER ELEVATIONS (ft msl)
MONITORING
WELL NAME AND WATER LEVEL (ft msl)
BASE WELL
CITY WELL
EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
MW-1012
-24.32
MW-101
-32.04
MW-165
-33.17
MW-226
-32.21
-30.3
MW-1026
-35.08
MW-1064
-35.77
MW-1009
-36.25
MW-1041
MW-1019
-36.86
MW-1029
-36.38
MW-1004
-36.23
MW-1002
-36.76
MW-107
-36.08
EW-85
-42.5
EW-83
-41.23
EW-73
-50.9
EW-84
-30.16
MW-72
-36.82
MW-12
-38.06
MW-92
-37.12
MW-37
-36

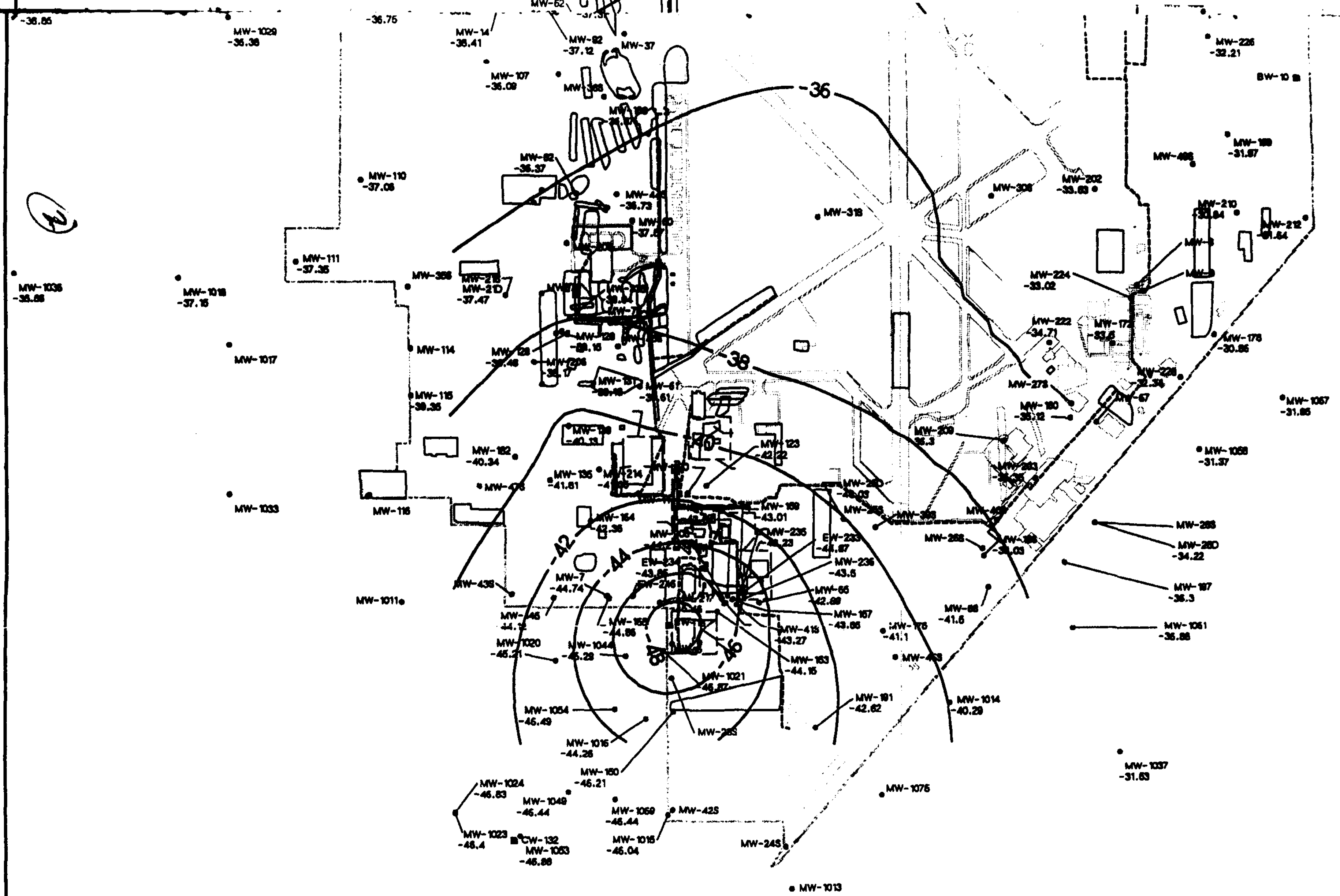
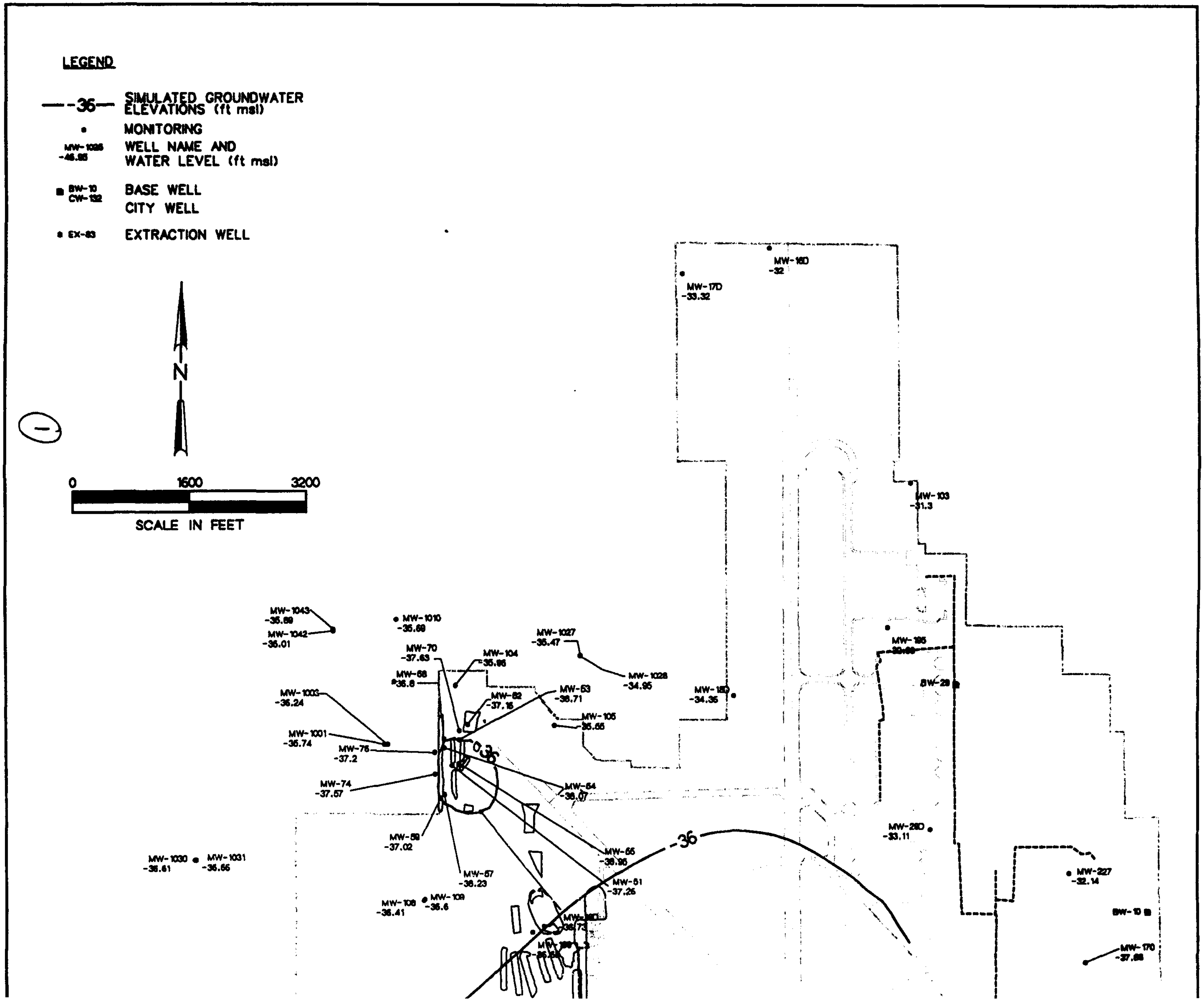


FIGURE J-9
SIMULATED GROUNDWATER CONTOURS VS OBSERVED WATER LEVELS ZONE A, JANUARY 1993
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

RDD1464
GWOU/J-9.DGN


LEGEND
-36- SIMULATED GROUNDWATER ELEVATIONS (ft msl)
MONITORING
MW-1035 -46.85 WELL NAME AND WATER LEVEL (ft msl)
BW-10 BASE WELL
CW-132 CITY WELL
EX-83 EXTRACTION WELL
N
0
1600
3200
SCALE IN FEET
MW-17D -33.32
MW-18D -32
MW-103 -31.3
MW-185
BW-28
MW-28D -33.11
MW-227 -32.14
BW-10
MW-170 -37.88
MW-18D -34.36
MW-1027 -35.47
MW-1028 -34.95
MW-1043 -35.89
MW-1042 -36.01
MW-1010 -35.69
MW-70 -37.63
MW-104 -35.86
MW-68 -36.8
MW-82 -37.15
MW-53 -36.71
MW-105 -35.55
MW-1003 -36.24
MW-1001 -36.74
MW-76 -37.2
MW-74 -37.57
MW-54 -36.07
MW-59 -37.02
MW-55 -36.95
MW-51 -37.26
MW-57 -36.23
MW-108 -36.41
MW-109 -36.6
MW-1030 -36.61
MW-1031 -36.66
-36

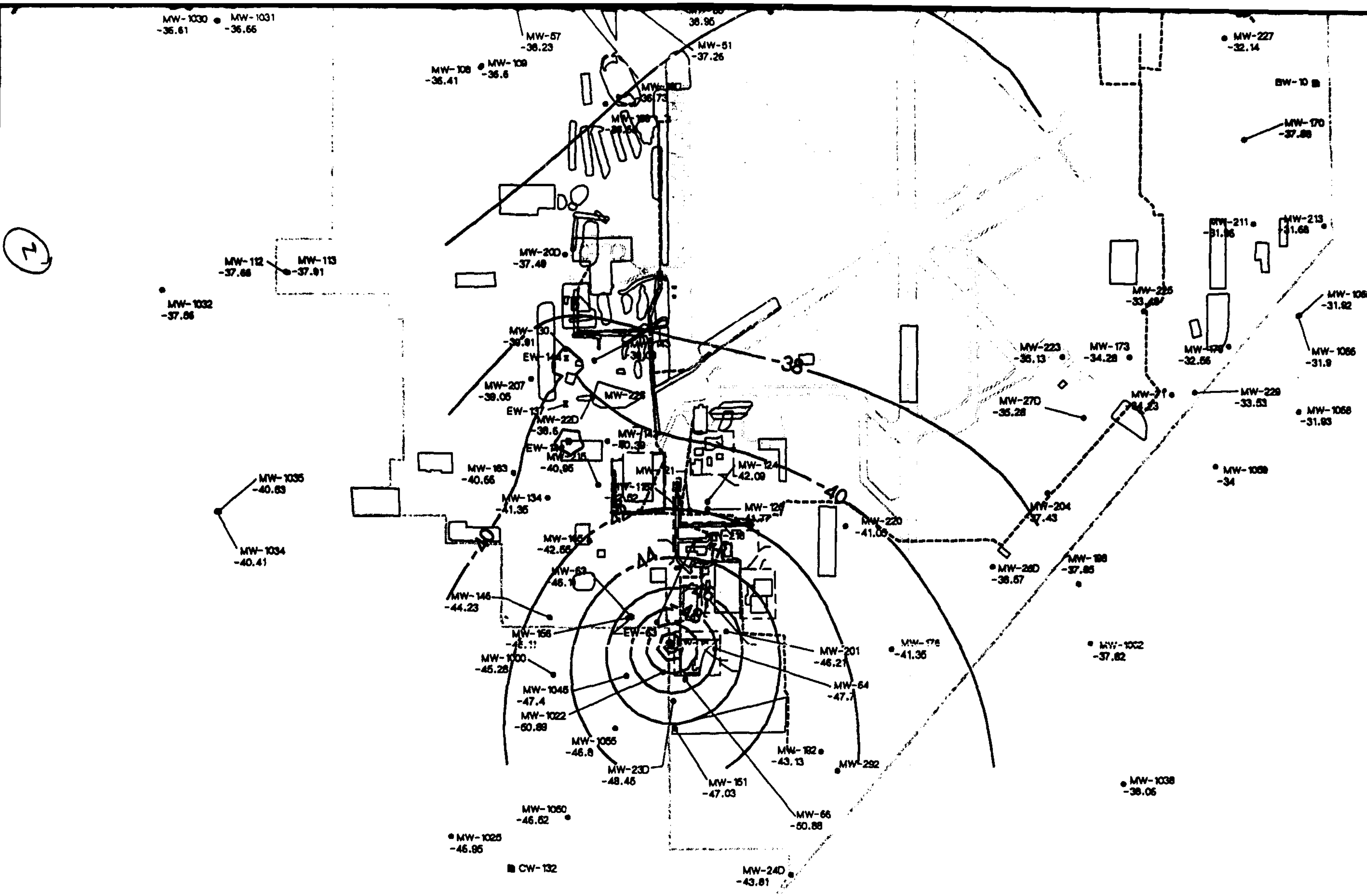
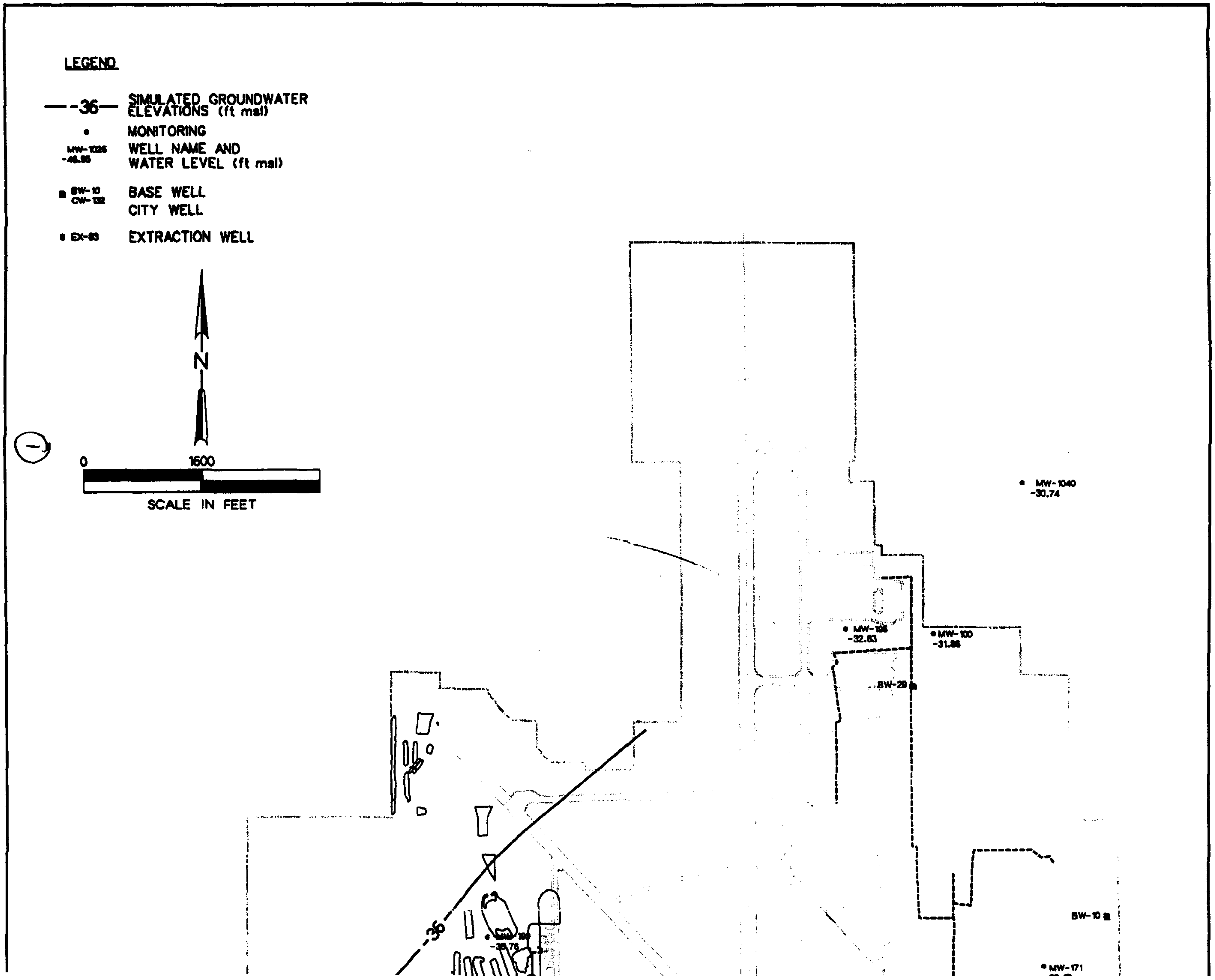


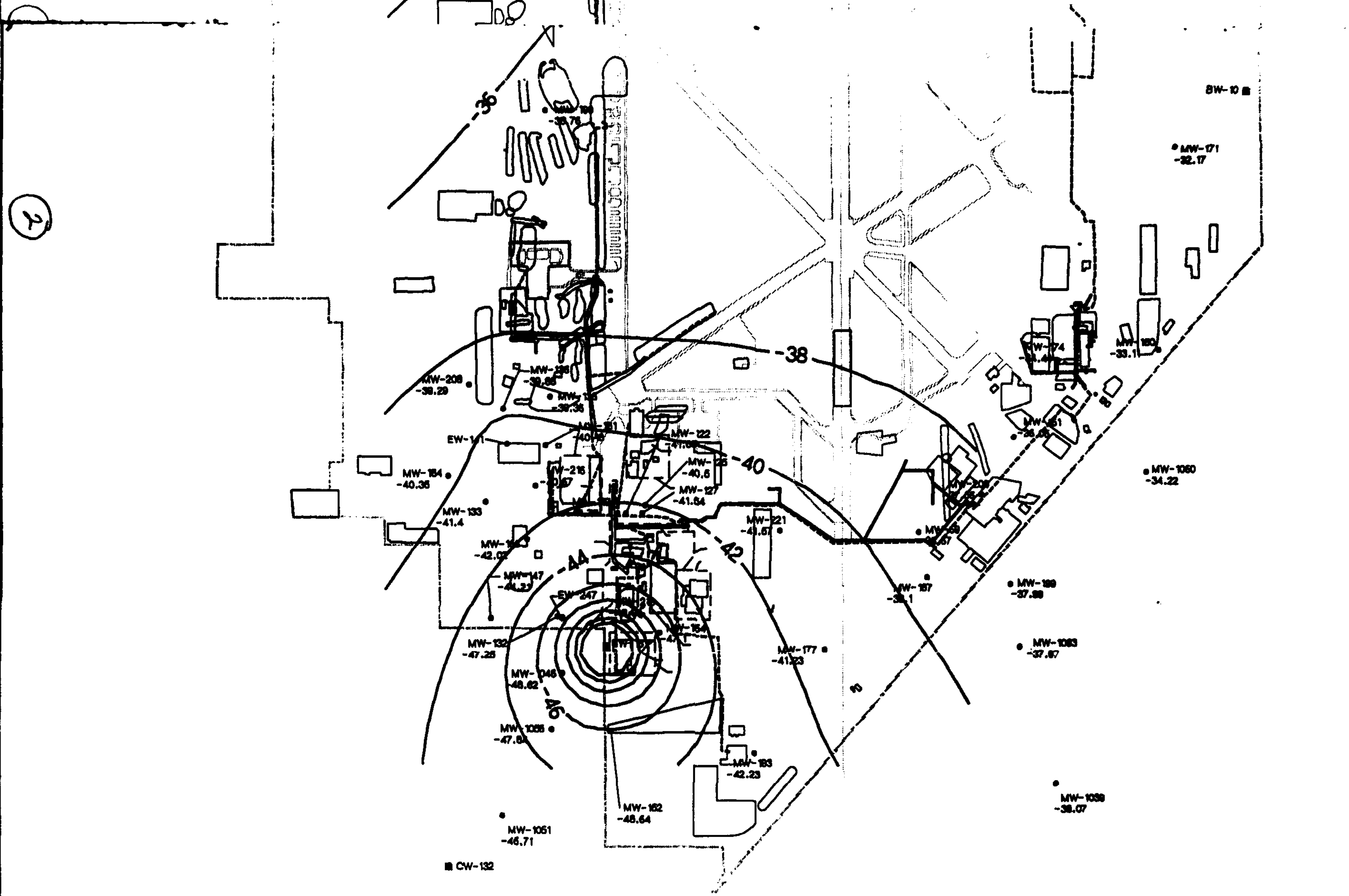
FIGURE J-10
SIMULATED GROUNDWATER CONTOURS VS OBSERVED WATER LEVELS ZONE B, JANUARY 1993

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

CH2M HILL

RDD1454
GWOU/J-10.DGN


LEGEND
-36- SIMULATED GROUNDWATER ELEVATIONS (ft msl)
MONITORING
MW-1026 -46.86 WELL NAME AND WATER LEVEL (ft msl)
BW-10 BASE WELL
CW-132 CITY WELL
EX-63 EXTRACTION WELL
N
0
1600
SCALE IN FEET
MW-1040 -30.74
MW-196 -32.63
MW-100 -31.86
BW-28
BW-10
MW-171
-36



(2)

FIGURE J-11
SIMULATED GROUNDWATER CONTOURS VS OBSERVED WATER LEVELS ZONE C, JANUARY 1993

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

CH2M HILL

RDD1454
MEY84/J-11.DGN

Table J-5 Results of Histogram Analysis		
Water Level Difference	Frequency	Cumulative Percent
0 to 2	152	78.35
2 to 4	39	98.45
4 to 6	3	100.00
6 to 8	0	100.00

Sensitivity Analysis

Sensitivity analysis is frequently used to study the sensitivity of model results to changes in input parameters. This is done, even though the model is well calibrated, because it is recognized that the calibration may not be unique. There may be more than one combination of parameters that produces equally good agreement between simulation results and field measurements. The normal procedure for sensitivity analysis is to vary individual input parameters, such as transmissivity, and to observe the amount of resulting variation in simulation results. The resulting information may help quantify the degree of uncertainty associated with the model results.

At McClellan AFB, the model parameters that have the greatest uncertainty are the transmissivities of the four model layers and the vertical conductance between layers. A total of 14 model runs were made to study the impact of varying the model transmissivities and vertical leakances on the calibrated heads and capture zones. The model was run using transmissivity and vertical leakance values equal to 50 percent and 200 percent of the calibration value, respectively. Table J-6 presents predicted head values for each model layer at 8 nodes for the basic calibration run and the additional 14 sensitivity analysis runs. The assumed conditions for each of the 14 sensitivity simulations are described below (Table J-7):

The results of these simulations showed no significant impact on the calibrated heads, along with a negligible increase/decrease in the volume of water requiring extraction when 50 percent and 200 percent of the calibrated transmissivity was used. The results also showed that when the transmissivity value used in the model was reduced to half the calibration value, Monitoring Zone A was not able to sustain the withdrawal rate in several areas. The results of this sensitivity analysis indicate that a reasonable degree of parameter uncertainty and error associated with parameter estimation does not unreasonably impact model predictions.

Table J-6
Results of Sensitivity Analysis
Head (ft) predicted at the 4 Model Layers

Page 1 of 2

Node No.	Layer Number	Calibration Run	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14
1,000	Layer 1	-44.638	-40.56	-45.684	-39.779	-40.529	-43.696	-45.194	-43.636	-45.41	-44.381	-44.723	-44.678	-44.519	-44.326	-44.801
	Layer 2	-44.972	-41.135	-45.772	-40.367	-41.11	-43.986	-45.5	-44.326	-45.443	-44.78	-45.041	-45.118	-44.776	-45.057	-44.92
	Layer 3	-46.081	-42.3	-44.719	-41.585	-42.29	-43.6	-44.36	-43.798	-44.27	-43.96	-44.057	-43.888	-44.211	-44.109	-44.059
	Layer 4	-43.77	-43.728	-46.169	-43.551	-43.57	-43.731	-43.79	-43.753	-43.78	-43.75	-43.795	-43.763	-43.781	-43.713	-43.774
2,000	Layer 1	-44.739	-40.365	-45.634	-39.53	-40.243	-43.918	-45.238	-43.684	-45.481	-44.86	-44.563	-44.812	-44.264	-44.653	-44.796
	Layer 2	-45.031	-40.936	-45.911	-40.1	-40.79	-44.073	-45.04	-44.293	-45.556	-45.83	-44.788	-45.164	-44.882	-45.037	-44.998
	Layer 3	-44.309	-41.94	-45.151	-41.1	-41.7	-43.853	-44.58	-44.95	-44.552	-44.71	-43.867	-44.182	-44.409	-44.297	-44.313
	Layer 4	-42.803	-43.052	-43.587	-42.5	-42.5	-42.73	-42.84	-42.76	-42.83	-42.74	-42.851	-42.789	-44.812	-42.802	-42.804
4,000	Layer 1	-39.485	-37.686	-40.125	-37.24	-37.7	-39.104	-39.665	-40.031	-38.96	-39.200	-39.579	-39.399	-39.502	-39.686	-39.313
	Layer 2	-38.674	-37.217	-39.396	-36.7	-37.2	-38.198	-38.92	-38.935	-38.46	-38.36	-38.768	-38.609	-38.660	-38.512	-38.861
	Layer 3	-38.311	-37.243	-38.988	-36.7	-37.3	-38.021	-38.44	-38.43	-38.2	-37.98	-38.41	-38.241	-38.376	-38.257	-38.376
	Layer 4	-38.399	-38.133	-38.806	-38.1	-38.1	-38.335	-38.43	-38.41	-38.4	-38.35	-38.43	-38.386	-38.405	-38.393	-38.604
6,000	Layer 1	-36.839	-35.905	-37.443	-35.4	-35.26	-36.391	-37.04	-36.99	-36.73	-36.14	-37.231	-36.409	-37.086	-36.38	-37.143
	Layer 2	-37.428	-36.552	-38.025	-36.05	-36.6	-36.995	-37.6	-37.52	-37.35	-36.73	-37.821	-36.989	-37.684	-37.428	-37.45
	Layer 3	-38.111	-37.523	-38.628	-37.1	-37.6	-37.876	-38.2	-38.15	-38.1	-37.4	-38.503	-38.158	-38.068	-38.098	-38.13
	Layer 4	-38.836	-38.584	-39.234	-38.5	-38.5	-38.809	-38.8	-38.84	-38.83	-38.82	-38.846	-38.831	-38.821	-38.834	-38.838

Table J-6
Results of Sensitivity Analysis
Head (ft) predicted at the 4 Model Layers

Node No.	Layer Number	Calibration Run	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14
8,000	Layer 1	-38.653	-32.564	-32.708	-32.5	-32.5	-32.57	-32.69	-32.656	-32.66	-32.37	-32.806	-32.468	-32.74	-32.515	-32.72
	Layer 2	-32.785	-32.698	-32.838	-32.66	-32.72	-32.702	-32.8	-32.796	-32.78	-32.5	-32.939	-32.603	-32.87	-32.283	-32.78
	Layer 3	-32.948	-32.862	-32.989	-32.82	-32.9	-32.88	-32.97	-32.954	-32.93	-32.65	-33.098	-32.934	-32.9	-2.939	-32.84
	Layer 4	-33.267	-33.231	-33.289	-33.03	-33.3	-33.854	-33.27	-33.27	-33.26	-33.26	-33.269	-33.264	-32.3	-32.263	-33.267
10,000	Layer 1	-44.03	-36.42	-38.545	-36.25	-36.32	-37.868	-37.85	-38.160	-37.7	-37.98	-37.868	-37.987	-37.85	-37.795	-37.97
	Layer 2	-44.972	-36.892	-38.780	-36.65	-36.72	-38.121	-38.06	-38.239	-38.015	-38.21	-38.082	-38.204	-38.092	-38.128	-38.11
	Layer 3	-44.081	-37.262	-38.820	-37.10	-37.15	-38.097	-38.14	-38.229	-38.04	-38.21	-38.131	-38.165	-38.134	-38.138	-38.15
	Layer 4	-43.774	-37.603	-38.798	-37.46	-37.5	-38.043	-38.13	-38.133	-38.086	-38.057	-38.133	-38.087	-38.116	-38.101	-38.109
11,000	Layer 1	-35.751	-35.370	-36.015	-35.2	-35.39	-35.662	-35.785	-35.87	-35.668	-35.50	-35.884	-35.633	-35.814	-35.633	-35.82
	Layer 2	-35.881	-35.552	-36.158	-35.34	-35.54	-35.8	-35.911	-35.94	-35.82	-35.63	-36.015	-35.76	-35.948	-35.878	-35.88
	Layer 3	-36.022	-35.703	-36.307	-35.52	-35.72	-35.95	-36.05	-36.07	-35.98	-35.76	-36.158	-36.014	-36.025	-36.015	-36.028
	Layer 4	-36.274	-36.022	-36.581	-36	-35.28	-36.23	-36.29	-36.29	-36.26	-36.25	-36.268	-36.263	-36.281	-36.871	-36.276
11,500	Layer 1	-37.881	-36.467	-38.285	-36.29	-36.40	-37.743	-37.94	-38.04	-37.84	-37.97	-37.802	-38.124	-37.736	-38.051	-37.78
	Layer 2	-37.416	-36.437	-37.845	-36.25	-36.42	-37.267	-37.43	-37.6	-37.3	-37.52	-37.33	-37.679	-37.262	-37.311	-37.506
	Layer 3	-36.995	-36.315	-37.468	-36.111	-36.3	-36.889	-37.04	-37.1	-36.31	-37.13	-36.88	-36.925	-37.038	-36.94	-37.04
	Layer 4	-36.661	-36.228	-37.200	-36.116	-36.15	-36.6	-36.7	-36.694	-36.64	-36.61	-36.694	-36.637	-36.677	-36.65	-36.668

Table J-7 Summary of Sensitivity Runs	
Run No.	**Conditions**
1	The transmissivity of layer 4 (regional aquifer) was double the calibrated value for this run while all other parameters were held constant.
2	The transmissivity of layer 4 (regional aquifer) was reduced to half the calibrated value for this run while all other parameters were held constant.
3	The transmissivity of layer 3 was double the calibrated value for this run while all other parameters were held constant.
4	The transmissivity of layer 4 (regional aquifer) was reduced to half the calibrated value for this run while all other parameters were held constant.
5	The transmissivity of layer 2 was double the calibrated value for this run while all other parameters were held constant.
6	The transmissivity of layer 2 was reduced to half the calibrated value for this run while all other parameters were held constant.
7	The transmissivity of layer 1 was double the calibrated value for this run while all other parameters were held constant.
8	The transmissivity of layer 1 was reduced to half the calibrated value for this run while all other parameters were held constant.
9	The Leakance between layer 3 and layer 4 was double the calibrated value for this run while all other parameters were held constant.
10	The Leakance between layer 3 and layer 4 was reduced to half the calibrated value for this run while all other parameters were held constant.
11	The Leakance between layer 3 and layer 2 was double the calibrated value for this run while all other parameters were held constant.
12	The Leakance between layer 3 and layer 2 was reduced to half the calibrated value for this run while all other parameters were held constant.
13	The Leakance between layer 1 and layer 2 was double the calibrated value for this run while all other parameters were held constant.
14	The leakance between layer 1 and layer 2 was reduced to half the calibrated value for this run while all other parameters were held constant.

Simulation of Containment Scenarios

The following section describes the simulations performed to develop the extraction well networks required to contain a particular remedial action target volume.

Three target volumes were considered for containment:

- Containment of all contaminated groundwater above background VOC concentrations (0.5 μg/l)

- Containment of all contaminated groundwater exceeding a federal or state MCL

- Containment of all contaminated groundwater that poses a 10^{-6} or greater risk

Three containment scenarios were investigated for each remedial action target volume:

- Basic containment with high contaminant concentrations isolated in the current hot spot areas

- Containment with injection of treated groundwater to speed cleanup of the hot spots

- Containment with end-use injection into the regional aquifer

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, and where contamination levels exceed the assumed background concentration for VOCs (0.5 μg/l).

It was assumed in the scenario 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 Monitoring Zone A 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 lie east of the runway in OU A and are shown on Figure J-12.

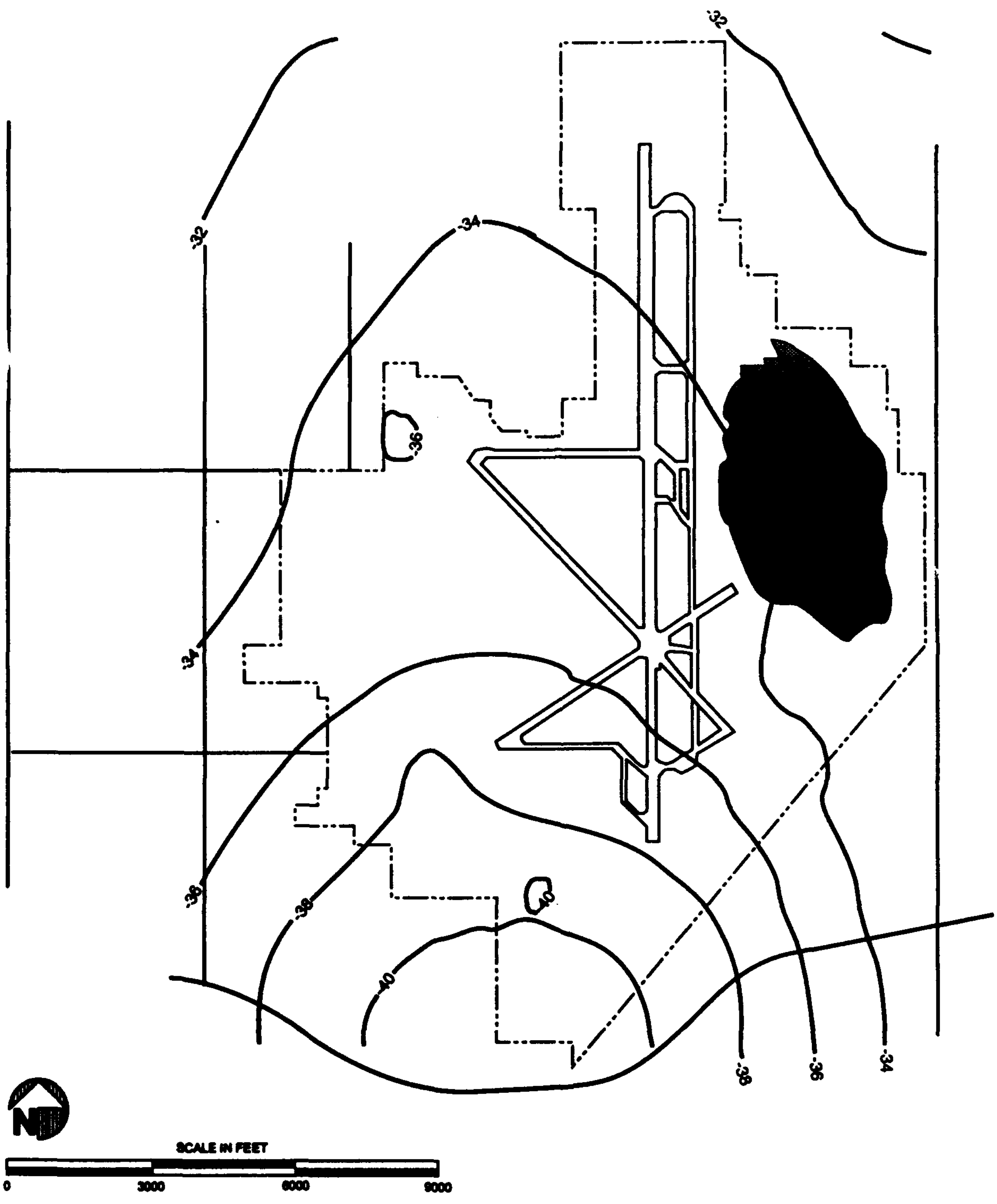
Operational Strategy

The strategy used in developing the extraction alternatives contained the following main elements:

- Each extraction system must completely contain the specified target volume, and most contamination is captured in the aquifer where it resides.

- A limited quantity of contamination is allowed to move between aquifers as long as the location where contaminants enter the receptor aquifer lies inside the target volume for that aquifer.

- In no case is contamination allowed to leave a contaminated aquifer and enter an adjacent aquifer outside of the specified target volume.



Legend

Areas Susceptible to De-Watering

—-42— Contour of equal groundwater elevation (ft msl)

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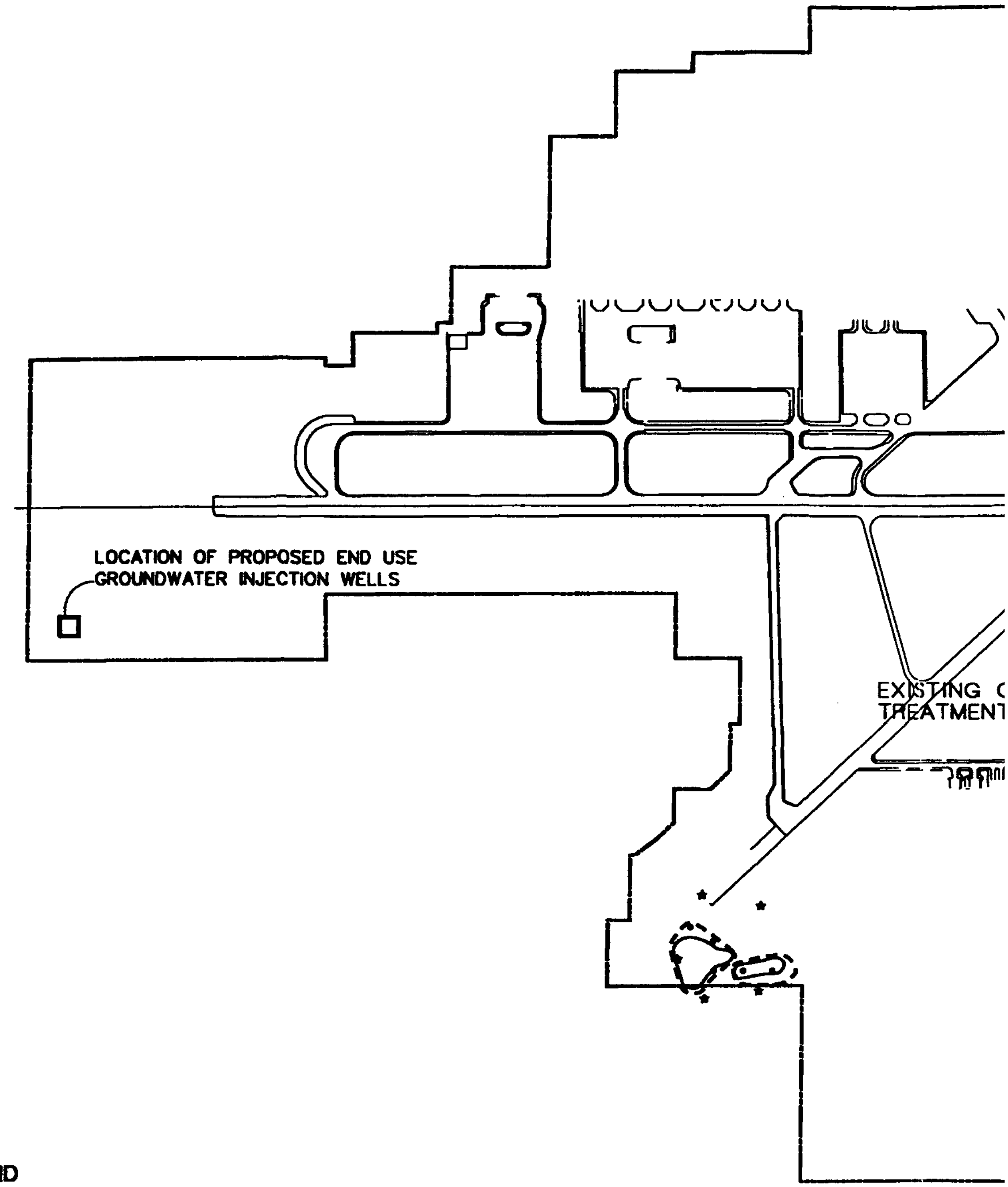
FIGURE J-12
AREAS SUSCEPTIBLE TO DE-WATERING - MONITORING ZONE A

GROUNDWATER OPERABLE UNIT RI/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 Location of Model Nodes)
- Extraction Well

1

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MEY94/8-9.DGN (J-13-LEV 62)

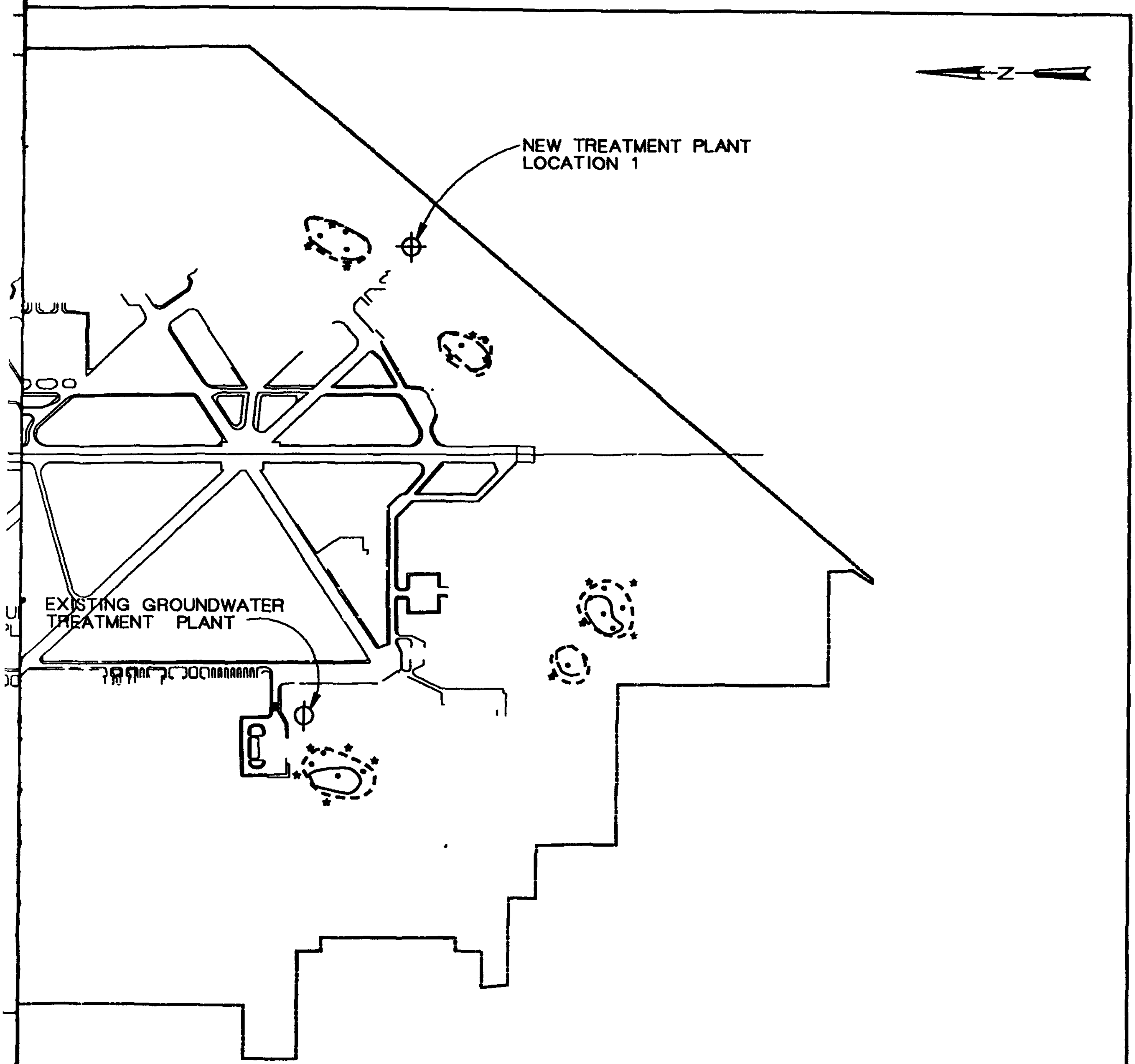
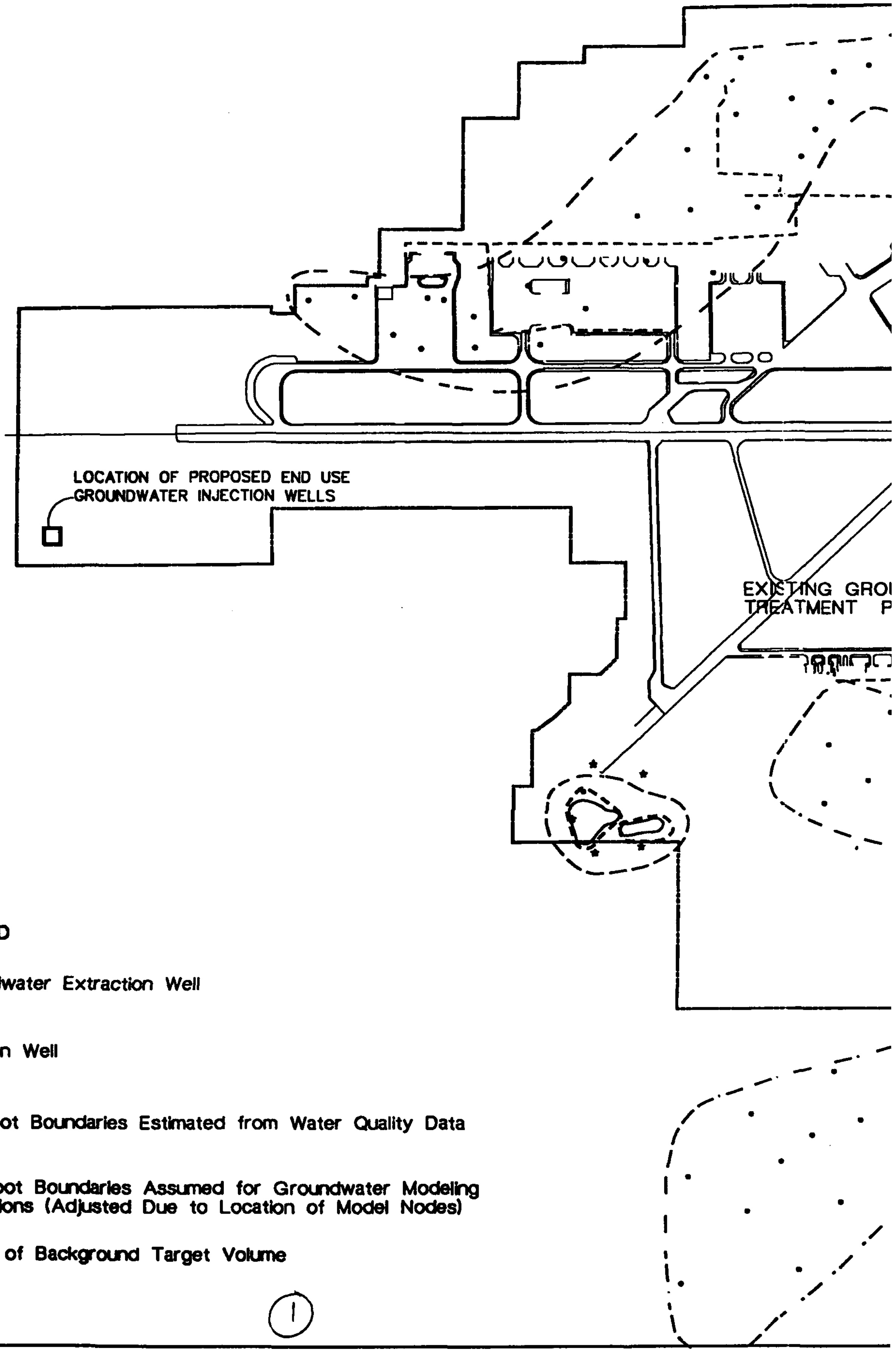


FIGURE J-13
EXTRACTION AND INJECTION WELL LOCATIONS MONITORING ZONE A HOT SPOTS

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

CH2M HILL

(2)



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 Background Target Volume

1

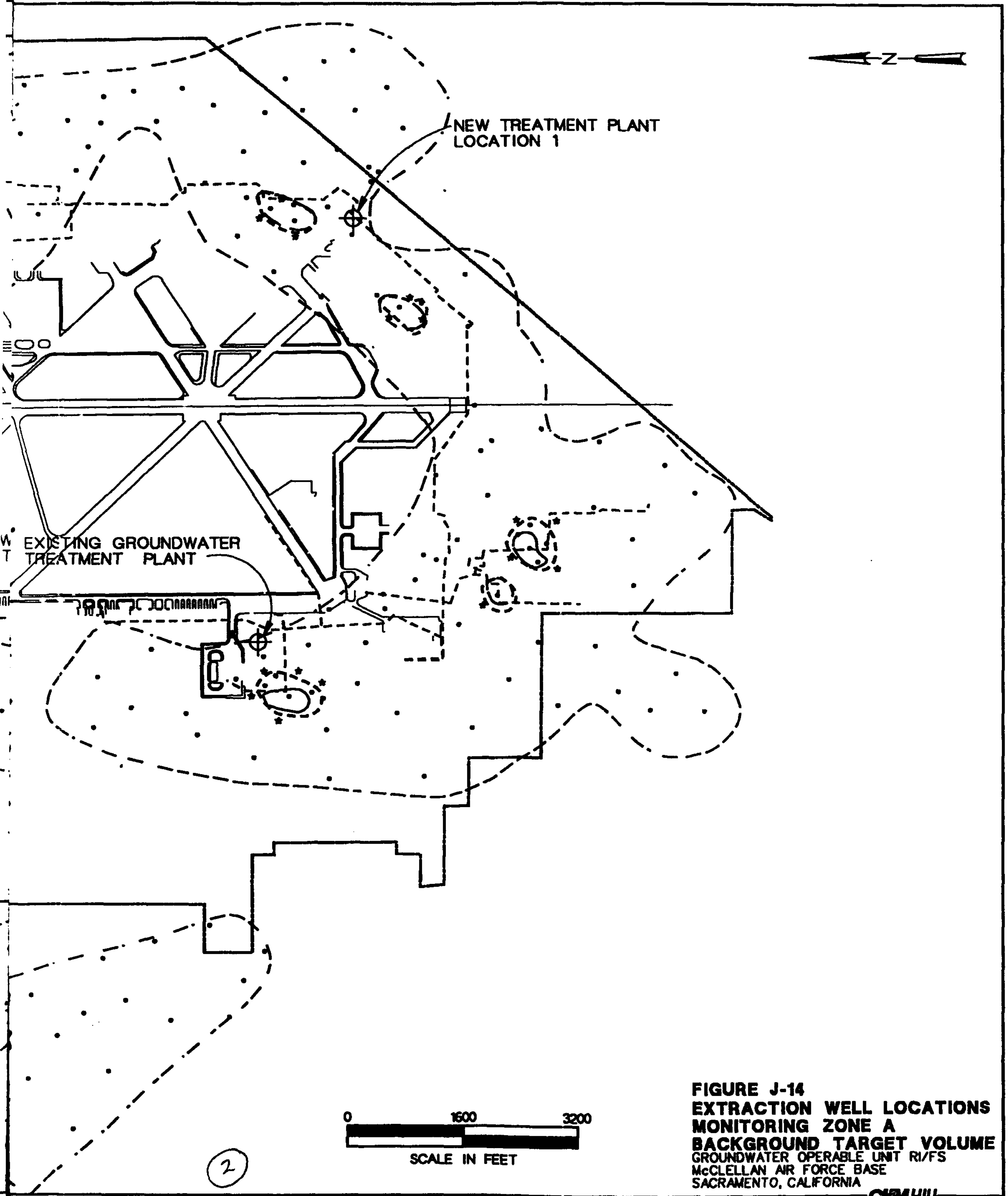


FIGURE J-14
EXTRACTION WELL LOCATIONS
MONITORING ZONE A
BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA
CH2M HILL

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. Flow lines for each alternative started at the perimeter of the target volume in each monitoring zone are presented in the following sections. These figures show the movement of groundwater from the boundaries of the target volumes into the groundwater extraction wells. It is apparent from these figures 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.

Another significant characteristic of all extraction networks is that the highly contaminated portions of Monitoring Zone A (hot spots) are isolated independently and removed by dedicated extraction wells. This was 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 dense nonaqueous-phase liquids (DNAPLs) are suspected to reside. It is advantageous to remove 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 extremely high groundwater concentrations have been identified in Monitoring Zone A. These locations are shown in Figure J-13. It is also noted on this figure that the boundaries of the hot spot target areas were modified slightly when input to the groundwater model. This was necessary as the target areas must be defined by existing model nodes, and nodes were not always available in the exact locations of the hot spot boundaries. When the estimated boundary fell between two model nodes, the outer node was selected to ensure that the entire hot spot was contained by the proposed extraction wells.

Alternatives Evaluation

The alternatives evaluated are grouped according to common elements contained in them. The first set of extraction alternatives consists of basic containment of each of the target volumes described, with hot spot extraction by designated wells. The next set of extraction alternatives is the basic containment alternatives, coupled with injection end use of the treated groundwater. It was necessary to quantitatively evaluate injection of the treatment plant effluent into the regional aquifer to demonstrate that the injection will not alter the hydraulic conditions enough to compromise the containment of the extraction network designs. The final set of evaluations investigate the potential for strategic placement of injection wells surrounding the hot spot contamination areas so that the flushing of the hot spots can be augmented with reinjected treated groundwater.

A comparison of average time per pore volume flushed with and without hot spot injection is provided in Table J-8.

Table J-8 Comparison of Average Time per Pore Volume Flushed with and without Hot Spot Injection		
	Time Per Pore Volume (yrs)	
Hot Spot Location	**Without Injection**	**With Injection**
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 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 injection.

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 injection 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 also apply to this evaluation.

The extraction alternatives evaluated using the groundwater flow model are summarized as follows:

- The No-Action Alternative with BW-18 abandoned.
- Containment of the background target volume.
- Containment of the background target volume with treated groundwater injection surrounding contamination hot spots.

- Containment of the background target volume with injection of treated groundwater into the regional aquifer 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 treated groundwater injection surrounding contamination hot spots.

- Containment of the 10^{-6} incremental cancer risk target volume with injection of treated groundwater into the regional aquifer through an injection well located northwest of the runway.

- Containment of the MCL target volume.

- Containment of the MCL target volume with treated groundwater injection surrounding contamination hot spots.

- Containment of the MCL target volume with injection of treated groundwater into the regional aquifer through an injection well located northwest of the runway.

Background Target Volume

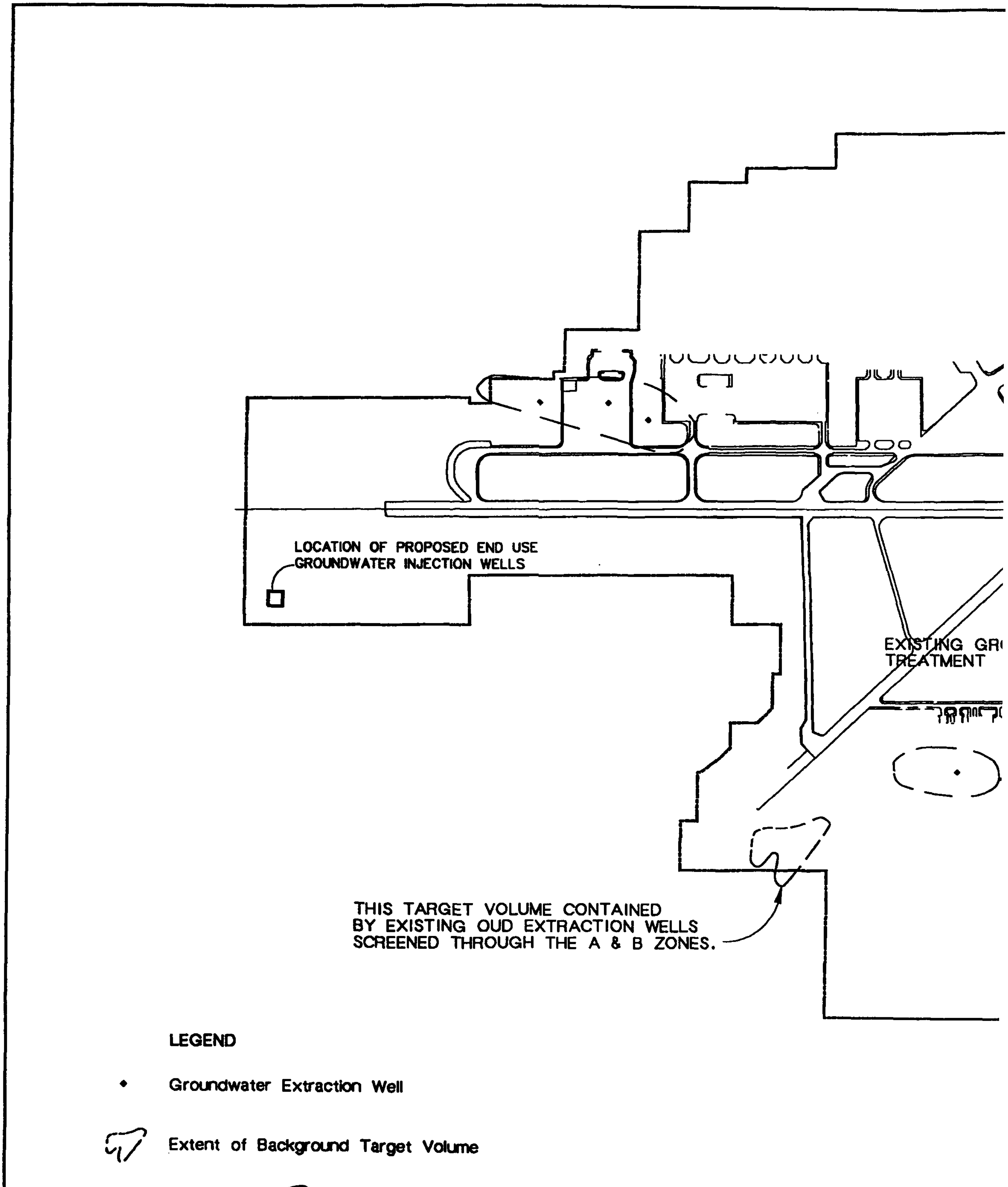
The background target volume comprises groundwater where VOCs have been detected above 0.5 μg/l. The extent of this target volume in Monitoring Zones A, B, and C is shown in Figures J-14 through J-16, respectively. Included on these figures is the number of extraction wells that are required to contain the associated target volume, in conformance with the operational strategies. The extraction well locations were determined based on 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. The groundwater injection wells surrounding the hot spots shown in Figure J-14 only apply to alternatives including hot spot injection. The number of extraction wells required for containment of each monitoring zone, and the extraction rate of high concentration versus low concentration contaminated groundwater is summarized in Table J-9. 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 drawdown of 75 percent of the initial saturated thickness. Existing extraction wells were simulated at pumping rates that reflect current operation.

Table J-9
Summary of Groundwater Modeling Runs
Containment of Target Volume with Isolated Hot Spot Containment

Operable Unit	Monitoring Zone A No. Wells	A Q (gpm)	B No. Wells	B Q (gpm)	C No. Wells	C Q (gpm)	Per OU No. Wells	Per OU 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 Injection)								
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 Injection)—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 Injection)—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 injection options.

Note:
N/A = Not applicable.



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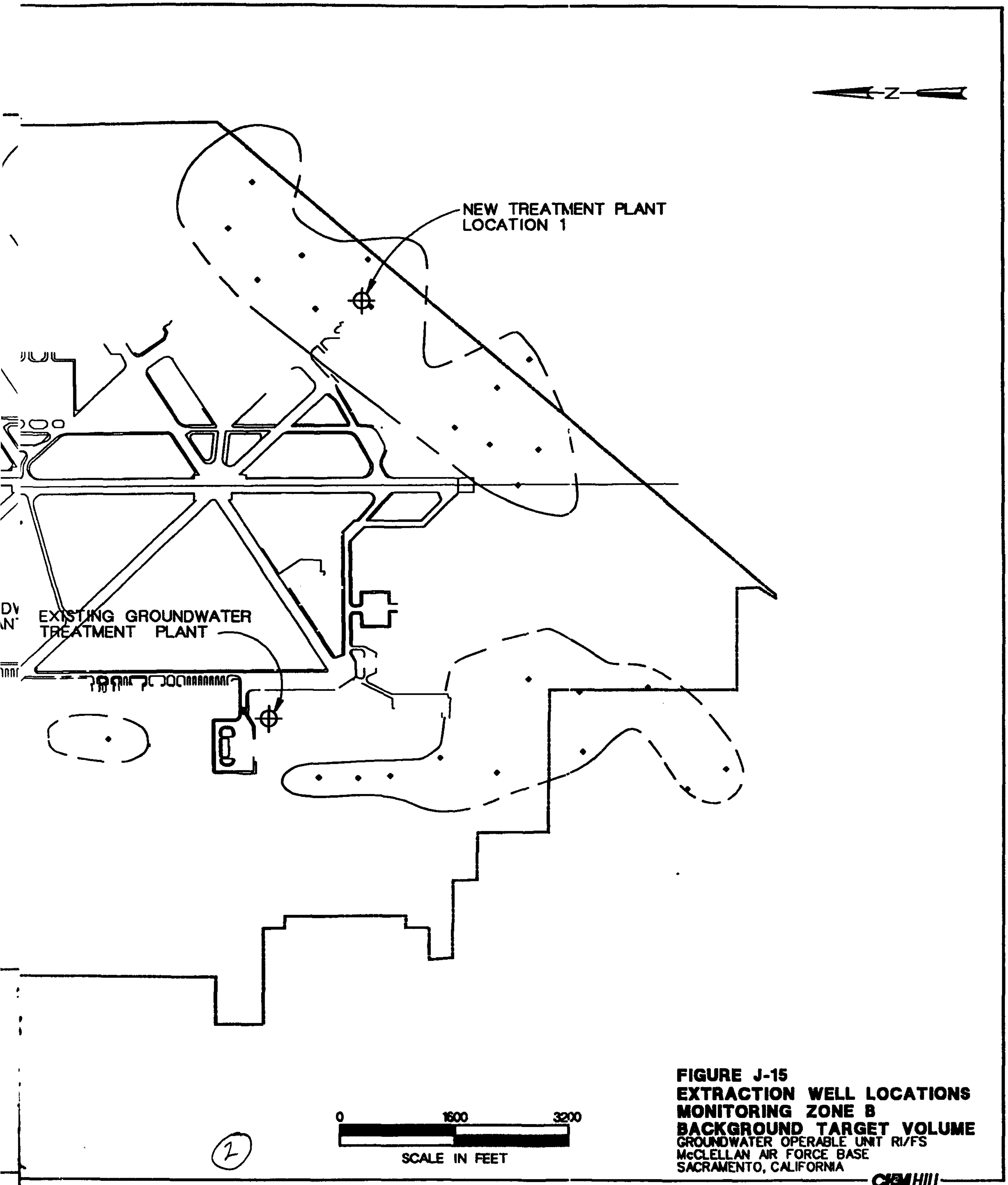
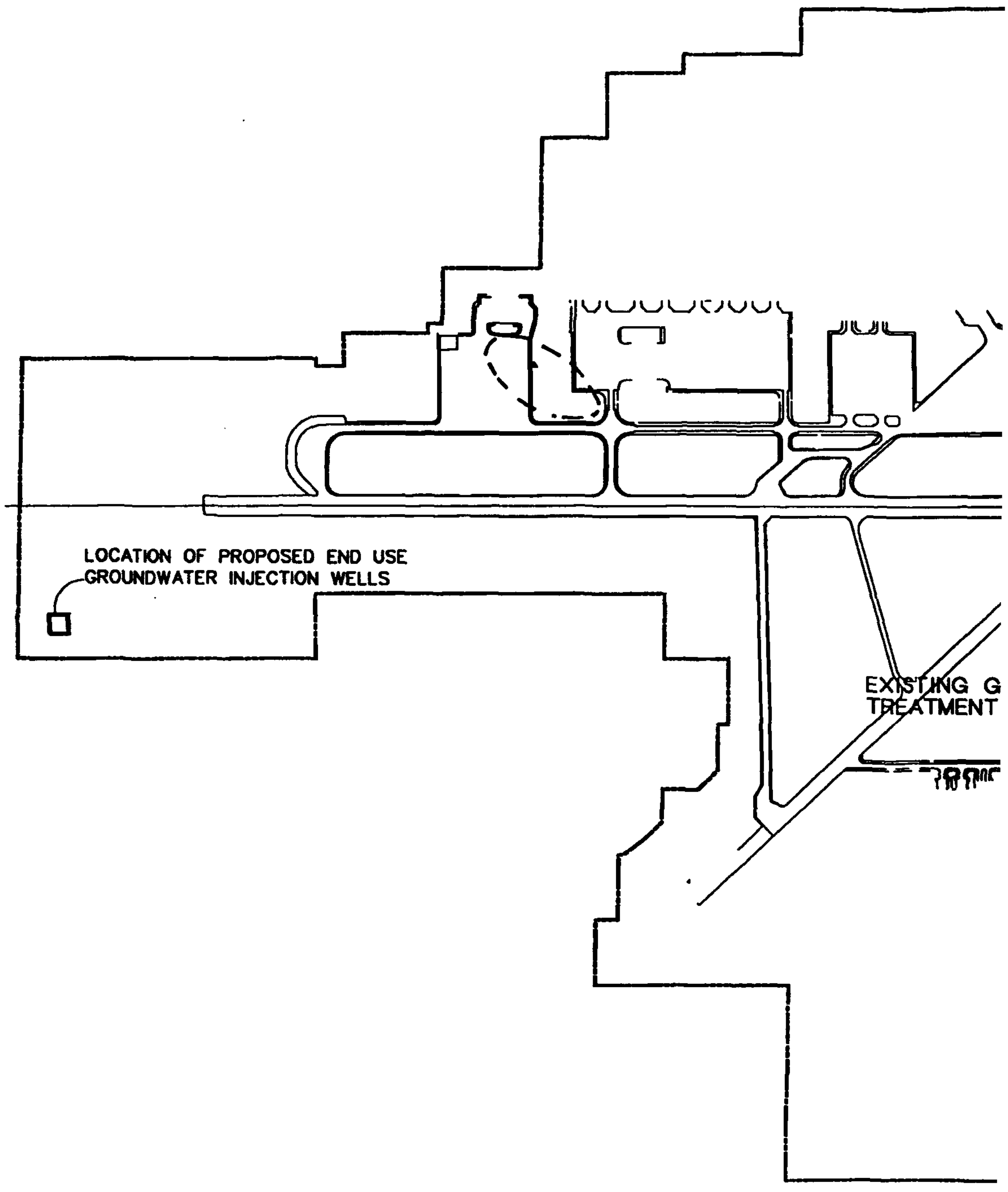


FIGURE J-15
EXTRACTION WELL LOCATIONS
MONITORING ZONE B
BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA
CH2M HILL



LEGEND

Groundwater Extraction Well

Extent of Background Target Volume

1

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MEY94/8-12.DGN (J-16-LEV 62)

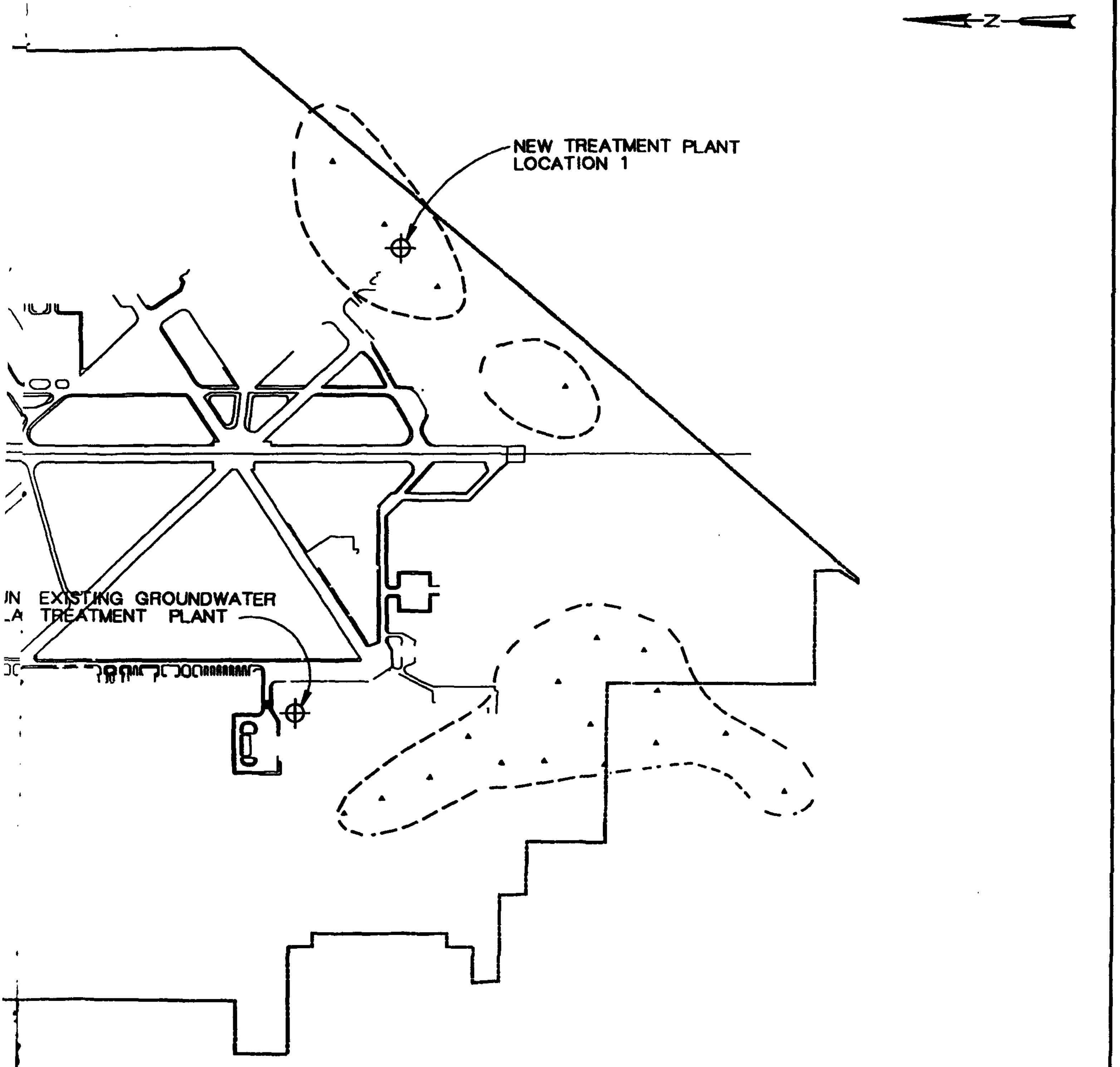


FIGURE J-16
EXTRACTION WELL LOCATIONS
MONITORING ZONE C
BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Figures J-17 through J-19 present the groundwater pathlines for the basic containment alternative. These pathlines originate from the target area boundaries in Monitoring Zones A, B, and C, and confirm that groundwater contained in the target volume is moving toward, and eventually removed by, the extraction system. Figures J-20 through J-22 show similar flow lines for the basic containment alternative with hot spot flushing by injection of treated groundwater. The locations of the groundwater injection wells near the hot spots are presented on Figures J-14 through J-16. Figure J-23 through J-25 show the estimated pathlines for the basic containment alternative combined with injection end use of all treated groundwater into the regional aquifer. The injection location is assumed to be adjacent to the northern end of the runway as shown on Figures J-14 through J-16.

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 1 in 10,000. Figures J-26 through J-28 include the locations of extraction wells required to contain this target volume. The groundwater injection wells surrounding the hot spots shown in Figure J-26 only apply to alternatives including hot spot injection. The number of extraction wells and approximate flushing rates are summarized in Table J-9. The assumed extraction well pumping capacities for each zone are identical to those assumed for the background target volumes.

Figures J-29 through J-31 present the groundwater pathlines for the basic containment alternative. These pathlines originate from the target area boundaries in Monitoring Zones A, B, and C, and confirm that groundwater contained in the target volume is moving toward, and eventually removed by, the extraction system. Figures J-32 through J-34 show similar flow lines for the basic containment alternative with hot spot flushing by injection of treated groundwater. Figure J-35 through J-37 show the estimated pathlines for the basic containment alternative combined with injection end use of all treated groundwater into the regional aquifer.

MCL Target Volumes

The MCL target volumes comprise all groundwater that contains any contaminant above the federal or state MCL. Figures J-38 through J-40 include the extraction well locations required to contain this target volume. The groundwater injection wells surrounding the hot spots shown in Figure J-38 only apply to alternatives including hot spot injection. The results of the simulations performed assuming this target volume, including pumping rates and flushing time estimates, are summarized in Table J-9.

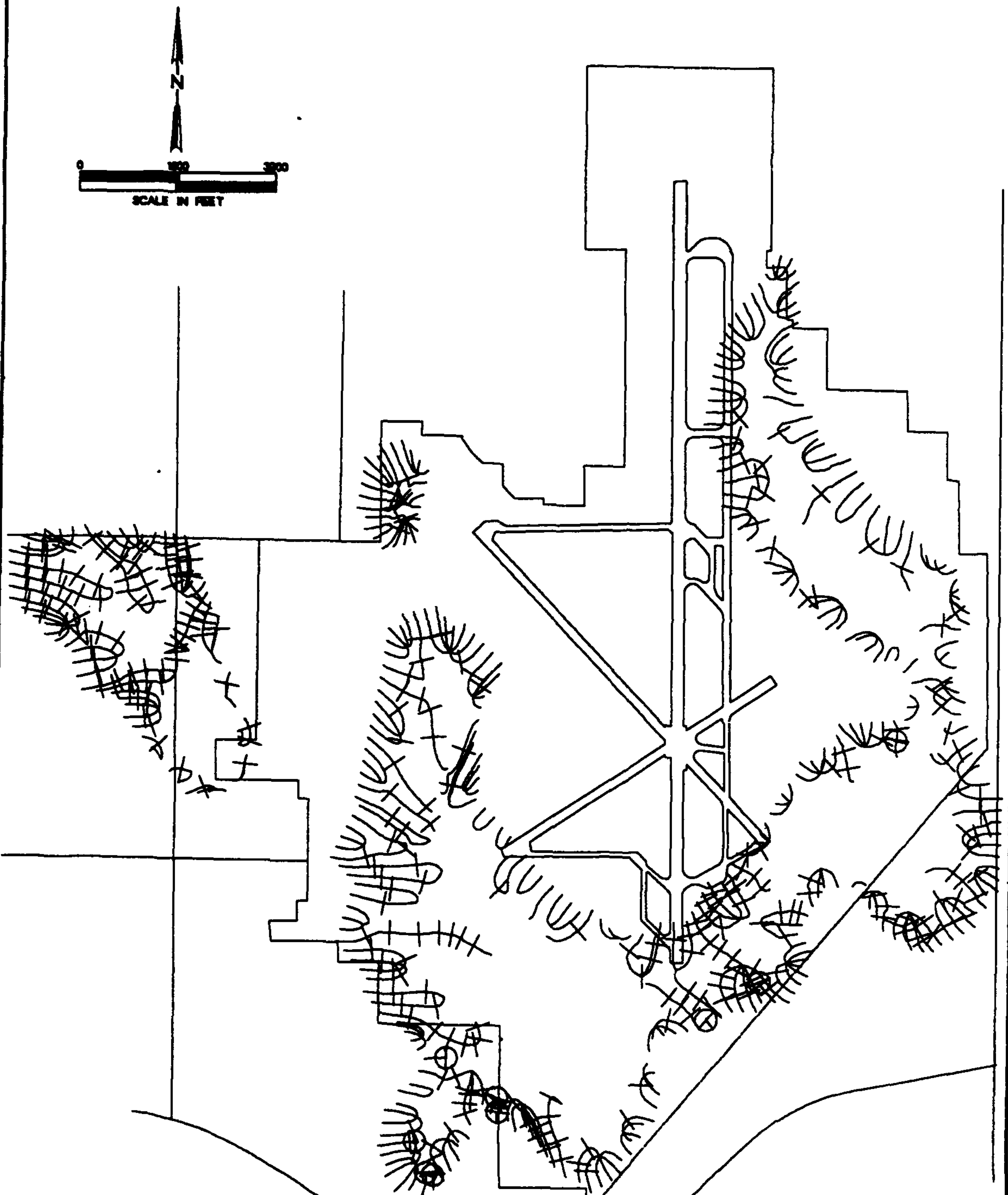


FIGURE J-17
FLOWLINES SHOWING BASIC CONTAINMENT IN MONITORING ZONE A BACKGROUND TARGET VOLUME

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

CH2M HILL

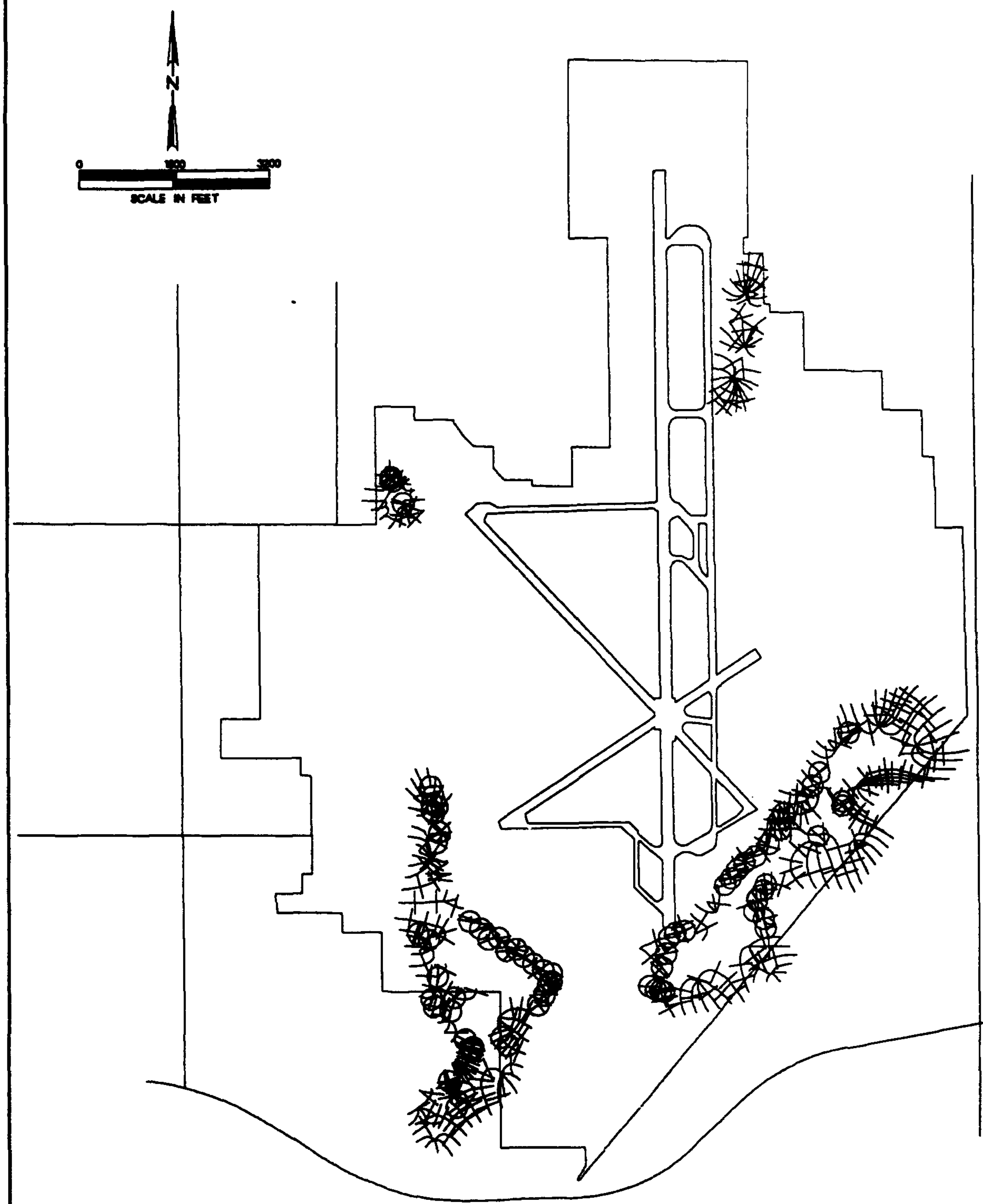


FIGURE J-18
FLOWLINES SHOWING BASIC CONTAINMENT IN MONITORING ZONE B BACKGROUND TARGET VOLUME

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

CH2M HILL

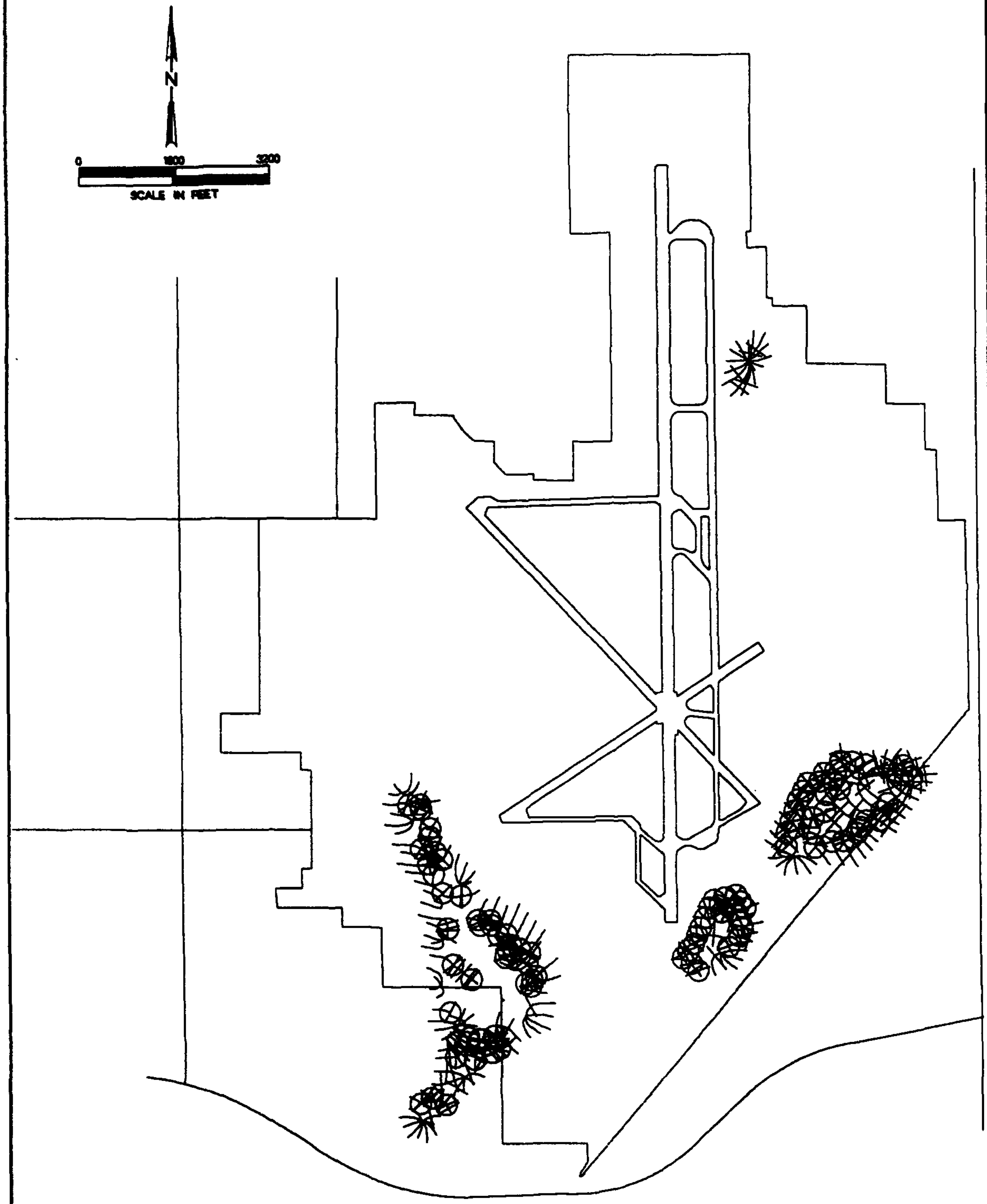


FIGURE J-19
FLOWLINES SHOWING BASIC CONTAINMENT IN MONITORING ZONE C BACKGROUND TARGET VOLUME

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

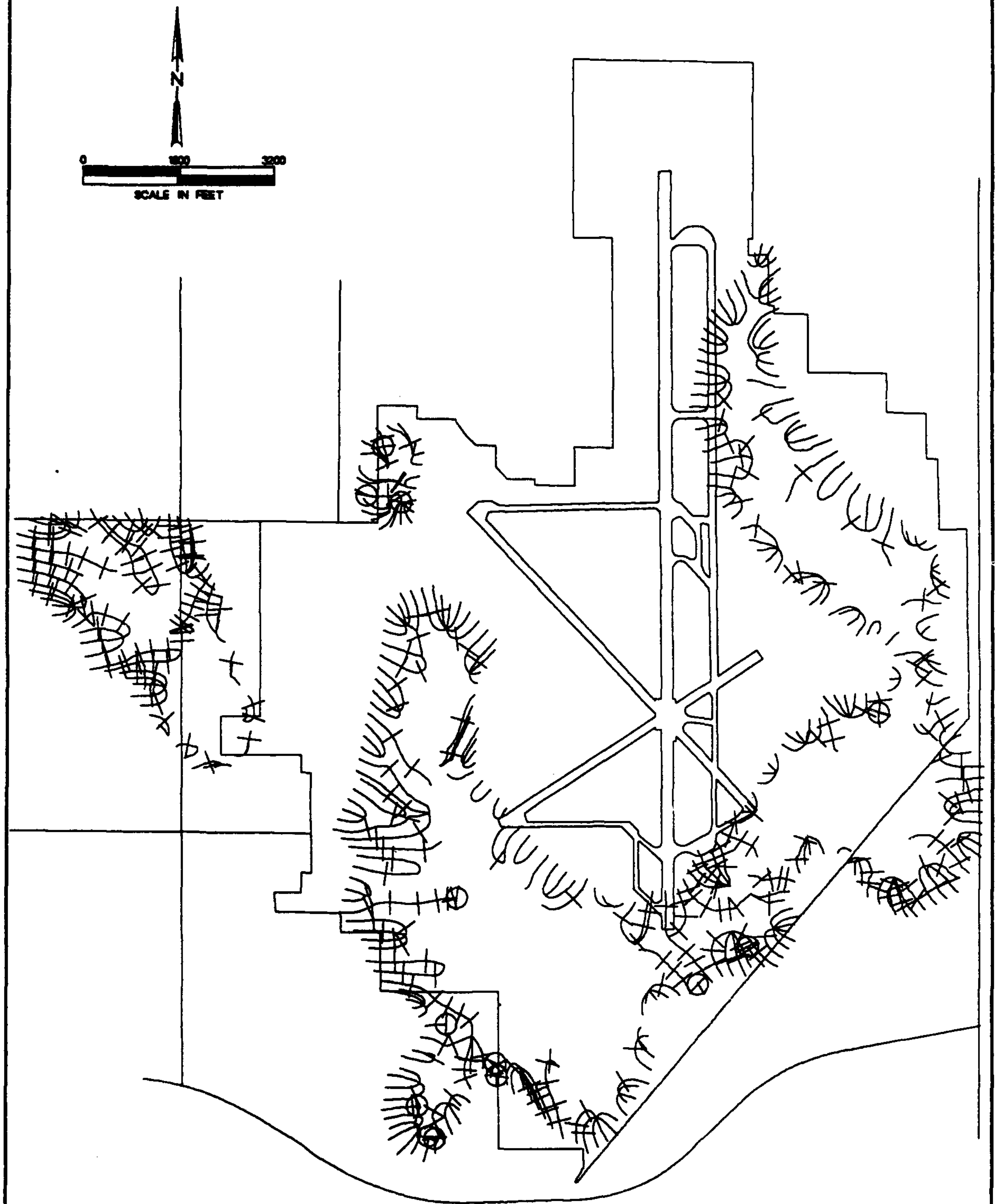


FIGURE J-20
FLOWLINES SHOWING HOT SPOT INJECTION IN MONITORING ZONE A BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

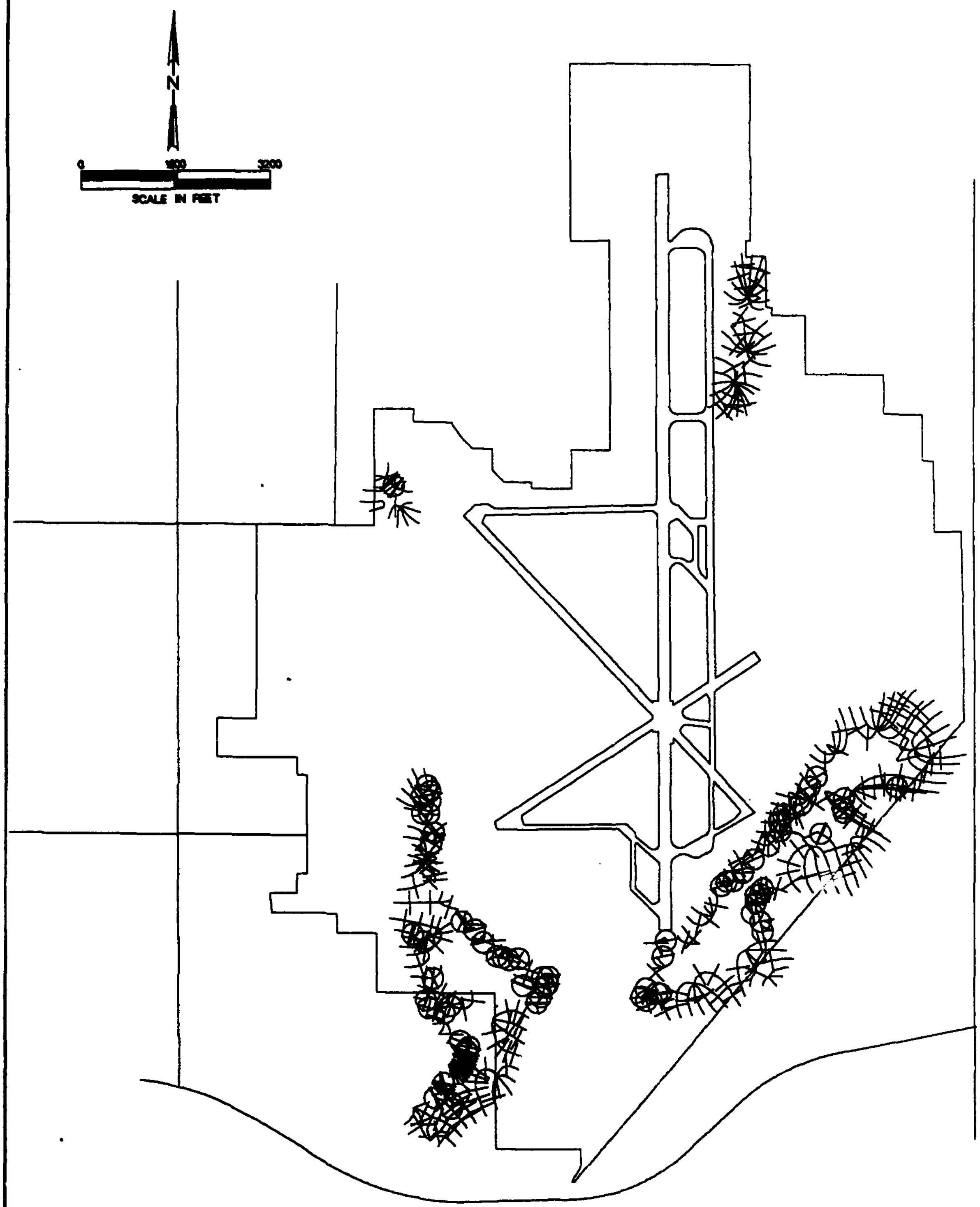


FIGURE J-21
FLOWLINES SHOWING HOT SPOT INJECTION IN MONITORING ZONE B BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

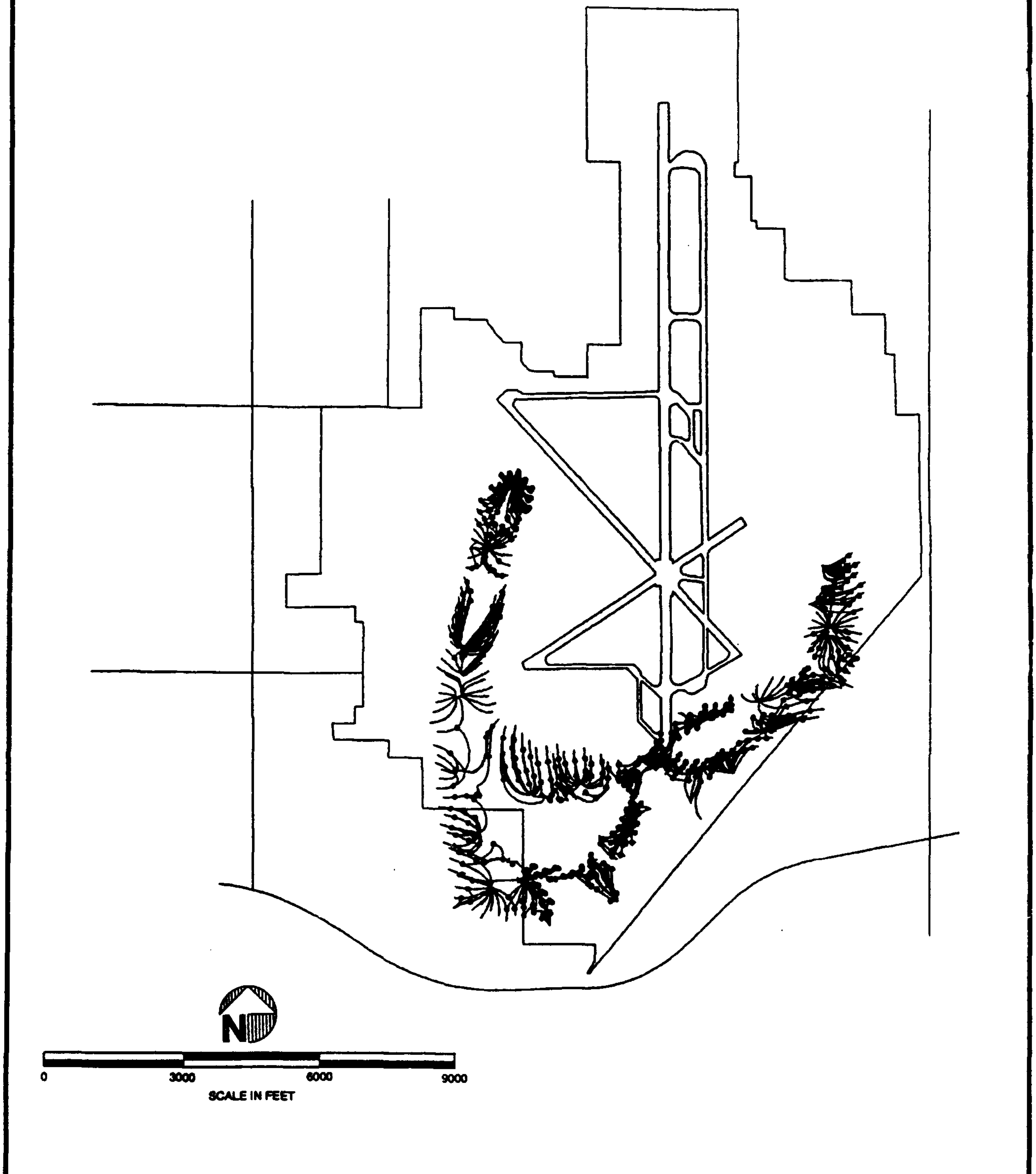


FIGURE J-22
FLOWLINES SHOWING HOT SPOT INJECTION IN MONITORING ZONE C BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDO1312_230

CH2M HILL

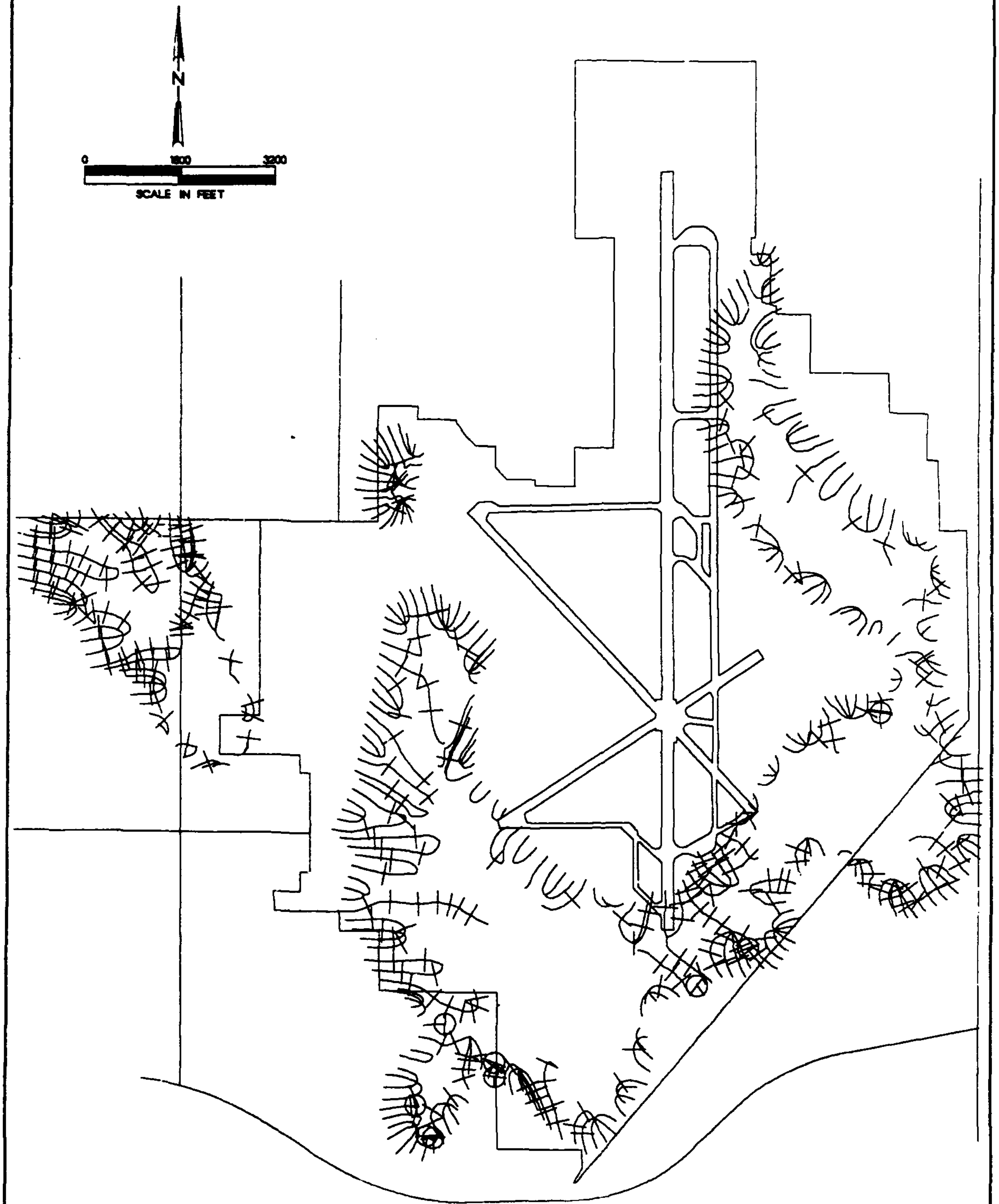


FIGURE J-23
FLOWLINES SHOWING END-USE INJECTION IN MONITORING ZONE A BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

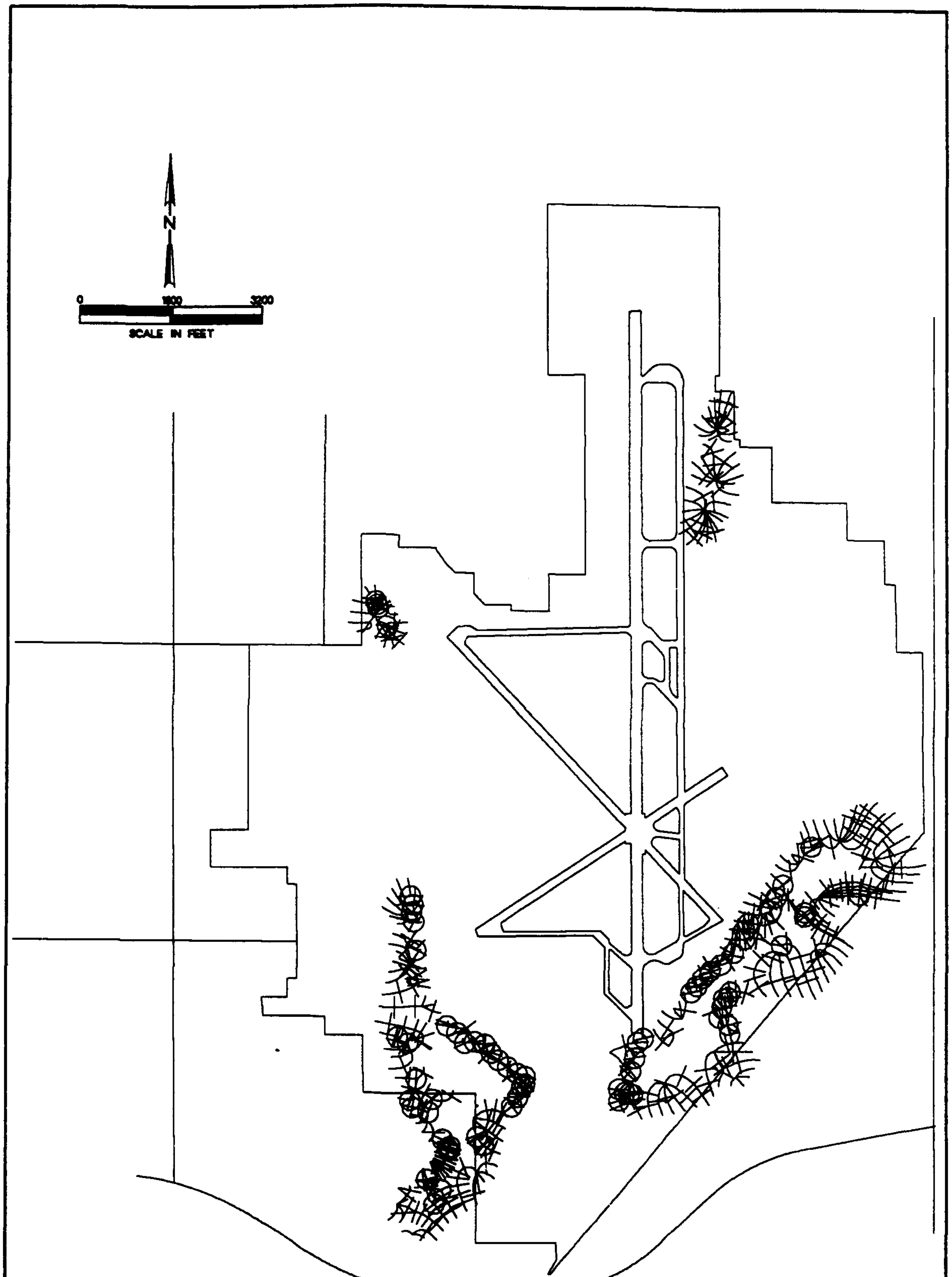


FIGURE J-24
FLOWLINES SHOWING END-USE INJECTION IN MONITORING ZONE B BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

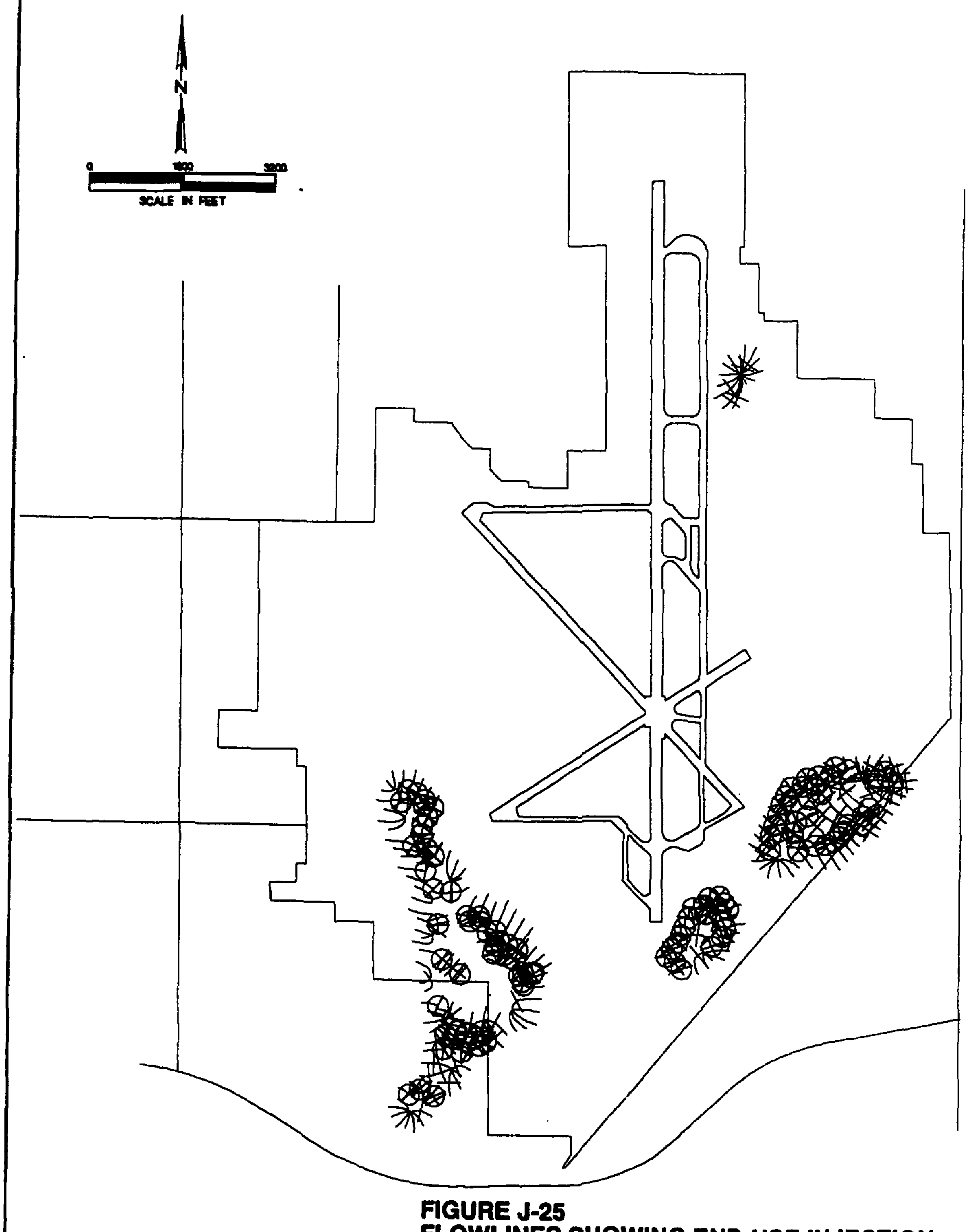
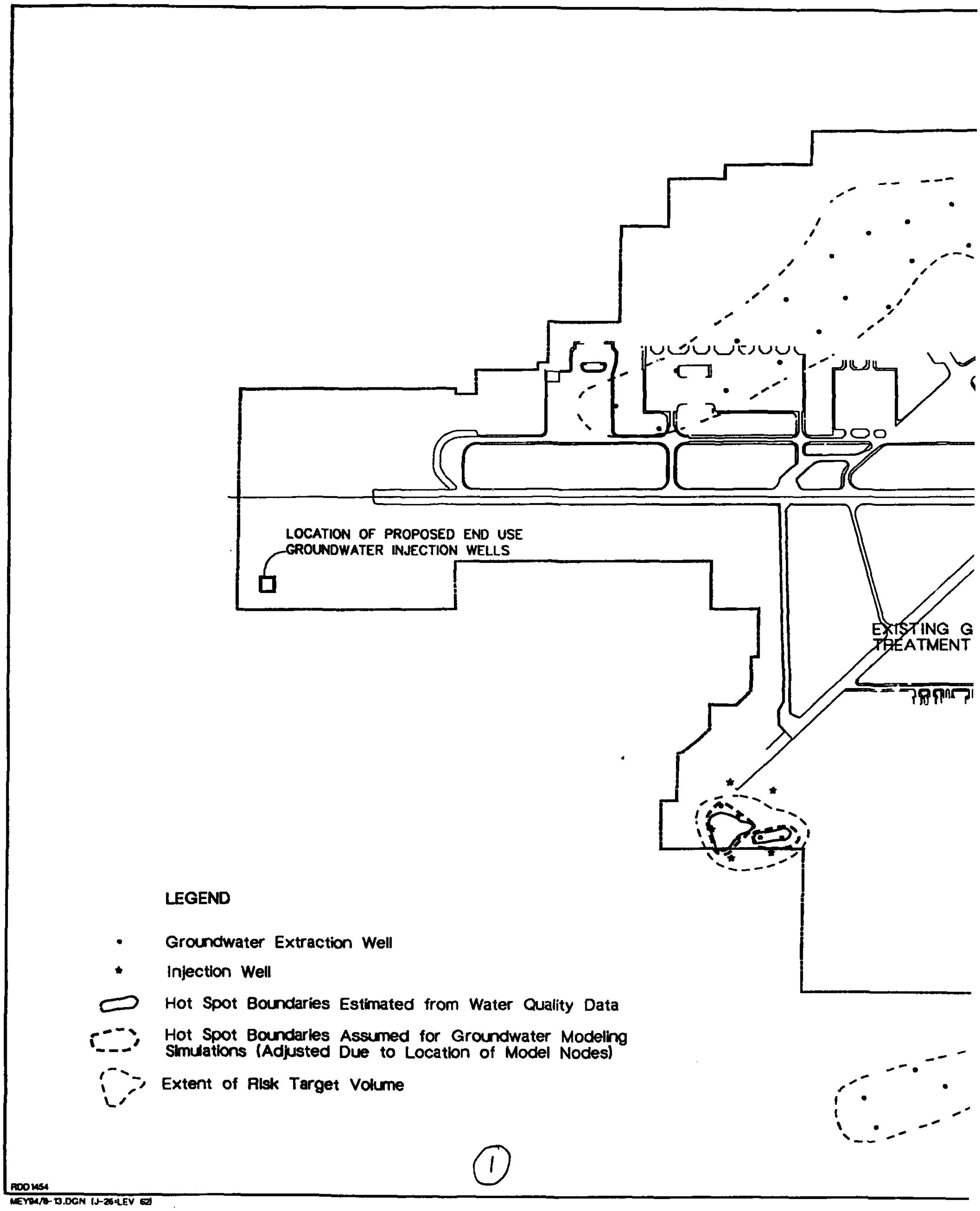


FIGURE J-25
FLOWLINES SHOWING END-USE INJECTION IN MONITORING ZONE C BACKGROUND TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



LOCATION OF PROPOSED END USE GROUNDWATER INJECTION WELLS
EXISTING G
TREATMENT
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
1
RDD 1454
MEY94/8-13.DGN (J-26-LEV 62)

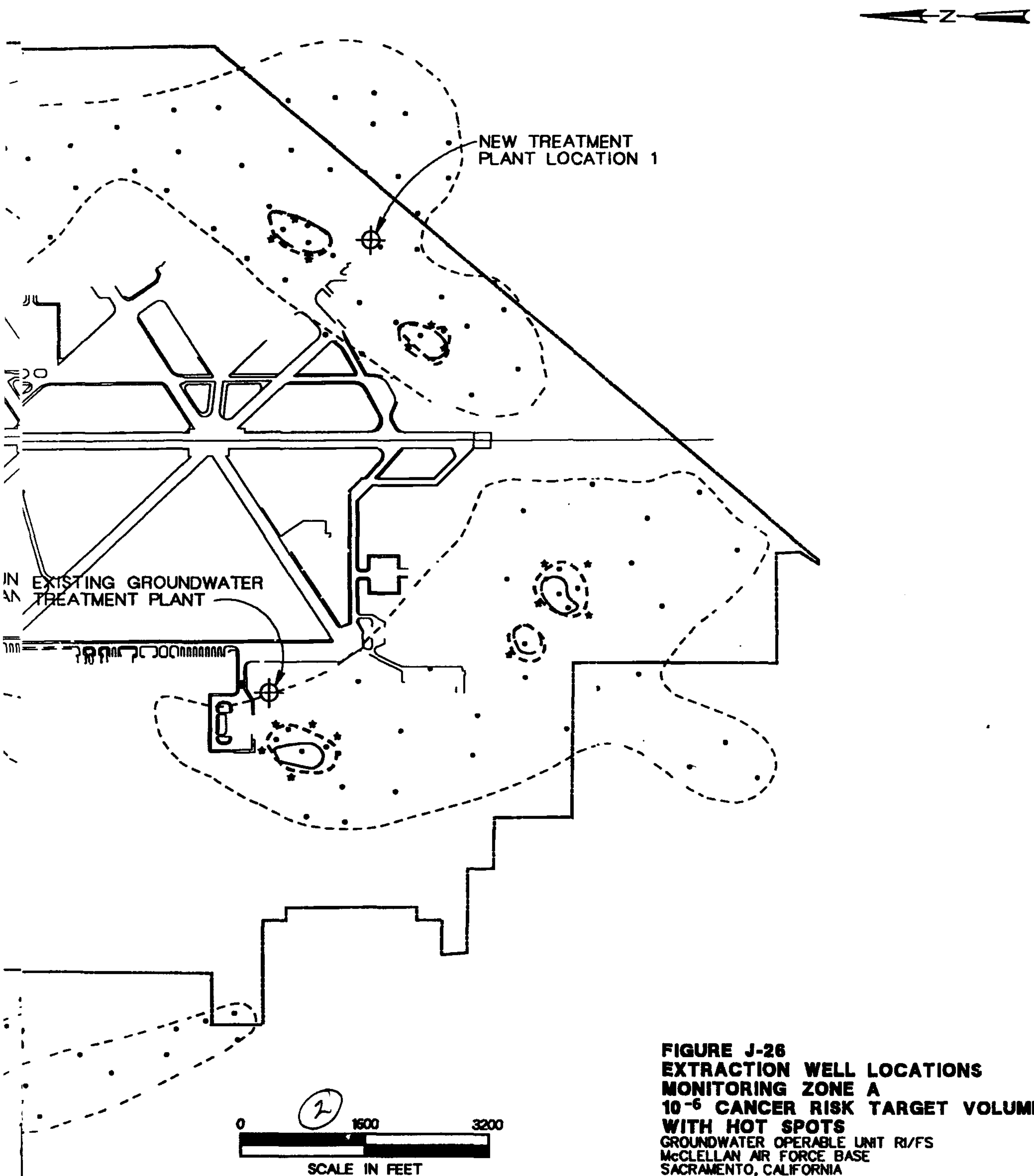
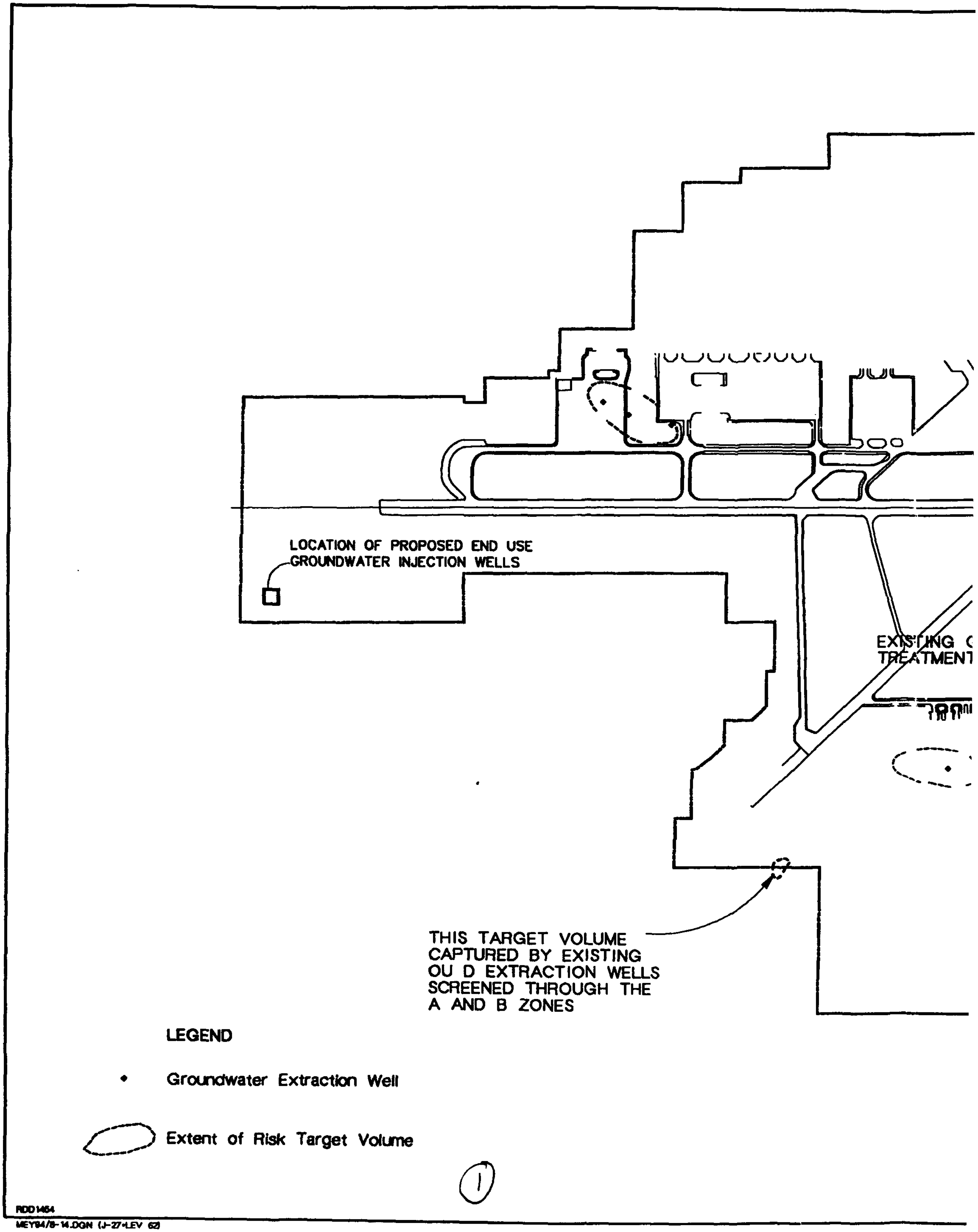


FIGURE J-26
EXTRACTION WELL LOCATIONS
MONITORING ZONE A
10^{-6} CANCER RISK TARGET VOLUME
WITH HOT SPOTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Figures J-41 through J-43 present the groundwater pathlines for the basic containment alternative. These pathlines originate from the target area boundaries in


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
RDD1464
MEY94/8-14.DGN (J-27-LEV 62)
1

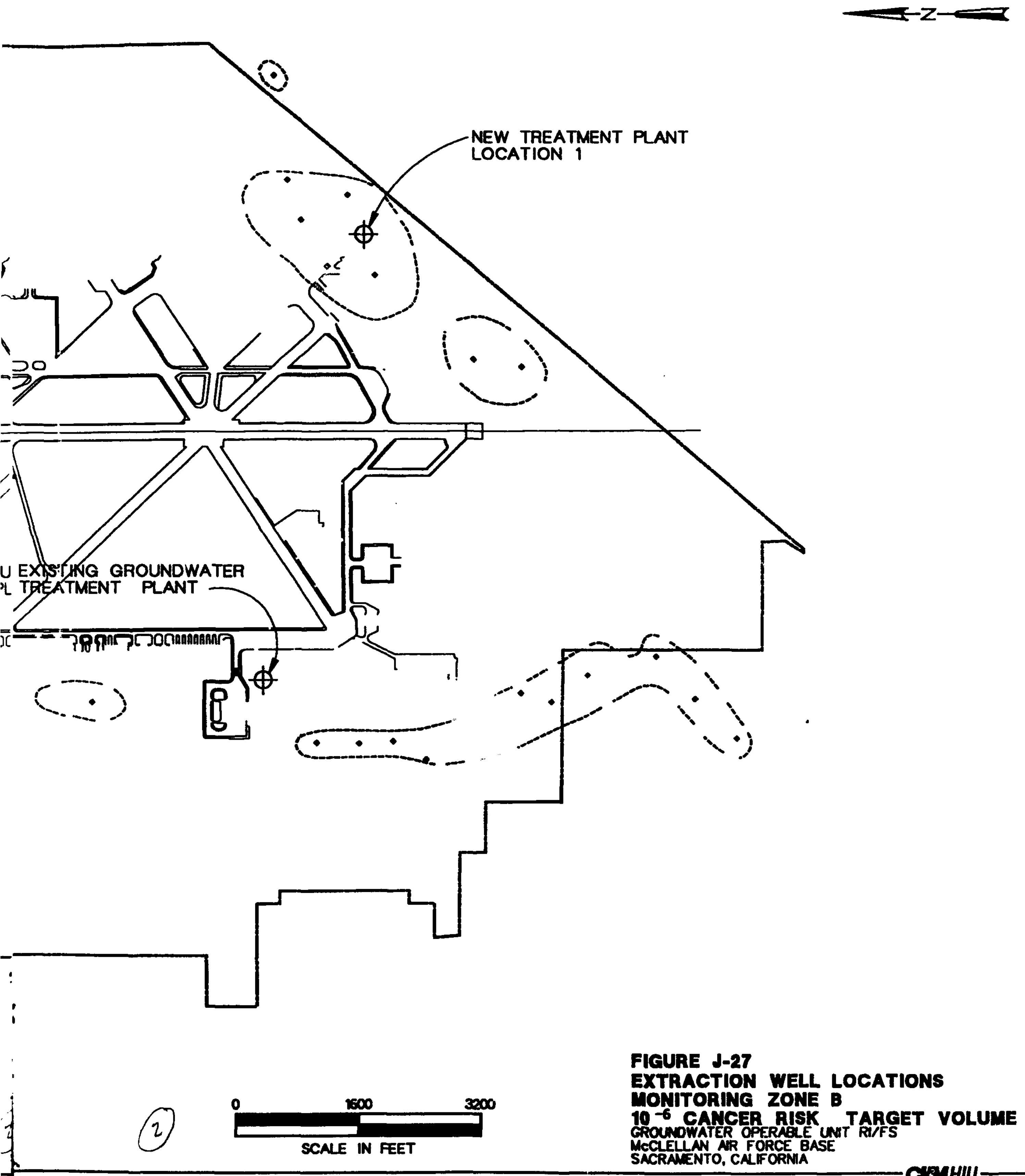
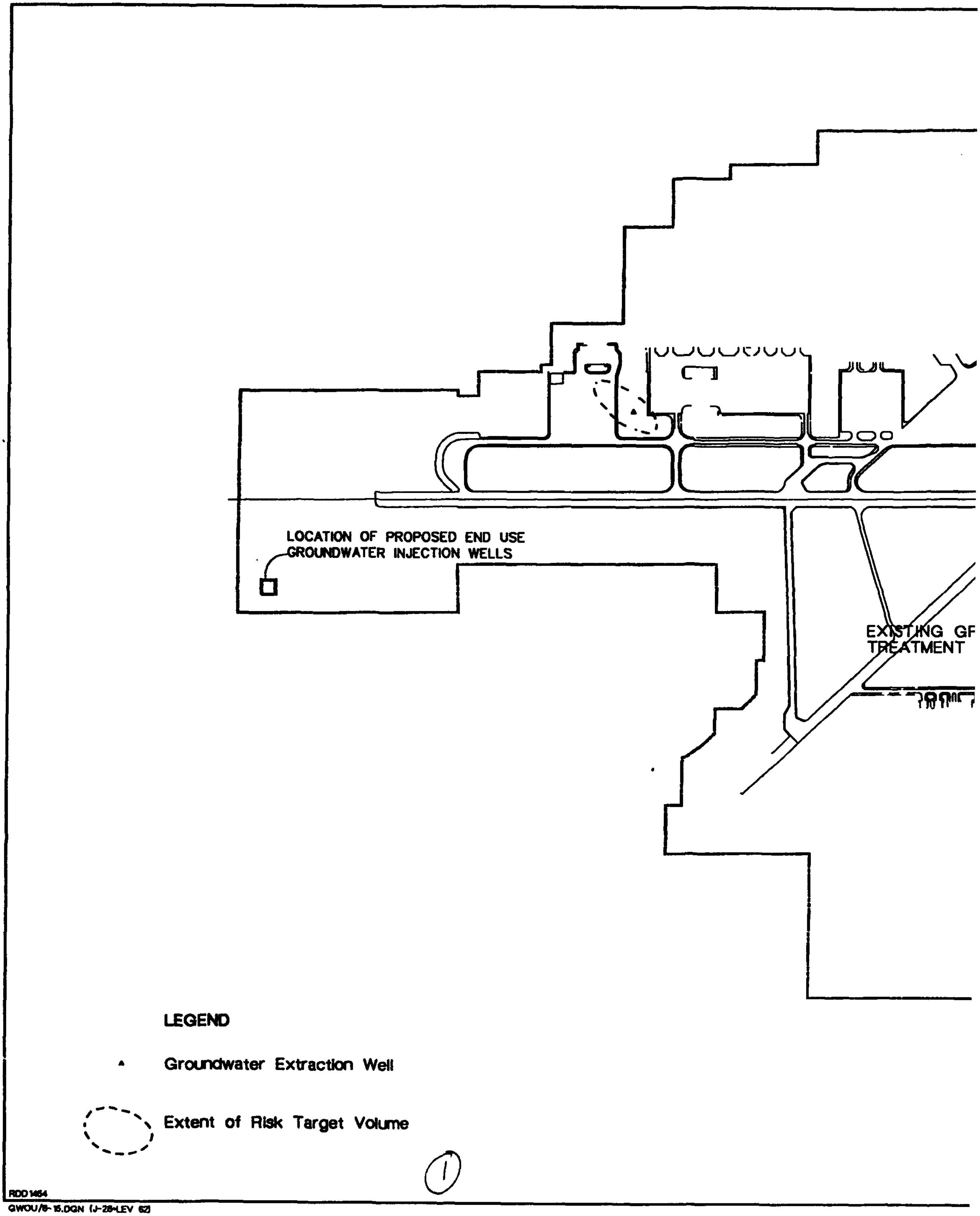


FIGURE J-27
EXTRACTION WELL LOCATIONS
MONITORING ZONE B
10^{-6} CANCER RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA
CH2M HILL



1

RDD1464
GWOU/8-15.DGN (J-28-LEV 62)

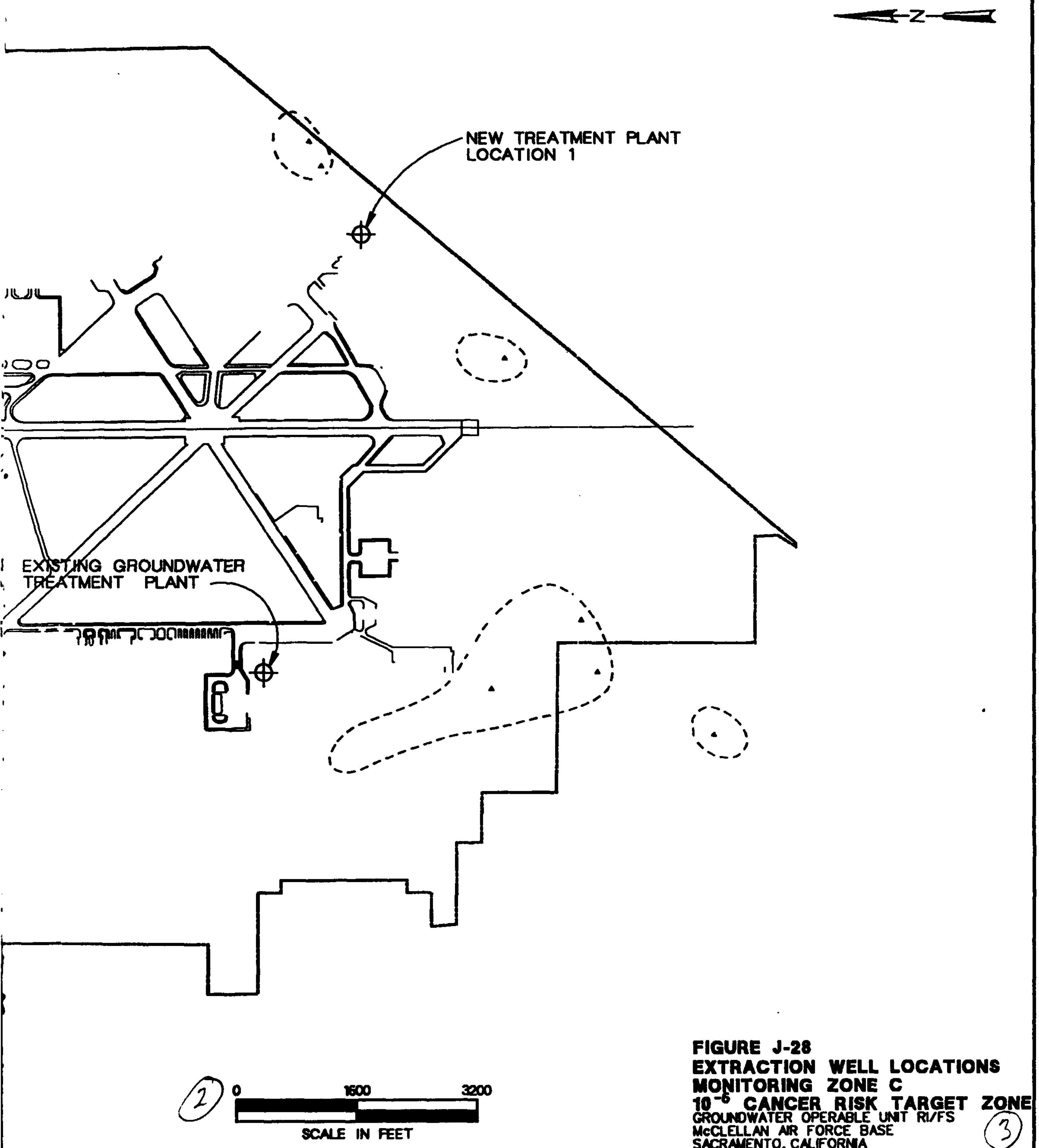


FIGURE J-28
EXTRACTION WELL LOCATIONS
MONITORING ZONE C
10^{-6} CANCER RISK TARGET ZONE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA
CH2M HILL

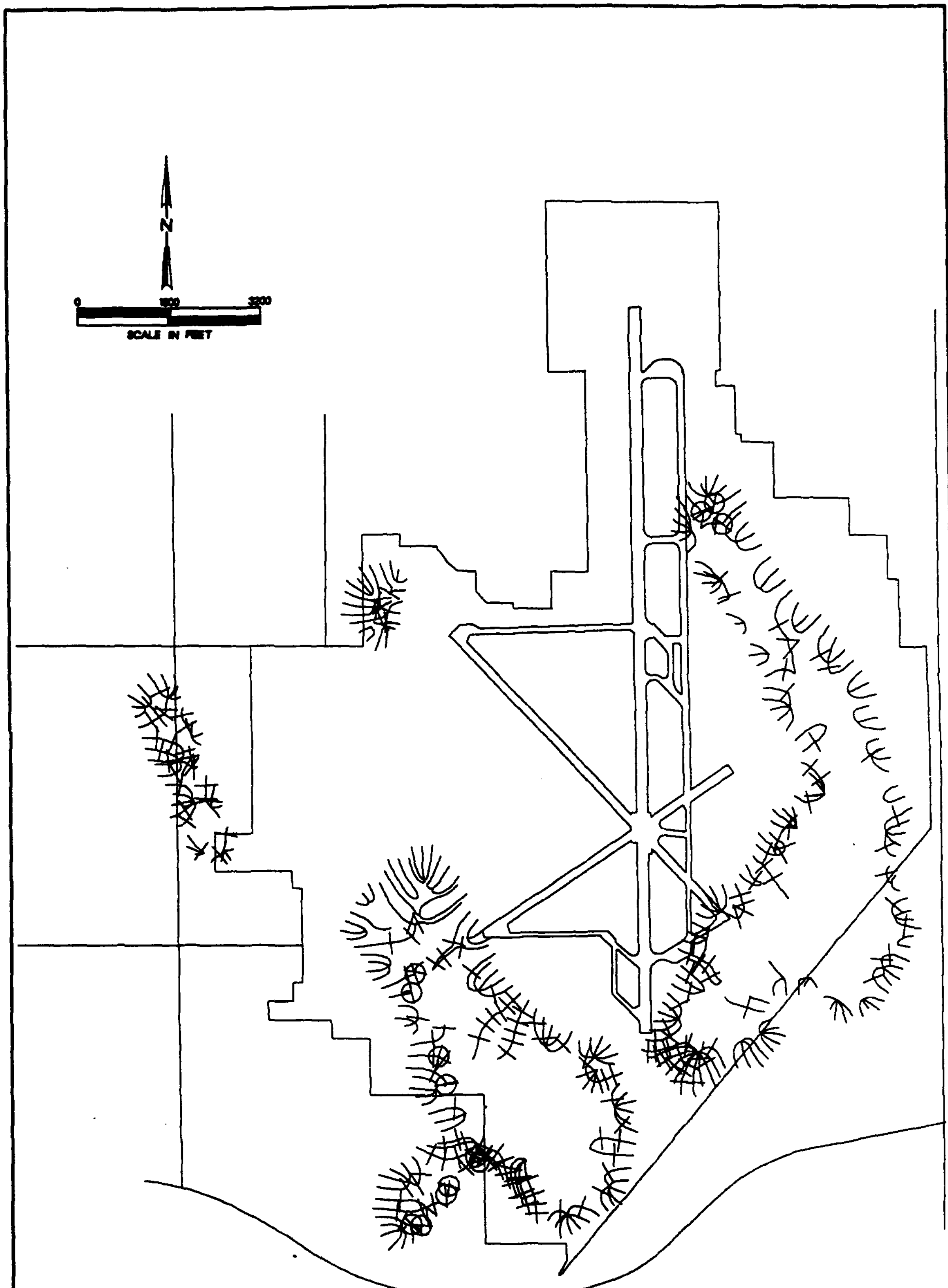


FIGURE J-29
FLOWLINES SHOWING BASIC CONTAINMENT IN MONITORING ZONE A RISK TARGET VOLUME

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

CH2M HILL

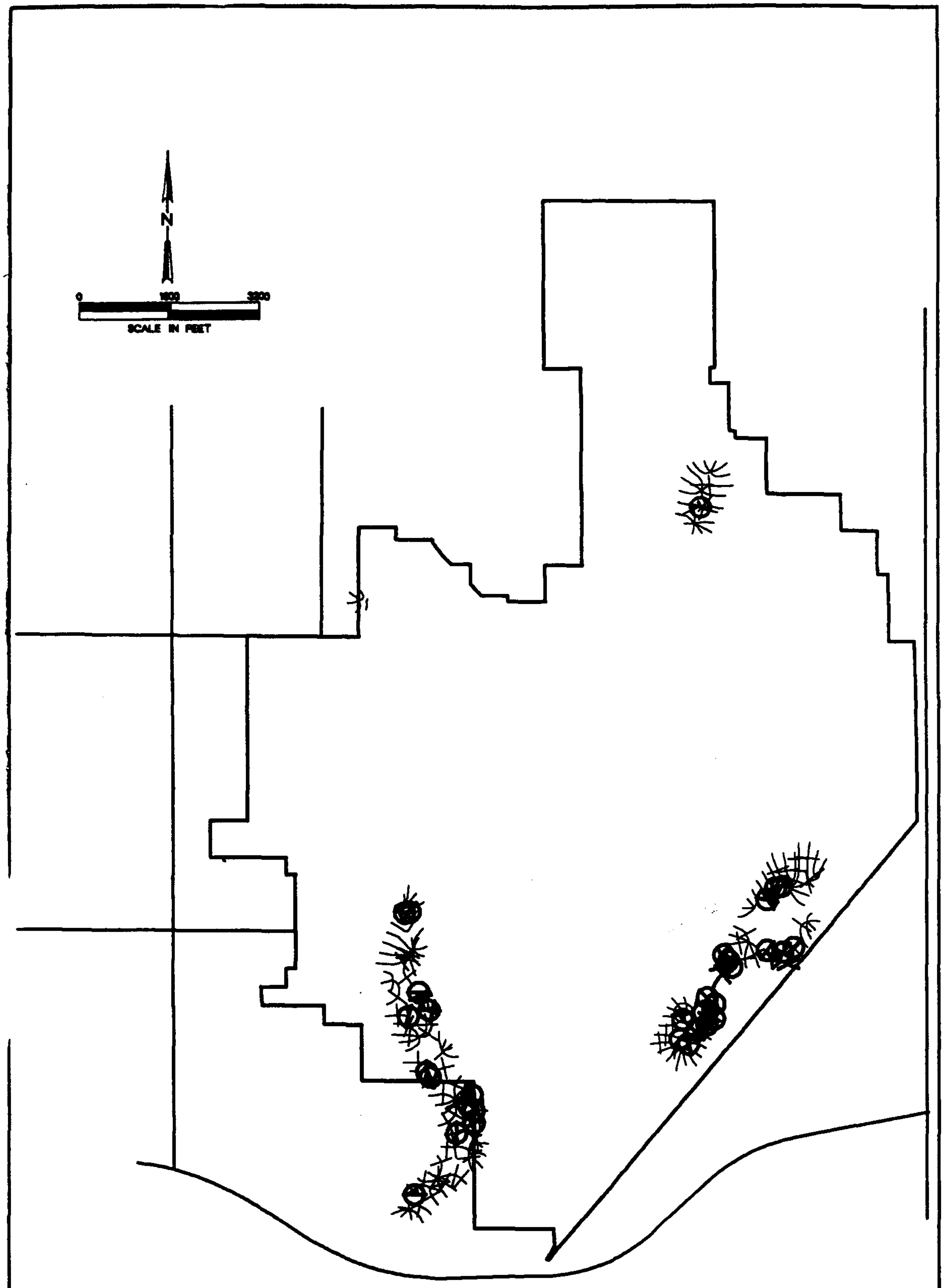


FIGURE J-30
FLOWLINES SHOWING BASIC CONTAINMENT IN MONITORING ZONE B RISK TARGET VOLUME

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

CH2M HILL

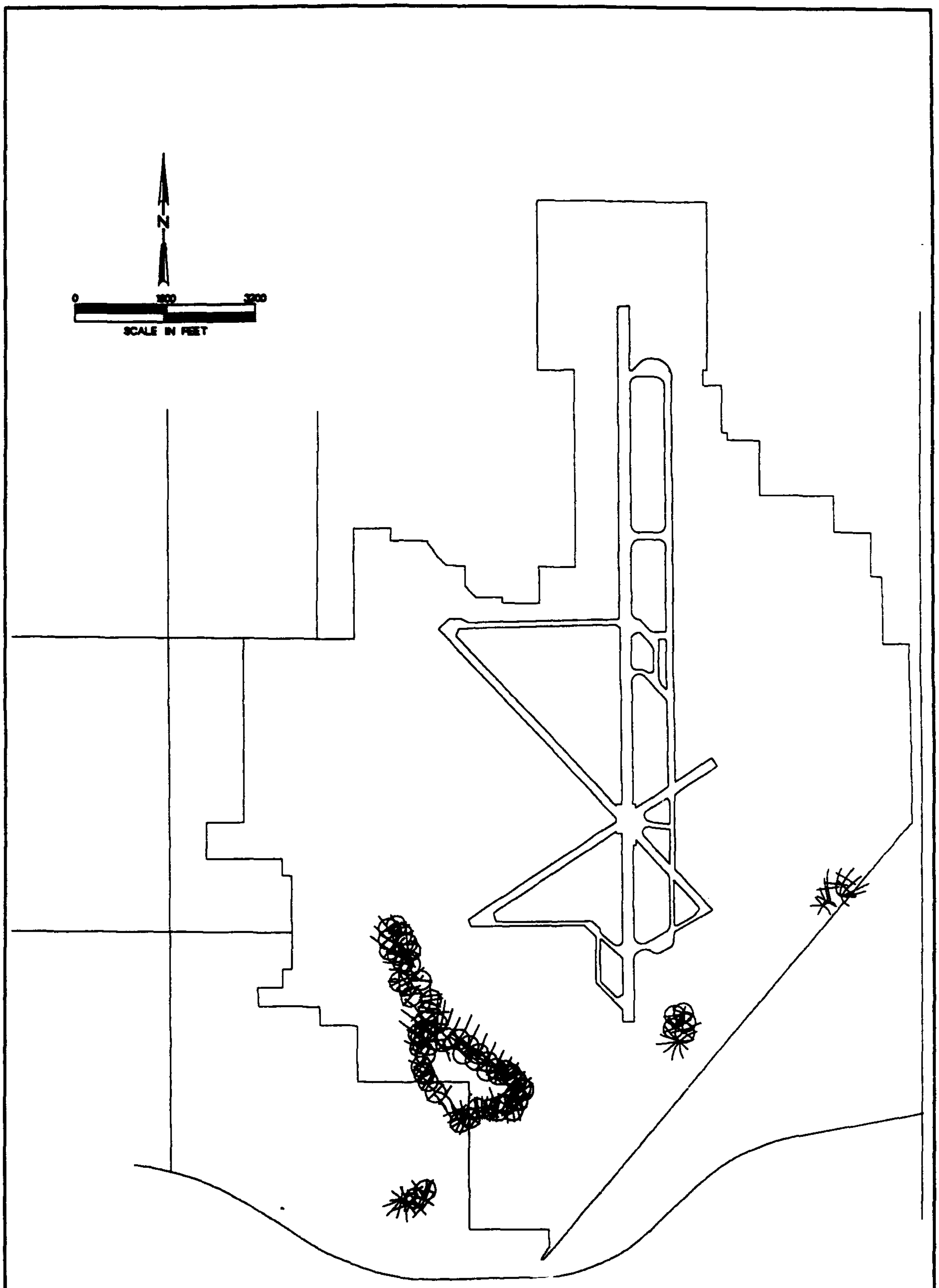


FIGURE J-31
FLOWLINES SHOWING BASIC CONTAINMENT IN MONITORING ZONE C RISK TARGET VOLUME

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

CH2M HILL

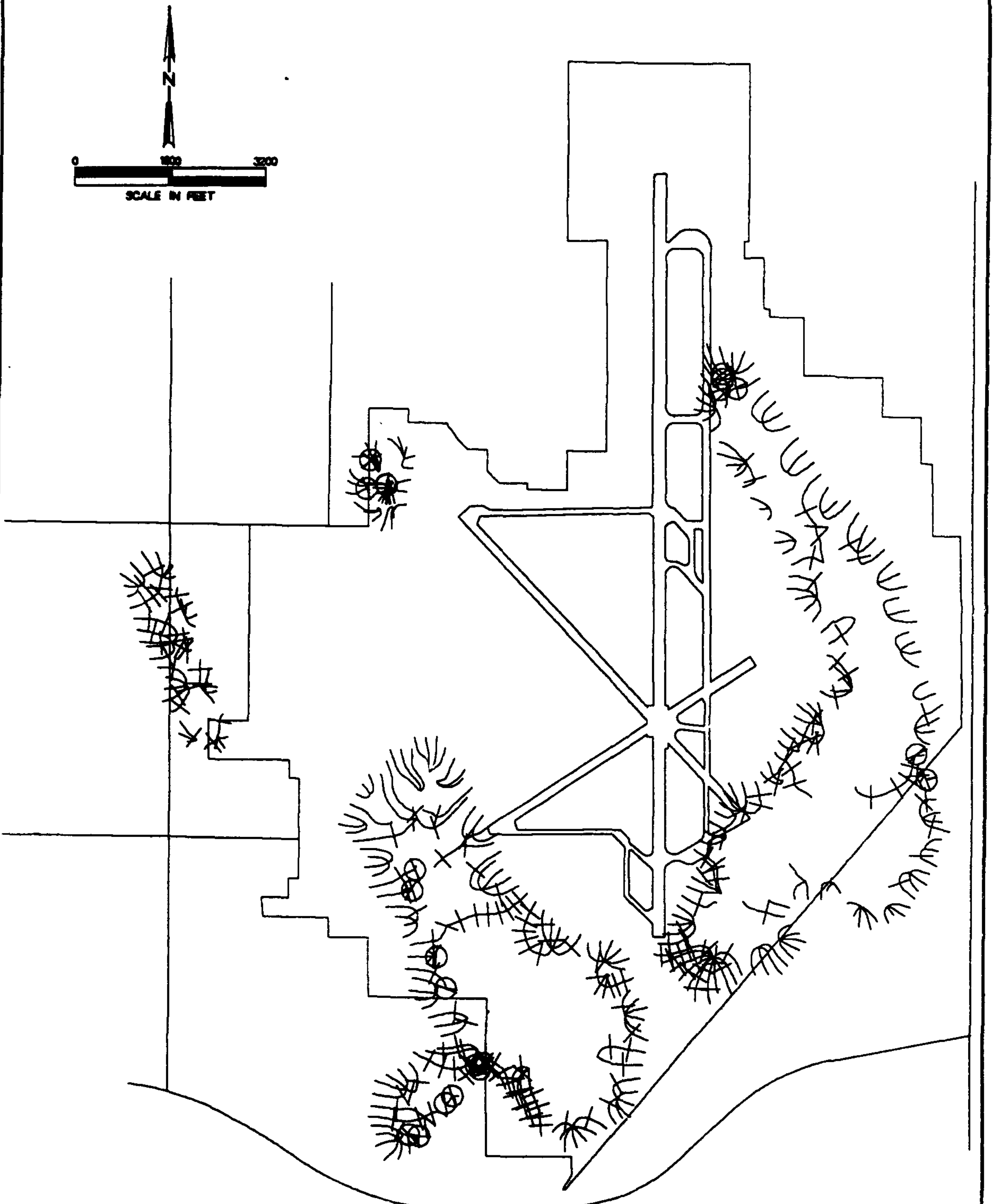


FIGURE J-32
FLOWLINES SHOWING HOT SPOT INJECTION IN MONITORING ZONE A RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

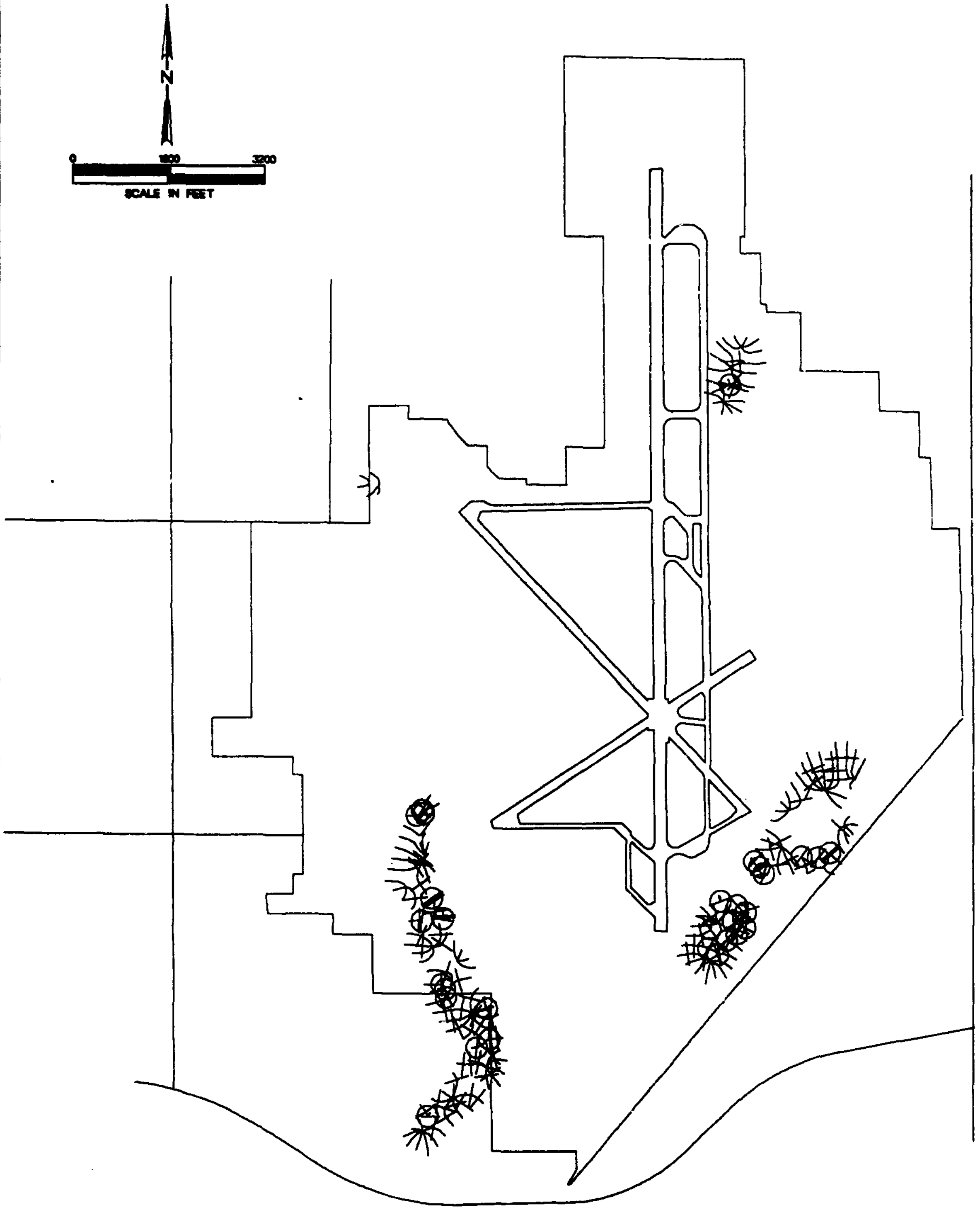


FIGURE J-33
FLOWLINES SHOWING HOT SPOT INJECTION IN MONITORING ZONE B RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

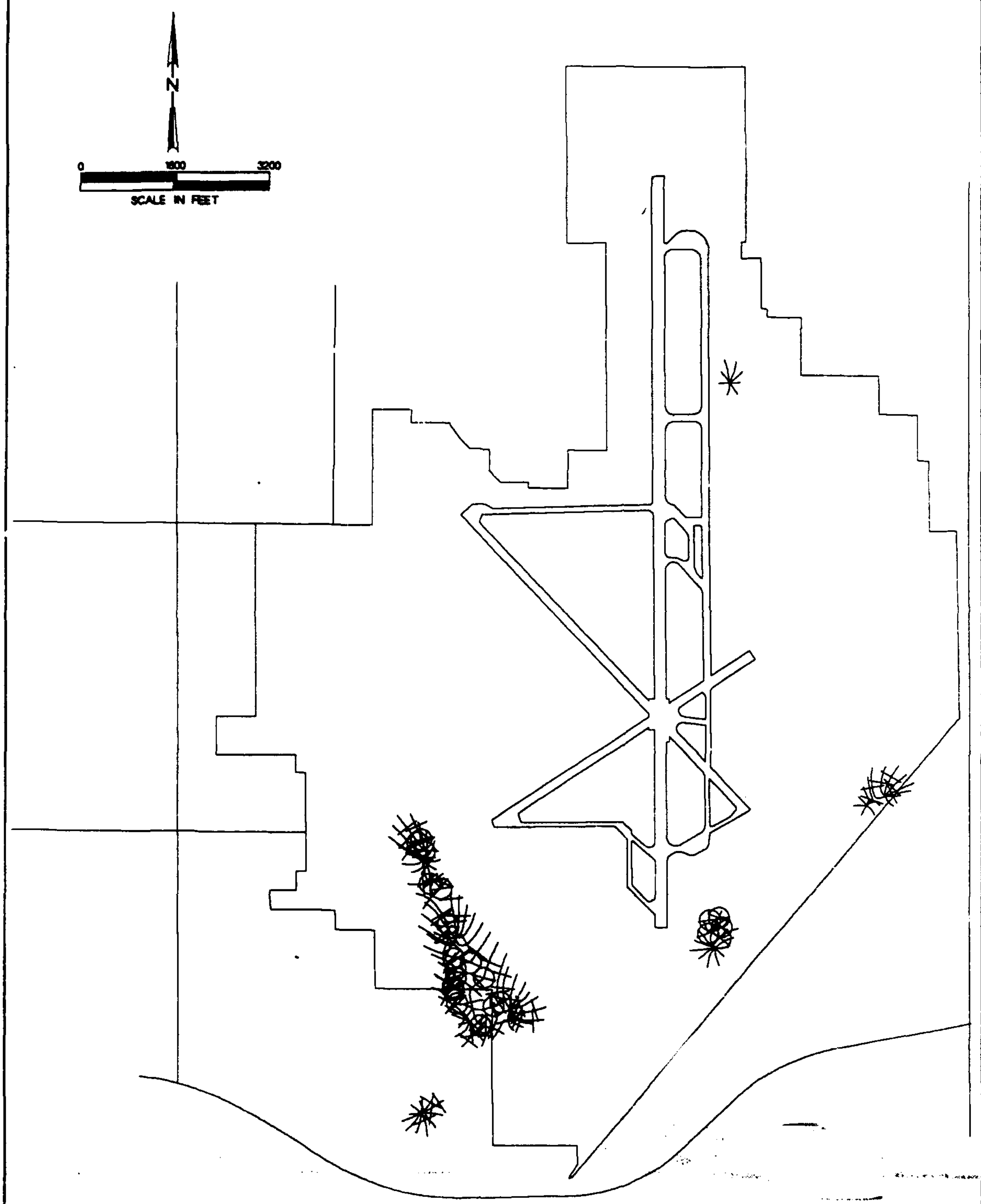


FIGURE J-34
FLOWLINES SHOWING HOT SPOT INJECTION IN MONITORING ZONE C RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

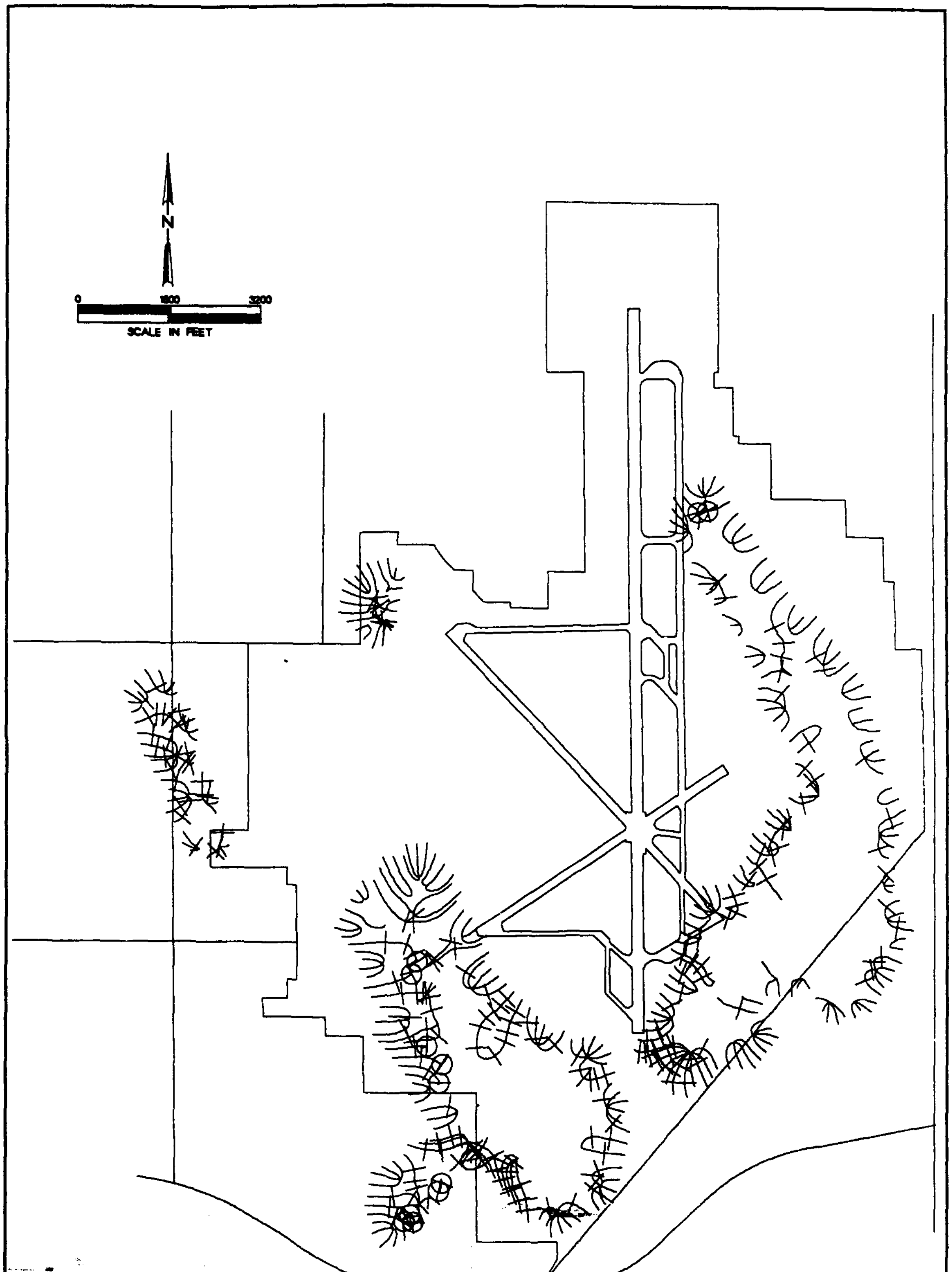


FIGURE J-35
FLOWLINES SHOWING END-USE INJECTION IN MONITORING ZONE A RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

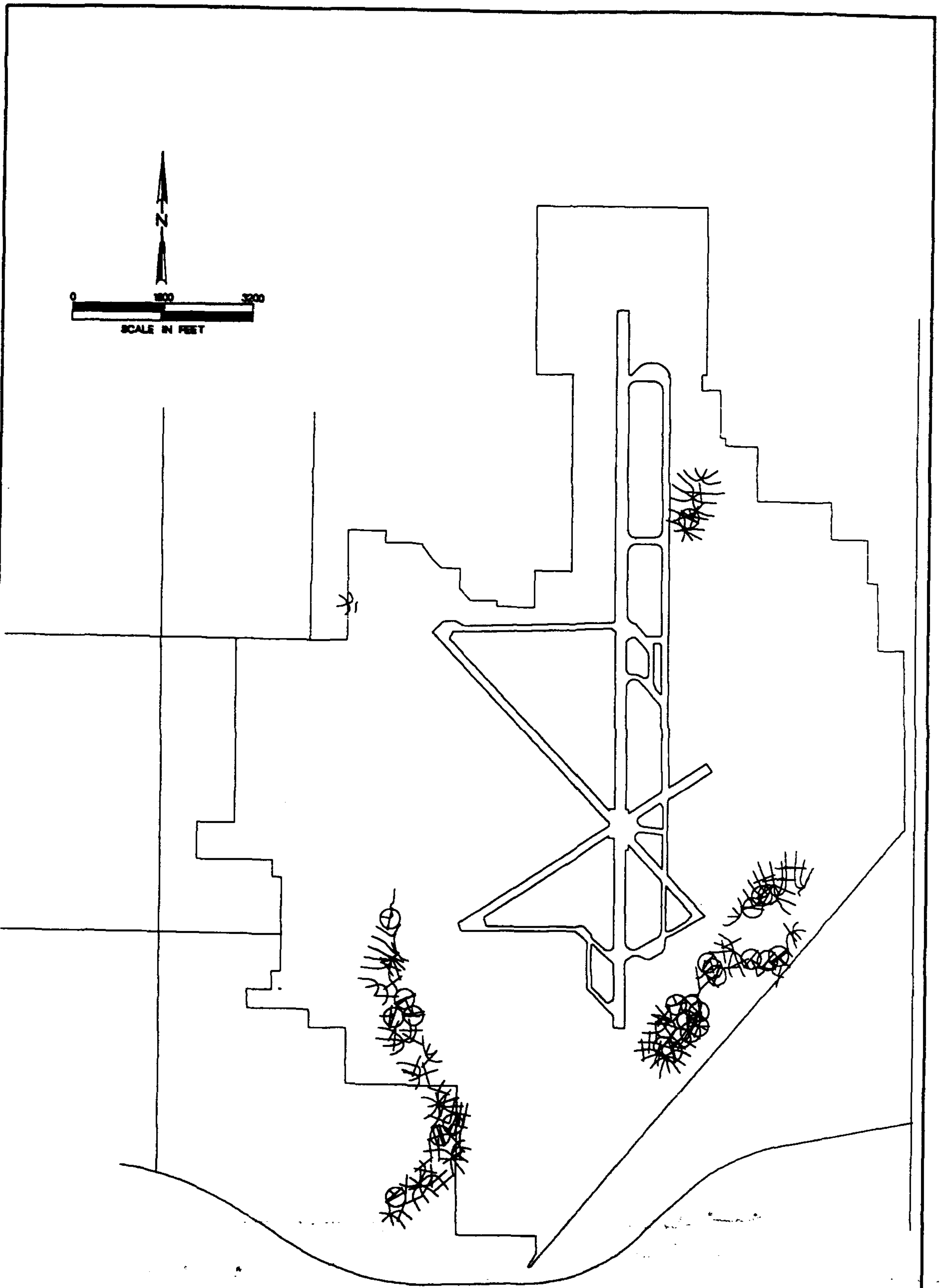


FIGURE J-36
FLOWLINES SHOWING END-USE INJECTION IN MONITORING ZONE B RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

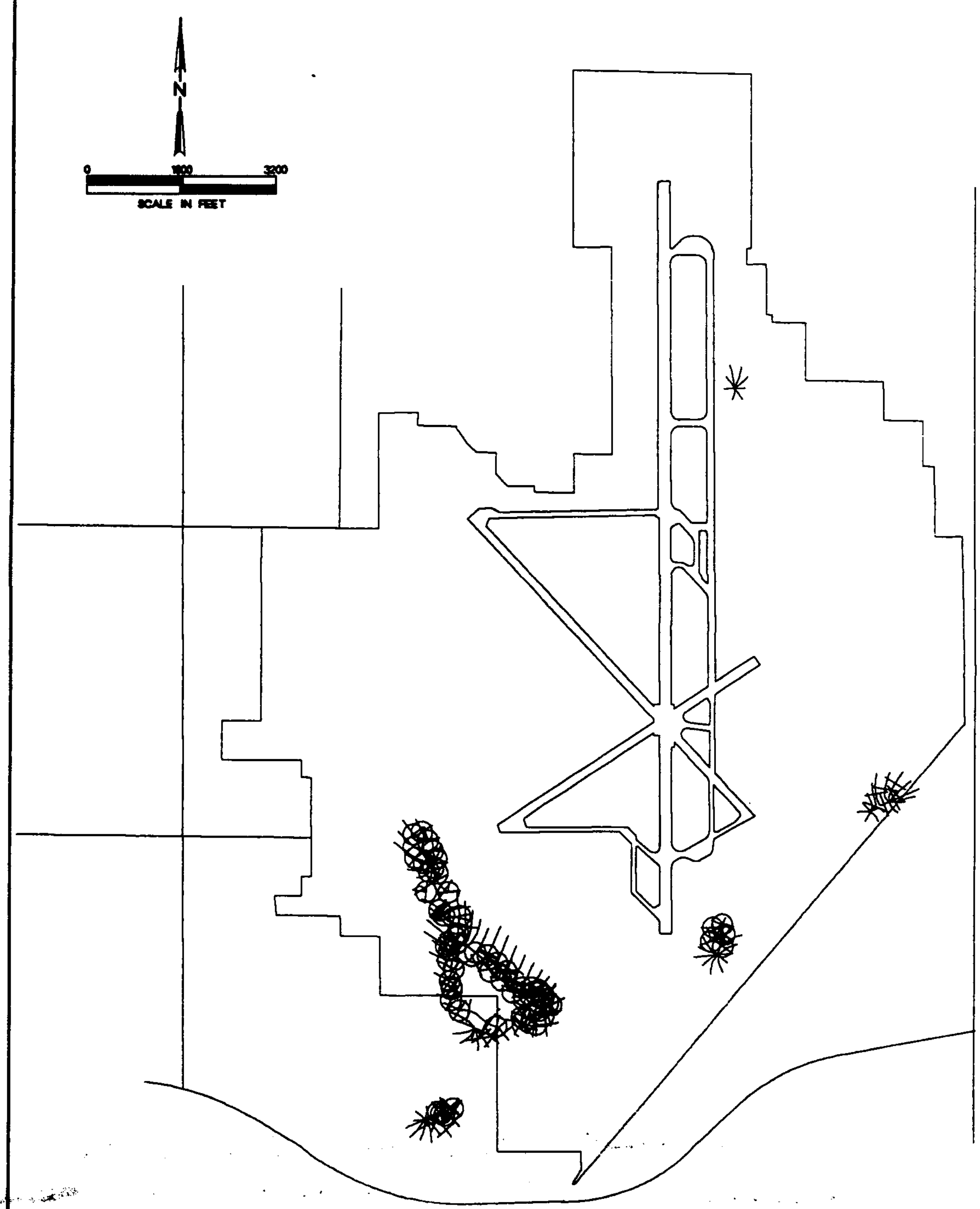


FIGURE J-37
FLOWLINES SHOWING END-USE INJECTION IN MONITORING ZONE C RISK TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Figures J-41 through J-43 present the groundwater pathlines for the basic containment alternative. These pathlines originate from the target area boundaries in Monitoring Zones A, B, and C, and confirm that groundwater contained in the target volume is moving toward, and eventually removed by, the extraction system. Figures J-44 through J-46 show similar flow lines for the basic containment alternative with hot spot flushing by injection of treated groundwater. Figure J-47 through J-49 show the estimated pathlines for the basic containment alternative combined with injection end use of all treated groundwater into the regional aquifer.

No-Action Alternative

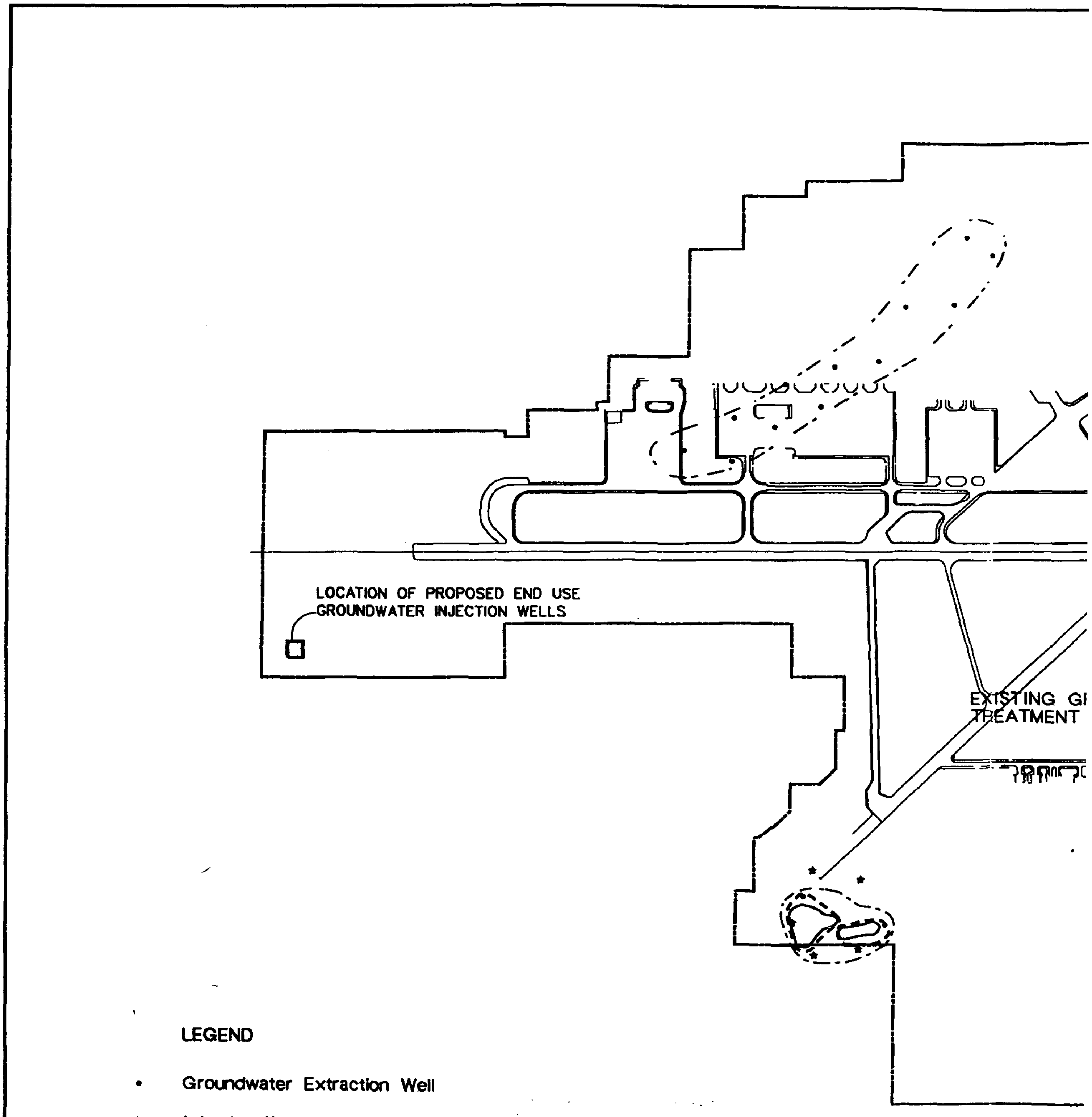
The No-Action Alternative was investigated to develop a baseline set of conditions with which to measure the benefit that any additional groundwater remedial action will have on conditions at the Base. In this simulation, BW-18 was assumed to be abandoned because state agencies and the U.S. EPA have expressed concern that this well is a potential conduit for cross-contamination between aquifers and should be abandoned. Existing extraction wells currently operating at the Base were included in this simulation. Predicted groundwater elevations under this alternative, existing extraction well locations, and target volumes for a particular aquifer are shown in Figures J-50 through J-52. It is apparent from these figures that contamination in all of the aquifers would continue to migrate to the south-southwest and threaten groundwater production wells downgradient. Predicted vertical gradients from this simulation are predominantly downward over the Base area, indicating that contamination will also move downward into deeper aquifers as it continues to move to the south and southwest.

Modeling Limitations

The simulations performed in the modeling analysis were steady-state. The use of a steady state model is appropriate as the objective of the groundwater modeling effort is to evaluate the long-term performance of an extraction system at containing and extracting contaminated groundwater.

The predicted heads are based on efficiencies of 100 percent for both extraction and injection wells. The actual efficiency of the wells may be substantially lower than 100 percent, with the injection well efficiencies lower than that of the extraction wells. However, well efficiency was accounted for in the simulations by restricting the available drawdown in the extraction wells to 75 percent of the saturated thickness. Additional head rise in the injection wells due to well inefficiency was not a concern as site water levels are approximately 100 feet below ground surface.

The actual performance of the extraction system may be influenced by changes in future hydrologic conditions. This is an uncertainty impossible to resolve at this time



LEGEND

• Groundwater Extraction Well

★ Injection Well

Hot Spot Boundaries Estimated from Water Quality Data

Extent of MCL Target Volume

Hot Spot Boundaries Assumed for Groundwater Modeling Simulations (Adjusted Due to Location of Model Nodes)

1

ROD 1454
MEY94/8-16.DGN (J-38-LEV 62)

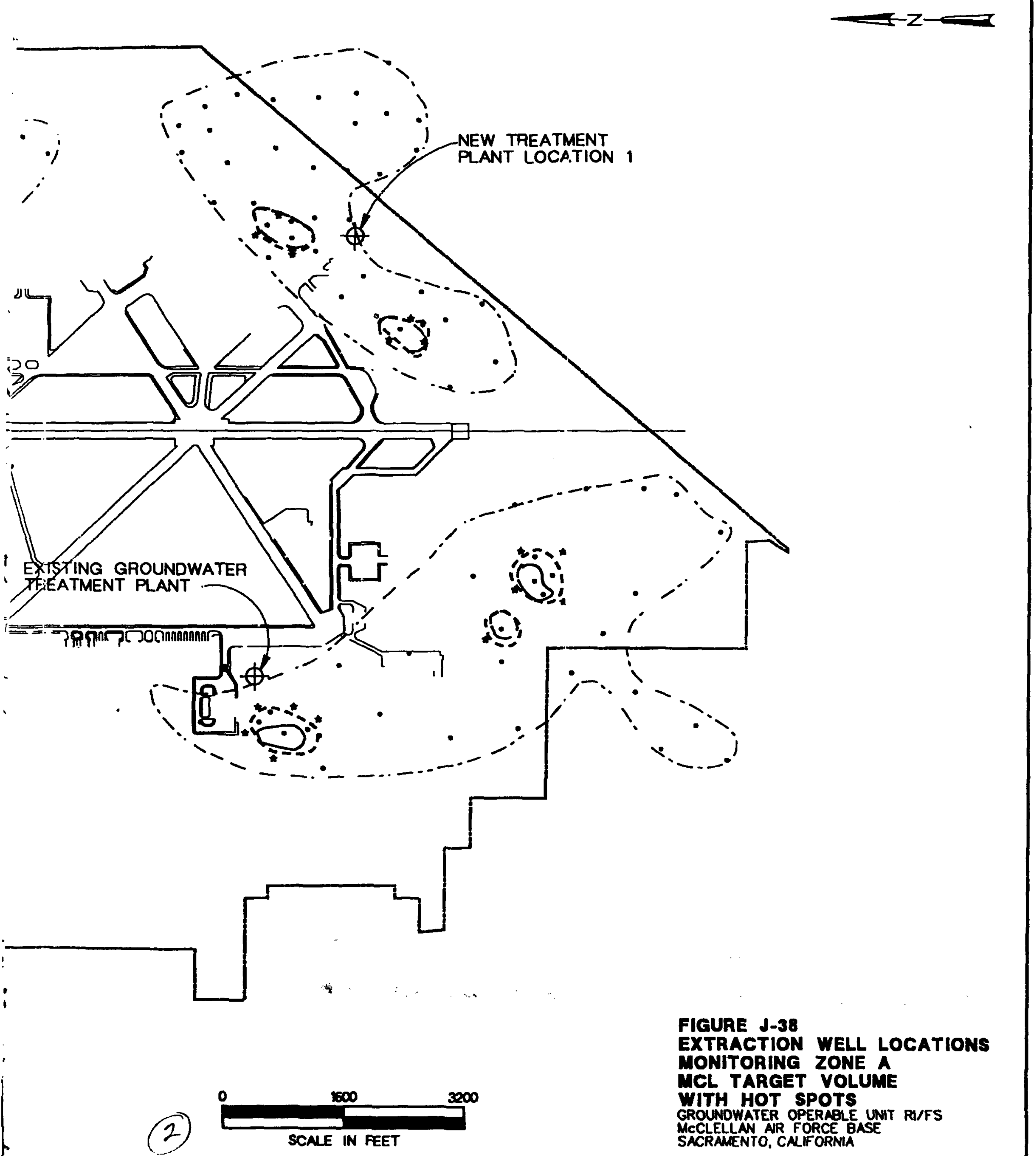
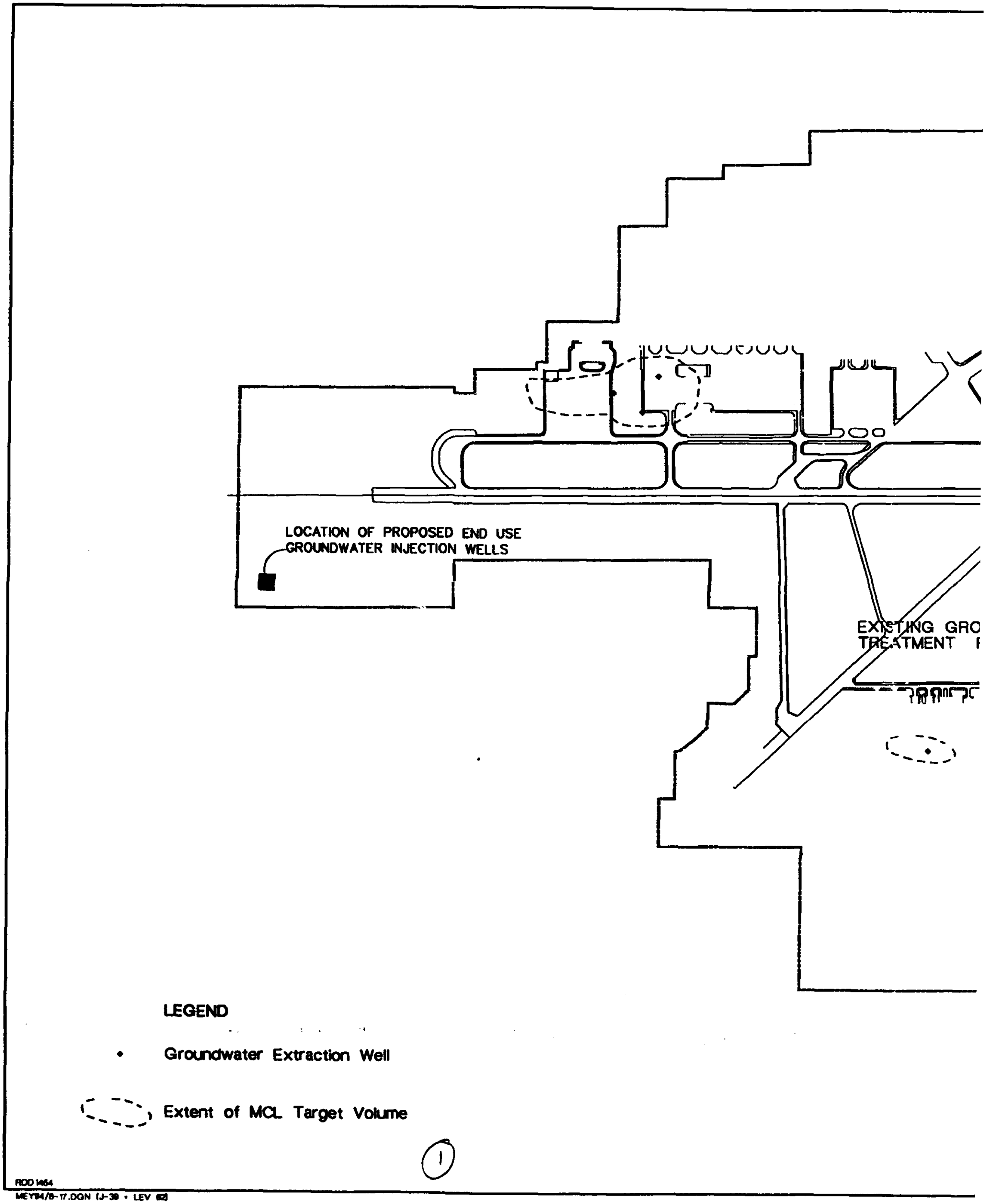


FIGURE J-38
EXTRACTION WELL LOCATIONS MONITORING ZONE A MCL TARGET VOLUME WITH HOT SPOTS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



LOCATION OF PROPOSED END USE GROUNDWATER INJECTION WELLS
EXISTING GRO
TREATMENT
LEGEND
Groundwater Extraction Well
Extent of MCL Target Volume
1
ROD 1464
MEY94/8-17.DGN (J-39 - LEV 62)

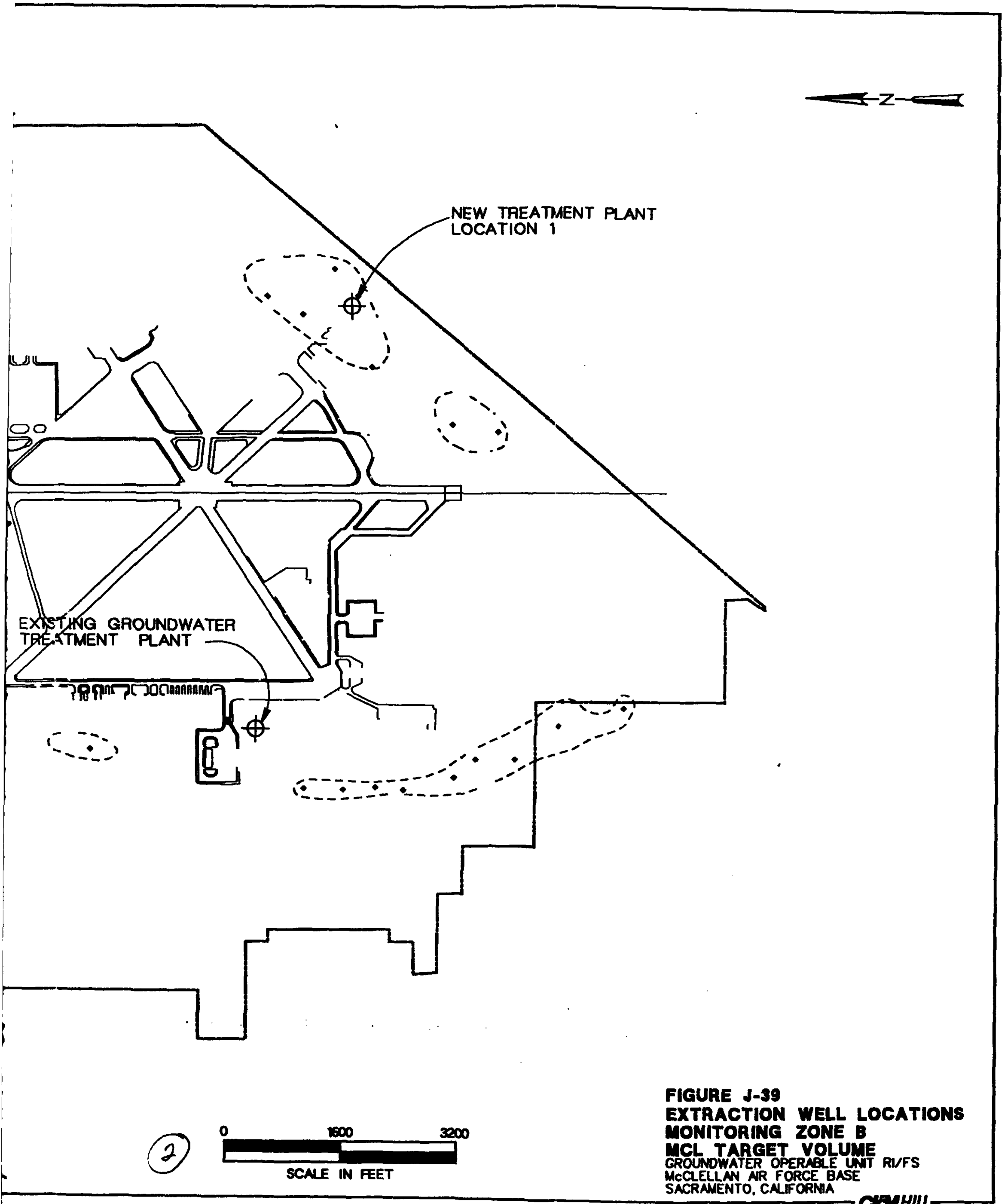
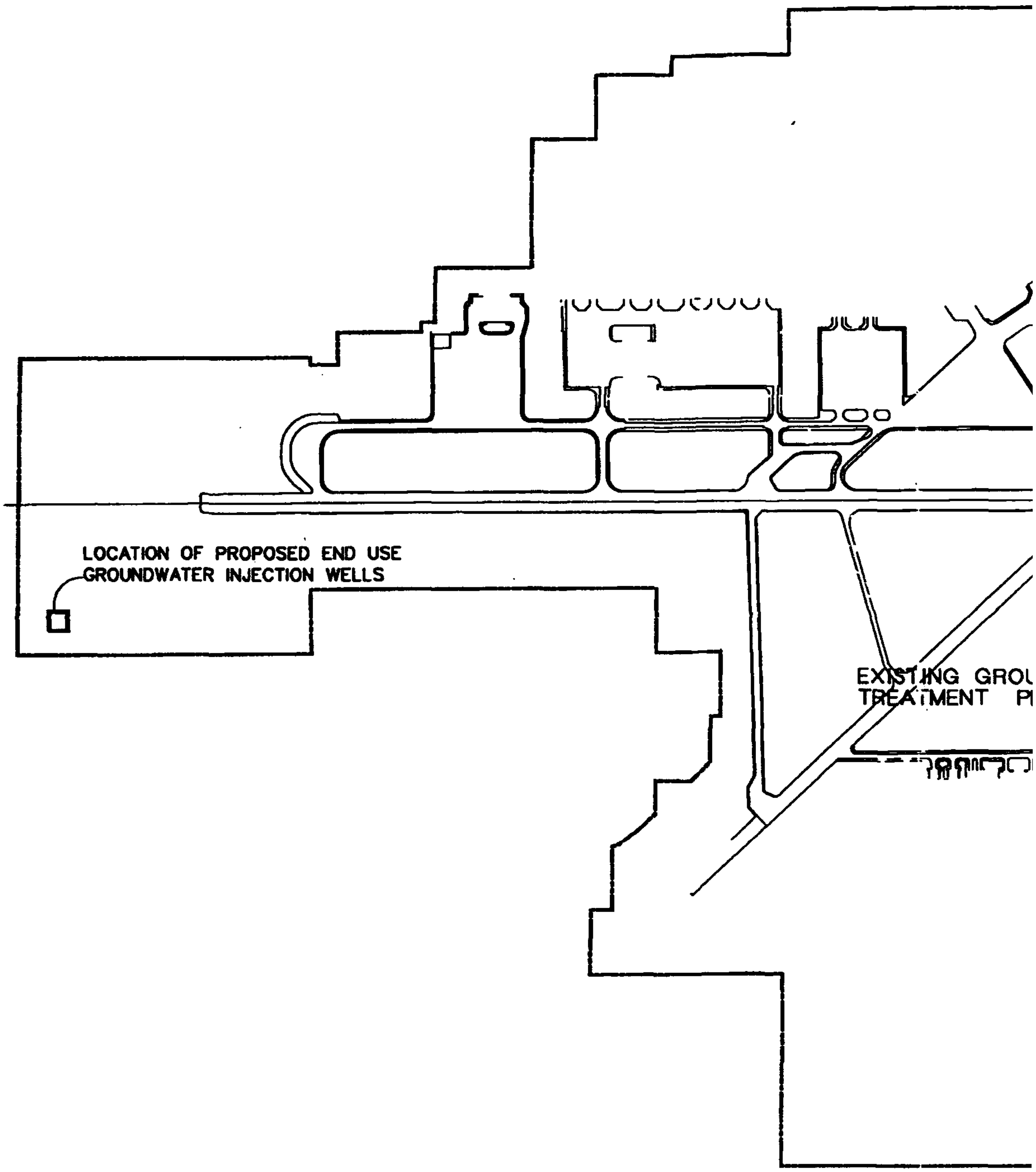


FIGURE J-39
EXTRACTION WELL LOCATIONS
MONITORING ZONE B
MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL



LEGEND

▲ Groundwater Extraction Well

Extent of MCL Target Volume

1

RDD 1464
MEY94/8-18.DGN (J-40-LEV 62)

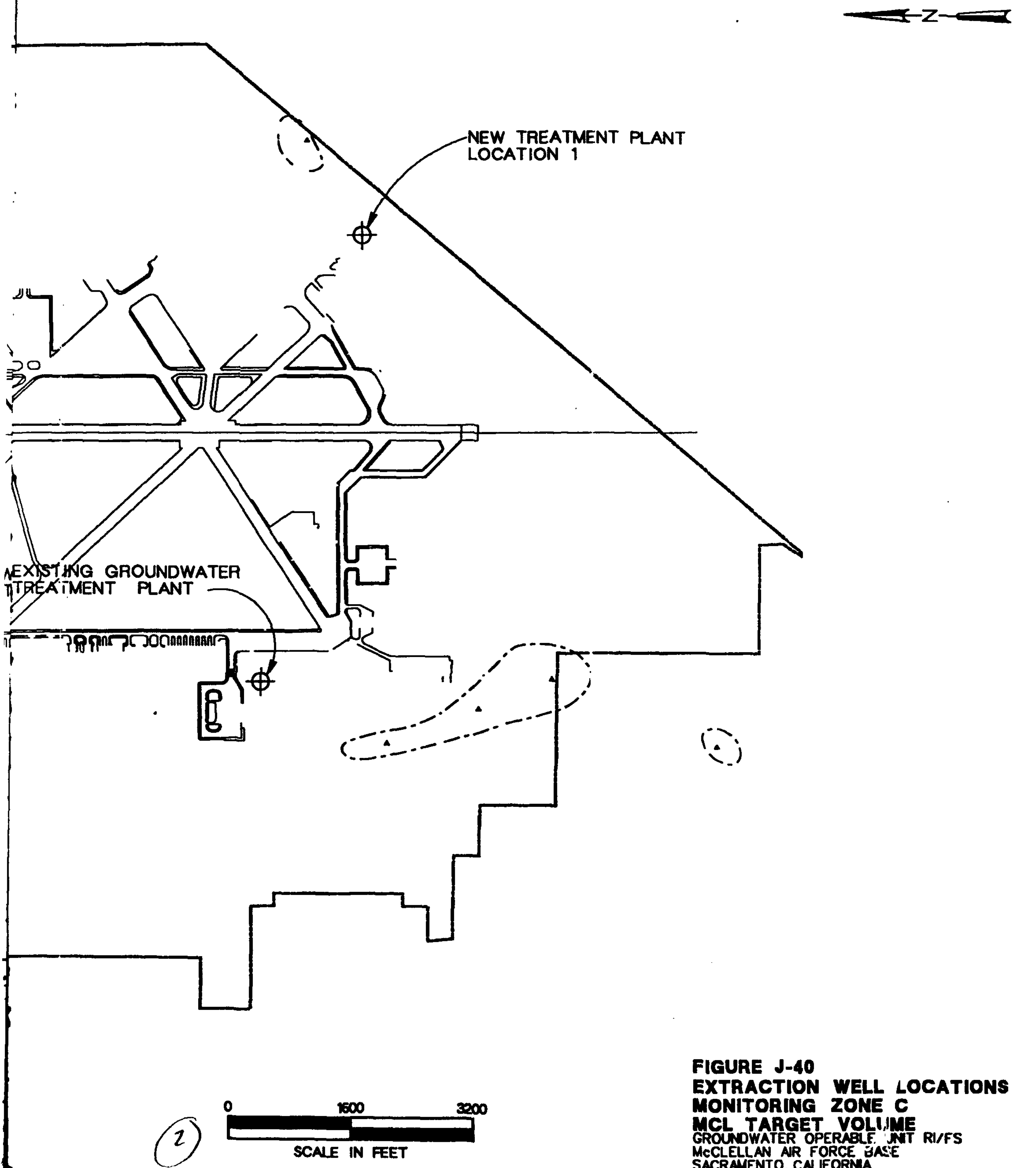


FIGURE J-40
EXTRACTION WELL LOCATIONS
MONITORING ZONE C
MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

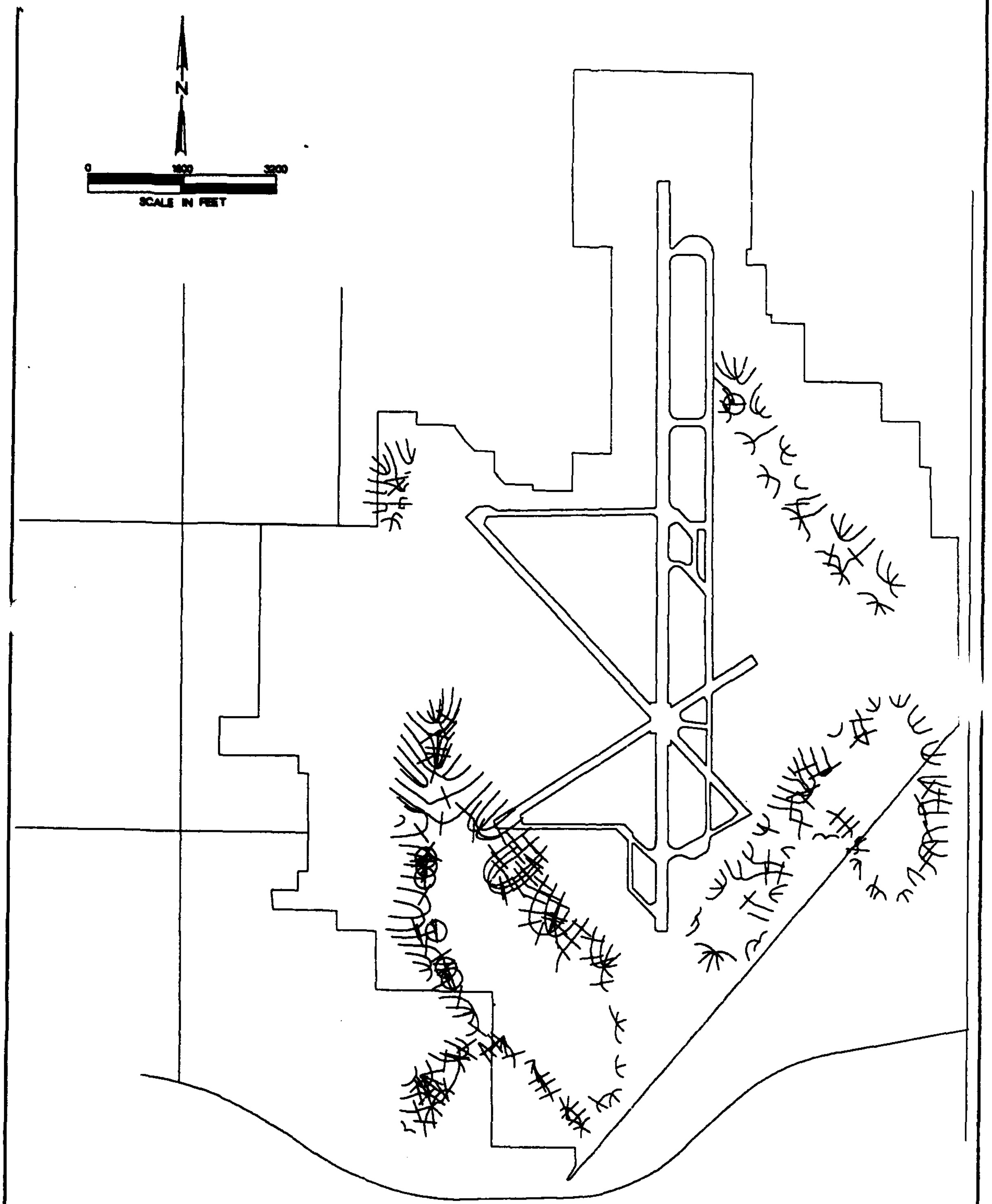


FIGURE J-41
FLOWLINES SHOWING BASIC CONTAINMENT IN MONITORING ZONE A MCL TARGET VOLUME

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

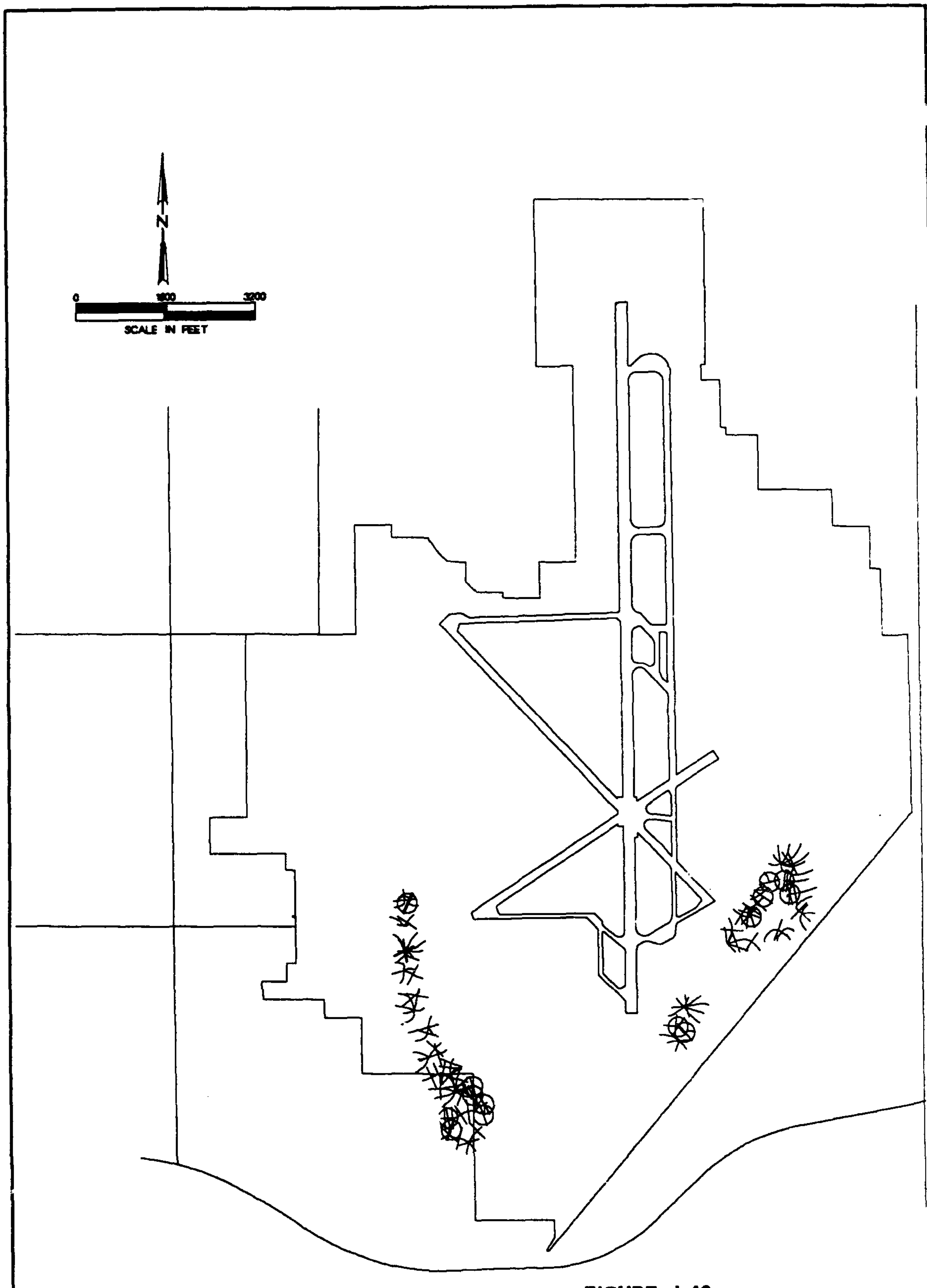


FIGURE J-42
FLOWLINES SHOWING BASIC CONTAINMENT IN MONITORING ZONE B MCL TARGET VOLUME

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

CH2M HILL

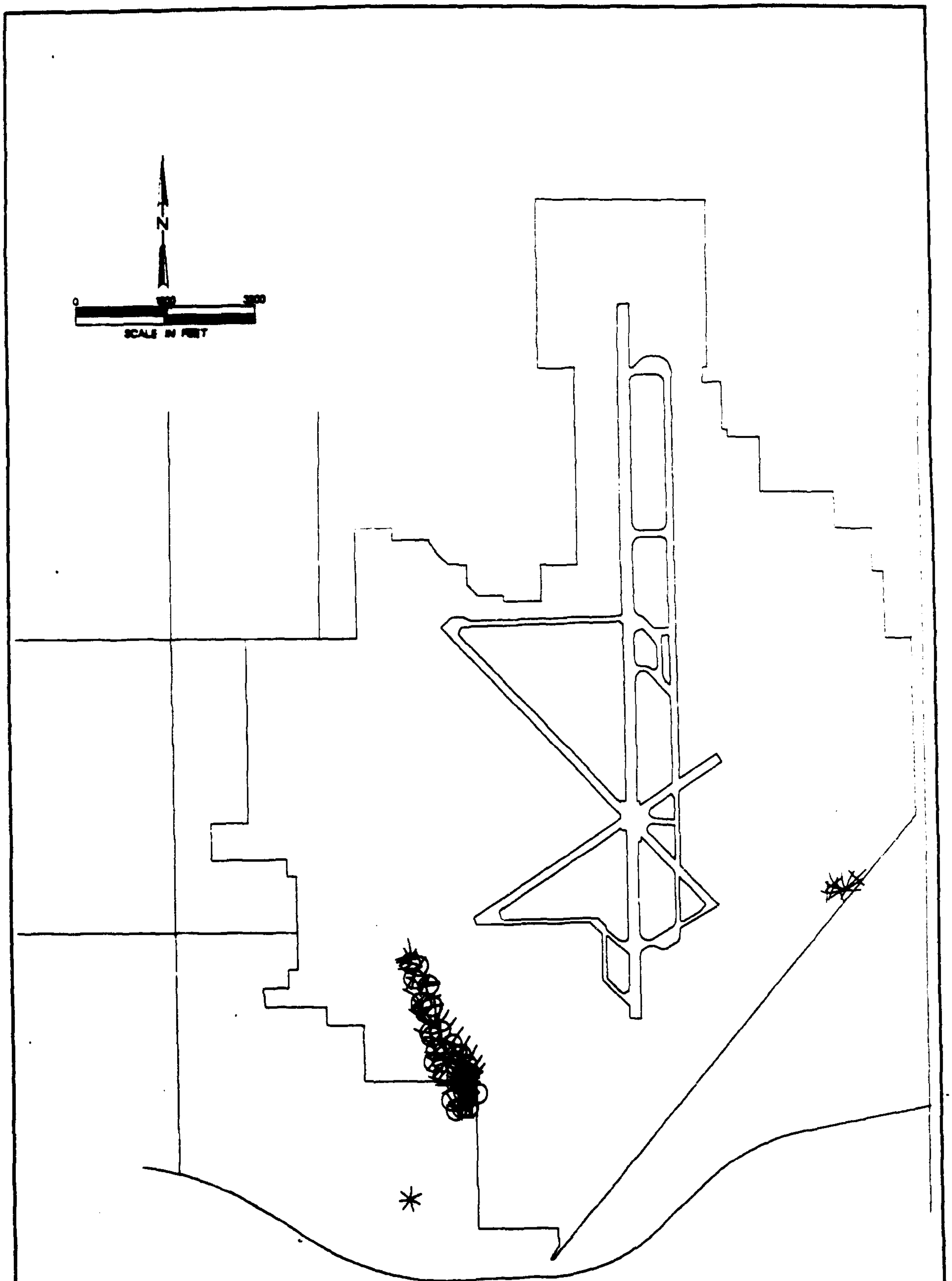


FIGURE J-43
FLOWLINES SHOWING BASIC CONTAINMENT IN MONITORING ZONE C MCL TARGET VOLUME

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

CH2M HILL

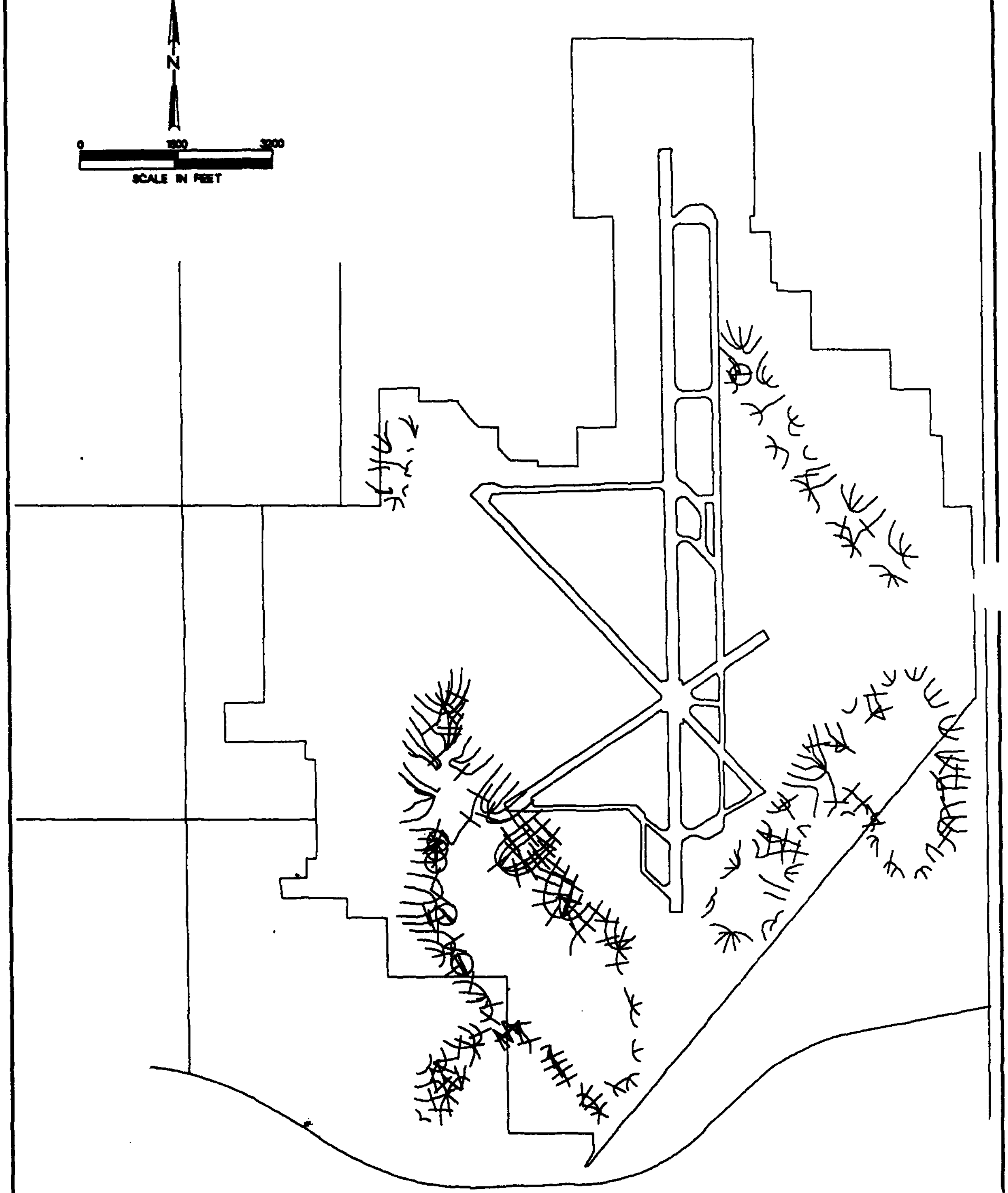


FIGURE J-44
FLOWLINES SHOWING HOT SPOT INJECTION IN MONITORING ZONE A MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

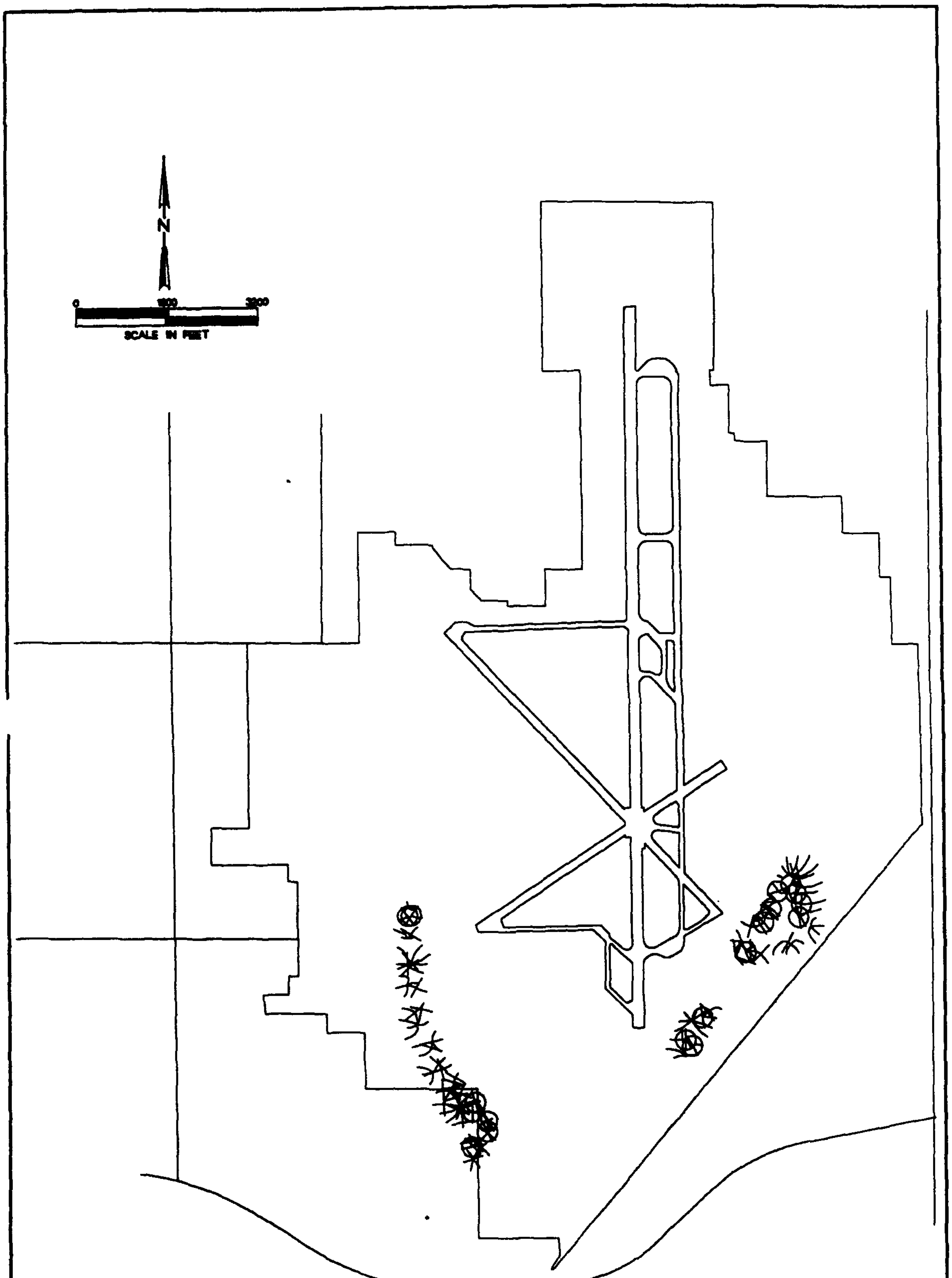


FIGURE J-45
FLOWLINES SHOWING HOT SPOT INJECTION
IN MONITORING ZONE B
MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

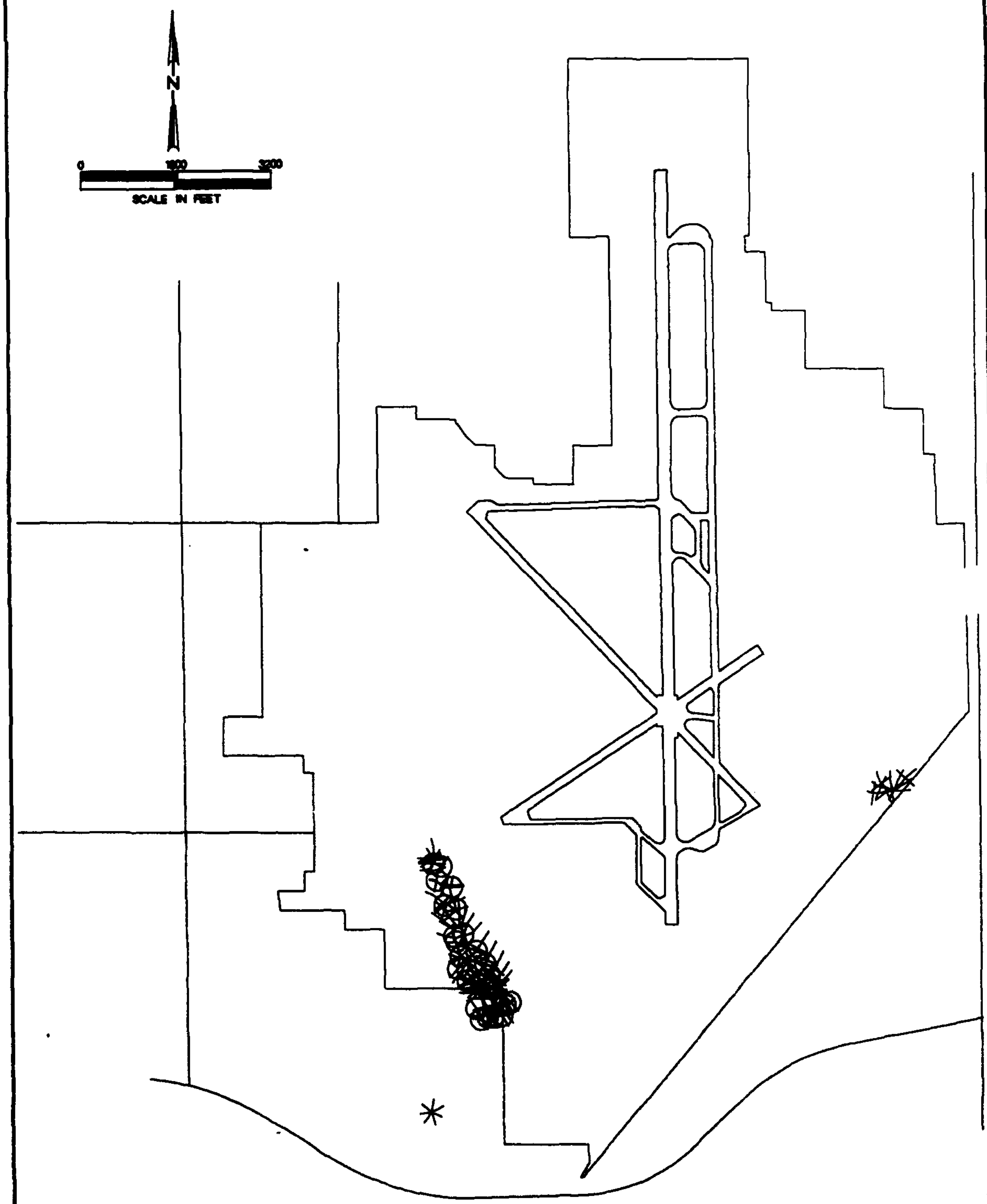


FIGURE J-46
FLOWLINES SHOWING HOT SPOT INJECTION IN MONITORING ZONE C
MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

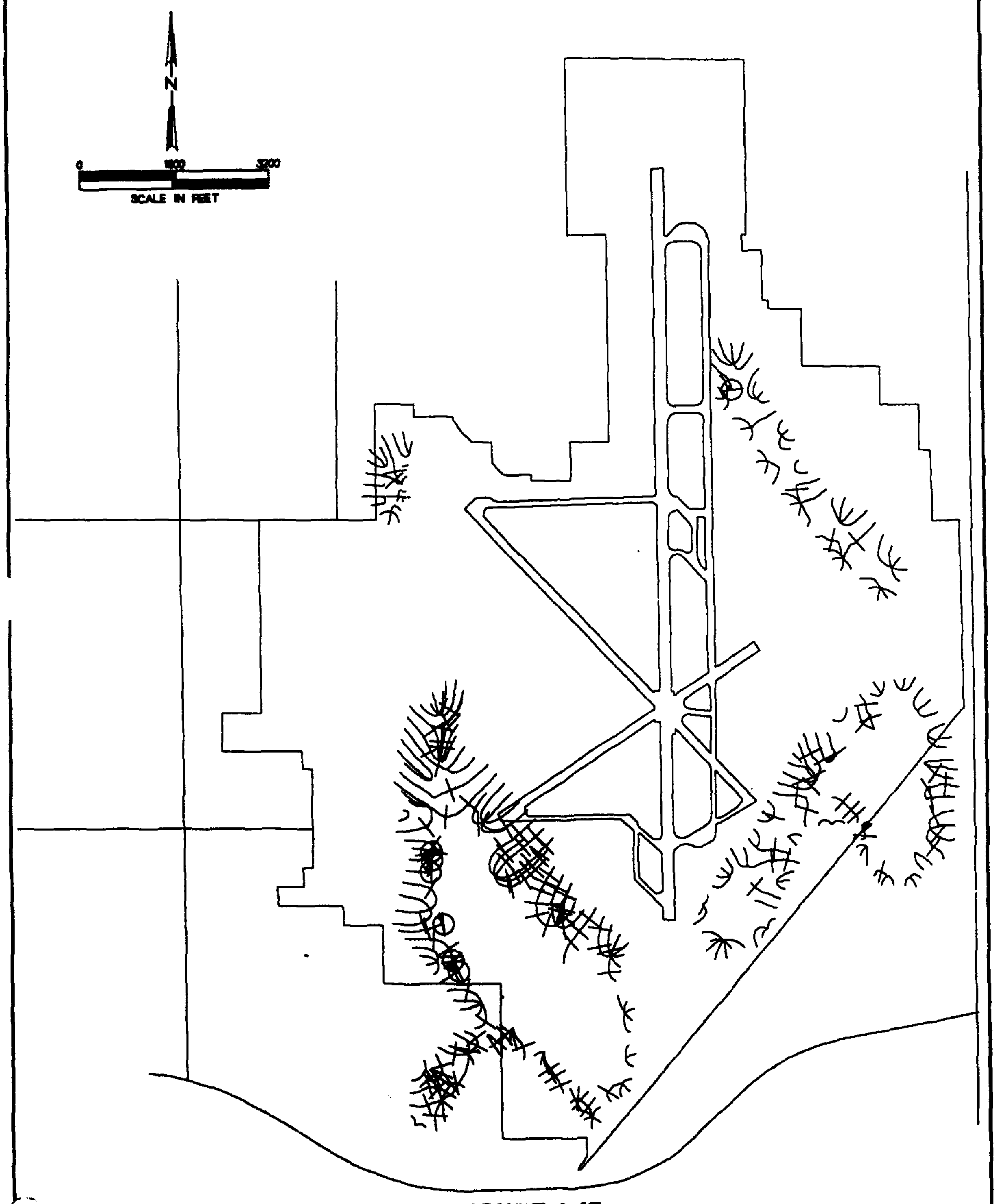


FIGURE J-47
FLOWLINES SHOWING END-USE INJECTION IN MONITORING ZONE A MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

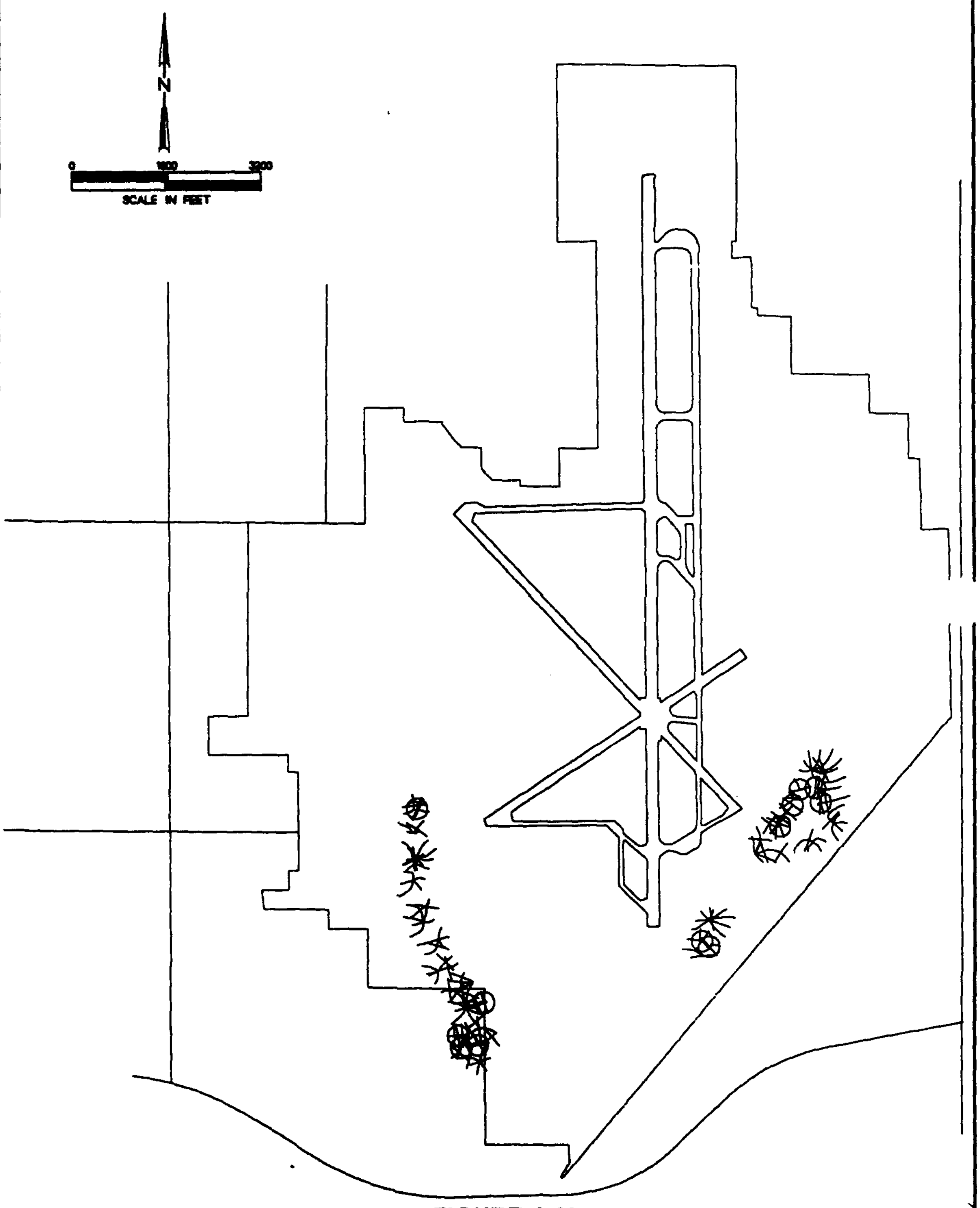


FIGURE J-48
FLOWLINES SHOWING END-USE INJECTIO[N]
IN MONITORING ZONE B
MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

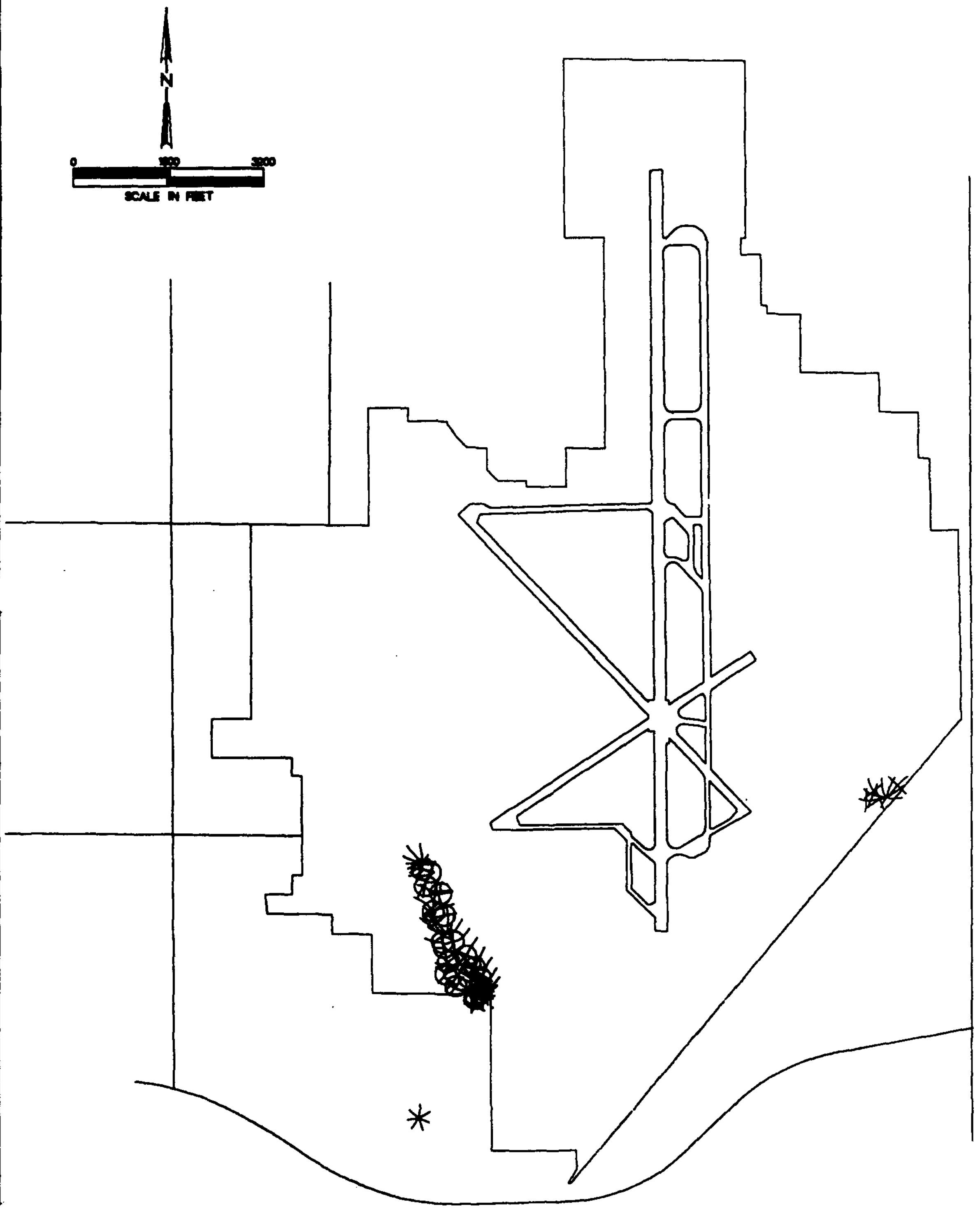
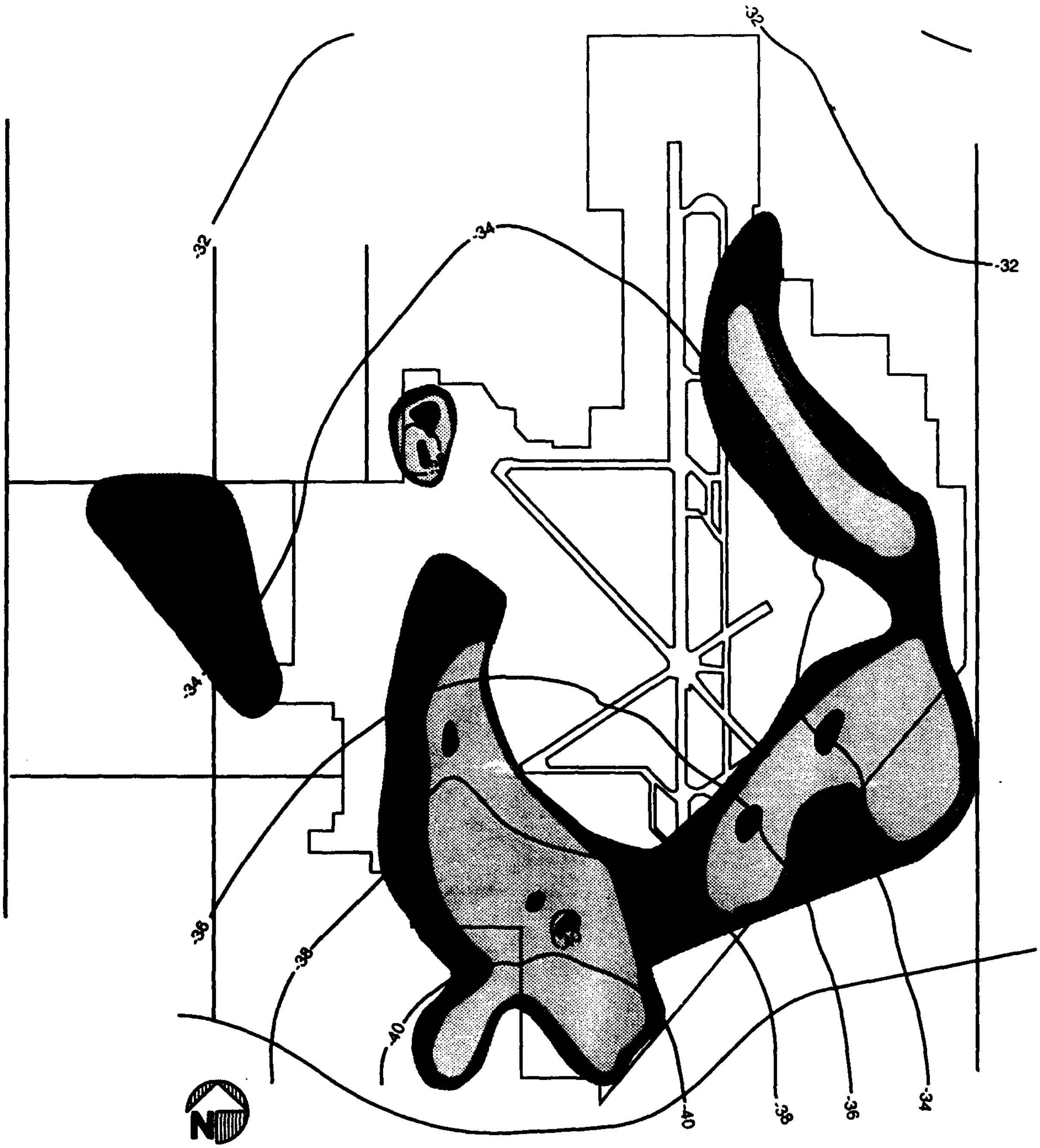


FIGURE J-49
FLOWLINES SHOWING END-USE INJECTION IN MONITORING ZONE C MCL TARGET VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA



SCALE IN FEET (Approximate)

0 3000 6000 9000

Legend

- Hot spots
- MCL
- Background
- Risk
- -42 Contour of equal groundwater elevation (ft msl)

RDD1454_361

FIGURE J-50
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

CH2M HILL

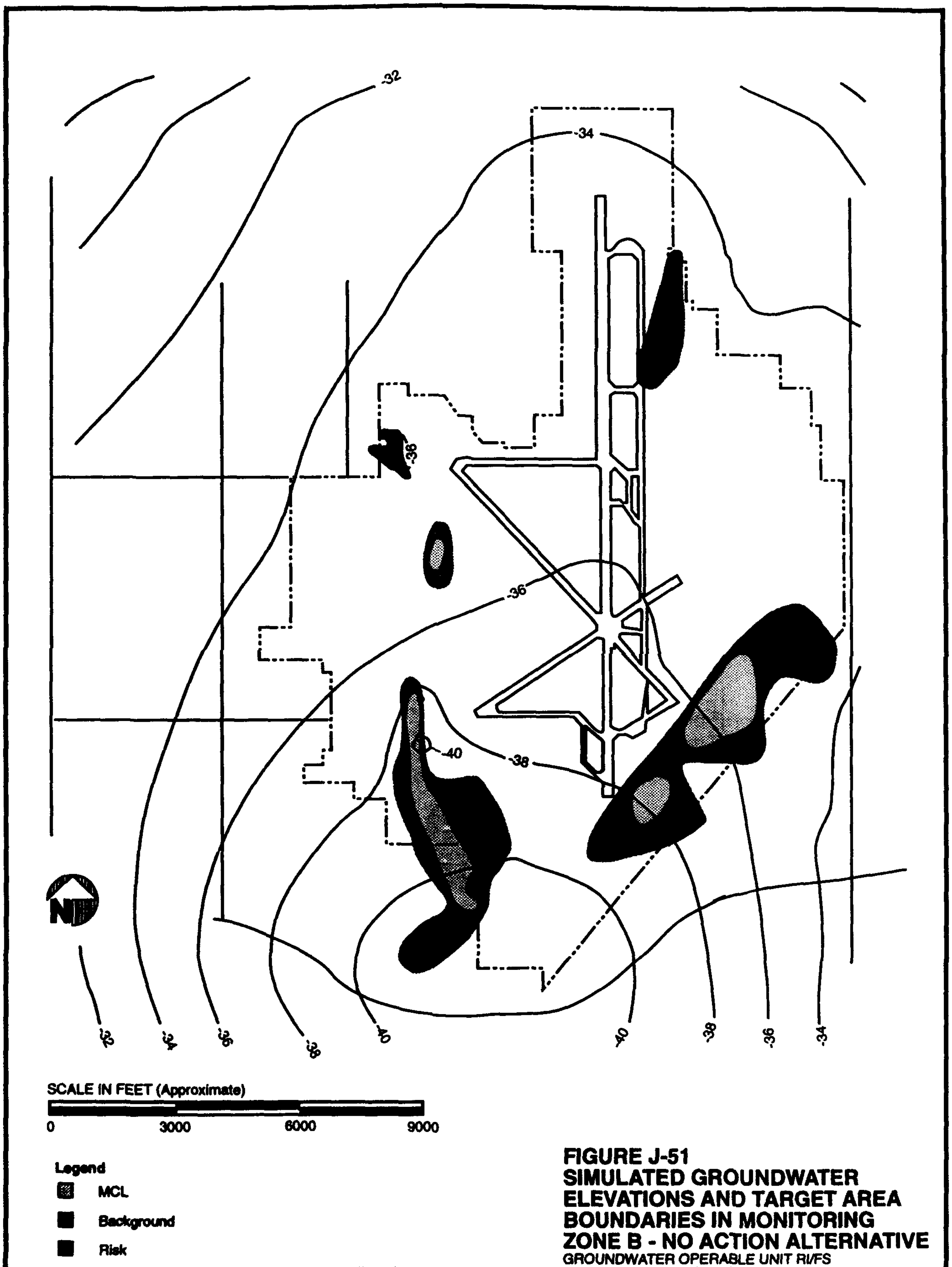


FIGURE J-51
SIMULATED GROUNDWATER ELEVATIONS AND TARGET AREA BOUNDARIES IN MONITORING ZONE B - NO ACTION ALTERNATIVE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
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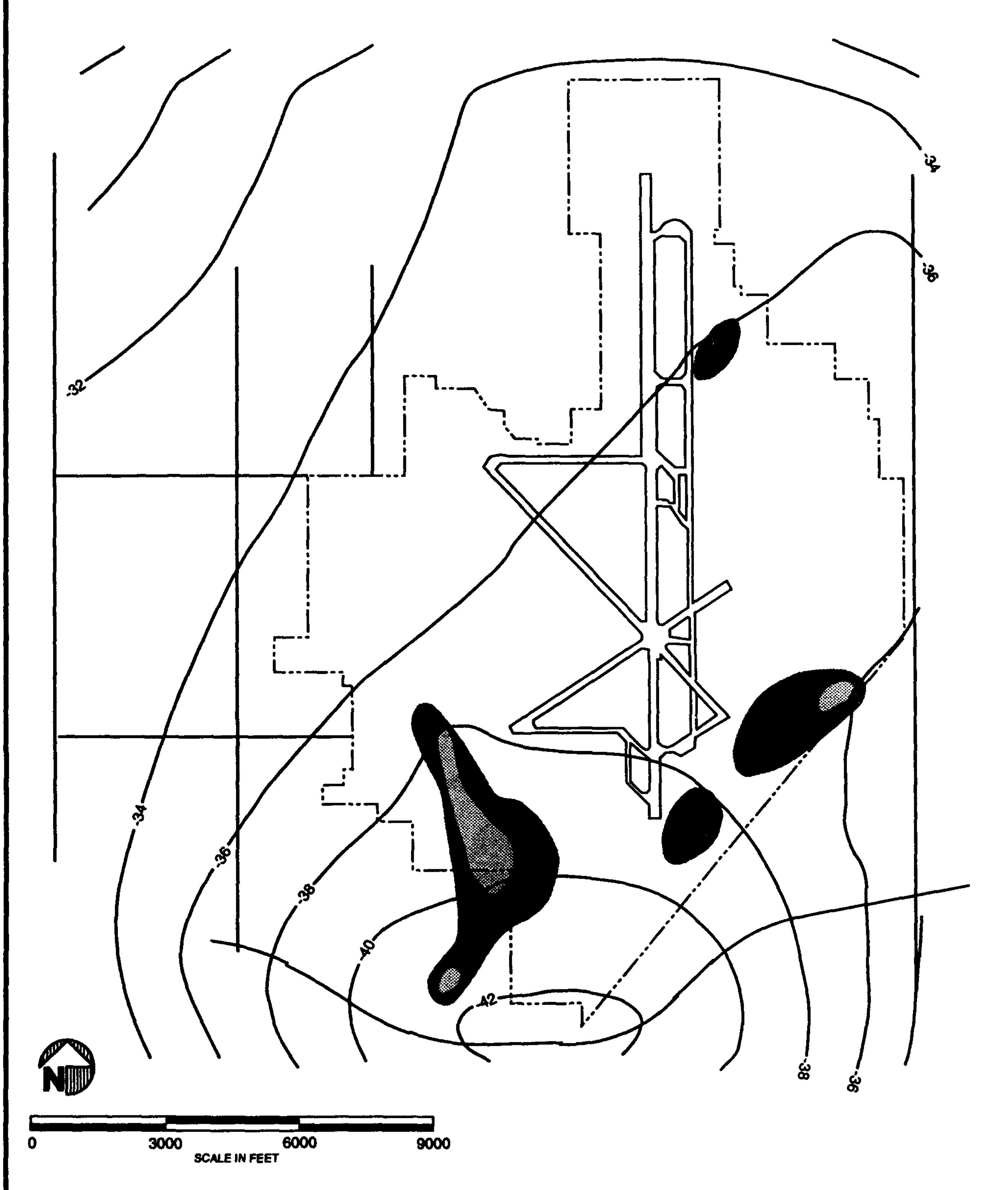

FIGURE J-52
SIMULATED GROUNDWATER ELEVATIONS AND TARGET AREA BOUNDARIES IN MONITORING ZONE C - NO ACTION ALTERNATIVE
GROUNDWATER OPERABLE UNIT RI/FS
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because it is dependent on future activities near the Base such as groundwater production practices 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 the monitoring zones will dewater, and contamination will have to be removed by alternative means.

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PREPARED FOR: McClellan Air Force Base

DATE: June 22, 1994

SUBJECT: VOC Mass Estimates
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SWE28722.66.FS

Introduction

The goals of this technical memorandum are to identify the contaminants of concern (COCs), to estimate the extent of contamination, and to estimate the mass of COCs in the groundwater. The quantity and spacial distribution of contaminant mass influences the method of remediation. For example, contaminant mass influences the priority of each required remedial action. The mix of contaminants influences treatment options. The quantity and type of contaminant influences the length of time required for remediation.

A detailed discussion of the nature and extent of contamination, as well as the methodology used in the delineation of the target areas for extraction and remedial action options, is presented in Chapter 4, Conceptual Model of the GW OU RI/FS report and will not be discussed in this technical memorandum.

Identification of Contaminants of Concern

The COCs were selected by examining the summary statistics from the Groundwater Sampling and Analysis Program (GSAP) maintained by Radian Corporation by identifying the primary risk drivers and by studying the spatial distribution of contaminant concentrations above MCLs. TCE, cis-1,2-DCE, PCE, 1,2-DCA, 1,1,1-TCA, and 1,1-DCE have been selected as COCs for performing mass estimates for the following reasons:

- They are the most frequently detected VOCs and are frequently detected above MCLs.
- They are risk drivers. At present groundwater concentrations, these contaminants posed hazards to human health.
- The areal extent of these contaminants is widespread.

The identification of COCs is necessary in defining the contamination problem and in evaluating the different facets of solutions, such as treatment options and length of time required for remediation.

Frequency of Detection

Most recent VOC samples collected during or after 1988 for all wells were used to calculate the summary statistics presented in Table K-1. TCE, cis-1,2-DCE, PCE, and 1,2-DCA have clearly been detected above MCLs more often than the other VOCs. Chloroform, carbon tetrachloride, and methylene chloride have been frequently detected, but only rarely above MCLs.

The data set presented in Section 4.6.1 was reviewed to select the COCs. The water quality trends of wells that have been sampled in the past 2 years was examined in conjunction with data from wells that had not been sampled as recently to extrapolate current groundwater conditions. The frequency of detects and the mean sampling result time series for TCE, PCE, cis-1,2-DCE, 1,2-DCA, 1,1,1-TCA, and 1,1-DCE are presented in Figure K-1.

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 relatively low groundwater contamination areas.

Hence, compounds have been detected in more sampled wells, but at lower concentrations.

Some discrepancy may be noted with the maximum nondetected reporting limit when compared to the detected values. The reporting limit was raised because of sample dilutions. Sample dilutions are necessary when there is a high concentration of one or more compounds in the given sample. The reporting limit is increased as a function of the dilutions, and all compounds are reported at the values detected in the final dilution and qualified using the final reporting limit value. Procedures to keep the reporting limits at or below MCLs, for contaminants with MCLs, are included in the Basewide RI/FS QAPP Update (Radian, 1994).

Table K-1

Summary Statistics on Groundwater VOC Data Set[a]

Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[c] (%)	Nondetected Value		Detected Value		Mean[b]	Standard Deviation
				Minimum	Reporting Limit[d]	Minimum	Maximum		
TRICHLOROETHYLENE (TCE)	132	260	51	0.04	5	0.28	26,000.00	453.47	2,450.35
ACETONE	2	4	50	7.50	100	8.00	14.00	5.50	6.81
cis-1,2-DICHLOROETHYLENE	51	196	26	0.04	120	0.36	210.00	3.54	16.54
CARBON DISULFIDE	1	4	25	1.70	5	3.10	3.10	0.78	1.55
METHYLENE CHLORIDE	49	231	21	0.04	800	0.40	351.00	6.99	38.78
TETRACHLOROETHYLENE(PCE)	29	260	11	0.04	200	0.10	2,100.00	13.61	140.71
CHLOROFORM	29	260	11	0.03	200	0.11	22.00	0.29	1.57
1,1-DICHLOROETHENE	26	260	10	0.06	700	1.06	13,600.00	110.32	965.22
1,2-DICHLOROETHANE	24	260	9	0.03	200	0.17	120.00	1.18	10.11
1,1-DICHLOROETHANE	20	260	8	0.02	1,000	0.34	230.00	1.90	17.17
1,1,1-TRICHLOROETHANE	15	260	6	0.14	770	0.65	1,290.00	10.27	111.30
TOLUENE	9	184	5	0.03	400	0.24	51.00	0.29	3.76
TOTAL 1,2-DICHLOROETHENE	1	21	5	0.10	400	2.20	2.20	0.10	0.48
CARBON TETRACHLORIDE	11	260	4	0.04	300	0.41	22.40	0.29	2.25
XYLENES, TOTAL	6	184	3	0.05	400	0.23	2.69	0.03	0.21
BENZENE	3	184	2	0.01	400	0.94	820.00	4.47	60.45
1,2-DICHLOROBENZENE	4	261	2	0.03	1,000	0.42	57.30	0.32	3.88
1,2-DICHLOROPROPANE	3	260	1	0.02	200	0.22	0.85	0.01	0.06
TRICHLOROFLUOROMETHANE	2	260	1	0.06	1,100	3.70	15.00	0.07	0.96
VINYL CHLORIDE	2	260	1	0.08	400	83.00	360.00	1.70	22.89
1,3-DICHLOROBENZENE	2	261	1	0.02	640	0.27	1.05	0.01	0.07
1,4-DICHLOROBENZENE	2	261	1	0.01	480	3.80	37.70	0.16	2.34

Notes:

[a] Most recent VOC concentrations sampled during or after 1988 for all wells in the database.

[b] Mean concentration calculated with nondetects as zero.

[c] Only parameters that were detected are presented in this table, *i.e., frequency of detection greater than zero.*

[d] The values presented as maximums are the reporting limit for the sample. The reporting limits have been elevated because of sample dilution.

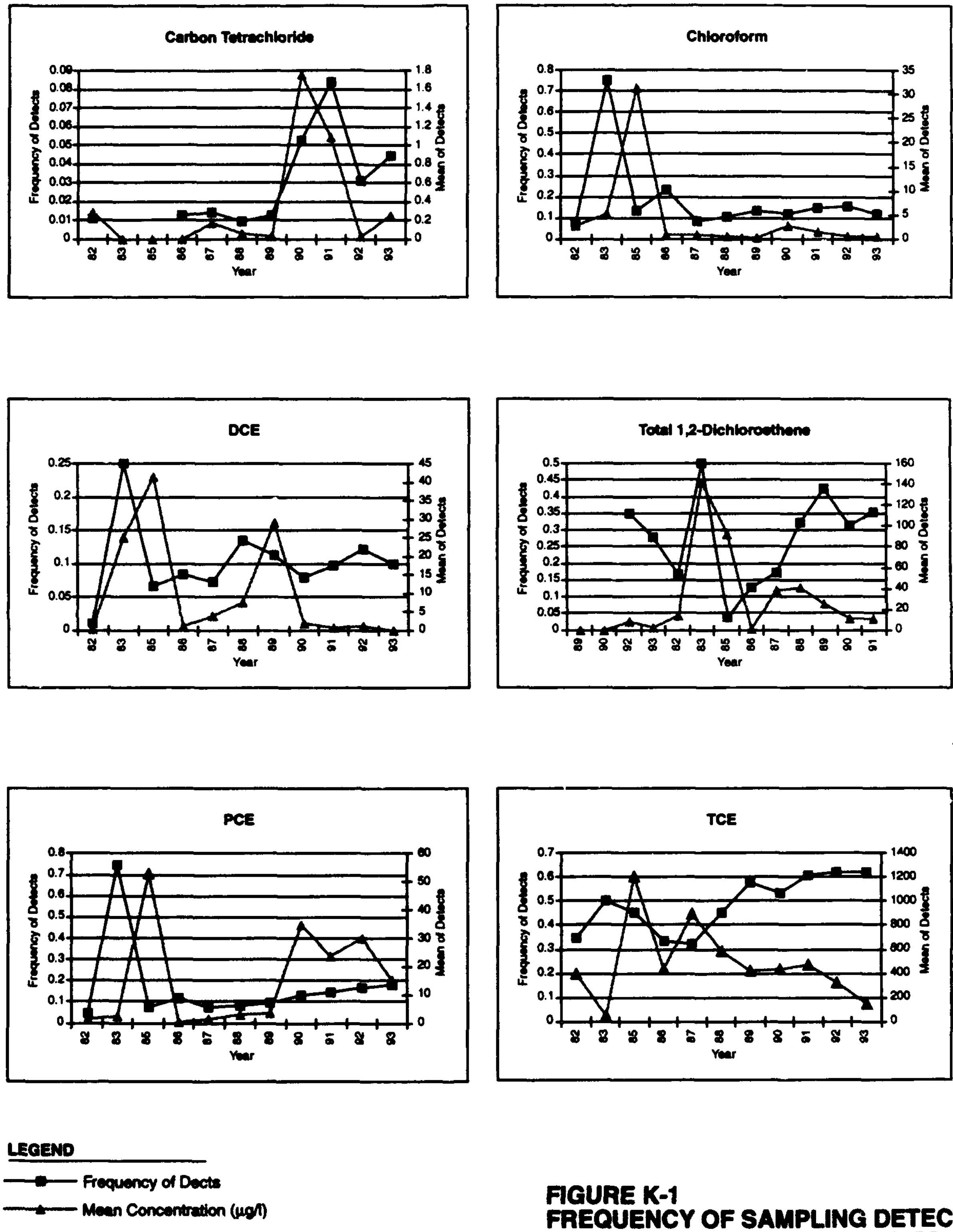

FIGURE K-1
FREQUENCY OF SAMPLING DETECTS AND MEAN CONCENTRATIONS FOR SELECTED VOCs
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
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Risk Drivers

In addition to being frequently detected above MCLs, TCE, PCE, 1,2-DCA, 1,1,1-TCA, and 1,1-DCE have been identified as primary risk drivers based on mean estimates of increased lifetime cancer risks or hazard quotients in Appendix B, Risk Assessment Methodology. Chloroform, methylene chloride, and carbon tetrachloride were also identified as risk drivers, but are not COCs in determining the extent of target areas for the following reasons (based on 1992 sampling):

- Chloroform was never detected above MCLs.

- Less than 2.4 percent of all methylene chloride results were above MCLs. In addition, methylene chloride is a common laboratory contaminant; samples with associated blank contamination were not rejected from the risk assessment and therefore it is likely that a portion of the methylene chloride detects reflect laboratory contamination rather than groundwater contamination.

- Less than 0.4 percent of all carbon tetrachloride results were above MCLs.

While cis-1,2-DCE was not identified as a risk driver by the risk assessment, it was detected in 26 percent of the samples collected. Cis-1,2-DCE had a mean concentration of 3.5 $\mu g/l$ and is considered to be equivalent to total 1,2-DCE as trans-1,2-DCE was not detected. Since the extent of this contaminant appears to be widespread, cis-1,2-DCE was selected as a COC. 1,1,1-TCA was also selected although it was only detected in approximately 6 percent of the samples. 1,1,1-TCA had a mean concentration of 10.3 $\mu g/l$ and was considered to be a prevalent contaminant.

Areal Extent of Contamination

TCE is the most frequently detected contaminant and the most widespread. For this reason, the extent of VOC contaminant migration, and consequently the extent of the target volumes described in Chapter 4, the Conceptual Model, was based on the extent of observed TCE contamination. The approximate areal extent of the TCE, PCE, cis-1,2-DCE, 1,2-DCA, 1,1,1-TCA, and 1,1-DCE in each zone are presented in Figures K-2, K-3, and K-4. The mass of the COCs in these zones were calculated and are presented in the VOC Mass Estimate section of this technical memorandum.

Delineation of the Extent of Contamination

The location of the source areas, time of contaminant release, contaminant transport properties, and groundwater flow directions all influence the extent of VOC contamination at the Base.

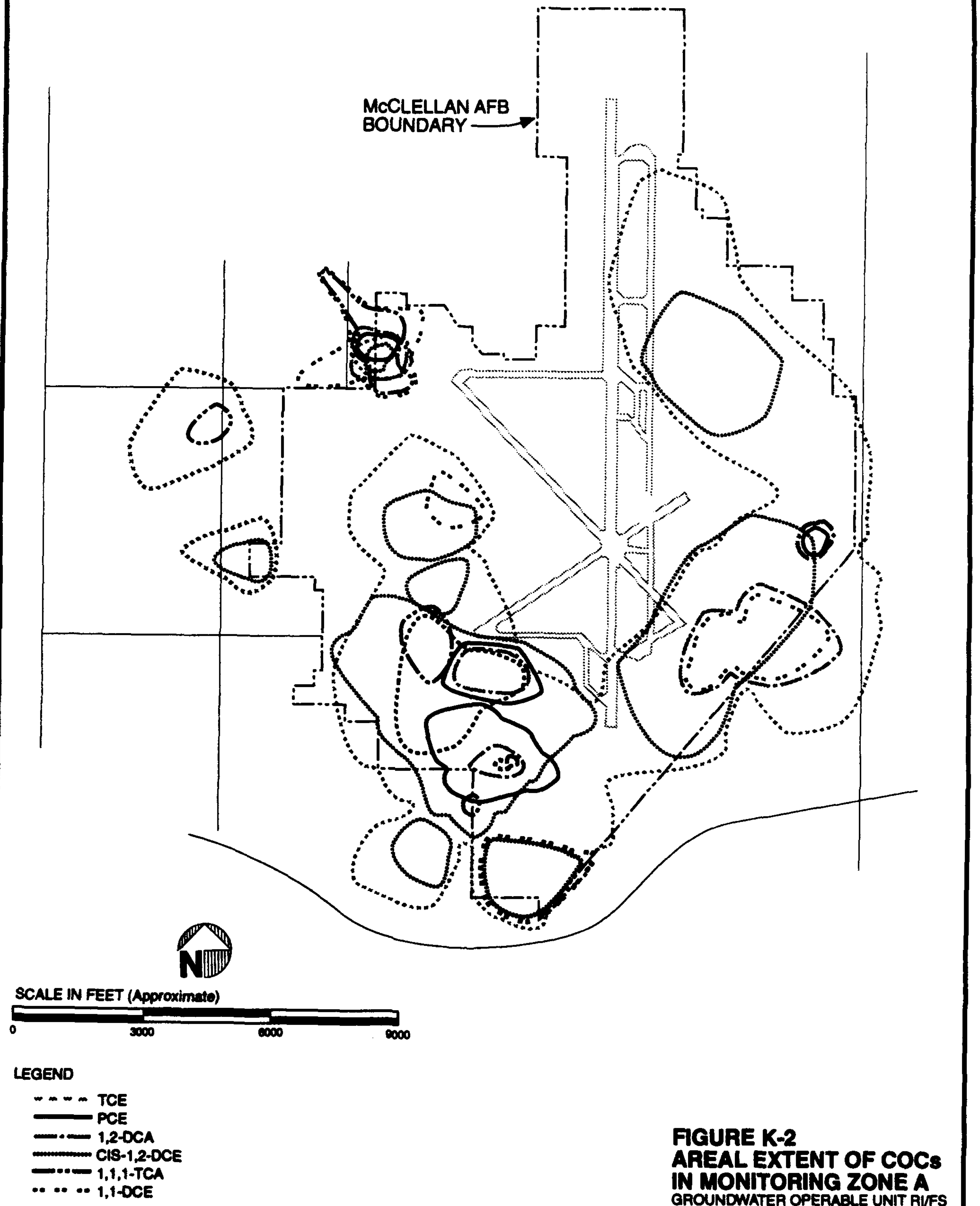

FIGURE K-2
AREAL EXTENT OF COCs IN MONITORING ZONE A
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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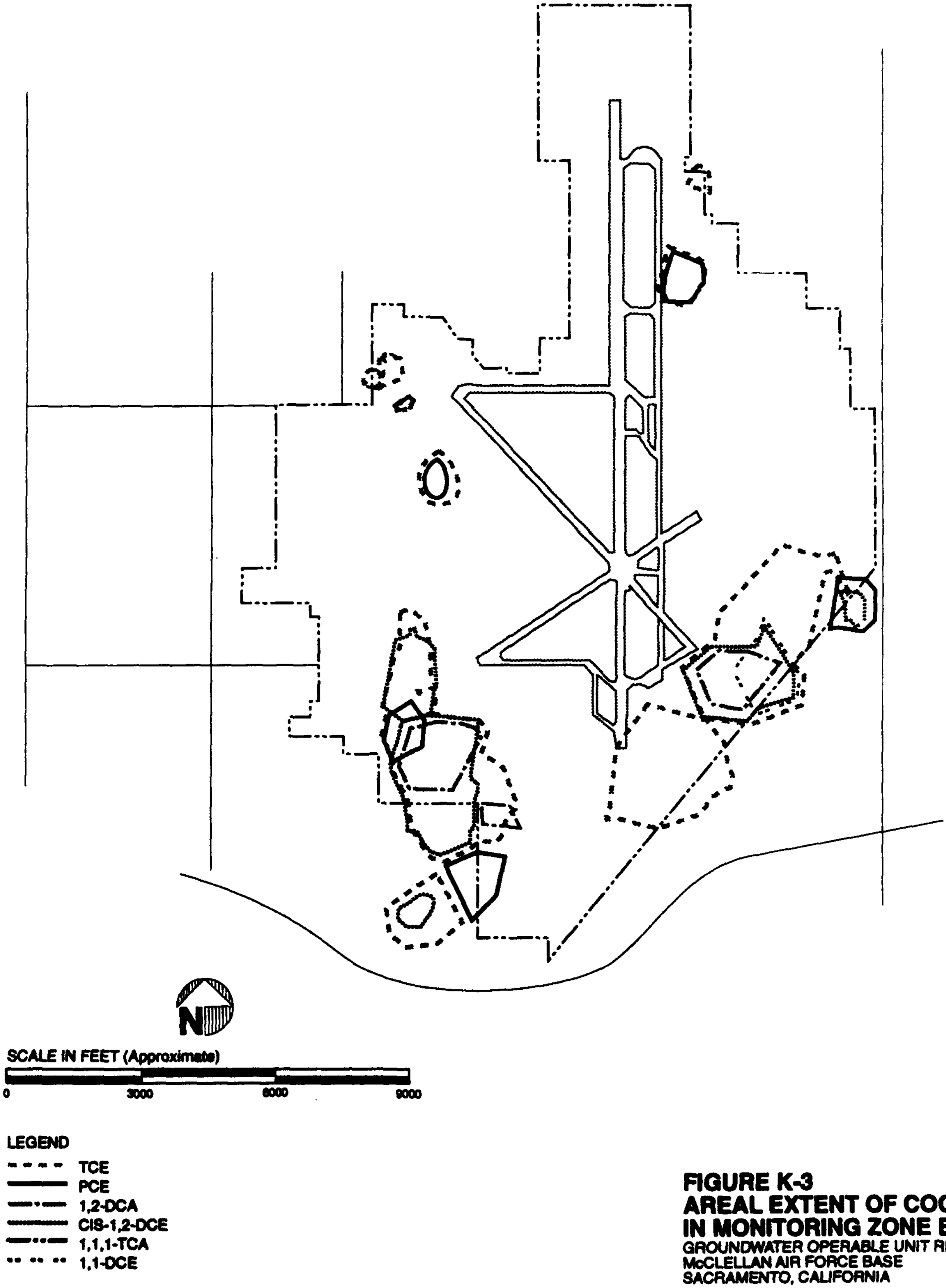

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FIGURE K-3
AREAL EXTENT OF COCs IN MONITORING ZONE B
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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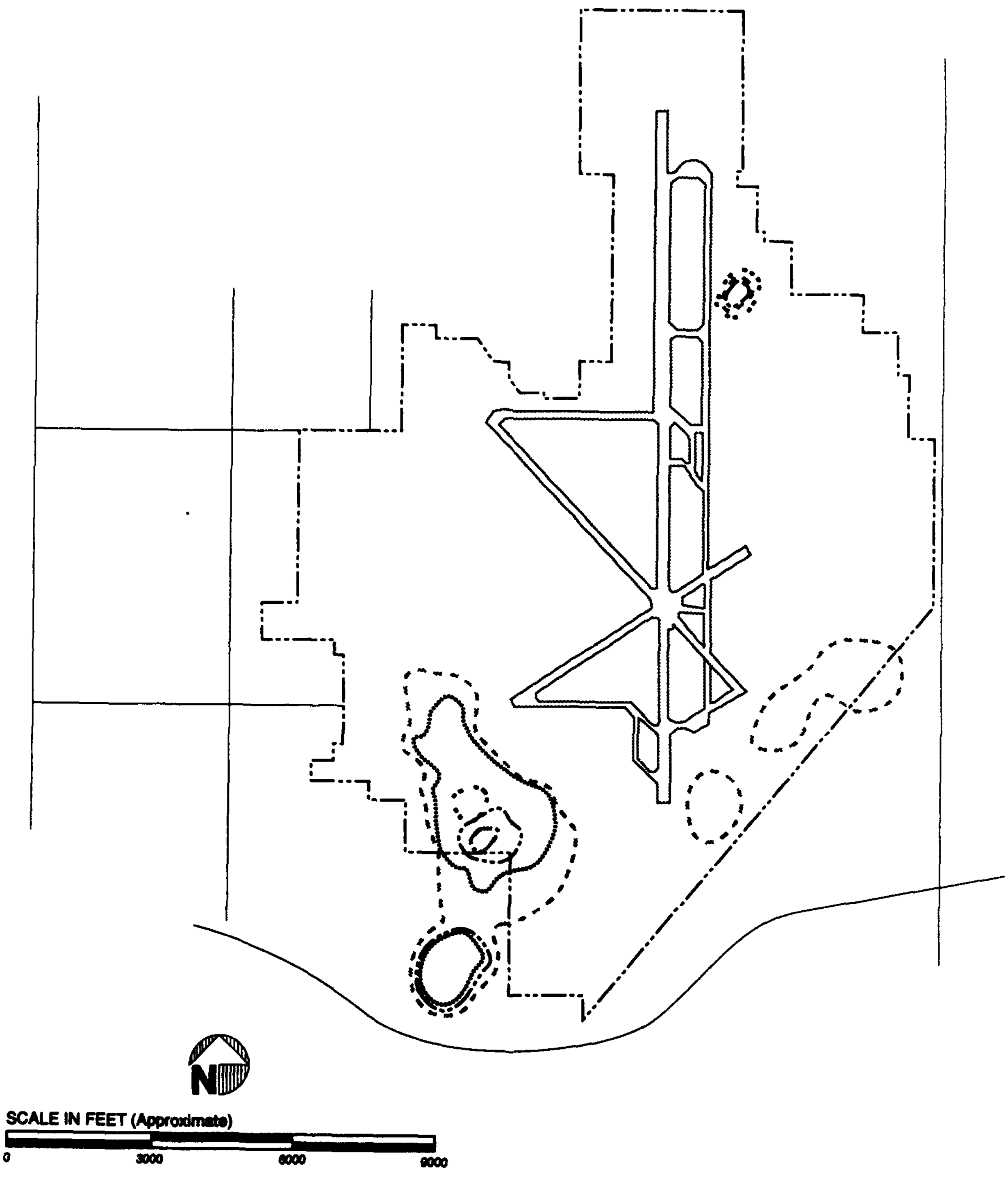

LEGEND

- TCE
- PCE
- 1,2-DCA
- CIS-1,2-DCE
- 1,1,1-TCA
- 1,1-DCE

FIGURE K-4
AREAL EXTENT OF COCs IN MONITORING ZONE C
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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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.

The data set representing current groundwater conditions was assembled and used to estimate the extent of contamination, VOC mass, and target volumes. Only 161 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 data base, the most recent result for each well sampled during 1992 or 1993 collected was 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 data base that were last sampled during 1988 to 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 weeks with fluctuating concentrations, MW-131, MW-165 and MW-211, were available in 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 risk associated was incorporated in the data set. Concentration 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.

The interpretation of the VOC extent of contamination in a particular monitoring zone is a function of the monitoring network. VOC concentration isopleths are known with certainty in regions where the monitoring network is dense (e.g., in the A zone of OU D). In regions where there are fewer monitoring wells, and thus less data spatially, the delineation of the extent of contamination is based on proximity to source areas and groundwater flow directions. This is the case in all zones of OUs G and H. Generally, well networks are more dense in areas of high concentration and less dense in areas of low concentration.

Background level target volumes were established based on the data set described above and are presented in Chapter 4. Contaminant mass was calculated only in the background target volume.

VOC Mass Estimates

This section discusses the methodology used to estimate the mass of the COCs dissolved in groundwater and sorbed to the soil matrix. The mass of free product was not considered in this calculation because the presence of NAPLs in the groundwater system has not been confirmed and insufficient data exist to estimate the mass of DNAPL that may exist.

The mass of each COC dissolved in groundwater or sorbed to the aquifer matrix was determined by calculating the mass within each contaminant isopleth. A linear isotherm relating contaminant concentrations in solution to concentrations sorbed to soil were assumed. The mass of the COCs as well as the volume of aquifer that these contaminants currently occupy is presented in this technical memorandum. This section will discuss the estimation of VOC mass in the groundwater system followed by the assumptions made and the methodology followed to perform these calculations.

Mass of VOCs and Volume of Contaminated Aquifer

TCE is the most prevalent COC by mass and by contaminated aquifer volume, followed by PCE. Approximately 67 percent of the COC mass is attributable to TCE. Sixty-two percent of that TCE mass exists in Monitoring Zone A. Table K-2 presents the estimated mass of the COCs in each monitoring zone and the estimated volume of contaminated aquifer that each COC occupies. TCE is the most widespread contaminant spatially; and with few exceptions, all other COCs exist in areas where TCE also exists.

The mass of each COC by monitoring zone of each OU is presented in Table K-3. The distribution of the COC mass in each zone of each OU is summarized in Figures K-5, K-6, K-7, K-8, K-9, and K-10. The mass of contaminants in Monitoring Zone C of OU D was not calculated because monitoring wells do not exist in Monitoring Zone C in OU D. Mass in Monitoring Zones D and E of OU B/C were not calculated because the D and E zone wells are located in a north-south line, and it was not possible to determine the east-west extent of contamination.

Cumulative mass versus cumulative volume of each COC is compared in Figures K-11, K-12, K-13, K-14, K-15, and K-16. Comparison of cumulative mass versus cumulative volume show that the mass of contaminants per volume of aquifer in the high concentration areas are significantly higher than the mass of contaminants per volume of aquifer in the low concentration areas. The highest mass exists in the smallest volumes associated with regions of high concentrations (>500 μg/l). Conversely, the regions of low concentrations (<1 μg/l) make up large volumes of aquifer, but contain little mass. This difference is significant because the characteristics of the groundwater extracted from each area will be different and may require different treatment technologies to achieve remedial cleanup goals. Total groundwater extraction from the limited areas where concentrations are greater than 500 μg/l would be relatively small, but the influent concentrations from these areas would be high. Conversely, total groundwater extraction from regions where concentrations are less than 1 μg/l would be high, but the influent concentrations from these areas would be low.

Assumptions

On the basis of transport mechanisms, contaminant concentration and contaminant properties, the concentrations of contaminants in the subsurface are constantly changing. Therefore, to perform VOC mass estimates, the following assumptions will be made:

- Contaminants in solution (groundwater and porewater) are in equilibrium with contaminants sorbed to the aquifer matrix.

- The concentration of a VOC sorbed to soil is linearly related to the concentration of a VOC in solution (i.e., linear sorption isotherms).

Table K-2
Mass of COCs and Volume of Contaminated Aquifer By Zone
Groundwater Operable Unit

COCs	Zone A	Zone B	Zone C	Total	Percent of Total Mass
TCE					
Mass (kg)	7,900	400	170	8,500	
Percent of Total Mass	62	3.1	1.3		**67**
Volume (million ft^3)	2,200	1,300	1,000	4,600	
Percent of Total Volume	48	29	23		
PCE					
Mass (kg)	760	33	--	790	
Percent of Total Mass	6	0.26	--		**6.2**
Volume (million ft^3)	180	250	--	420	
Percent of Total Volume	42	58	--		
1,1,1-TCA					
Mass (kg)	250	0.45	4.5	260	
Percent of Total Mass	2.0	0	0.04		**2.0**
Volume (million ft^3)	97	20	210	330	
Percent of Total Volume	30	6	64		
Cis-1,2-DCE					
Mass (kg)	170	43	34	250	
Percent of Total Mass	1.0	0.00	0.00		**2.0**
Volume (million ft^3)	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 Total Mass	0.14	0.070	0.00		**0.21**
Volume (million ft^3)	130	830	8.6	970	
Percent of Total Volume	13	86	1.0		
1,1-DCE					
Mass (kg)	2,900	1.5	0.63	2,900	
Percent of Total Mass	23	0.01	0.01		**23**
Volume (million ft^3)	360	86	46	490	
Percent of Total Volume	73	18	9.0		
Total Mass of COCs	12,000	490	210	13,000	**100**

Table K-3
Mass of COCs and Volume of Contaminated Aquifer By Zone
Groundwater Operable Unit

Operable Unit	Zone	Mass Per Zone Per OU (kg)	Total Mass in Each OU (kg)	Percent of Total Mass in Each OU (kg)	Volume Per Zone Per OU (million ft^3)	Volume Per OU (million ft^3)	Percent of Total Volume in Each OU (million ft^3)
TCE							
A	A	2,500	2,500	30	780	1,000	41
	B	0.84			41		
	C	8.3			210		
B/C	A	5,000	5,500	65	1,100	3,100	42
	B	400			1,200		
	C	160			810		
D	A	390	390	4.6	70	97	3.9
	B	0.61			27		
	C	--			--		
G/H and Offbase	A	6.9	7.4	0.09	310	340	13
	B	0.19			10		
	C	0.28			14		
Total		8,500		100	4,600		100

Table K-3
Mass of COCs and Volume of Contaminated Aquifer By Zone
Groundwater Operable Unit

Operable Unit	Zone	Mass Per Zone Per OU (kg)	Total Mass in Each OU (kg)	Percent of Total Mass in Each OU (kg)	Volume Per Zone Per OU (million ft^3)	Volume Per OU (million ft^3)	Percent of Total Volume in Each OU (million ft^3)
cis-1,2-DCE							
A	A	120	120	48	210	360	17
	B	5.9			152		
	C	--			--		
B/C	A	57	130	51	788	1,700	78
	B	37			357		
	C	34			550		
D	A	0.16	0.16	0.06	11	11	0.51
	B	--			--		
	C	--			--		
G/H and Offbase	A	1.6	1.6	0.61	110	110	5.1
	B	--			--		
	C	--			--		
Total		250		100	2,200		100

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Table K-3
Mass of COCs and Volume of Contaminated Aquifer By Zone
Groundwater Operable Unit

Operable Unit	Zone	Mass Per Zone Per OU (kg)	Total Mass in Each OU (kg)	Percent of Total Mass in Each OU (kg)	Volume Per Zone Per OU (million ft^3)	Volume Per OU (million ft^3)	Percent of Total Volume in Each OU (million ft^3)
PCE							
A	A	0.070	2.4	0.30	2.0	43	10
	B	2.3			41		
	C	--			--		
B/C	A	750	760	96	160	260	63
	B	14			1.0×10^2		
	C	--			--		
D	A	9.0	24	3.0	12	81	19
	B	15			69		
	C	--			--		
G/H and Offbase	A	--	1.8	0.23	--	33	7.8
	B	1.8			33		
	C	--			--		
Total		790		100	420		100

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Table K-3
Mass of COCs and Volume of Contaminated Aquifer By Zone
Groundwater Operable Unit

Operable Unit	Zone	Mass Per Zone Per OU (kg)	Total Mass in Each OU (kg)	Percent of Total Mass in Each OU (kg)	Volume Per Zone Per OU (million ft^3)	Volume Per OU (million ft^3)	Percent of Total Volume in Each OU (million ft^3)
1,2-DCA							
A	A	5.4	13	49	63	780	81
	B	8.0			720		
	C	--			--		
B/C	A	0.43	2.0	7.2	35	150	16
	B	1.5			110		
	C	0.060			8.6		
D	A	12	12	44	28	28	2.9
	B	--			--		
	C	--			--		
Total		27		100	970		100

Table K-3
Mass of COCs and Volume of Contaminated Aquifer By Zone
Groundwater Operable Unit

Operable Unit	Zone	Mass Per Zone Per OU (kg)	Total Mass in Each OU (kg)	Percent of Total Mass in Each OU (kg)	Volume Per Zone Per OU (million ft^3)	Volume Per OU (million ft^3)	Percent of Total Volume in Each OU (million ft^3)
1,1,1-TCA							
A	A	--			--		
	B	--			--		
	C	--			--		
B/C	A	0.97	5.7	2.2	51	270	82
	B	0.35			16		
	C	4.4			200		
D	A	250	250	98	46	51	15
	B	0.10			4.4		
	C	--			--		
G/H and Offbase	A	--	0.10	0.04	--	7.5	2.3
	B	0.10			7.5		
	C	--			--		
Total		260		100	330		100

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Table K-3
Mass of COCs and Volume of Contaminated Aquifer By Zone
Groundwater Operable Unit

Operable Unit	Zone	Mass Per Zone Per OU (kg)	Total Mass in Each OU (kg)	Percent of Total Mass in Each OU (kg)	Volume Per Zone Per OU (million ft^3)	Volume Per OU (million ft^3)	Percent of Total Volume in Each OU (million ft^3)
1,1-DCE							
A	A	1.6	2.8	0.10	50	120	25
	B	1.3			73		
	C	--			--		
B/C	A	6.7	6.7	0.24	200	230	47
	B	--			--		
	C	0.21			22		
D	A	2,900	2,900	100	100	110	23
	B	0.21			13		
	C	--			--		
G/H and Offbase	A	--	0.43	0.01	--	24	4.9
	B	0.43			24		
	C	--			--		
Total		2,900		100		490	100

RDD100136D1.WP5-6

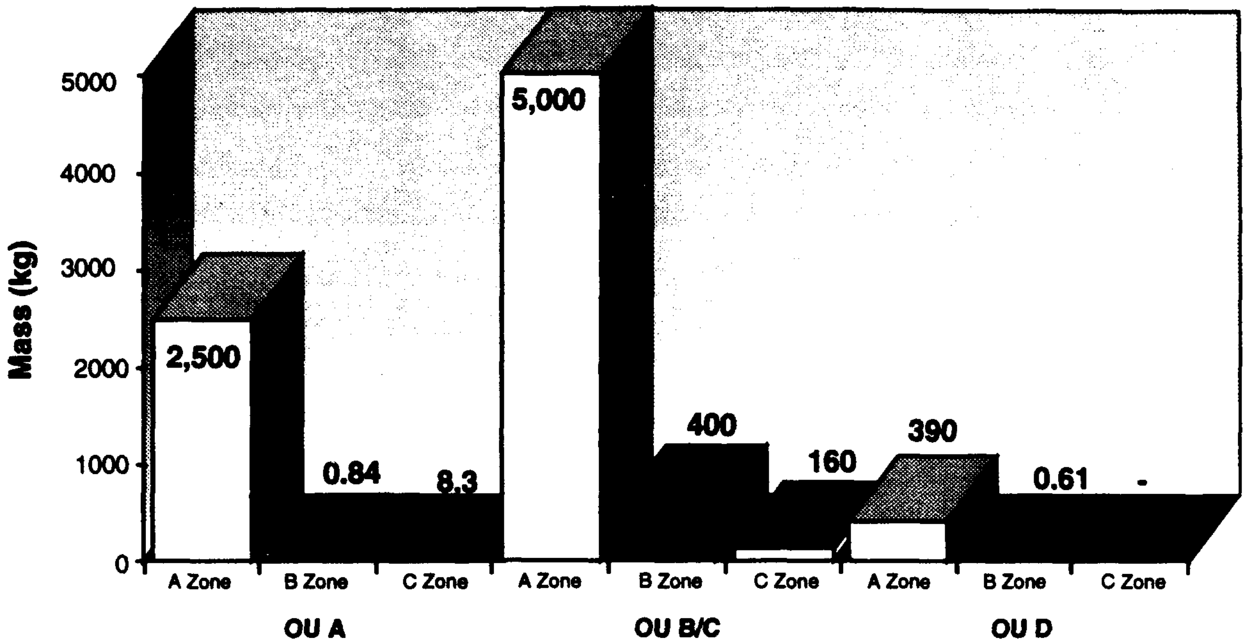


FIGURE K-5
DISTRIBUTION OF TCE IN EACH ZONE OF EACH OPERABLE UNIT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

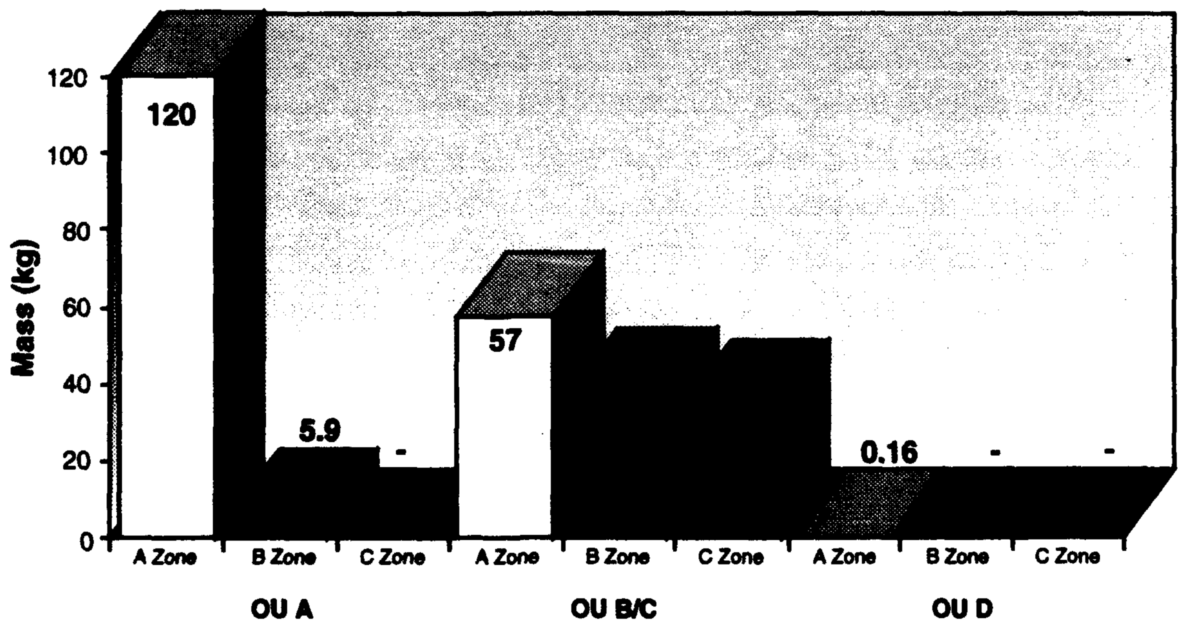


FIGURE K-6
DISTRIBUTION OF CIS-1,2-DCE IN EACH ZONE OF EACH OPERABLE UNIT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_211

CH2M HILL

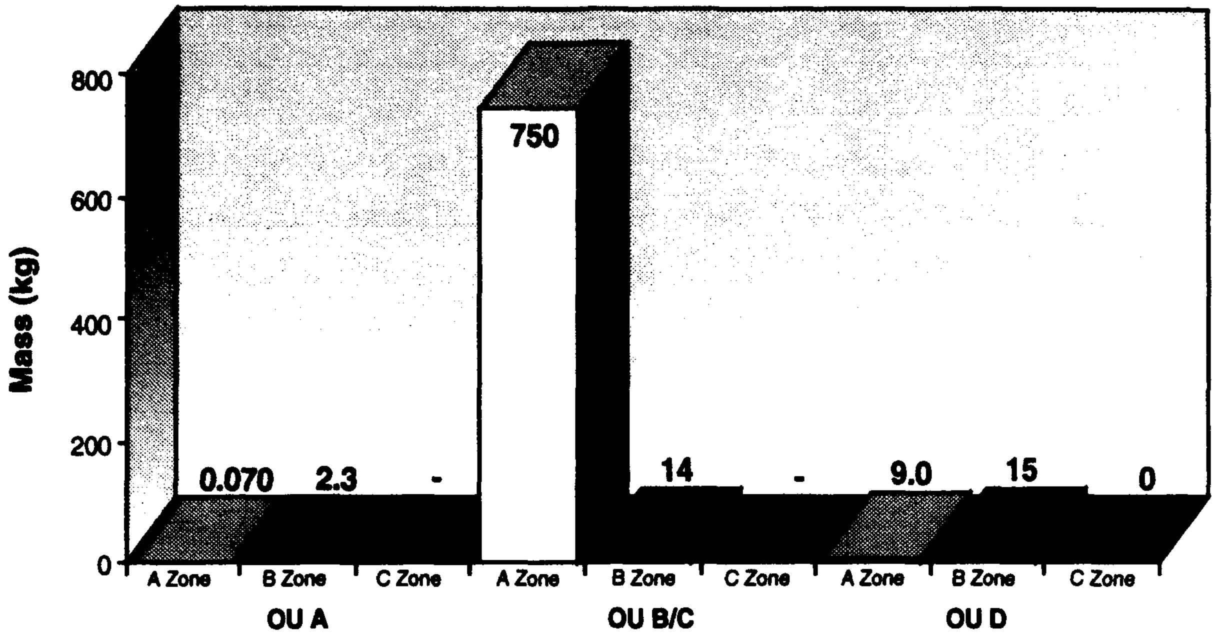


FIGURE K-7
DISTRIBUTION OF PCE IN EACH ZONE OF EACH OPERABLE UNIT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

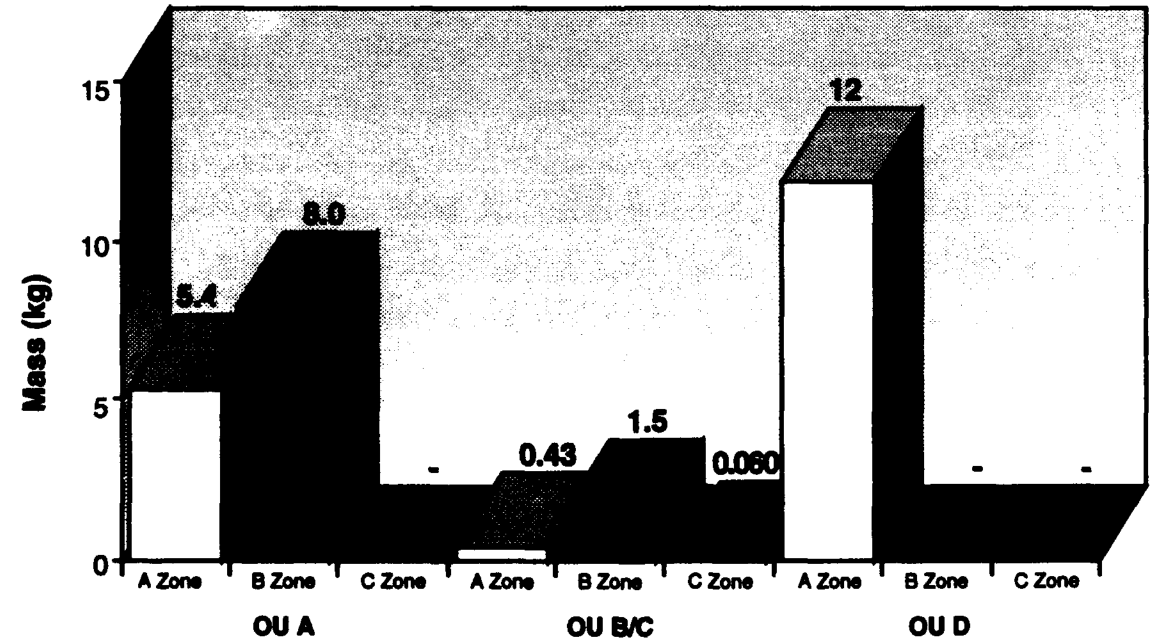


FIGURE K-8
DISTRIBUTION OF 1,2-DCA IN EACH ZONE OF EACH OPERABLE UNIT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_210

CH2MHILL

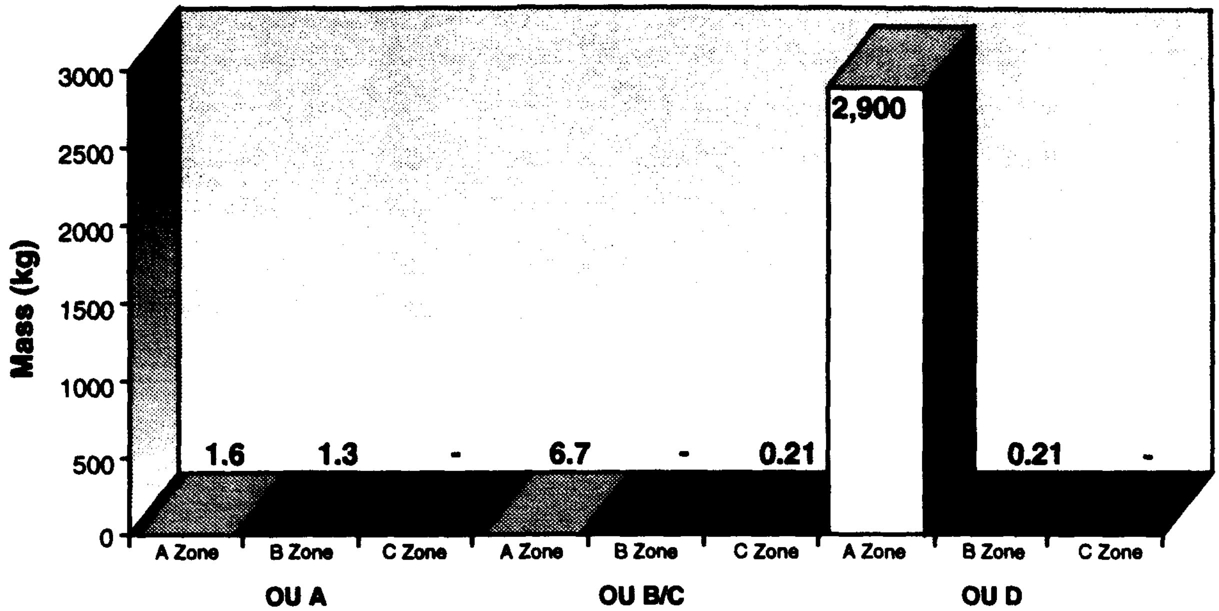


FIGURE K-9
DISTRIBUTION OF 1,1-DCE IN EACH ZONE OF EACH OPERABLE UNIT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

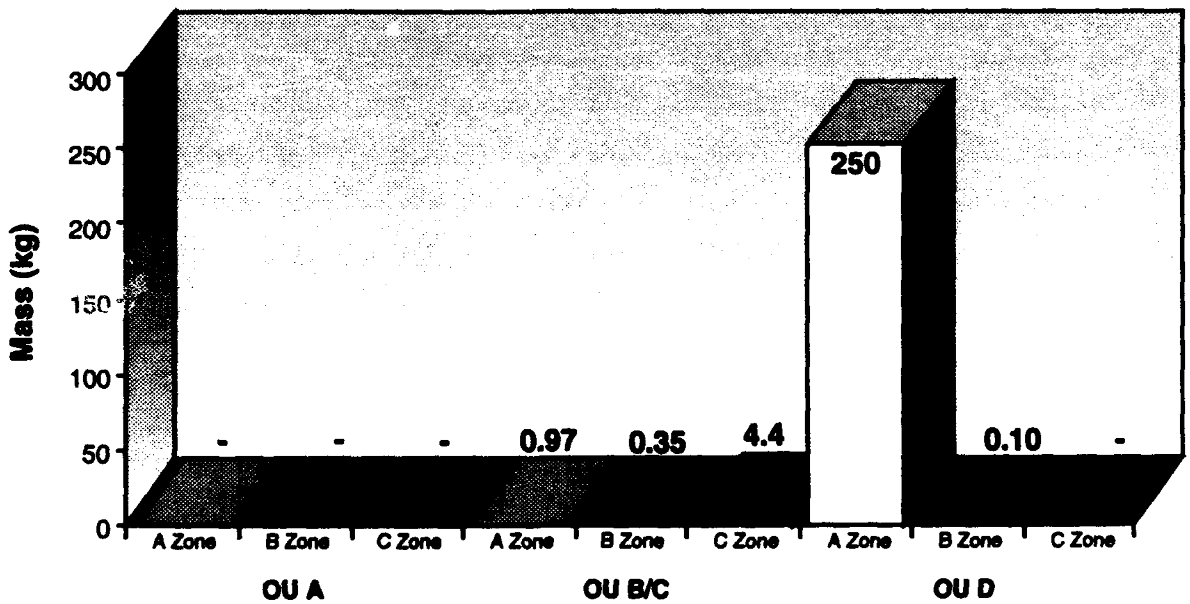
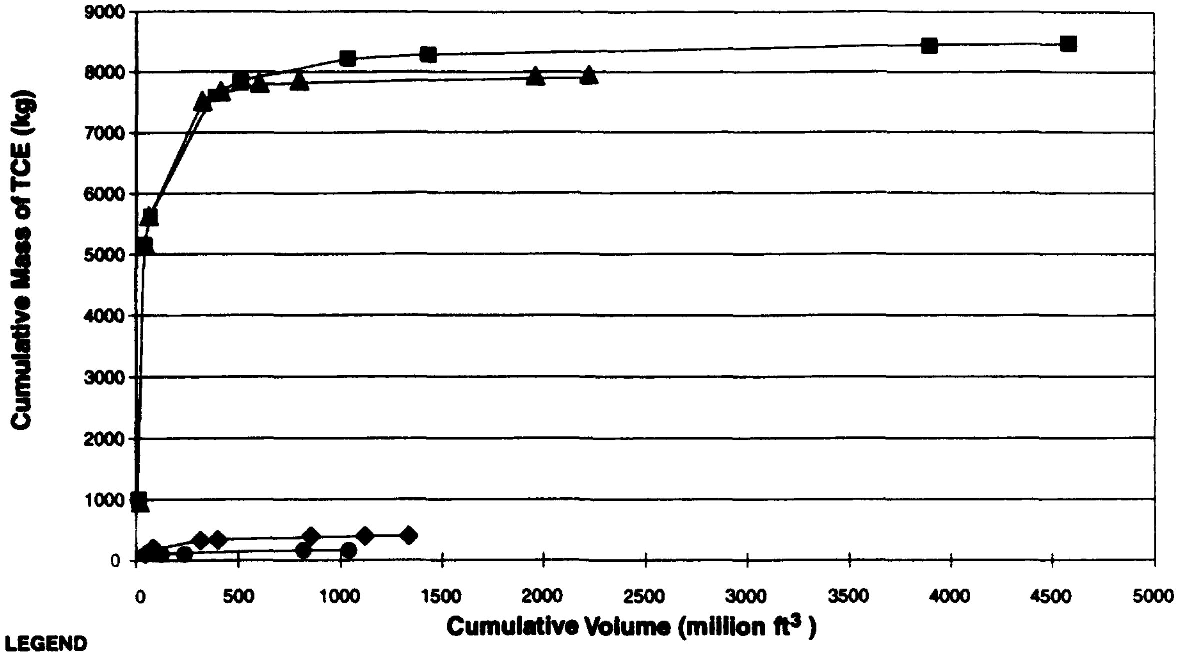


FIGURE K-10
DISTRIBUTION OF 1,1,1-TCA IN EACH ZONE OF EACH OPERABLE UNIT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_710

CH2M HILL



LEGEND

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

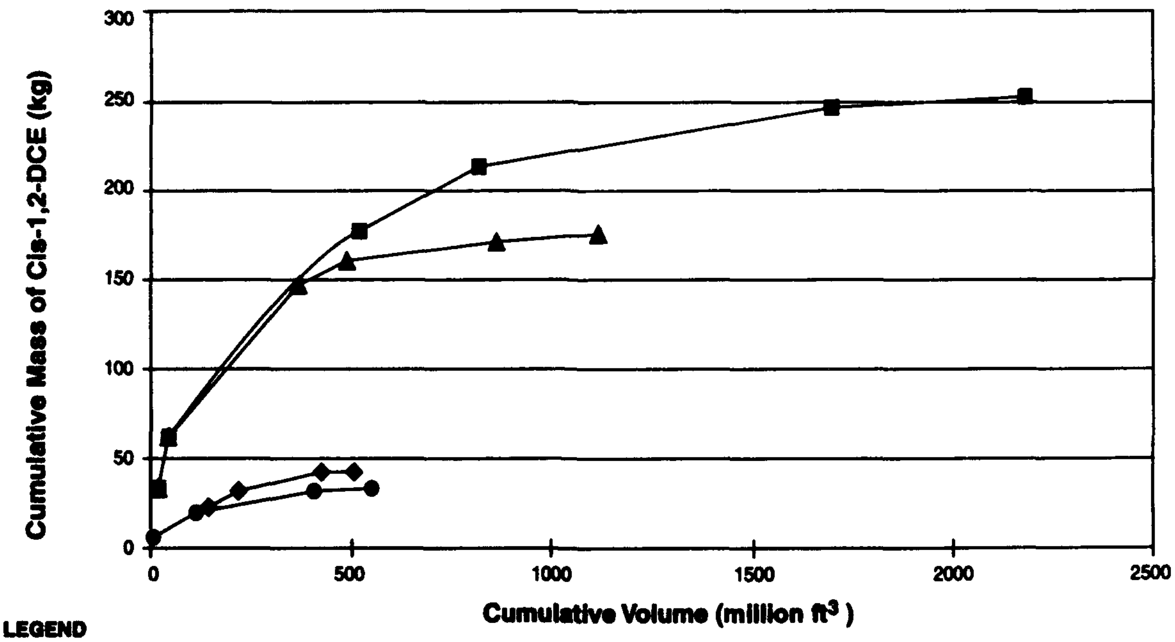
—■— Totals: 1,000-10,000; 500-1,000; 100-500; 50-100; 10-50; 5-10; 5 -1; 0.5-1

—▲— 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 K-11
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

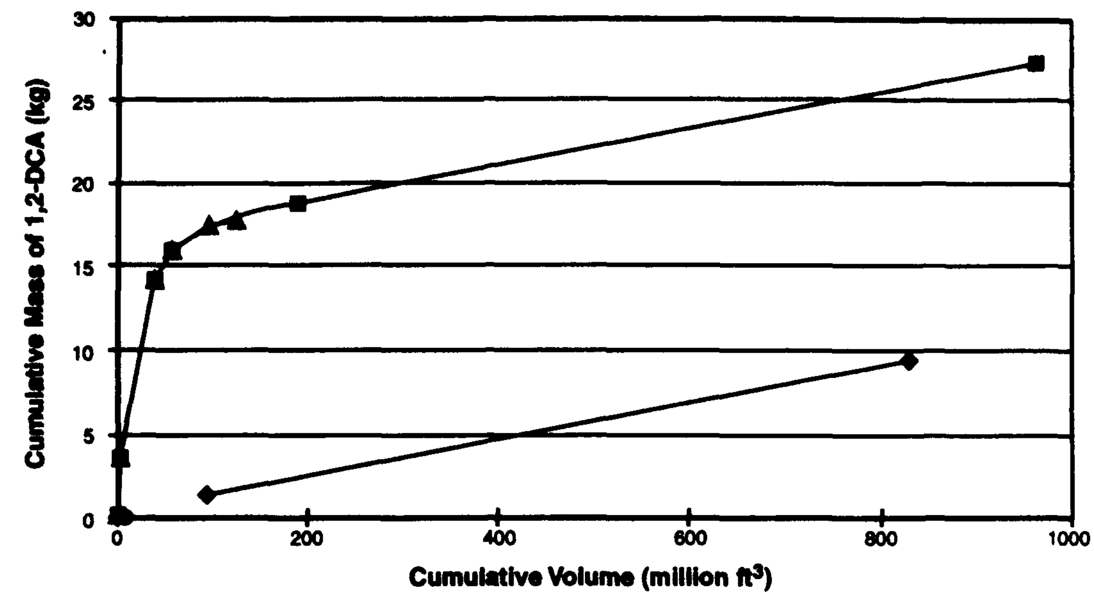
—◆— B Zone: 5-10; 1-5; 0.5-1

—●— C Zone: 5-10; 1-5; 0.5-1

FIGURE K-12
CUMULATIVE OF Cis-1,2-DCE VERSUS VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_281

CH2MHILL



LEGEND

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

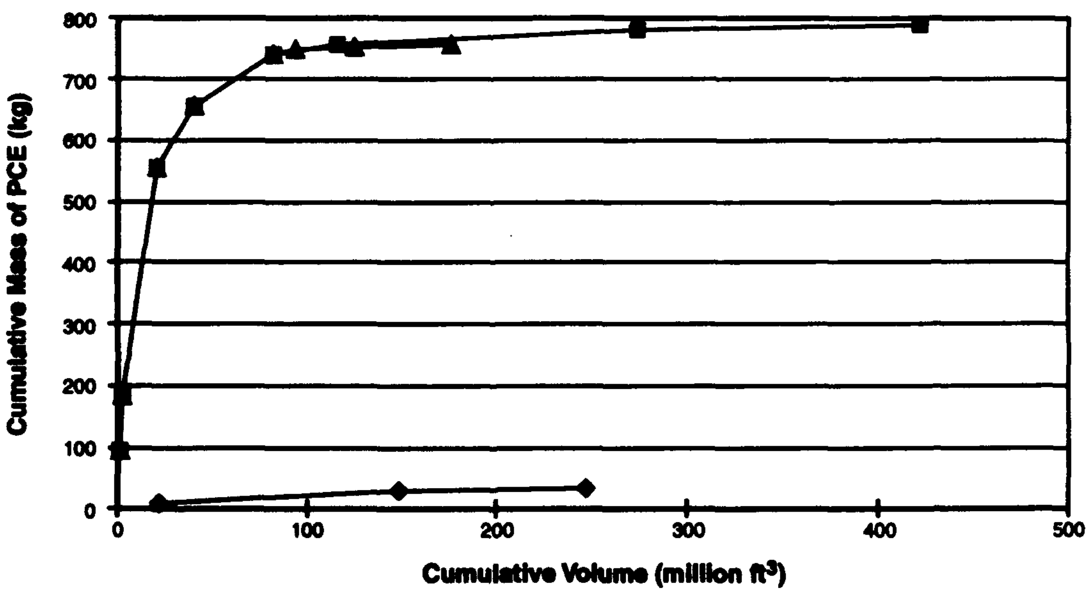
—■— Totals: 50-100; 10 -50; 5 -10; 1-5; 0.5-1

—▲— A Zone: 50-100; 10 -50; 5-10; 1-5; 0.5-1

—◆— B Zone: 0.5-1

—●— C Zone: 0.5

FIGURE K-13
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

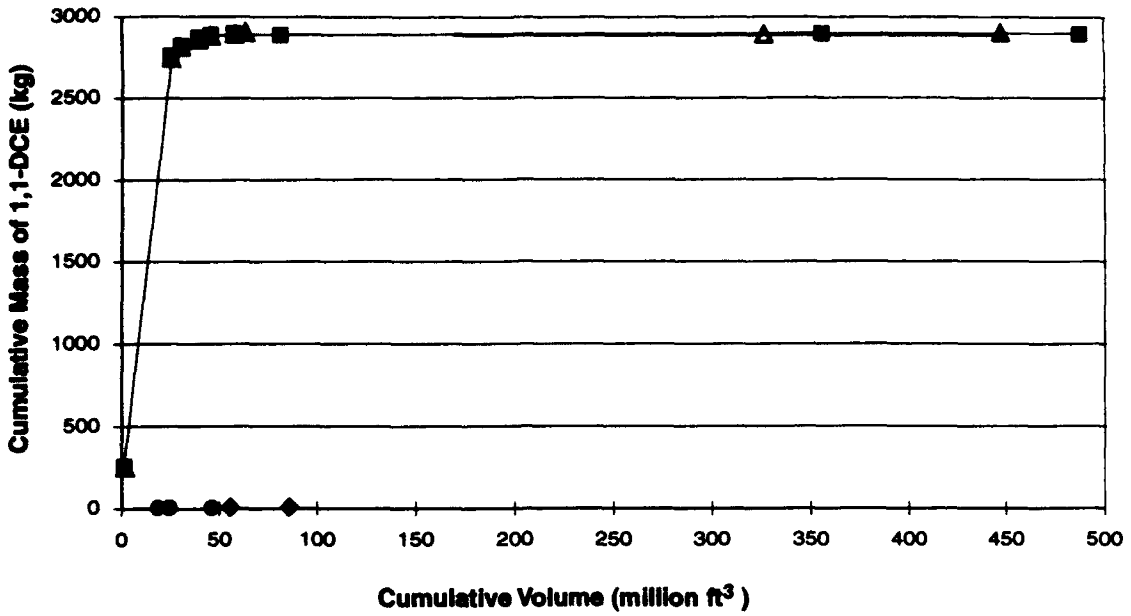
—▲— A Zone: 500-1000; 100-500; 50-100; 10-50; 5-10; 1-5; 0.5-1

—◆— B Zone: 1-5; 0.5-1

FIGURE K-14
CUMULATIVE MASS OF PCE VERSUS VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_282

CH2MHILL

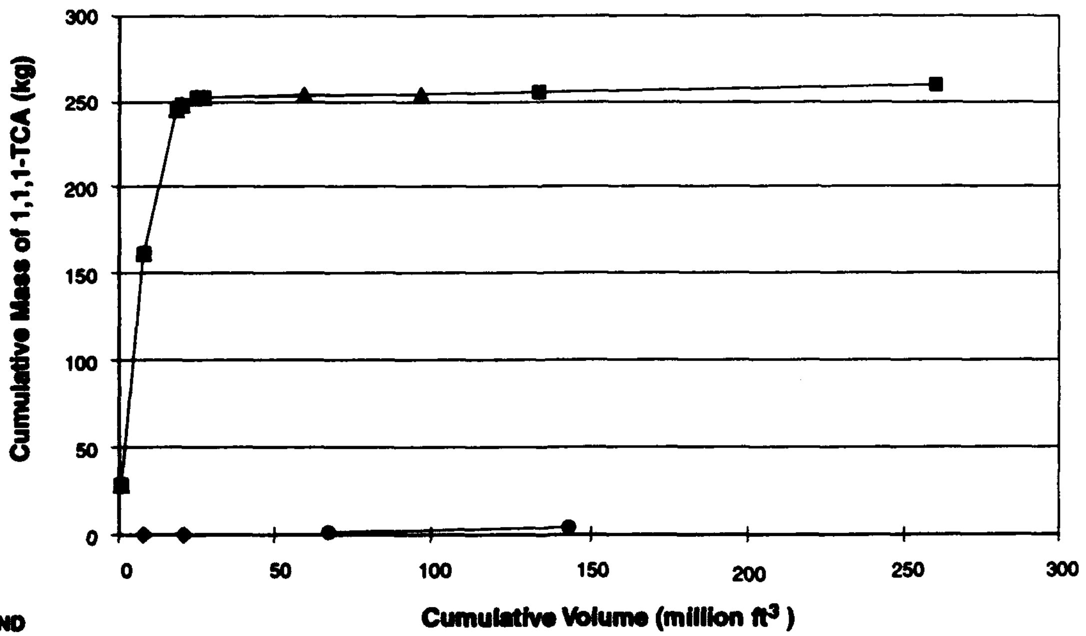


LEGEND

The following TCE 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: 0.5-1
- —●— C Zone: 1-5; 0.5-1

FIGURE K-15
CUMULATIVE MASS OF 1,1-DCE 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: 500-1000; 100-500; 50-100; 10-50; 1-5; 0.5-1
- —▲— A Zone: 500-1000; 100-500; 50-100; 10-50; 1-5; 0.5-1
- —◆— B Zone: 0.5-1
- —●— C Zone: 1-5; 0.5-1

FIGURE K-16
CUMULATIVE MASS OF 1,1,1-TCA VERSUS VOLUME
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1464_711

CH2M HILL

The following assumptions regarding the physical groundwater system were made in performing the mass estimates:

- Porosity = 0.48
- Water saturation = 100 percent
- Saturated water content by weight = 0.34
- Dry bulk density = 1.4 g/cm^3
- Percent of organic carbon, f_{oc} = 0.30 percent
- Wet bulk density = 1.9 g/cm^3

The thicknesses of the aquifer zones were calculated in the following manner by using the bottoms of Monitoring Zones A, B, and C presented in the PGOURI (Radian, 1992):

- The thickness of the A zone was calculated from the difference between the January 1993 water levels and the bottom of the A zone.

- The thickness of the B zone was calculated from the difference between the bottom of the A zone and the bottom of the B zone.

- The thickness of the C zone is calculated from the difference between the bottom of the B zone and the bottom of the C zone.

The thickness of these zones varies Basewide and significantly affects the volume of the contaminated aquifer and subsequently the estimation of VOC mass.

Methodology

The following section presents the equations that govern the distribution of contaminant mass between the aqueous and sorbed phases.

The concentration of sorbed contaminants is related to the concentration of contaminants in solution by the following relationship:

$$C_s = K_d \times C_w$$

where

C_s *is the concentration sorbed to soil in* $\dfrac{\text{mass contaminant}}{\text{mass soil}}$

C_w *is the concentration in water in* $\dfrac{\text{mass contaminant}}{\text{vol water}}$

K_d *is the partition coefficient* $= K_{oc}\ F_{oc}$

Table K-4 presents the partition coefficients used in the mass estimates.

Table K-4 Parameters Used in Mass Estimate Calculations			
VOC	K_{oc} (cm^3/gram	f_{oc} (%)	Kd
TCE	126	0.30	0.378
cis-1,2-DCE	32	0.30	0.096
1,2-DCA	14	0.30	0.042
PCE	661	0.30	1.98
1,1,1-TCA	151	0.30	0.453
1,1-DCE	65	0.30	0.195
Source: U.S. EPA, 1990.			

The mass of contaminants in solution and sorbed to the soil are related to the volume of matrix and the contaminant concentration in that matrix in the following manner:

Mass Sorbed:

$$\begin{aligned} M_s &= C_s\, M_{soil} \\ &= K_d\, C_w\, V_{aquifer} \rho_{soil} (1-n) \end{aligned}$$

Mass in Groundwater:

$$\begin{aligned} M_w &= C_w\, V_w \\ &= C_w\, V_{aquifer}\, n \rho_w \end{aligned}$$

where:

ρ_{soil} *is the wet bulk density of the soil*

ρ_w *is the density of water at 60°F*

n = *water filled porosity of aquifer*

Therefore, the total mass of contaminant in a volume of contaminated aquifer is defined by:

Mass Total:

$$= M_s + M_w$$
$$= K_d \, C_w \, V_{aquifer} \, \rho_{soil} \, (1-n) + n \, C_w \, V_{aquifer} \, \rho_w$$

The maximum COC concentration measured at each well between January 1988 to January 1993 were used to calculate the mass estimates. The mass and volume of contaminated aquifer in each of the following contours was estimated to be 0.5, 1, 5, 10, 50, 100, 500, 1,000, and 10,000 µg/l. The outer boundary contour, set at a value of O, was determined by the background level target volumes previously determined for each zone. The mass of TCE, cis-1,2-DCE, PCE, 1,2-DCA, 1,1,1-TCA, and 1,1-DCE between each contour and the associated volume of aquifer between each contour are presented in Table K-5. The average contaminant concentration between each contour interval was used to determine the mass within the contours. The cumulative mass versus volume graphs in Figures K-11, K-12, K-13, K-14, K-15, and K-16 summarize the mass/volume relationship based on these calculations. For example, the first data point represents the mass and volume within the 10,000 µg/l contour; the second data point represents the summation of the mass and volume within the 10,000 µg/l contour and the 1,000 to 10,000 µg/l contour.

The GSAP results for the VOCs of concern for all McClellan AFB monitoring wells are presented in Table K-6.

Table K-5
COC Mass and Contaminated Aquifer Volume By Concentration Contour Intervals
Groundwater Operable Unit

Concentration (µg/l)	A Zone Volume (million ft³)	A Zone Mass (kg)	B Zone Volume (million ft³)	B Zone Mass (kg)	C Zone Volume (million ft³)	C Zone Mass (kg)	Total Volume (million ft³)	Total Mass (kg)
TCE								
0.5	2,200	7,900	1,300	400	1,000	170	4,600	8,500
1.0	2,000	7,900	1,100	390	820	160	3,900	8,400
5.0	800	7,800	400	340	240	120	1,400	8,300
10	600	7,800	310	330	120	100	1,000	8,200
50	410	7,600	85	180	13	24	510	7,900
100	320	7,500	47	110	1.4	3.4	370	7,600
500	65	5,600					65	5,600
1,000	37	5,100					37	5,100
10,000	4.2	1,000					4.2	1,000
PCE								
0.5	180	760	250	33	0.0	0.0	420	790
1.0	120	750	150	28			270	780
5.0	94	750	22	7.7			120	760
10	82	740					82	740
50	41	660					41	660
100	21	550					21	550
500	3.1	180					3.1	180
1000	1.4	96					1.4	96
1,1,1-TCA								
0.5	97	250	20	0.45	210	4.5	330	260
1.0	59	250	7.6	0.20	67	1.8	130	260
5.0	27	250					27	250
10	24	250					24	250
50	20	250					20	250
100	19	240					19	240
500	7.9	160					7.9	160
1000	1.1	28					1.1	28

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Table K-5
COC Mass and Contaminated Aquifer Volume By Concentration Contour Intervals
Groundwater Operable Unit

Concentration (µg/l)	A Zone Volume (million ft ^{3})	A Zone Mass (kg)	B Zone Volume (million ft ^{3})	B Zone Mass (kg)	C Zone Volume (million ft ^{3})	C Zone Mass (kg)	Total Volume (million ft ^{3})	Total Mass (kg)
cis-1,2-DCE								
0.5	1,100	170	510	43	550	34	2,200	250
1.0	860	170	430	42	410	32	1,700	250
5.0	480	160	220	32	110	20	820	210
10	370	150	150	24	8.7	7	520	180
50	44	62					44	62
100	21	34					21	34
1,2-DCA								
0.5	130	18	830	9.5	8.6	0.06	970	27
1.0	97	17	93	1.4			190	19
5.0	57	16					57	16
10	40	14					40	14
50	3.2	3.6					3.2	3.6
100	0.14	0.21					0.14	0.21
1,1-DCE								
0.5	360	2,900	86	1.5	46	0.63	490	2,900
1.0	63	2,900	56	1.1	24	0.43	140	2,900
5.0	58	2,900			18	0.34	76	2,900
10	45	2,900					45	2,900
50	39	2,900					39	2,900
100	30	2,800					30	2,800
500	25	2,800					25	2,800
1000	1.4	260					1.4	260

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0004	31-Mar-82	0	0		0	0	0	0	0	G	ATF
MW-0004	02-Oct-84								0	G	ATF
MW-0006	30-Mar-82	0	0		0	0	24	0	7.49E-06	B	A
MW-0006	01-Oct-84								0	B	A
MW-0006	13-Jun-85	0	0		0	0	86.2	0	2.69E-05	B	A
MW-0007	17-Mar-82	0	0		0	0	30	0	9.36E-06	B	A
MW-0007	29-Mar-82	0	0		0	0	29	0	9.05E-06	B	A
MW-0007	21-Sep-84								0	B	A
MW-0007	31-May-85	0	0		0	0	38.2	0	1.93E-05	B	A
MW-0007	28-Apr-89	0	0		0	0	26	0	1.09E-05	B	A
MW-0007	04-Aug-89	0	0		0	0	29	0	9.05E-06	B	A
MW-0007	04-Aug-89	0.5	0		0	0	30	0	9.05E-06	B	A
MW-0007	11-Dec-89	0	0		0	0	36	0	1.36E-05	B	A
MW-0007	11-Dec-89	1.3	0		0	0	45	0	1.36E-05	B	A
MW-0007	07-Feb-90	0	0		0	2.8	47	0	1.47E-05	B	A
MW-0007	25-Apr-90	0	0		0	0	41	0	1.66E-05	B	A
MW-0007	25-Apr-90	0.5	0		0	0	40	0	1.66E-05	B	A
MW-0007	02-Jul-90	0.26	0		0	0	36	0	1.38E-05	B	A
MW-0007	29-Oct-90	0	0		0	0	30	0	1.14E-05	B	A
MW-0007	10-Jan-91	0.48	0		0.46	0.25	23	0	1.72E-05	B	A
MW-0007	10-Jan-91	0.77	0		0.99	0	39	0	1.72E-05	B	A
MW-0007	01-May-91	0	0		0	0	31	0	9.68E-06	B	A
MW-0007	01-Aug-91	0.45	0		0	0	24	0	1.02E-05	B	A
MW-0007	01-Aug-91	0.74	0		0	0	23	0	1.02E-05	B	A
MW-0007	09-Oct-91	0.83	0		0	0	26	0	1.70E-05	B	A
MW-0007	29-Jan-92	0.78	0		0	0	39	0	1.99E-05	B	A
MW-0007	23-Jul-92	0.76	0	19	0	0	19	0	9.69E-06	B	A
MW-0007	19-Oct-92	0.54	3.6	13	0	0	20	0	1.06E-05	B	A
MW-0007	26-Jan-93	0.34	0	13	0	0	21	0	1.18E-05	B	A
MW-0007	26-Jan-93	0.4	0	16	0	0	24	0	1.18E-05	B	A
MW-0007	09-Apr-93	0.33	0	16	0	0	28	0	2.58E-05	B	A
MW-0007	21-Jul-93	0.456	0	13.20	0	0	21	0	1.93E-05	B	A
MW-0008	31-Mar-82	0	0		0	0	61	0	1.90E-05	A	A
MW-0009	31-Mar-82	0	0		0	0	0	0	0	A	A
MW-0009	28-Apr-82	0	0		0	0	225	0	1.88E-04	A	A
MW-0009	30-Sep-84								0	A	A
MW-0009	16-Jun-85	0.2	0.4		0	0	134	0	9.52E-05	A	A
MW-0010	30-Mar-82	17	500		0	0	140	0	8.03E-05	D	A
MW-0010	20-Jun-85	94.7	1500		64.9	327	826	0	5.56E-04	D	A
MW-0010	26-Oct-87	330	1100		0	21	910	810	2.22E-02	D	A
MW-0010	07-Apr-88	390	910		2.4	36	1500	400	1.18E-02	D	A
MW-0010	22-Jul-88	410	1400		0	0	2100	360	1.10E-02	D	A
MW-0010	20-Oct-88	270	1000		0	23	1600	100	3.71E-03	D	A
MW-0010	25-Jan-89	270	900		0	0	1300	73	2.91E-03	D	A
MW-0010	25-Apr-89	320	450		0	12	810	51	2.28E-03	D	A
MW-0010	04-Aug-89	280	590		0	0	1100	49	2.24E-03	D	A
MW-0010	29-Dec-89	7000	370		0	0	1300	0	1.54E-02	D	A
MW-0010	21-Feb-90	250	350		0	30	780	0	7.82E-04	D	A
MW-0010	27-Apr-90	200	550		0	0	1000	0	7.82E-04	D	A
MW-0010	27-Apr-90	200	730		0	0	1100	0	7.82E-04	D	A
MW-0010	30-Apr-91	210	370		0	0	790	0	6.99E-04	D	A
MW-0010	24-Jul-92	110	250	0	0	0	400	0	3.64E-04	D	A
MW-0010	06-Apr-93	120	170	0	0	0	390	0	8.64E-04	D	A
MW-0011	30-Mar-82	0	19300		10	4300	2100	20	2.02E-03	D	A
MW-0011	18-Aug-82	0	63000		0	12000	5000	0	1.56E-03	D	A
MW-0011	19-Sep-84								0	D	A
MW-0011	20-Jun-85	0	64300		2480	18100	11900	0	7.54E-03	D	A
MW-0011	27-Oct-87	0	40000		0	6900	5600	0	4.48E-03	D	A
MW-0011	06-Apr-88	86	17000		25	3800	6200	13	2.81E-03	D	A
MW-0011	25-Jul-88	0	20000		0	2700	2900	0	9.05E-04	D	A
MW-0011	31-Jan-89	0	19000		0	5600	2900	0	9.05E-04	D	A

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0011	27-Apr-89	0	14000		0	2100	2000	0	6.24E-04	D	A
MW-0011	04-Aug-89	0	17000		0	2800	2800	0	8.74E-04	D	A
MW-0011	04-Aug-89	0	17000		0	2900	3000	0	8.74E-04	D	A
MW-0011	28-Dec-89	0	20000		0	3400	3200	0	9.99E-04	D	A
MW-0011	22-Feb-90	0	17000		0	3700	3900	0	1.22E-03	D	A
MW-0011	22-Feb-90	0	21000		0	4400	3000	0	1.22E-03	D	A
MW-0011	11-May-90	0	27000		0	3900	5000	0	1.56E-03	D	A
MW-0011	01-May-91								5.31E-04	D	A
MW-0011	01-May-91	0	12000		0	990	1700	0	5.31E-04	D	A
MW-0011	28-Jul-93	0	13600	0	0	1290	1400	0	1.00E-03	D	A
MW-0012	29-Apr-82	0	4200		70	2700	930	0	3.80E-04	D	A
MW-0012	18-Aug-82	0	2500		18	520	160	0	7.30E-05	D	A
MW-0012	20-Sep-84								0	D	A
MW-0012	19-Jun-85	0	25500		1260	12400	121[illegible]	0	5.39E-03	D	A
MW-0012	23-Oct-87	0	11000		280	3200	4700	0	1.83E-03	D	A
MW-0012	07-Apr-88	0	8400		200	1200	2500	0	1.04E-03	D	A
MW-0012	26-Jul-88	0	22000		610	4500	6900	0	2.93E-03	D	A
MW-0012	21-Oct-88	0	4000		70	590	1200	0	4.64E-04	D	A
MW-0012	25-Jan-89	0	2600		38	360	590	0	2.33E-04	D	A
MW-0012	27-Apr-89	0	2600		0	370	600	0	1.87E-04	D	A
MW-0012	04-Aug-89	0	5700		270	840	1400	0	7.83E-04	D	A
MW-0012	28-Dec-89	0	8800		0	1600	2300	0	7.18E-04	D	A
MW-0012	20-Feb-90	0	7800		140	860	1400	0	6.16E-04	D	A
MW-0012	27-Apr-90	0	8300		94	470	1200	0	4.95E-04	D	A
MW-0012	24-Jul-91	0	3700		0	0	720	0	2.25E-04	D	A
MW-0012	19-Oct-92	0	6100	0	0	470	1100	0	4.64E-04	D	A
MW-0012	20-Jul-93	0	6610	0	0	0	976	0	7.26E-04	D	A
MW-0013	30-Mar-82	0	1100		20	300	1470	50	2.01E-03	D	A
MW-0013	18-Aug-82	0	780		0	68	230	0	7.18E-05	D	A
MW-0014	30-Mar-82	0	4600		0	8700	5800	25	3.25E-03	D	A
MW-0014	18-Aug-82	0	17000		0	2300	11000	0	3.43E-03	D	A
MW-0014	20-Sep-84								0	D	A
MW-0014	19-Jun-85	2790	22600		0	22800	26600	0	1.97E-02	D	A
MW-0014	26-Oct-87	0	260		0	350	350	0	1.09E-04	D	A
MW-0014	06-Apr-88	36	5700		7.6	3100	6500	1.4	2.17E-03	D	A
MW-0014	22-Jul-88	0	13000		0	5500	11000	0	3.43E-03	D	A
MW-0014	20-Oct-88	0	4400		0	3200	3800	0	1.19E-03	D	A
MW-0014	26-Jan-89	34	4600		0	2600	4100	0	1.35E-03	D	A
MW-0014	26-Apr-89	0	2900		0	1100	1500	0	5.08E-04	D	A
MW-0014	04-Aug-89	0	2300		0	1600	1400	0	4.37E-04	D	A
MW-0014	28-Dec-89	0	3400		0	2900	2400	0	7.49E-04	D	A
MW-0014	21-Feb-90	0	1800		0	1700	1900	0	5.93E-04	D	A
MW-0014	11-May-90	0	3700		0	1900	5000	0	1.56E-03	D	A
MW-0014	30-Jul-91	0	4300		0	4700	3700	0	1.15E-03	D	A
MW-0014	26-Jan-93	0	2100	0	0	1100	1700	0	5.32E-04	D	A
MW-0014	06-Apr-93	0	2100	0	0	1200	2100	0	1.49E-03	D	A
MW-0014	06-Apr-93	0	2400	0	0	1300	2300	0	1.49E-03	D	A
MW-0015	29-Apr-82	0	5980		0	2200	2800	0	3.58E-03	D	A
MW-0015	18-Aug-82	0	9600		0	2500	3000	0	1.01E-03	D	A
MW-0015	18-Sep-84								1.88E-02	D	A
MW-0015	16-Jun-85	0	16500		0	4100	18000	0	5.98E-03	D	A
MW-0015	26-Oct-87	0	1500		0	180	1000	0	3.12E-04	D	A
MW-0015	06-Apr-88	6.8	83		0	110	550	1.5	2.29E-04	D	A
MW-0015	22-Jul-88	5.6	800		0	110	590	0	1.96E-04	D	A
MW-0015	20-Oct-88	0	850		0	320	570	0	1.78E-04	D	A
MW-0015	25-Jan-89	0	580		0	170	340	0	1.06E-04	D	A
MW-0015	26-Apr-89	5.9	230		0	19	140	0	5.64E-05	D	A
MW-0015	03-Aug-89	0	520		0	130	310	0	9.68E-05	D	A
MW-0015	28-Dec-89	0	860		0	360	630	0	1.97E-04	D	A
MW-0015	15-Feb-90	0	470		0	140	320	0	9.99E-05	D	A
MW-0015	07-May-90	0	2100		0	670	1400	0	4.37E-04	D	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0015	07-May-90	0	2300		0	700	1300	0	4.37E-04	D	A
MW-0015	19-Jul-91	0	550		0	310	430	0	1.34E-04	D	A
MW-0015	13-Jan-93	0	320	0	0	170	310	0	9.68E-05	D	A
MW-0015	28-Jul-93	0	151	0	0	6.71	82.10	0	5.45E-05	D	A
MW-0016D	16-Jun-82	0	0		0	0	0	0	0	F	AB
MW-0016D	17-Aug-82	0	0		0	0	0	0	0	F	AB
MW-0016D	24-Sep-84								0	F	AB
MW-0016D	14-Jun-85	0	0		0	0	0	0	0	F	AB
MW-0016S	16-Jun-82	0	0		0	0	0	0	0	F	A
MW-0016S	17-Aug-82	0	10		0	0	10	0	3.12E-06	F	A
MW-0016S	26-Sep-84								0	F	A
MW-0016S	30-May-85	0	0		0	0	0	0	4.98E-07	F	A
MW-0017D	16-Jun-82	0	0		0	0	0	0	0	F	AB
MW-0017D	17-Aug-82	0	0		0	0	0	0	0	F	AB
MW-0017D	26-Sep-84								0	F	AB
MW-0017D	30-May-85	0	0		0	0	0	0	0	F	AB
MW-0017D	14-May-87	0	0		0	0	0	0	0	F	AB
MW-0017D	11-Aug-87	0	0		0	0	0	0	0	F	AB
MW-0017D	22-Oct-87	0.33	0.32		0	0	0.39	0	8.32E-07	F	AB
MW-0017D	27-Jan-88	0	0		0	0	0	0	0	F	AB
MW-0017D	08-Apr-88	0	0		0	0	0	0	0	F	AB
MW-0017D	21-Jul-88	0	0		0	0	0	0	0	F	AB
MW-0017D	18-Oct-88	0	0		0	0	0	0	0	F	AB
MW-0017D	27-Dec-89	0	0		0	0	0	0	0	F	AB
MW-0017D	30-Jul-90	0	0		0.27	0	0	0	3.46E-07	F	AB
MW-0017D	16-Jul-91	0	0		0	0	0	0	1.56E-07	F	AB
MW-0017S	16-Jun-82	0	0		0	0	0	0	0	F	A
MW-0017S	17-Aug-82	0	0		0	0	0	0	0	F	A
MW-0017S	13-Sep-84								0	F	A
MW-0017S	05-Jun-85	0	0		0	0	0	0	0	F	A
MW-0018D	15-Jun-82	0	0		0	0	0	0	0	E	B
MW-0018D	16-Aug-82	0	0		0	0	0	0	0	E	B
MW-0018D	25-Sep-84								0	E	B
MW-0018D	14-Jun-85	0	0		0	0	0	0	0	E	B
MW-0018D	28-Mar-86	0	0		0	0	0	0	3.85E-06	E	B
MW-0018D	01-Oct-86	0	0		0	0	0	0	3.31E-07	E	B
MW-0018D	12-Jan-87	0	0		0	0	0	0	0	E	B
MW-0018D	29-Apr-87	0	0		0	0	0	0	0	E	B
MW-0018D	11-Aug-87	0	0		0	0	0	0	0	E	B
MW-0018D	08-Oct-87	0	0		0	0	0	0	0	E	B
MW-0018D	22-Jan-88	0	0		0	0	0	0	1.32E-07	E	B
MW-0018D	27-Apr-88	0	0		0	0	0	0	0	E	B
MW-0018D	18-Jul-88	0	0		0	0	0	0	1.59E-07	E	B
MW-0018D	10-Oct-88	0	0		0	0	0	0	0	E	B
MW-0018D	12-Oct-89	0	0		0	0	0	0	1.72E-07	E	B
MW-0018D	30-Jul-90	0	0		0	0	0	0	0	E	B
MW-0018D	25-Jul-91	0	0		0	0	0	0	0	E	B
MW-0018D	10-Oct-91	0	0		0	0	0	0	0	E	B
MW-0018D	06-Feb-92	0	0		0	0	0	0	0	E	B
MW-0018S	15-Jun-82	0	0		0	0	0	0	0	E	A
MW-0018S	16-Aug-82	0	0		0	0	0	0	0	E	A
MW-0018S	29-Sep-84								0	E	A
MW-0018S	06-Jun-85	0	0		0	0	1.1	0	3.43E-07	E	A
MW-0019D	28-Apr-82	0	0		0	0	0	0	0	D	B
MW-0019D	16-Aug-82	0	0		0	0	0	0	0	D	B
MW-0019D	09-Aug-83	0	3.6		0	0	0	0	2.65E-06	D	B
MW-0019D	13-Sep-84								0	D	B
MW-0019D	16-Jun-85	0	0		0	0	0	0	0	D	B
MW-0019D	26-Oct-87	0	0		0	0	0	0	2.08E-07	D	B
MW-0019D	08-Apr-88	0	0.25		0	0	0	0	0	D	B
MW-0019D	21-Oct-88	0	0		0	0	0	0	0	D	B

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0019D	11-Jan-90	0	0		0	0.28	0	0	0	D	B
MW-0019D	28-Feb-90	0	0		0	0	0	0	1.15E-06	D	B
MW-0019D	30-Apr-90	0	0		0	0	0	0	0	D	B
MW-0019D	10-Oct-90	0	0		0	0	0	0	0	D	B
MW-0019D	24-Jul-91	0	0		0	0	0	0	0	D	B
MW-0019D	27-Jan-93	0	1.6	0	0	2.7	2.9	0	9.05E-07	D	B
MW-0019S	16-Aug-82	0	0		0	0	0	0	0	D	A
MW-0019S	09-Aug-83	0	7		3.8	0	0	0	6.46E-06	D	A
MW-0019S	14-Sep-84								0	D	A
MW-0019S	14-Jun-85	0	0.9		0	0	4.3	0	1.34E-06	D	A
MW-0019S	16-Oct-86	0	1.2		0	0	8.2	0	2.56E-06	D	A
MW-0020D	28-Apr-82	0	0		0	0	0	0	0	C	B
MW-0020D	11-Aug-82	0	0		0	0	0	0	0	C	B
MW-0020D	19-Sep-84								0	C	B
MW-0020D	18-Jun-85	0	0		0	0	0	0	0	C	B
MW-0020D	27-Oct-86	0	0		0	0	0	0	0	C	B
MW-0020D	29-Jan-87	0	0		0	0	0	0	0	C	B
MW-0020D	05-May-87	0	0		0	0	0	0	0	C	B
MW-0020D	28-Jul-87	0	0		0	0	0	0	0	C	B
MW-0020D	12-Oct-87	0	0		0	0	0	0	0	C	B
MW-0020D	22-Jan-88	0	0		0	0	0	0	0	C	B
MW-0020D	11-Apr-88	0	0		0	0	0	0	0	C	B
MW-0020D	13-Jul-88	0	0		0	0	0	0	0	C	B
MW-0020D	07-Oct-88	0	0		0	0	0	0	0	C	B
MW-0020D	23-Jan-89	0	0		0	0	0	0	0	C	B
MW-0020D	11-Apr-89	0	0		0	0	0	0	0	C	B
MW-0020D	14-Jul-89	0	0		0	0	0	0	0	C	B
MW-0020D	09-Oct-89	0	0		0	0	0	0	0	C	B
MW-0020D	23-Jan-90	0	0		0	0.42	0	0	0	C	B
MW-0020D	11-Apr-90	0	0		0	0	0	0	0	C	B
MW-0020D	12-Jul-90	0	0		0	0	0.3	0	9.36E-08	C	B
MW-0020D	10-Jan-91	0	0		0	0	0	0	0	C	B
MW-0020D	26-Jul-91	0	0		0	0	0	0	0	C	B
MW-0020D	19-Apr-93	0	0	0	0	0	0	0	0	C	B
MW-0020S	25-May-82	0	0		0	0	0	0	1.09E-04	C	A
MW-0020S	11-Aug-82	0	0		0	0	0	0	0	C	A
MW-0020S	30-Sep-84								0	C	A
MW-0020S	03-Jun-85	0	0		0	3.2	2.3	0	7.18E-07	C	A
MW-0020S	27-Oct-86	0	0.35		0.4	0.91	0	0	5.12E-07	C	A
MW-0021D	15-Jun-82	0	0		0	0	0	0	0	C	A
MW-0021D	17-Sep-84								0	C	A
MW-0021D	03-Jun-85	0	0		0	0	0.8	0	2.50E-07	C	A
MW-0021D	19-Mar-86	0	0		0	0	0	0	0	C	A
MW-0021D	30-Sep-86	0	0		0	0	0	0	0	C	A
MW-0021D	21-Jan-87	0	0		0	0	0	0	0	C	A
MW-0021D	01-May-87	0	0		0	0	0	0	0	C	A
MW-0021D	14-Aug-87	0	0		0	0	0	0	0	C	A
MW-0021D	17-Oct-87	0	0		0	0	0	0	0	C	A
MW-0021D	25-Jan-88	0	0		0	0	0	0	0	C	A
MW-0021D	13-Apr-88	0	0		0	0	0	0	0	C	A
MW-0021D	18-Jul-88	0	0		0	0	0	0	0	C	A
MW-0021D	18-Oct-88	0	0		0	0	0	0	0	C	A
MW-0021D	23-Jan-89	0	0		0	0	0	0	0	C	A
MW-0021D	18-Apr-89	0	0		0	0	0	0	0	C	A
MW-0021D	17-Jul-89	0	0		0	0	0	0	0	C	A
MW-0021D	16-Dec-89	0	0		0	0	0	0	0	C	A
MW-0021D	31-Jan-90	0	0		0	0	0	0	0	C	A
MW-0021D	13-Apr-90	0	0		0	0	0	0	0	C	A
MW-0021D	12-Jul-90	0	0		0	0	0.36	0	1.12E-07	C	A
MW-0021D	15-Oct-90	0	0		0	0	0	0	0	C	A
MW-0021D	10-Jan-91								0	C	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0021D	22-Jul-91	0	0		0	0	0	0	2.28E-07	C	A
MW-0021S	15-Jun-82	0	0		0	0	0	0	0	C	A
MW-0021S	13-Aug-82	0	0		0	0	0	0	0	C	A
MW-0021S	17-Sep-84								0	C	A
MW-0021S	20-Jun-85	0	0		0	0	2.1	0	6.55E-07	C	A
MW-0021S	19-Mar-86	0	0		0	0	0.2	0	6.52E-07	C	A
MW-0021S	30-Sep-86	0	0		0.12	0	0.99	0	7.14E-07	C	A
MW-0021S	30-Jan-87	0	0		0	0	0	0	0	C	A
MW-0021S	14-Aug-87	0	0		0	0	1.9	0	5.93E-07	C	A
MW-0021S	17-Oct-87	0	0		0	0	0.4	0	2.97E-07	C	A
MW-0021S	25-Jan-88	0	0		0	0	0.48	0	3.62E-07	C	A
MW-0021S	13-Apr-88	0	0		0	0	0.57	0	3.63E-07	C	A
MW-0021S	26-Jul-88	0	0		0	0	1.1	0	6.61E-07	C	A
MW-0021S	21-Oct-88	0	0		0	0	0.77	0	2.40E-07	C	A
MW-0021S	24-Jan-89	0	0		0	0	1.5	0	6.14E-07	C	A
MW-0022D	28-Apr-82	0	0		0	0	0	0	0	C	B
MW-0022D	13-Aug-82	0	0		0	0	0	0	0	C	B
MW-0022D	20-Sep-84								0	C	B
MW-0022D	20-Jun-85	0	297		13.5	133	213	0	8.66E-05	C	B
MW-0022D	29-Oct-86	0	0		0	0	0	0	0	C	B
MW-0022D	23-Jan-87	0	0		0	0	0	0	0	C	B
MW-0022D	06-May-87	0	0		0	0	0	0	0	C	B
MW-0022D	06-Aug-87	0	0		0	0	0	0	0	C	B
MW-0022D	14-Oct-87	0	0		0	0	0	0	0	C	B
MW-0022D	19-Jan-88	0	0		0	0	0	0	0	C	B
MW-0022D	25-Apr-88	0	0		0	0	0	0	0	C	B
MW-0022D	14-Jul-88	0	0		0	0	0	0	0	C	B
MW-0022D	17-Oct-88	0	0		0	0	0	0	0	C	B
MW-0022D	12-Jan-89	0	0		0	0	0	0	0	C	B
MW-0022D	12-Apr-89	0	0		0	0	0	0	0	C	B
MW-0022D	17-Jul-89	0	0		0	0	0	0	0	C	B
MW-0022D	17-Oct-89	0	0		0	0	0	0	0	C	B
MW-0022D	26-Jan-90	0	0		0	0		0	0	C	B
MW-0022D	19-Apr-90	0	0		0.49	0	0	0	6.27E-07	C	B
MW-0022D	13-Jul-90	0	0		0	0	0.68	0	2.12E-07	C	B
MW-0022D	15-Oct-90	0	0		0	0	0	0	0	C	B
MW-0022D	09-Jan-91	0	0		0	0	0	0	0	C	B
MW-0022D	04-Feb-91								0	C	B
MW-0022D	29-Jul-91	0	0		0	0	0	0	0	C	B
MW-0022S	04-Jun-82	0	0		0	0	8	0	2.50E-06	C	AB
MW-0022S	13-Aug-82	0	0		0	0	16	0	4.99E-06	C	AB
MW-0022S	21-Sep-84								0	C	AB
MW-0023D	28-Apr-82	0	0		0	0	0	0	0	B	B
MW-0023D	13-Aug-82	0	0		0	0	0	0	0	B	B
MW-0023D	26-Sep-84								0	B	B
MW-0023D	10-Jun-85	0	0		0	0	0	0	5.19E-07	B	B
MW-0023D	17-Mar-86	0	0		0	0	0	0	1.25E-06	B	B
MW-0023D	22-Jan-87	0	0		0	0	0	0	0	B	B
MW-0023D	05-May-87	0	0		0	0	0	0	0	B	B
MW-0023D	12-Aug-87	0	0		0	0	0	0	0	B	B
MW-0023D	25-Oct-87	0	0		0	0	0	0	0	B	B
MW-0023D	21-Jan-88	0	0		0	0	0	0	0	B	B
MW-0023D	21-Apr-88	0	0		0	0	0	0	0	B	B
MW-0023D	21-Jul-88	0	0		0	0.3	0	0	0	B	B
MW-0023D	19-Oct-88	0	0		0	0	0	0	0	B	B
MW-0023D	09-Jan-89	0	0		0	0	0	0	0	B	B
MW-0023D	19-Apr-89	0	0		0	0	0	0	0	B	B
MW-0023D	13-Jul-89	0	0		0	0	0	0	0	B	B
MW-0023D	14-Dec-89	0	0		0	0	0	0	1.22E-07	B	B
MW-0023D	16-Jan-90	0	0		0	0	0	0	0	B	B
MW-0023D	23-Jul-90	0	0		0	0	0	0	0	B	B

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0023D	09-Jan-91	0	0		0	0	0	0	1.85E-07	B	B
MW-0023D	04-Feb-91								0	B	B
MW-0023D	01-Aug-91	0	0		0	0	0	0	0	B	B
MW-0023D	07-Oct-91	0	0		0	0	0	0	0	B	B
MW-0023D	14-Jan-92	0	0		0	0	0.27	0	8.43E-08	B	B
MW-0023D	06-Jul-92	0	0	0	0	0	0	0	0	B	B
MW-0023D	07-Oct-92	0	0	0	0	0	0	0	0	B	B
MW-0023D	07-Jan-93	0	0	0	0	0	0	0	0	B	B
MW-0023D	21-Jul-93	0	0	0	0	0	0	0	0	B	B
MW-0023S	28-Apr-82	0	0		0	0	0	0	0	B	A
MW-0023S	13-Aug-82	0	0		0	0	0	0	0	B	A
MW-0023S	29-Sep-84								0	B	A
MW-0023S	03-Jun-85	0	0		0	0	2.7	0	4.15E-06	B	A
MW-0024D	28-Apr-82	0	0		0	0	0	0	0	B	B
MW-0024D	12-Aug-82	0	0		0	0	0	0	0	B	B
MW-0024D	27-Sep-84								0	B	B
MW-0024D	07-Jun-85	0	0		0	0	0	0	0	B	B
MW-0024D	20-Mar-86	0	0		0	0	0	0	0	B	B
MW-0024D	22-Jan-87	0	0		0	0	0	0	0	B	B
MW-0024D	05-May-87	0	0		0	0	0	0	0	B	B
MW-0024D	13-Aug-87	0	0		0	0	0	0	0	B	B
MW-0024D	19-Jan-88	0	0		0	0	0	0	0	B	B
MW-0024D	21-Apr-88	0	0		0	0	0	0	0	B	B
MW-0024D	12-Jul-88	0	0		0	0	0	0	0	B	B
MW-0024D	05-Oct-88	0	0		0	0	0	0	0	B	B
MW-0024D	13-Jan-89	0	0		0	0.25	0	0	1.35E-07	B	B
MW-0024D	11-Apr-89	0	0		0	0	0	0	0	B	B
MW-0024D	18-Jul-89	0	0		0	0	0	0	0	B	B
MW-0024D	20-Dec-89	0	0		0	0	0	0	0	B	B
MW-0024D	16-Jan-90	0	0		0	0	0	0	0	B	B
MW-0024D	20-Apr-90	0	0		0	0	0	0	0	B	B
MW-0024D	15-Oct-90	0	0		0	0	0	0	0	B	B
MW-0024D	09-May-91	0	0		0	0	0	0	0	B	B
MW-0024D	21-Jul-93	0.17	0	0	0	0	0	0	8.50E-07	B	B
MW-0024S	28-Apr-82	0	0		0	0	0	0	0	B	A
MW-0024S	12-Aug-82	0	0		0	0	0	0	0	B	A
MW-0024S	12-Sep-84								0	B	A
MW-0024S	02-Jun-85	0	0		0	0	0	0	0	B	A
MW-0025D	15-Jun-82	0	0		0	0	0	0	0	B	A
MW-0025D	12-Aug-82	0	0		0	0	0	0	0	B	A
MW-0025D	25-Sep-84								0	B	A
MW-0025D	13-Jun-85	0	0		0	0	2.9	0	9.05E-07	B	A
MW-0025D	21-Oct-88	0.15	0		0	0	1.2	0	1.00E-06	B	A
MW-0025D	24-Jan-89	0.24	0		0	0	1.1	0	1.30E-06	B	A
MW-0025D	24-Jan-89	0.24	0		0	0	1.2	0	1.30E-06	B	A
MW-0025D	24-Apr-89	0.34	0		0	0	1	0	1.60E-06	B	A
MW-0025D	01-Aug-89	0	0		0	0	0.8	0	2.50E-07	B	A
MW-0025D	01-Aug-89	0	0		0	0	2.3	0	2.50E-07	B	A
MW-0025D	29-Dec-89	0	0		0	0	1.6	0	4.99E-07	B	A
MW-0025D	31-Jan-90	0	0		0	0	2.8	0	1.97E-06	B	A
MW-0025D	10-Apr-90	0.25	0		0	0	1.2	0	2.05E-06	B	A
MW-0025D	02-Jul-90	0	0		0	0	5.9	0	4.35E-06	B	A
MW-0025D	10-Oct-90	0	0		0	0	0.44	0	1.37E-07	B	A
MW-0025D	10-Jan-91	0.25	0		0	0	1	0	1.73E-06	B	A
MW-0025D	08-Apr-91	0.22	0		0	0	1.5	0	1.56E-06	B	A
MW-0025D	17-Jul-91	0	0		0	0	1.1	0	3.43E-07	B	A
MW-0025D	21-Jul-93	0	0	0.58	0	0	0.67	0	1.40E-06	B	A
MW-0025S	15-Jun-82	0	0		0	0	50	0	1.56E-05	B	A
MW-0025S	12-Aug-82	0	0		0	0	0	0	0	B	A
MW-0025S	29-Sep-84								0	B	A
MW-0025S	30-May-85	0	0		0	0	2.4	0	7.49E-07	B	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0026D	28-Apr-82	0	0		0	0	0	0	0	A	B
MW-0026D	11-Aug-82	0	0		0	0	0	0	0	A	B
MW-0026D	27-Sep-84								0	A	B
MW-0026D	18-Jun-85	0	3.8		0	2.6	8.7	0	6.03E-06	A	B
MW-0026D	25-Oct-88	0	0		0	0	8.1	0	3.48E-06	A	B
MW-0026D	23-Jan-89	0	0		0	0	22	0	1.00E-05	A	B
MW-0026D	26-Apr-89	0	0		0	0	20	0	1.06E-05	A	B
MW-0026D	26-Apr-89	0	0		0	0	22	0	1.06E-05	A	B
MW-0026D	01-Aug-89	0	0		0	0	34	0	1.14E-05	A	B
MW-0026D	04-Jan-90	0	0		0	0	42	0	2.21E-05	A	B
MW-0026D	04-Jan-90	0	0		0	0	50	0	2.21E-05	A	B
MW-0026D	31-Jan-90	0	0		0	0	44	0	1.37E-05	A	B
MW-0026D	31-Jan-90	0	0		0	0	50	0	1.37E-05	A	B
MW-0026D	19-Apr-90	0	0		0	0	65	0	2.37E-05	A	B
MW-0026D	17-Jul-90	0	0		0	0	71	0	2.63E-05	A	B
MW-0026D	10-Oct-90	0	0		0	0	72	0	2.25E-05	A	B
MW-0026D	11-Jan-91	0	0		0	0	41	0	1.58E-05	A	B
MW-0026D	06-May-91	0	0		0	0	44	0	1.69E-05	A	B
MW-0026D	18-Jul-91	0	0		0	0	69	0	2.15E-05	A	B
MW-0026D	08-Jan-93	0	0	0	0	0	37	0	1.15E-05	A	B
MW-0026D	08-Jan-93	0	0	0	0	0	47	0	1.15E-05	A	B
MW-0026S	16-Jun-82	0	0		0	0	0	0	0	A	A
MW-0026S	11-Aug-82	0	0		0	0	0	0	0	A	A
MW-0026S	29-Sep-84								0	A	A
MW-0026S	02-Jun-85	0	0		0	6.5	21.3	0	1.15E-05	A	A
MW-0027D	28-Apr-82	0	0		0	0	0	0	0	A	B
MW-0027D	12-Aug-82	0	0		0	0	0	0	0	A	B
MW-0027D	01-Oct-84								0	A	B
MW-0027D	30-May-85	0	0		0	0	4.6	0	1.44E-06	A	B
MW-0027D	13-May-87	0	0		0	0	195	0	1.79E-04	A	B
MW-0027D	11-Aug-87	0	0		0	0	71	0	8.28E-05	A	B
MW-0027D	11-Aug-87	0	0		0	0	76	0	8.28E-05	A	B
MW-0027D	22-Oct-87	0.69	0		0	0	39	0	5.79E-05	A	B
MW-0027D	22-Oct-87	0.74	0		0	0	40	0	5.79E-05	A	B
MW-0027D	26-Jan-88	0.41	0		0	0	35	0	4.12E-05	A	B
MW-0027D	08-Apr-88	0.98	0		0	0	56	0	7.39E-05	A	B
MW-0027D	20-Jul-88	0	0		0	0	56	0	3.47E-05	A	B
MW-0027D	20-Jul-88	0.88	0		0	0	91	0	3.47E-05	A	B
MW-0027D	24-Oct-88	0.5	0		0	0	67	0	6.49E-05	A	B
MW-0027D	09-Aug-89	0	0		0	0	87	0	7.36E-05	A	B
MW-0027D	18-Dec-89	0	0		0	0	110	0	7.22E-05	A	B
MW-0027D	18-Dec-89	0	0		0	0	150	0	7.22E-05	A	B
MW-0027D	20-Apr-90	1.9	0		0.98	0		0	2.33E-05	A	B
MW-0027D	18-Jul-90	0	0		0	0	41	0	1.74E-05	A	B
MW-0027D	19-Oct-90	0	0		0	0	63	0	2.38E-05	A	B
MW-0027D	10-Jan-91	0.64	0		0	0	52	0	2.82E-05	A	B
MW-0027D	09-May-91	0	0		0	0	75	0	3.36E-05	A	B
MW-0027D	09-May-91	2.3	0		0	0	74	0	3.36E-05	A	B
MW-0027D	18-Jul-91	0.84	0		0	0	71	0	2.40E-05	A	B
MW-0027D	08-Jan-93	1.4	0	4.1	0	0	26	0	1.13E-04	A	B
MW-0027D	08-Jan-93	1.6	0	6	0	0	35	0	1.13E-04	A	B
MW-0027S	28-Apr-82	0	0		0	0	0	0	0	A	A
MW-0027S	12-Aug-82	0	0		0	0	15	0	4.68E-06	A	A
MW-0027S	12-Sep-84								0	A	A
MW-0027S	05-Jun-85	0	0		0	0	63.4	0	4.48E-05	A	A
MW-0028D	16-Jun-82	0	0		0	0	0	0	0	A	A
MW-0028D	17-Aug-82	0	0		0	0	0	0	0	A	A
MW-0028D	26-Sep-84								0	A	A
MW-0028D	16-Jun-85	0	6.5		0	2.5	8.9	0	2.78E-06	A	A
MW-0028D	15-May-87	0	0		0	0	0	0	0	A	A
MW-0028D	07-Aug-87	0	0		0	0	0	0	0	A	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0028D	23-Oct-87	0	0		0	0	0	0	0	A	A
MW-0028D	27-Jan-88	0	0		0	0	0	0	0	A	A
MW-0028D	13-Apr-88	0	0		0	0	0	0	0	A	A
MW-0028D	21-Jul-88	0	0		0	0	0	0	0	A	A
MW-0028D	13-Oct-88	0	0		0	0	0	0	0	A	A
MW-0028D	23-Jan-89	0	0		0	0	0	0	0	A	A
MW-0028D	12-Apr-89	0	0		0	0	0	0	0	A	A
MW-0028D	28-Jul-89	0	0		0	0	0	0	0	A	A
MW-0028D	19-Dec-89	0	0		0	0	0	0	4.57E-07	A	A
MW-0028D	24-Jan-90	0	0		0	0	0	0	0	A	A
MW-0028D	24-Apr-90	0	0		0	0	0	0	8.93E-08	A	A
MW-0028D	16-Oct-90	0	0		0	0	0	0	0	A	A
MW-0028D	10-May-91	0	0		0	0	0	0	0	A	A
MW-0028D	16-Apr-93	0	0	0	0	0	0	0	0	A	A
MW-0028S	16-Jun-82	0	0		0	0	0	0	0	A	A
MW-0029D	28-Apr-82	0	0		0	0	0	0	0	H	B
MW-0029D	16-Aug-82	0	0		0	0	10	0	3.12E-06	H	B
MW-0029D	01-Oct-84								0	H	B
MW-0029D	17-Jun-85	0	0		0	0	0	0	0	H	B
MW-0029D	03-Apr-86	0	0		0	0	0	0	5.60E-05	H	B
MW-0029D	01-Oct-86	0	0		0	0	0	0	0	H	B
MW-0029D	15-Jan-87	0	0		0	0	0	0	0	H	B
MW-0029D	29-Apr-87	0	0		0	0	0	0	0	H	B
MW-0029D	12-Aug-87	0	0		0	0	0	0	0	H	B
MW-0029D	24-Oct-87	0	0		0	0	0	0	0	H	B
MW-0029D	19-Jan-88	0	0		0	0	0	0	0	H	B
MW-0029D	12-Apr-88	0	0		0	0	0	0	0	H	B
MW-0029D	12-Jul-88	0	0		0	0	0	0	0	H	B
MW-0029D	13-Oct-88	0	0		0	0	0	0	0	H	B
MW-0029D	18-Dec-89	0	0		0	0	0	0	0	H	B
MW-0029D	19-Oct-90	0	0		0	0	0	0	0	H	B
MW-0029S	28-Apr-82	0	0		0	0	0	0	0	H	A
MW-0029S	16-Aug-82	0	0		0	0	10	0	3.12E-06	H	A
MW-0030S	16-Jun-82	0	0		0	0	0	0	5.40E-04	A	A
MW-0030S	17-Aug-82	0	0		0	0	10	0	3.12E-06	A	A
MW-0030S	18-Sep-84								0	A	A
MW-0030S	13-Jun-85	0	0		0	0	0	0	0	A	A
MW-0031S	16-Jun-82	0	0		0	0	0	0	5.40E-04	C	A
MW-0031S	17-Aug-82	0	0		0	0	10	0	3.12E-06	C	A
MW-0031S	25-Sep-84								0	C	A
MW-0031S	11-Jun-85	0	0		0	0	0	0	0	C	A
MW-0031S	28-Mar-86	0	0		0	0	0	0	1.32E-07	C	A
MW-0031S	22-Jan-87	0	0		0	0	0	0	0	C	A
MW-0031S	29-Apr-87	0	0		0	0	0	0	0	C	A
MW-0031S	12-Aug-87	0	0		0	0	0	0	0	C	A
MW-0031S	27-Oct-87	0	0		0	0	0	0	0	C	A
MW-0031S	27-Jan-88	0	0		0	0	0	0	0	C	A
MW-0031S	13-Apr-88	0	0		0	0	0	0	0	C	A
MW-0033S	29-Sep-82	0	0		0	0	2000	0	6.31E-04	C	A
MW-0033S	07-Jun-85	0	0		0	0	21500	0	7.04E-03	C	A
MW-0033S	07-Jun-85	0	0		0	0	22600	0	7.04E-03	C	A
MW-0033S	30-Oct-86	62	2.6		0	0	25000	2.9	8.14E-03	C	A
MW-0033S	29-Jan-87	79	4.6		9.8	0.27	27000	15	7.38E-03	C	A
MW-0033S	29-Jan-87	88	4.1		0	0	22000	10	7.38E-03	C	A
MW-0033S	16-Apr-87	100	0		8.7	0.49	25000	10	8.38E-03	C	A
MW-0033S	16-Apr-87	110	0		8.5	0.27	24000	11	8.38E-03	C	A
MW-0033S	31-Jul-87	0	0		0	0	52000	0	1.40E-02	C	A
MW-0033S	31-Jul-87	0	0		0	280	45000	0	1.40E-02	C	A
MW-0033S	17-Sep-87	140	3.5		6.9	45	20000	5.1	6.84E-03	C	A
MW-0033S	26-Oct-87	0	0		0	0	35000	0	1.09E-02	C	A
MW-0033S	08-Jan-88	0	0		0	0	22000	0	6.86E-03	C	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0033S	25-Apr-88	450	1.7		26	1.4	26000	4.9	9.37E-03	C	A
MW-0033S	21-Jul-88	0	0		0	0	28000	0	1.20E-02	C	A
MW-0033S	21-Jul-88	0	0		0	0	38000	0	1.20E-02	C	A
MW-0033S	18-Oct-88	400	0		0	0	27000	0	9.27E-03	C	A
MW-0033S	11-Jan-89	200	0		0	0	17000	0	5.73E-03	C	A
MW-0033S	08-Apr-89	0	0		0	0	17000	0	5.30E-03	C	A
MW-0033S	25-Jul-89	0	0		0	0	12000	0	3.74E-03	C	A
MW-0033S	13-Dec-89	0	0		0	0	12000	0	3.74E-03	C	A
MW-0033S	29-Jan-90	0	0		0	0	12000	0	3.74E-03	C	A
MW-0033S	26-Apr-90	0	0		0	0	26000	0	8.10E-03	C	A
MW-0036S	29-Sep-82	0	0		0	0	5	0	1.56E-06	C	A
MW-0036S	17-Sep-84								0	C	A
MW-0036S	06-Jun-85	0	0		0	0	2.9	0	9.05E-07	C	A
MW-0036S	14-Apr-87								0	C	A
MW-0036S	16-Apr-87	0	0		0	0	3.4	0	2.10E-06	C	A
MW-0036S	16-Apr-87	0	0		0.3	0	3.7	0	2.10E-06	C	A
MW-0036S	30-Jul-87	0	0		0	0	5.3	0	2.11E-06	C	A
MW-0036S	21-Oct-87	0	0		0.35	0	1.8	0	1.71E-06	C	A
MW-0036S	13-Jan-88	0	0.24		0	0	1.9	0	5.93E-07	C	A
MW-0036S	11-Apr-88	0	0		0	0	2.5	0	1.12E-06	C	A
MW-0036S	11-Apr-88	0	0		0	0	2.6	0	1.12E-06	C	A
MW-0036S	25-Oct-88	0	0		0	0	1.8	0	5.62E-07	C	A
MW-0037	28-Sep-82	0	0		0	0	0	0	0	C	A
MW-0038D	27-Sep-82	0	500		0	55	30	0	1.61E-05	D	AB
MW-0038D	09-Aug-83	0	570		2.8	120	52	0	5.89E-05	D	AB
MW-0038D	27-Oct-83	100	2000		3.2	170	140	420	1.15E-02	D	AB
MW-0038D	14-Sep-84								4.98E-04	D	AB
MW-0038D	19-Jun-85	300	11500		260	1870	296	2230	5.88E-02	D	AB
MW-0039S	14-Sep-82	0	0		0	0	0	0	0	A	A
MW-0040S	29-Sep-82	0	0		0	0	5	0	1.56E-06	A	A
MW-0040S	30-Sep-84								0	A	A
MW-0040S	02-Jun-85	0	0		0	0	190	0	7.72E-05	A	A
MW-0041S	14-Sep-82	0	5		0	0	20	0	6.24E-06	B	A
MW-0041S	24-Sep-84								0	B	A
MW-0041S	10-Jun-85	0	0		3.3	2.3	23.2	0	1.15E-05	B	A
MW-0041S	13-Mar-86	0	0		0.6	0	20	0	8.86E-06	B	A
MW-0041S	18-Nov-86	0	0		0	0	43	0	1.54E-05	B	A
MW-0041S	18-Nov-86	0	0		0.18	0	44	0	1.54E-05	B	A
MW-0041S	15-Jan-87	0	0		0	0	37	0	1.29E-05	B	A
MW-0041S	24-Apr-87	0.99	0		0.75	0	91	0	3.66E-05	B	A
MW-0041S	05-Aug-87	0	0		0	0	130	0	4.19E-05	B	A
MW-0041S	20-Oct-87	0	0		0	0	100	0	3.43E-05	B	A
MW-0041S	20-Oct-87	0	0		0	0	110	0	3.43E-05	B	A
MW-0041S	26-Jan-88	0	0		6.2	0	140	0	5.29E-05	B	A
MW-0041S	18-Apr-88	0	0		10	0	220	0	8.21E-05	B	A
MW-0041S	13-Jul-88	0	0		0	0	1100	0	3.43E-04	B	A
MW-0041S	13-Jul-88	0	0		42	0	870	0	3.43E-04	B	A
MW-0041S	07-Oct-88	0	0		370	0	2900	0	1.38E-03	B	A
MW-0041S	16-Jan-89	0	0		240	0	3400	0	1.37E-03	B	A
MW-0041S	11-Apr-89	0	0		150	0	2700	0	1.03E-03	B	A
MW-0041S	25-Jul-89	0	0		230	0	2500	0	1.07E-03	B	A
MW-0041S	17-Oct-89	0	0		200	0	3500	0	1.35E-03	B	A
MW-0041S	17-Oct-89	0	0		320	0	0	0	1.35E-03	B	A
MW-0041S	12-Jan-90	0	0		130	0	1800	0	7.28E-04	B	A
MW-0041S	13-Apr-90	0	0		70	0	1500	0	5.58E-04	B	A
MW-0041S	18-Jul-90	0	0		58	0	1000	0	3.86E-04	B	A
MW-0041S	16-Oct-90	0	0		0	0	780	0	2.43E-04	B	A
MW-0041S	11-Jan-91	0	0		71	0	970	0	3.94E-04	B	A
MW-0041S	30-Jul-91	0	0		21	0	720	0	2.67E-04	B	A
MW-0041S	30-Jul-91	0	0		21	0	770	0	2.67E-04	B	A
MW-0041S	10-Oct-91	0	0		19	0	370	0	1.40E-04	B	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0041S	20-Jan-92	0	0		9.3	0	760	0	2.57E-04	B	A
MW-0041S	06-Jul-92	0	0	0	11	0	520	0	1.76E-04	B	A
MW-0041S	07-Oct-92	0	0	0	0	0	520	0	1.62E-04	B	A
MW-0041S	07-Jan-93	0	0	0	16	0	460	0	1.64E-04	B	A
MW-0041S	16-Apr-93	0	0	0	42	0	360	0	4.09E-04	B	A
MW-0041S	16-Apr-93	0	0	0	55	0	390	0	4.09E-04	B	A
MW-0041S	27-Jul-93	0	0	23.80	0	0	299	0	2.05E-04	B	A
MW-0042S	27-Sep-82	0	0		0	0	0	0	0	B	A
MW-0042S	28-Sep-84								0	B	A
MW-0042S	02-Jun-85	0	0		0	0	0	0	2.18E-07	B	A
MW-0042S	02-Jun-85	0	0		0	0	0.7	0	2.18E-07	B	A
MW-0043S	14-Sep-82	0	0		0	0	0	0	0	B	A
MW-0043S	13-Sep-84								0	B	A
MW-0043S	31-May-85	0	0		0	0	0	0	0	B	A
MW-0044S	13-Sep-82	0	30		0	0	10	0	3.12E-06	C	A
MW-0044S	21-Sep-84								0	C	A
MW-0044S	21-Mar-86	0	0		0	0	0	0	0	C	A
MW-0044S	17-Sep-86	0	0.55		0	0	0	0	0	C	A
MW-0044S	12-Jan-87	0	0		0	0	0	0	0	C	A
MW-0044S	03-Feb-87								0	C	A
MW-0044S	06-May-87	0	0		0	0	0	0	0	C	A
MW-0044S	13-Aug-87	0	8.5		0	0	0	0	0	C	A
MW-0044S	23-Oct-87	0	3.3		0	0	0.4	0	1.25E-07	C	A
MW-0044S	22-Jan-88	0	3.3		0	0	0.63	0	1.97E-07	C	A
MW-0044S	26-Apr-88	0	2.8		0	0	0.5	0	1.56E-07	C	A
MW-0044S	20-Jul-88	0	4.8		0	0	0.95	0	2.97E-07	C	A
MW-0044S	06-Oct-88	0	3.5		0	0	0.69	0	6.87E-07	C	A
MW-0044S	06-Oct-88	0	5.6		0	0	2.2	0	6.87E-07	C	A
MW-0044S	18-Jan-89	0	4.7		0	0	1.1	0	3.43E-07	C	A
MW-0044S	17-Apr-89	0	2.9		0	0	0.73	0	2.28E-07	C	A
MW-0044S	14-Jul-89	0	6		0	0	1.3	0	4.06E-07	C	A
MW-0044S	13-Dec-89	0	5.5		0	0	1.6	0	4.99E-07	C	A
MW-0044S	13-Dec-89	0	6.6		0	0	2.2	0	4.99E-07	C	A
MW-0044S	30-Jan-90	0	4.4		0	0		0	0	C	A
MW-0044S	09-Apr-90	0	6		0	0	1.6	0	4.99E-07	C	A
MW-0044S	09-Apr-90	0	6.8		0	0	2	0	4.99E-07	C	A
MW-0044S	18-Jul-90	0	8.6		0	0	1.8	0	5.62E-07	C	A
MW-0044S	15-Oct-90	0	5		0	0	1.2	0	3.75E-07	C	A
MW-0044S	30-Jan-91	0	5.2		0	0	1.8	0	5.62E-07	C	A
MW-0044S	09-May-91	0	7.1		0	0	2.3	0	1.35E-06	C	A
MW-0044S	13-Aug-91	0	5.1		0.45	0	16	0	5.57E-06	C	A
MW-0045S	14-Sep-82	0	0		0	0	0	0	0	C	A
MW-0045S	19-Sep-84								0	C	A
MW-0045S	04-Jun-85	0	0		0	0	4.1	0	1.28E-06	C	A
MW-004[illegible]S	29-Sep-82	0	0		0	0	0	0	6.62E-06	A	A
MW-0046S	29-Sep-84								0	A	A
MW-0046S	03-Jun-85	0	0		0	0	2.7	0	8.43E-07	A	A
MW-0047S	29-Sep-82	0	0		0	0	0	0	0	B	A
MW-0047S	01-Oct-84								0	B	A
MW-0047S	04-Jun-85	0	0		0	0	0	0	0	B	A
MW-0049S	29-Sep-82	0	0		0	0	0	0	0	A	
MW-0049S	25-Jul-88	0	0		0	0	0	0	0	A	
MW-0049S	01-May-89	0	0		0	0	0	0	0	A	
MW-0051	22-Nov-86	0	0		0	0	0	0	1.54E-06	D	B
MW-0051	14-Jan-87	0	0		0	0	0	0	0	D	B
MW-0051	23-Apr-87	0	0		0	0	0	0	0	D	B
MW-0051	03-Aug-87	0	0		0	0	0	0	0	D	B
MW-0051	15-Oct-87	0	0		0	0	0	0	3.11E-07	D	B
MW-0051	11-Jan-88	0	0		0	0	0	0	0	D	B
MW-0051	08-Apr-88	0	0		0	0	0	0	0	D	B
MW-0051	07-Jul-88	0	0		0	0	0	0	0	D	B

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0051	07-Oct-88	0	0		0	0	0	0	0	D	B
MW-0051	06-Jan-89	0	0		0	0	0	0	0	D	B
MW-0051	18-Apr-89	0	0		0	0	0	0	0	D	B
MW-0051	27-Jul-89	0	0		0	0	0	0	0	D	B
MW-0051	12-Oct-89	0	0		0	0	0.37	0	1.15E-07	D	B
MW-0051	12-Jan-90	0	0		0	0	0	0	0	D	B
MW-0051	17-Jul-90	0	0		0	0	0	0	0	D	B
MW-0051	10-Jul-91	0	0		0	0	0	0	0	D	B
MW-0051	06-Apr-93	0	0	0	0	0	0	0	0	D	B
MW-0052	24-Nov-86	0	0		0	0	0	0	0	D	AB
MW-0052	29-Jan-87	0	0		0	0	2.1	0	7.65E-07	D	AB
MW-0052	11-May-87	0	0		0	0	0	0	0	D	AB
MW-0052	27-Jul-87	0	0		0	0	0	0	0	D	AB
MW-0052	16-Oct-87	0	0		0	0	0	0	0	D	AB
MW-0052	07-Jan-88	0	0		0	0	0	0	0	D	AB
MW-0052	07-Apr-88	0	0		0	0	0	0	0	D	AB
MW-0052	05-Jul-88	0	0		0	0	0	0	0	D	AB
MW-0052	18-Oct-88	0	0		0	0	0	0	0	D	AB
MW-0052	18-Jan-89	0	0		0	0	0	0	0	D	AB
MW-0052	03-Apr-89	0	0		0	0	0	0	0	D	AB
MW-0052	19-Jul-89	0	0		0	0	0	0	0	D	AB
MW-0052	05-Oct-89	0	0		0	0	0	0	0	D	AB
MW-0052	23-Jan-90	0	0		0	0	0	0	0	D	AB
MW-0052	23-Jul-90	0	0		0	0	0	0	0	D	AB
MW-0052	24-Apr-91	0	0		0	0	0	0	0	D	AB
MW-0052	07-Jul-92	0	0	0	0	0	0	0	0	D	AB
MW-0052	23-Jul-93	0	0	0	0	0	0	0	0	D	AB
MW-0053	21-Nov-86	0	0		0	0	0	0	0	D	AB
MW-0053	20-Jan-87	0	0		0	0	0	0	0	D	AB
MW-0053	08-May-87	0	0		0	0	0	0	0	D	AB
MW-0053	28-Jul-87	0	2.1		0	0	0	0	3.94E-07	D	AB
MW-0053	21-Oct-87	0	13		0.27	2.9	3.4	0	1.41E-06	D	AB
MW-0053	06-Jan-88	0	8.7		0.16	1.3	2.3	0	9.23E-07	D	AB
MW-0053	07-Apr-88	0	2.5		0	0.22	0.32	0	9.99E-08	D	AB
MW-0053	05-Jul-88	0	12		0.22	1.3	2.9	0	1.19E-06	D	AB
MW-0053	04-May-89	0	0		0	0	0.49	0	1.53E-07	D	AB
MW-0053	18-Jul-89	0	0		0	0	0.23	0	7.18E-08	D	AB
MW-0053	04-Jan-90	0	0		0	0	0	0	0	D	AB
MW-0053	18-Jan-90	0	0		0	1.2	0	0	0	D	AB
MW-0053	11-Apr-90	0	0		0	0	0	0	0	D	AB
MW-0053	09-May-91	0	0		0	0	0	0	0	D	AB
MW-0053	21-Jul-92								1.62E-07	D	AB
MW-0053	21-Jul-92	0	2.8	0	0	0	0.52	0	1.62E-07	D	AB
MW-0053	22-Apr-93	0	1.10	0	0	0	0.32	0	2.03E-07	D	AB
MW-0054	20-Nov-86	39	430		4.1	19	9	1200	3.14E-02	D	AB
MW-0054	15-Jan-87	14	171		0	0	3.9	1224	3.19E-02	D	AB
MW-0054	27-Apr-87	0	52		0	0	0	180	4.73E-03	D	AB
MW-0054	27-Apr-87	0	52		0	0	0	190	4.73E-03	D	AB
MW-0054	10-Aug-87	0	11		0	0	0	17	3.69E-04	D	AB
MW-0054	10-Aug-87	0.23	8.9		0	0	0	14	3.69E-04	D	AB
MW-0054	19-Oct-87	1	19		0	0.3	1.8	39	1.06E-03	D	AB
MW-0054	19-Oct-87	1.2	22		0	0.58	1.7	40	1.06E-03	D	AB
MW-0054	06-Jan-88	0.16	8.5		0	0	1.4	3.6	1.32E-04	D	AB
MW-0054	06-Jan-88	0.17	8.2		0	0	1.4	5	1.32E-04	D	AB
MW-0054	06-Apr-88	0	0.36		0	0	0	0	0	D	AB
MW-0054	11-Jul-88	1	100		0	0.46	7.3	2.9	8.25E-05	D	AB
MW-0054	14-Oct-88	0	0		0	0	0	0	0	D	AB
MW-0054	17-Jan-89	0	0		0	0	0	0	0	D	AB
MW-0054	03-Apr-89	0	0		0	0	0	0	0	D	AB
MW-0054	26-Jul-89	0	0		0	0	0	0	0	D	AB
MW-0054	05-Oct-89	0	0		0	0	0	0	0	D	AB

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0054	24-Jan-90	0	0		0	0	0	0	0	D	AB
MW-0054	17-Apr-90	0	2.1		0	0	0	0.46	1.21E-05	D	AB
MW-0054	02-May-91	0	0		0	0	0	0	0	D	AB
MW-0054	21-Jul-92	0	0	0	0	0	0.34	0	1.06E-07	D	AB
MW-0054	07-Apr-93	0	0	0	0	0	0	0	0	D	AB
MW-0055	22-Nov-86	2.9	210		13	15	110	0.34	1.33E-04	D	AB
MW-0055	05-Jan-87	2.9	160		46	41	70	0.34	9.67E-05	D	AB
MW-0055	20-Apr-87	0.7	310		38	58	29	0	7.25E-05	D	AB
MW-0055	20-Apr-87	0.93	110		47	69	33	0	7.25E-05	D	AB
MW-0055	13-Aug-87	0	130		0	71	37	0	1.15E-05	D	AB
MW-0055	14-Oct-87	0	18		7.9	17	6.9	0	1.23E-05	D	AB
MW-0055	11-Jan-88	1.1	33		6.8	10	11	0	1.45E-05	D	AB
MW-0055	08-Apr-88	0.27	11		2.8	5.5	4.2	0	5.48E-06	D	AB
MW-0055	08-Apr-88	0.34	13		3	5.2	4.6	0	5.48E-06	D	AB
MW-0055	11-Jul-88	0.6	31		0.8	0.8	10	0	5.44E-06	D	AB
MW-0055	11-Jul-88	0.96	51		1.7	2.8	18	0	5.44E-06	D	AB
MW-0055	04-Oct-88	1.4	60		1.5	2.6	14	0	9.39E-06	D	AB
MW-0055	04-Oct-88	1.5	61		1.4	2.9	14	0	9.39E-06	D	AB
MW-0055	06-Jan-89	0	4.1		1.4	3.9	1.4	0	2.23E-06	D	AB
MW-0055	04-Apr-89	0	4.6		1.6	3.5	1.5	0	2.52E-06	D	AB
MW-0055	27-Jul-89	0	7.9		1.8	1.9	2.3	0	3.02E-06	D	AB
MW-0055	27-Jul-89	0	8.6		1.9	1.9	3.2	0	3.02E-06	D	AB
MW-0055	10-Oct-89	0.28	13		1.2	1.6	2.7	0	2.98E-06	D	AB
MW-0055	10-Oct-89	0.31	14		1.2	1.6	2.9	0	2.98E-06	D	AB
MW-0055	15-Jan-90	0.11	3.9		0	3	1.8	0	1.22E-05	D	AB
MW-0055	16-Apr-90	0	3.5		1.4	2.6	2.8	0	2.67E-06	D	AB
MW-0055	03-Jul-90	0	5.8		1.3	2.2	3	0	4.17E-06	D	AB
MW-0055	31-Oct-90	0	2.9		0.97	0	0.3	0	1.34E-06	D	AB
MW-0055	21-Jan-91	0	3		0.64	0.93	0.98	0	1.13E-06	D	AB
MW-0055	21-Jan-91	0	3.2		0.73	0.99	1.1	0	1.13E-06	D	AB
MW-0055	19-Apr-91	0	2.8		0.72	0	2	0	1.55E-06	D	AB
MW-0055	24-Jul-91	0	2.9		0.11	0	1.2	0	5.15E-07	D	AB
MW-0055	24-Jul-91	0	3.3		0.14	0	1.2	0	5.15E-07	D	AB
MW-0055	12-Jan-93	0	0	0	0.24	0	4.4	0	1.68E-06	D	AB
MW-0057	19-Nov-86	0	2.3		0	0	2.5	0	7.80E-07	D	AB
MW-0057	13-Jan-87	0	13		0	0.88	14	0	4.37E-06	D	AB
MW-0057	28-Apr-87	0	0		0	0	0	0	0	D	AB
MW-0057	30-Jul-87	0	1.6		0	0	0	0	3.94E-07	D	AB
MW-0057	12-Oct-87	0	1.2		0	0	0.58	0	1.81E-07	D	AB
MW-0057	08-Jan-88	0	3.6		0	0	2.3	0	7.18E-07	D	AB
MW-0057	22-Apr-88	0	0.31		0	0	0	0	0	D	AB
MW-0057	06-Jul-88	0	0		0	0	0	0	0	D	AB
MW-0057	12-Oct-88	0	0.36		0	0	0.35	0	1.09E-07	D	AB
MW-0057	09-Jan-89	0	0		0	0	0	0	0	D	AB
MW-0057	19-Apr-89	0	0		0	0	0	0	0	D	AB
MW-0057	01-Aug-89	0	0		0	0	0	0	0	D	AB
MW-0057	09-Oct-89	0	0		0	0	0	0	0	D	AB
MW-0057	25-Jan-90		0		1.1	0	0	0	1.41E-06	D	AB
MW-0057	18-Apr-90	0	0		1.3	0	0	0	1.66E-06	D	AB
MW-0057	05-Jul-90	0	0		0	0	0.24	0	7.49E-08	D	AB
MW-0057	12-Oct-90	0	0		0	0	0	0	0	D	AB
MW-0057	29-Jan-91	0	0		0	0	0.39	0	1.22E-07	D	AB
MW-0057	22-Apr-91	0	0		0	0	0.26	0	8.12E-08	D	AB
MW-0057	31-Jul-91	0	0		0	0	0	0	0	D	AB
MW-0057	27-Jan-93	0	0	0	0	0	0	0	0	D	AB
MW-0058	21-Nov-86	0	1.7		0	0.36	0.62	1.3	3.44E-05	D	B
MW-0058	19-Jan-87	0	2.9		0	2.1	1.2	0	4.37E-07	D	B
MW-0058	19-Jan-87	0	3.3		0	2.4	1.4	0	4.37E-07	D	B
MW-0058	30-Apr-87	0	0		0	2.3	1.5	0	4.68E-07	D	B
MW-0058	06-Aug-87	0	0		0	0	0	0	0	D	B
MW-0058	13-Oct-87	0	0		0	0	0	0	0	D	B

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0058	11-Jan-88	0	0.27		0	0.25	0	0	0	D	B
MW-0058	06-Apr-88	0	0.55		0	0	0.24	0	3.41E-07	D	B
MW-0058	07-Jul-88	0	0.14		0	0	0	0	0	D	B
MW-0058	17-Oct-88	0	0		0	0	0	0	0	D	B
MW-0058	09-Jan-89	0	0.11		0	0.33	0	0	0	D	B
MW-0058	04-Apr-89	0	0.28		0	0.4	0	0	0	D	B
MW-0058	27-Jul-89	0	0		0	0	0	0	0	D	B
MW-0058	02-Jan-90	0	0		0	0	0	0	1.27E-07	D	B
MW-0058	22-Jan-90	0	0		0	0	0	0	0	D	B
MW-0058	16-Apr-90	0	0.42		0	0	0.47	0	1.47E-07	D	B
MW-0058	26-Jul-90	0	0		0.18	0	0	0	2.30E-07	D	B
MW-0058	17-Oct-90	0	0		0	0	0	0	0	D	B
MW-0058	17-Jan-91	0	0		0	0	0	0	0	D	B
MW-0058	29-Apr-91	0	0		0	0	0	0	0	D	B
MW-0058	23-Jul-91	0	0		0	0	0	0	0	D	B
MW-0058	22-Jan-93	0	0	0	0	0	0	0	0	D	B
MW-0059	02-Apr-86	0	11		0	1.1	12	0	4.23E-06	D	B
MW-0059	18-Nov-86	0	270		0.1	19	290	0	2.00E-04	D	B
MW-0059	12-Jan-87	0	58		0	5.3	71	0	2.22E-05	D	B
MW-0059	12-Jan-87	0	99		0	8.1	108	0	2.22E-05	D	B
MW-0059	21-Apr-87	0	47		0	3.2	38	0	1.19E-05	D	B
MW-0059	21-Apr-87	0	50		0	3.3	40	0	1.19E-05	D	B
MW-0059	10-Aug-87	0	15		0	0.9	11	0	4.24E-06	D	B
MW-0059	10-Aug-87	0	19		0	1	13	0	4.24E-06	D	B
MW-0059	09-Oct-87	0	15		0	0	6.2	0	1.94E-06	D	B
MW-0059	08-Jan-88	0	3.1		0	0.21	2.3	0	7.18E-07	D	B
MW-0059	08-Apr-88	0	0.53		0	0	0.49	0	1.53E-07	D	B
MW-0059	06-Jul-88	0	0		0	0	0	0	0	D	B
MW-0059	11-Oct-88	0	0		0	0	0.23	0	7.18E-08	D	B
MW-0059	05-Jan-89	0	0.11		0	0	0	0	0	D	B
MW-0059	04-Apr-89	0	0		0	0	0	0	0	D	B
MW-0059	01-Aug-89	0	0		0	0	0	0	0	D	B
MW-0059	10-Oct-89	0	0		0	0	0	0	0	D	B
MW-0059	24-Jan-90	0	0		2.3	0.3	0	0	2.95E-06	D	B
MW-0059	12-Apr-90	0	0		0	0	0	0	0	D	B
MW-0059	06-Jul-90	0	0		0	0	0	0	8.30E-08	D	B
MW-0059	07-Nov-90	0	0		0	0	0	0	1.99E-07	D	B
MW-0059	23-Jan-91	0	0		0	0	0	0	0	D	B
MW-0059	13-May-91	0	0		0	0	0	0	0	D	B
MW-0059	10-Jul-92	0	0	0	0	0	0	0	0	D	B
MW-0059	20-Jul-93	0	0	0	0	0	0	0	4.46E-07	D	B
MW-0060	28-Oct-86	0	0		0	0	0	0	0	C	A
MW-0060	13-Jan-87	0	0		0	0	0	0	0	C	A
MW-0060	24-Apr-87	0	0		0	0	0	0	0	C	A
MW-0060	13-Aug-87	0	0		0	0	0	0	0	C	A
MW-0060	25-Oct-87	0	0		0	0	0	0	0	C	A
MW-0060	22-Jan-88	0	0		0	0	0	0	0	C	A
MW-0060	18-Apr-88	0	0		0	0	0	0	0	C	A
MW-0060	20-Jul-88	0	0		0	0	0	0	0	C	A
MW-0060	10-Oct-88	0	0		0	0	0	0	0	C	A
MW-0060	13-Jan-89	0	0		0	0	0	0	0	C	A
MW-0060	11-Apr-89	0	0		0	0	0	0	0	C	A
MW-0060	17-Jul-89	0	0		0	0	0	0	0	C	A
MW-0060	09-Oct-89	0	0		0	0	0	0	0	C	A
MW-0060	30-Jan-90	0	0		0	0		0	0	C	A
MW-0060	12-Apr-90	0	0		0	0	0	0	0	C	A
MW-0060	16-Oct-90	0	0		0	0	0	0	1.04E-07	C	A
MW-0060	17-Jul-91	0	0		0	0	0	0	0	C	A
MW-0061	19-Mar-86	0	0		0	0	3.1	0	9.68E-07	C	A
MW-0061	01-Dec-86	0	0		0	0	7.4	0	2.31E-06	C	A
MW-0061	29-Jan-87	0	0		0	0	22	0	7.08E-06	C	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0061	07-May-87	0	0		0	0	15	0	4.68E-06	C	A
MW-0061	07-Aug-87	0	0		0	0	14	0	4.37E-06	C	A
MW-0061	13-Oct-87	0	0		0	0	5.3	0	1.65E-06	C	A
MW-0061	19-Jan-88	0	0		0	0	4.3	0	1.34E-06	C	A
MW-0061	22-Apr-88	0	0		0	0	5.2	0	1.62E-06	C	A
MW-0061	20-Jul-88	0	0		0	0	7.9	0	2.47E-06	C	A
MW-0061	07-Oct-88	0	0		0	0	14	0	4.37E-06	C	A
MW-0061	20-Jan-89	0	0		0	0	14	0	4.37E-06	C	A
MW-0061	12-Apr-89	0	0		0	0	7.2	0	2.25E-06	C	A
MW-0061	12-Apr-89	0	0		0	0	7.6	0	2.25E-06	C	A
MW-0061	01-Aug-89	0	0		0	0	9.8	0	3.06E-06	C	A
MW-0061	05-Jan-90	0	0		0	0	13	0	4.06E-06	C	A
MW-0061	07-Aug-90	0	0		0	0	24	0	7.49E-06	C	A
MW-0061	25-Oct-91	0	0		0	0	27	0	8.43E-06	C	A
MW-0061	26-Jan-93	0	0	0	0.32	0	36	0	1.16E-05	C	A
MW-0062	26-Apr-88	0	0		0	0	0.44	0	1.37E-07	C	A
MW-0062	26-Jul-88	0	0		0	0	1.3	0	4.06E-07	C	A
MW-0062	07-Oct-88	0	0		0	0	0.39	0	1.22E-07	C	A
MW-0062	11-Jan-89	0	0		0	0	0.46	0	1.44E-07	C	A
MW-0062	11-Apr-89	0	0		0	0	0.74	0	2.31E-07	C	A
MW-0062	28-Jul-89	0	0		0	0	0.6	0	1.87E-07	C	A
MW-0062	13-Dec-89	0	0		0	0	0.79	0	2.47E-07	C	A
MW-0062	23-Jan-90	0	0		0	0	1.2	0	3.75E-07	C	A
MW-0062	23-Jan-90	0	0		0	0.31	1.1	0	3.75E-07	C	A
MW-0062	11-Apr-90	0	0		0	0	0.92	0	2.87E-07	C	A
MW-0062	18-Jul-90	0	0		0.26	0	0.98	0	6.39E-07	C	A
MW-0062	16-Oct-90	0	0		0	0	0.63	0	1.97E-07	C	A
MW-0062	01-Feb-91	0	0		0	0	0.72	0	2.25E-07	C	A
MW-0062	23-Apr-91	0	0		0	0	1.2	0	3.75E-07	C	A
MW-0062	02-Aug-91	0	0		0	0	1	0	3.12E-07	C	A
MW-0062	26-Jul-93	0	0	2.87	0	0	2.62	0	1.66E-06	C	A
MW-0063	02-Apr-86	0.4	0		0	0	36	0	1.33E-05	B	B
MW-0063	02-Apr-86	0.4	0		0	0	40	0	1.33E-05	B	B
MW-0063	25-Nov-86	0	0.24		0	0	24	0	6.51E-06	B	B
MW-0063	25-Nov-86	0	0.25		0	0	20	0	6.51E-06	B	B
MW-0063	27-Jan-87	0	0		0	0	41	0	1.28E-05	B	B
MW-0063	11-May-87	0	0		0	0	210	0	6.55E-05	B	B
MW-0063	14-Aug-87	0	0		0	0	190	0	5.93E-05	B	B
MW-0063	22-Oct-87	0	0		0	0	52	0	1.62E-05	B	B
MW-0063	23-Jan-88	0.78	0.76		0	0	69	0	2.39E-05	B	B
MW-0063	15-Apr-88	0	0		0	0	44	0	1.37E-05	B	B
MW-0063	15-Jul-88	0.69	0		0	0	91	0	2.99E-05	B	B
MW-0063	07-Oct-88	0	0		0	0	58	0	1.81E-05	B	B
MW-0063	19-Jan-89	0.77	0		0	0	55	0	2.03E-05	B	B
MW-0063	19-Jan-89	1.3	0		0	0	59	0	2.03E-05	B	B
MW-0063	13-Apr-89	0.91	0		0	0	74	0	2.59E-05	B	B
MW-0063	13-Apr-89	1	0		0	0	76	0	2.59E-05	B	B
MW-0063	06-Jul-89	1.3	0.6		0	0	35	0	1.46E-05	B	B
MW-0063	11-Oct-89	0.84	0		0	0	75	0	2.67E-05	B	B
MW-0063	11-Oct-89	1.2	0		0	0	100	0	2.67E-05	B	B
MW-0063	16-Jan-90	0	0		0	5.2	110	0	3.43E-05	B	B
MW-0063	26-Apr-90	1.1	0		0	0	110	0	3.91E-05	B	B
MW-0063	07-Aug-90	0	0		0	0	56	0	1.75E-05	B	B
MW-0063	07-Aug-90	0	0		0	0	75	0	1.75E-05	B	B
MW-0063	06-Nov-90	0	0		0	0	33		1.03E-05	B	B
MW-0063	15-Jan-91	0	0		0	0	45	0	1.40E-05	B	B
MW-0063	08-May-91	0	0		0	0	57	0	1.78E-05	B	B
MW-0063	08-May-91	0	0		0	0	69	0	1.78E-05	B	B
MW-0063	08-Aug-91	0	0		0	0	56	0	1.75E-05	B	B
MW-0063	22-Oct-91	0	0		0	0	34	0	1.06E-05	B	B
MW-0063	22-Oct-91	0	0		0	0	36	0	1.06E-05	B	B

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0063	05-Feb-92	0.89	0		0	0	74	0	2.87E-05	B	B
MW-0063	20-Jul-92	0.3	0	16	0	0	47	0	1.53E-05	B	B
MW-0063	22-Oct-92	0	0	11	0	0	15	0	4.68E-06	B	B
MW-0063	28-Jan-93	0	0	15	0	0	40	0	1.25E-05	B	B
MW-0064	26-Oct-88	0	0		0	0	0	0	0	B	B
MW-0064	24-Jan-89	0	0		0	0	0	0	0	B	B
MW-0064	24-Apr-89	0	0		0	0	0	0	0	B	B
MW-0064	18-Jul-89	0	0		0	0	0	0	0	B	B
MW-0064	15-Dec-89	0	0		0	0	0.2	0	6.24E-08	B	B
MW-0064	13-Feb-90	0	0		0	0	0	0	0	B	B
MW-0064	24-Apr-90	0	0		0	0	0	0	0	B	B
MW-0064	05-Oct-90	0	0		0	0	0	0	0	B	B
MW-0064	12-Aug-91	0	0		0	0	0	0	0	B	B
MW-0064	14-Oct-91	0	0		0	0	0	0	0	B	B
MW-0064	30-Jan-92								0	B	B
MW-0064	26-Feb-92	0	0		0	0	0.99	0	3.09E-07	B	B
MW-0064	24-Jul-92	0	0	0	0	0	2.1	0	6.55E-07	B	B
MW-0064	22-Oct-92	0	0	0	0	0	0.74	0	2.31E-07	B	B
MW-0064	12-Jan-93	0	0	0	0	0	0.81	0	2.53E-07	B	B
MW-0064	27-Jul-93	0	0	0	0	1.66	0.583	0	6.97E-07	B	B
MW-0065	26-Apr-89	0	0		0.78	0	58	0	1.91E-05	B	A
MW-0065	18-Jul-89	0	0		0.28	0	16	0	3.13E-05	B	A
MW-0065	18-Jul-89	0	0		1.3	0	95	0	3.13E-05	B	A
MW-0065	15-Dec-89	0	0		1.8	0	110	0	3.66E-05	B	A
MW-0065	28-Feb-90	0	0		0	0	95	0	2.97E-05	B	A
MW-0065	02-May-90	0	0		0	0	120	0	1.28E-06	B	A
MW-0065	02-May-90	0	0		1	0		0	1.28E-06	B	A
MW-0065	06-Aug-90	0	0		0	0	120	0	3.75E-05	B	A
MW-0065	18-Dec-90	0	0		1.7	0	100	0	3.34E-05	B	A
MW-0065	04-Feb-91	0	0		1.6	0	82	0	2.76E-05	B	A
MW-0065	09-Apr-91	0	0		0	0	82	0	2.56E-05	B	A
MW-0065	02-Aug-91	0	0		0	0	53	0	1.65E-05	B	A
MW-0065	11-Oct-91	0	0		0.82	0	47	0	1.57E-05	B	A
MW-0066	25-Apr-89	0	0		0	0	0	0	0	B	B
MW-0066	26-Jul-89	0	0		0	0	0.7	0	2.18E-07	B	B
MW-0066	19-Dec-89	0	0		0	0	0	0	3.74E-07	B	B
MW-0066	19-Feb-90	0	0		0	0	0	0	3.94E-07	B	B
MW-0066	12-May-90	0	0		0	0	3.3	0	1.03E-06	B	B
MW-0066	07-Aug-90	0	0		0	0	0	0	1.04E-07	B	B
MW-0066	15-Oct-90	0	0		0	0	0	0	0	B	B
MW-0066	05-Feb-91	0	0		0	0	0.31	0	9.68E-08	B	B
MW-0066	29-Apr-91	0	0		0	0	8.5	0	2.65E-06	B	B
MW-0066	08-Aug-91	0	0		0	0	0	0	0	B	B
MW-0066	08-Oct-91	0	0		0	0	1.4	0	4.37E-07	B	B
MW-0066	04-Feb-92	0	0		0	0	0.57	0	1.78E-07	B	B
MW-0066	28-Jul-92								0	B	B
MW-0066	21-Oct-92	0	0	0	0	0	1.1	0	3.43E-07	B	B
MW-0066	18-Jan-93	0	0	0	0	0	1	0	3.12E-07	B	B
MW-0067	20-Mar-86	0	0		0	0	0	0	0	A	A
MW-0067	17-Oct-86	0	0		0	0	0	0	0	A	A
MW-0067	23-Jan-87	0	0		0	0	0	0	0	A	A
MW-0067	06-May-87	0	0		0	0	0	0	0	A	A
MW-0067	15-Aug-87	0	0		0	0	0	0	0	A	A
MW-0067	20-Oct-87	0	0		0	0	0	0	0	A	A
MW-0067	26-Jan-88	0	0		0	0	0	0	0	A	A
MW-0067	26-Apr-88	0	0		0	0	0	0	0	A	A
MW-0067	15-Jul-88	0	0		0	0	0	0	0	A	A
MW-0067	11-Oct-88	0	0		0	0	0	0	0	A	A
MW-0067	03-Jan-90	0	0		0	0	0	0	0	A	A
MW-0067	02-May-90	0	0		0	0	0	0	0	A	A
MW-0068	13-May-87	0	0		0	0	0	0	0	A	A

Table K-6											
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0068	07-Aug-87	0	0		0	0	0	0	0	A	A
MW-0068	23-Oct-87	0	0		0	0	0	0	0	A	A
MW-0068	25-Jan-88	0	0		0	0	0	0	0	A	A
MW-0068	08-Apr-88	0	0		0	0	0	0	0	A	A
MW-0068	20-Jul-88	0	0		0	0	0	0	0	A	A
MW-0068	25-Oct-88	0	0		0	0	0	0	0	A	A
MW-0068	11-Dec-89	0	0		0	0	0	0	1.47E-07	A	A
MW-0068	01-May-90	0	0		0	0	0	0	0	A	A
MW-0068	30-Oct-90	0	0		0	0	0	0	1.52E-07	A	A
MW-0068	09-May-91	0	0		0	0	0	0	0	A	A
MW-0068	22-Apr-93	0	0	0	0	0	0	0	0	A	A
MW-0069	25-Nov-86	0	0.1		0	0	0.65	0	3.35E-07	A	BC
MW-0069	28-Jan-87	0	0		0	0	0	0	0	A	BC
MW-0069	13-May-87	0	0		0	0	0	0	0	A	BC
MW-0069	01-Aug-87	0	0		0	0	0	0	1.99E-07	A	BC
MW-0069	20-Oct-87	0	0		0	0	0	0	0	A	BC
MW-0069	23-Jan-88	0	0		0	0	0	0	0	A	BC
MW-0069	19-Apr-88	0	0		0	0	0	0	0	A	BC
MW-0069	13-Jul-88	0	0		0	0	0	0	0	A	BC
MW-0069	05-Oct-88	0	0		0	0	0	0	0	A	BC
MW-0069	12-Dec-89	0	0		0	0	0	0	1.91E-07	A	BC
MW-0069	01-Aug-90	0	0		0.54	0	0	0	6.91E-07	A	BC
MW-0069	31-Jan-91	0	0		0	0	0	0	8.73E-07	A	BC
MW-0069	12-Aug-91	0	0		0	0	0	0	1.89E-06	A	BC
MW-0069	15-Jan-93	0	0	0	0	0	1.2	0	3.32E-06	A	BC
MW-0070	29-Jan-87	0	0		0	0	0	0	0	D	AB
MW-0070	12-May-87	0	0		0	0	0	0	0	D	AB
MW-0070	14-Aug-87	0	0		0	0	0.79	0	2.47E-07	D	AB
MW-0070	16-Oct-87	0	0.27		0	0	0	0	0	D	AB
MW-0070	07-Jan-88	0	0.25		0	0	0	0	0	D	AB
MW-0070	21-Apr-88	0	0		0	0	0	0	0	D	AB
MW-0070	05-Jul-88	0	0		0	0	0	0	0	D	AB
MW-0070	13-Oct-88	0	0		0	0	0	0	0	D	AB
MW-0070	05-Jan-89	0	0.11		0	0	0	0	0	D	AB
MW-0070	05-Apr-89	0	0		0	0	0	0	0	D	AB
MW-0070	28-Jul-89	0	0		0	0	0	0	0	D	AB
MW-0070	09-Oct-89	0	0		0	0	0	0	0	D	AB
MW-0070	25-Jan-90	0	0			0	0	0	0	D	AB
MW-0070	18-Jan-91	0	0		0	0	0	0	1.10E-07	D	AB
MW-0070	16-Jan-92	0	0		0	0	0	0	0	D	AB
MW-0071	22-Apr-88	0	0.1		0	0	0.7	0	9.87E-07	A	B
MW-0071	20-Jul-88	0	0		0	0	0.71	0	9.10E-07	A	B
MW-0071	27-Oct-88	0	0.11		0	0	0.74	0	6.15E-07	A	B
MW-0071	30-Jan-89	0	0		0	0	0.59	0	8.99E-07	A	B
MW-0071	25-Apr-89	0	0.18		0	0	1.3	0	1.86E-06	A	B
MW-0071	20-Jul-89	0	0		0	0	2	0	2.48E-06	A	B
MW-0071	02-Jan-90	0	0		0	0	2.6	0	2.93E-06	A	B
MW-0071	02-Jan-90	0	0		0	0	2.8	0	2.93E-06	A	B
MW-0071	02-Feb-90	0	0		0	0	3.5	0	1.09E-06	A	B
MW-0071	01-May-90	0	0.3		0	0	3.7	0	4.07E-06	A	B
MW-0071	12-Jul-90	0	0		0	0	10	0	7.23E-06	A	B
MW-0071	30-Oct-90	0	0		0	0	2.6	0	2.53E-06	A	B
MW-0071	29-Jan-91	0	0.36		0	0	3.3	0	3.94E-06	A	B
MW-0071	13-May-91	0	0.77		0	0	5.8	0	6.84E-06	A	B
MW-0071	13-Aug-91	0	1.2		0	0	9.6	0	1.76E-05	A	B
MW-0071	21-Jan-93	0.5	3.4	1.9	0	0	18	0	3.58E-05	A	B
MW-0072	08-May-87	28	550		0	5.9	410	41	1.27E-03	D	A
MW-0072	14-Aug-87	140	1900		0	43	1200	0	6.76E-04	D	A
MW-0072	20-Oct-87	86	320		0	7	580	0	3.66E-04	D	A
MW-0072	08-Jan-88	140	930		0	49	870	0	5.73E-04	D	A
MW-0072	11-Apr-88	210	800		0	17	1000	0	7.64E-04	D	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0072	21-Jul-88	120	500		0	0	820	0	5.14E-04	D	A
MW-0072	21-Jul-88	120	790		0	31	850	0	5.14E-04	D	A
MW-0072	13-Oct-88	80	460		0	24	660	0	3.78E-04	D	A
MW-0072	06-Jan-89	130	370		0	12	550	0	4.52E-04	D	A
MW-0072	05-Apr-89	110	100		0	11	300	0	3.30E-04	D	A
MW-0072	05-Apr-89	110	280		0	0	580	0	3.30E-04	D	A
MW-0072	17-Jul-89	120	280		0	0	530	0	4.24E-04	D	A
MW-0072	10-Oct-89	150	530		0	10	780	0	5.66E-04	D	A
MW-0072	10-Oct-89	160	510		0	12	790	0	5.66E-04	D	A
MW-0072	20-Feb-90	140	260		0	15	700	0	5.20E-04	D	A
MW-0072	10-Apr-90	92	150		0	0	340	0	3.04E-04	D	A
MW-0072	01-May-91	58	90		0	0	210	0	1.90E-04	D	A
MW-0072	23-Jul-92								1.82E-04	D	A
MW-0072	23-Jul-92	60	88	16	0	0	170	0	1.82E-04	D	A
MW-0072	23-Jul-93	37.90	88.30	2.43	0	0	246	0	3.58E-04	D	A
MW-0074	27-Apr-88	0	14		0	0	11	0	3.22E-06	D	AB
MW-0074	27-Apr-88	0.29	12		0	0	8.3	0	3.22E-06	D	AB
MW-0074	26-Jul-88	0.2	12		0	0	4.6	0	1.87E-06	D	AB
MW-0074	26-Oct-88	0	11		0	0	4.7	0	1.47E-06	D	AB
MW-0074	26-Oct-88	0	12		0	0	5.4	0	1.47E-06	D	AB
MW-0074	03-May-89	0	0.96		0	0	0	0	0	D	AB
MW-0074	24-Jul-89	0.15	10		0	0	5.5	0	2.04E-06	D	AB
MW-0074	14-Dec-89	0	11		0	0	6.7	0	2.22E-06	D	AB
MW-0074	14-Dec-89	0	12		0	0	7.1	0	2.22E-06	D	AB
MW-0074	27-Feb-90	0	9.8		0	0	4.8	0	1.50E-06	D	AB
MW-0074	02-May-90	0	5.6		0	0	3.4	0	1.06E-06	D	AB
MW-0074	13-Jul-90	0.13	9.5		0	0	4	0	1.55E-06	D	AB
MW-0074	13-Jul-90	0.17	12		0	0	3.8	0	1.55E-06	D	AB
MW-0074	31-Oct-90	0	6.5		0	0	1.9	0	5.93E-07	D	AB
MW-0074	29-Jan-91	0	3.6		0	0	3	0	9.36E-07	D	AB
MW-0074	10-May-91	0	4.4		0	0	2.9	0	9.05E-07	D	AB
MW-0074	12-Aug-91	0	2.9		0	0	3	0	9.36E-07	D	AB
MW-0074	28-Jan-93	0.21	3.3	0	0	0	2.9	0	1.36E-06	D	AB
MW-0075	21-Apr-88	0	0		0	0	17	0	5.31E-06	C	A
MW-0075	20-Jul-88	0	0		0	0	26	0	8.12E-06	C	A
MW-0075	28-Oct-88	0	0		0	0	20	0	6.24E-06	C	A
MW-0075	25-Jan-89	0	0		0	0.29	12	0	3.75E-06	C	A
MW-0075	25-Apr-89	0	0		0	0	17	0	5.31E-06	C	A
MW-0075	24-Jul-89	0	0		0	0.24	23	0	7.18E-06	C	A
MW-0075	11-Dec-89	0	0		0	0	34	0	1.06E-05	C	A
MW-0075	11-Dec-89	0	0		0	0	38	0	1.06E-05	C	A
MW-0075	05-Feb-90	0	0		17	0	5.7	0	2.35E-05	C	A
MW-0075	01-May-90	0	0		0	0	15	0	1.31E-05	C	A
MW-0075	01-May-90	0	0		0	0	42	0	1.31E-05	C	A
MW-0075	05-Jul-90	0	0		0	0	29	0	9.05E-06	C	A
MW-0075	31-Oct-90	0	0		0	0	49	0	1.72E-05	C	A
MW-0075	31-Oct-90	0	0		0	0	55	0	1.72E-05	C	A
MW-0075	29-Jan-91	0	0		0	0	76	0	2.37E-05	C	A
MW-0075	10-May-91	0	0		0	0	98	0	3.06E-05	C	A
MW-0075	12-Aug-91	0	0		0	0	79	0	2.50E-05	C	A
MW-0075	12-Aug-91	0	0		0	0	80	0	2.50E-05	C	A
MW-0075	27-Oct-92	0	0	13	0	0	390	0	1.22E-04	C	A
MW-0076	28-Apr-88	1.4	200		0.14	0.61	3.6	1.4	4.31E-05	D	AB
MW-0076	21-Jul-88	0	48		0	0	0	0	0	D	AB
MW-0076	27-Oct-88	0.37	33		0	0	0.6	0	9.84E-07	D	AB
MW-0076	27-Oct-88	0.38	39		0	0	0.71	0	9.84E-07	D	AB
MW-0076	03-May-89	0	9.9		0	0	4.9	0	1.53E-06	D	AB
MW-0076	24-Jul-89	0	0.74		0	0	0	0	0	D	AB
MW-0076	24-Jul-89	0	1.6		0	0.41	0	0	0	D	AB
MW-0076	14-Dec-89	0	0		0	0	0	0	3.11E-07	D	AB
MW-0076	28-Feb-90	0	0.29		0	0	0	0	0	D	AB

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0076	05-Apr-90	0	0.24		0	0	0	0	0	D	AB
MW-0076	06-Jul-90	0	0		0	0	0	0	5.40E-07	D	AB
MW-0076	05-Nov-90	0	0		0	0	0	0	0	D	AB
MW-0076	28-Jan-91	0	1.5		0	0	0	0	0	D	AB
MW-0076	13-May-91	0	0		0	0	0	0	0	D	AB
MW-0076	15-Aug-91	0	0		0	0	0	0	0	D	AB
MW-0076	29-Jan-93	0	0	0	0	0	0	0	0	D	AB
MW-0088	06-Jan-87	0	1.1		0	0	0	0	0	D	A
MW-0088	04-May-87	0	0		0	0	0	0	0	D	A
MW-0088	13-Aug-87	0	0		0	0	0	0	0	D	A
MW-0088	21-Jan-88	0	0		0	0	0	0	0	D	A
MW-0088	11-Apr-88	0	0		0	0	0	0	0	D	A
MW-0088	08-Jul-88	0	0		0	0	0	0	0	D	A
MW-0088	13-Oct-88	0	0		0	0	0	0	0	D	A
MW-0088	17-Jan-89	0	0		0	0	0	0	0	D	A
MW-0088	05-Apr-89	0	0		0	0	0	0	0	D	A
MW-0088	19-Jul-89	0	0		0	0	0	0	0	D	A
MW-0088	11-Oct-89	0	0		0	0	0	0	0	D	A
MW-0088	25-Jan-90	0	0			0	0	0	0	D	A
MW-0088	09-Apr-90	0	0		0	0	0	0	0	D	A
MW-0088	31-Oct-90	0	0		0	0	0	0	0	D	A
MW-0088	25-Jul-91	0	0		0	0	0	0	0	D	A
MW-0088	25-Jan-93	0	0	0	0	0	0	0	0	D	A
MW-0088	22-Jul-93	0	0	0	0	0	0	0	0	D	A
MW-0089	06-Jan-87	0	0		0	0	0	0	0	D	A
MW-0089	04-May-87	0	0		0	0	0	0	0	D	A
MW-0089	13-Aug-87	0	0		0	0	0	0	0	D	A
MW-0089	21-Oct-87	0	0		0	0	0	0	0	D	A
MW-0089	11-Jan-88	0	0.75		0	0	0	0	0	D	A
MW-0089	15-Apr-88	0	0.97		0	0	0	0	0	D	A
MW-0089	08-Jul-88	0	1.1		0	0	0	0	0	D	A
MW-0089	06-Oct-88	0	2.5		0	0	0	0	0	D	A
MW-0089	16-Jan-89	0	6.2		0	0	0	0	0	D	A
MW-0089	04-Apr-89	0	9.4		0	0	0	0	0	D	A
MW-0089	11-Jul-89	0			0	0	0	0	1.02E-07	D	A
MW-0089	04-Oct-89	0	16		0	0	0	0	1.43E-07	D	A
MW-0089	29-Jan-90	0			0	1.3	0	0	0	D	A
MW-0089	02-May-91	0	130		0	0	0	0	0	D	A
MW-0089	06-Jul-92	0	220	0	0	0	0	0	0	D	A
MW-0089	05-Apr-93	0	210	0	0	0	0	0	0	D	A
MW-0090	20-Jan-87	0	0		0	0	0	0	0	D	A
MW-0090	04-May-87	0	0		0	0	0	0	0	D	A
MW-0090	13-Aug-87	0	1.6		0	0	0	0	0	D	A
MW-0090	12-Oct-87	0	0.52		0	0.17	0	0	0	D	A
MW-0090	20-Jan-88	0	0.21		0	0	0	0	0	D	A
MW-0090	11-Apr-88	0	0		0	0	0	0	0	D	A
MW-0090	14-Jul-88	0	0		0	0	0	0	0	D	A
MW-0090	11-Oct-88	0	0		0	0	0	0	0	D	A
MW-0090	16-Jan-89	0	0		0	0	0	0	0	D	A
MW-0090	04-Apr-89	0	0		0	0	0	0	0	D	A
MW-0090	11-Jul-89	0	0		0	0	0	0	0	D	A
MW-0090	04-Oct-89	0	0		0	0	0	0	0	D	A
MW-0090	20-Feb-90	0	0		0	0	0	0	0	D	A
MW-0090	11-Apr-90	0	0		0	0	0	0	0	D	A
MW-0090	30-Apr-91	0	0		0	0	0	0	0	D	A
MW-0090	24-Jul-92	0	0	0	0	0	0	0	0	D	A
MW-0091	20-Jan-87	0	13		0	0	9.5	0	3.09E-06	D	A
MW-0091	20-Jan-87	0	14		0	0	9.9	0	3.09E-06	D	A
MW-0091	21-Apr-87	0	14		0	0	13	0	4.06E-06	D	A
MW-0091	28-Jul-87	0	8.1		0	0	18	0	5.62E-06	D	A
MW-0091	12-Oct-87	0	3		0	0	6.7	0	2.09E-06	D	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0091	12-Oct-87	0	3.3		0	0	6.4	0	2.09E-06	D	A
MW-0091	21-Jan-88	0	1.3		0	0	6.6	0	2.06E-06	D	A
MW-0091	18-Apr-88	0	0.65		0	0	7.6	0	2.37E-06	D	A
MW-0091	20-Jul-88	0	1.2		0	0	6.9	0	2.15E-06	D	A
MW-0091	05-Oct-88	0	0.74		0	0	3.8	0	1.19E-06	D	A
MW-0091	13-Jan-89	0	3.2		0	0	4.9	0	1.64E-06	D	A
MW-0091	12-Apr-89	0			0	0	3	0	9.36E-07	D	A
MW-0091	24-Jul-89	0	4		0	0	3.8	0	1.19E-06	D	A
MW-0091	14-Dec-89	0	8.8		0	0	5.9	0	1.84E-06	D	A
MW-0091	17-Jan-90	0	3		0	0	5.4	0	1.69E-06	D	A
MW-0091	01-May-90	0	13		0	0	11	0	3.43E-06	D	A
MW-0091	27-Jul-90	0	24		0	0	3.6	0	1.12E-06	D	A
MW-0091	27-Jul-90	0	31		0	0	5.5	0	1.12E-06	D	A
MW-0091	30-Apr-91	0	32		0	0	2.8	0	8.74E-07	D	A
MW-0091	30-Apr-91	0	33		0	0	8.8	0	8.74E-07	D	A
MW-0091	07-Jul-92	0	73	0	0	0	2.1	0	6.55E-07	D	A
MW-0091	20-Jul-93	0	94.90	0	0	10.60	0	0	2.15E-06	D	A
MW-0092	20-Jan-87	0	0		0	0	6.2	0	1.94E-06	D	A
MW-0092	21-Apr-87	0	0		0	0	7.9	0	2.47E-06	D	A
MW-0092	28-Jul-87	0	0		0	0	9.4	0	2.93E-06	D	A
MW-0092	26-Oct-87	0	0		0	0	3.7	0	1.19E-06	D	A
MW-0092	26-Oct-87	0	0		0	0	3.8	0	1.19E-06	D	A
MW-0092	21-Jan-88	0	0		0	0	3.7	0	1.37E-06	D	A
MW-0092	21-Jan-88	0	0		0	0	4.4	0	1.37E-06	D	A
MW-0092	12-Apr-88	0	0		0	0	4.1	0	1.28E-06	D	A
MW-0092	21-Jul-88	0	0		0	0	3.8	0	1.19E-06	D	A
MW-0092	05-Oct-88	0	0		0	0	3.25	0	1.01E-06	D	A
MW-0092	17-Jan-89	0	0		0	0	2.7	0	8.43E-07	D	A
MW-0092	20-Apr-89	0	0		0	0	1.9	0	5.93E-07	D	A
MW-0092	24-Jul-89	0	0		0	0	2.9	0	9.05E-07	D	A
MW-0092	16-Oct-89	0	0		0	0	3.7	0	1.15E-06	D	A
MW-0092	17-Jan-90	0	0		0	0	3	0	9.36E-07	D	A
MW-0092	17-Jan-90	0	0		0	0.22	2.3	0	9.36E-07	D	A
MW-0092	09-Apr-90	0	0		0	0	1.4	0	4.37E-07	D	A
MW-0092	27-Jul-90	0	0		0	0	1.3	0	2.01E-06	D	A
MW-0092	15-Oct-90	0	0		0	0	0.47	0	1.47E-07	D	A
MW-0092	13-Dec-90								0	D	A
MW-0092	22-Jan-91	0	0		0	0	1.4	0	4.37E-07	D	A
MW-0092	11-Jul-91	0	0		0	0	0.79	0	2.47E-07	D	A
MW-0092	14-Jan-93	0	0	0	0	0	0	0	0	D	A
MW-0100	21-Dec-85	0	0		0	0	0	0	0	G	BC
MW-0100	27-Feb-86	0	0		0	0	0	0	4.84E-07	G	BC
MW-0100	16-Sep-86	0	0		0	0	0	0	0	G	BC
MW-0100	09-Jan-87	0	0		0	0	0	0	0	G	BC
MW-0100	17-Apr-87	0	0		0	0	0	0	0	G	BC
MW-0100	07-Aug-87	0	0		0	0	0	0	0	G	BC
MW-0100	19-Oct-87	0	0		0	0	0	0	0	G	BC
MW-0100	22-Jan-88	0	0		0	0	0	0	0	G	BC
MW-0100	14-Apr-88	0	0		0	0	0	0	0	G	BC
MW-0100	19-Jul-88	0	0		0	0	0	0	0	G	BC
MW-0100	11-Oct-88	0	0		0	0	0	0	0	G	BC
MW-0100	29-Dec-89	0	0		0	0	0	0	0	G	BC
MW-0100	22-Oct-90	0	0		0	0	0	0	0	G	BC
MW-0100	10-Oct-91	0	0		0	0	0	0	0	G	BC
MW-0100	16-Jan-92	0	0		0	0	0	0	0	G	BC
MW-0100	13-Oct-92	0	0	0	0	0	0	0	0	G	BC
MW-0101	18-Nov-85	0	0		0	0	0	0	0	G	A
MW-0101	05-Mar-86	0	0		0	0	0	0	0	G	A
MW-0101	16-Sep-86	0	0		0	0	0	0	0	G	A
MW-0101	09-Jan-87	0	0		0	0	0	0	0	G	A
MW-0101	17-Apr-87	0	0		0	0	0	0	0	G	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0101	05-Aug-87	0	0		0	0	0	0	0	G	A
MW-0101	19-Oct-87	0	0		0	0	0	0	0	G	A
MW-0101	22-Jan-88	0	0		0	0	0	0	0	G	A
MW-0101	14-Apr-88	0	0		0	0	0	0	0	G	A
MW-0101	19-Jul-88	0	0		0	0	0	0	0	G	A
MW-0101	11-Oct-88	0	0		0	0	0	0	0	G	A
MW-0101	29-Dec-89	0	0		0	0	0	0	0	G	A
MW-0101	22-Oct-90	0	0		0	0	0	0	0	G	A
MW-0101	10-Oct-91	0	0		0	0	0	0	0	G	A
MW-0101	21-Jan-92	0	0		0	0	0	0	0	G	A
MW-0101	06-Jul-92	0	0	0	0	0	0	0	0	G	A
MW-0101	13-Oct-92	0	0	0	0	0	0	0	0	G	A
MW-0101	18-Jan-93	0	0	0	0	0	0	0	0	G	A
MW-0101	22-Jul-93	0	0	0	0	0	0	0	0	G	A
MW-0102	04-Nov-85	0	0		0	0	0	0	0	G	A
MW-0102	05-Nov-85								0	G	A
MW-0102	11-Mar-86	0	0		0	0	0	0	3.74E-07	G	A
MW-0102	09-Jan-87	0	0		0	0	0	0	0	G	A
MW-0102	22-Apr-87	0	0		0	0	0	0	0	G	A
MW-0102	07-Aug-87	0	0		0	0	0	0	0	G	A
MW-0102	19-Oct-87	0	0		0	0	0	0	0	G	A
MW-0102	20-Jan-88	0	0		0	0	0	0	0	G	A
MW-0102	25-Apr-88	0	0		0	0	0	0	0	G	A
MW-0102	12-Jul-88	0	0		0	0	0	0	0	G	A
MW-0102	04-Oct-88	0	0		0	0	0	0	0	G	A
MW-0102	11-Oct-89	0	0		0	0	0	0	0	G	A
MW-0102	30-Jul-90								0	G	A
MW-0102	04-Dec-90	0	0		0	0	0	0	0	G	A
MW-0102	18-Jul-91	0	0		0	0	0	0	0	G	A
MW-0102	15-Apr-93	0	0	0	0	0	0	0	0	G	A
MW-0103	20-Dec-85	0	0		0	0	0	0	8.10E-05	G	B
MW-0103	11-Mar-86	0	0		0	0	0	0	0	G	B
MW-0103	09-Jan-87	0	0		0	0	0	0	0	G	B
MW-0103	22-Apr-87	0	0		0	0	0	0	0	G	B
MW-0103	04-Aug-87	0	0		0	0	0	0	0	G	B
MW-0103	19-Oct-87	0	0		0	0	0	0	0	G	B
MW-0103	20-Jan-88	0	0		0	0	0	0	0	G	B
MW-0103	25-Apr-88	0	0		0	0	0	0	0	G	B
MW-0103	12-Jul-88	0	0		0	0	0	0	0	G	B
MW-0103	04-Oct-88	0	0		0	0	0	0	0	G	B
MW-0103	12-Oct-89	0	0		0	0	0	0	0	G	B
MW-0103	20-Jul-90	0	0		73	0	3.4	0	9.45E-05	G	B
MW-0103	29-Oct-90	0	0		0	0	0	0	0	G	B
MW-0103	18-Jul-91	0	0		0	0	0	0	0	G	B
MW-0103	26-Jul-93	0	0	0	0	0	1.22	0	9.30E-07	G	B
MW-0104	15-Dec-85	0	0		0	0	0	0	2.18E-06	D	B
MW-0104	26-Mar-86	0	0		0	0	0	0	1.81E-04	D	B
MW-0104	28-Jan-87	0	0		0	0	0	0	0	D	B
MW-0104	11-May-87	0	0		0	0	0	0	0	D	B
MW-0104	31-Jul-87	0	0		0	0	0	0	0	D	B
MW-0104	21-Oct-87	0	0		0	0	0	0	0	D	B
MW-0104	21-Jan-88	0	0		0	0	0	0	0	D	B
MW-0104	11-Apr-88	0	0		0	0	0	0	0	D	B
MW-0104	08-Jul-88	0	0		0	0	0	0	0	D	B
MW-0104	12-Oct-88	0	0		0	0	0	0	0	D	B
MW-0104	20-Jan-89	0	0		0	0	0	0	0	D	B
MW-0104	04-May-89	0	0		0	0	0	0	0	D	B
MW-0104	27-Jul-89	0	0		0	0	0	0	0	D	B
MW-0104	14-Dec-89	0	0		0	0	0	0	0	D	B
MW-0104	30-Jan-90	0	0		0	0		0	1.05E-06	D	B
MW-0104	02-Aug-90	0	0		0	0	0	0	2.43E-06	D	B

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0104	22-Jan-91	0	0		0	0	0	0	1.92E-07	D	B
MW-0104	11-Jul-91	0	0		0	0	0	0	0	D	B
MW-0104	19-Oct-92	0	0	0	0	0	0	0	0	D	B
MW-0105	21-Dec-85	0	0		0	0	0	0	4.57E-05	D	B
MW-0105	27-Mar-86	0	0		0	0	0	0	8.72E-05	D	B
MW-0105	07-Jan-87	0	0		0	0	0	0	0	D	B
MW-0105	22-Apr-87	0	0		0	0	0	0	0	D	B
MW-0105	11-Aug-87	0	0		0	0	0	0	0	D	B
MW-0105	23-Oct-87	0	0		0	0.31	0	0	0	D	B
MW-0105	22-Jan-88	0	0		0	0	0	0	0	D	B
MW-0105	26-Apr-88	0	0		0	0	0	0	0	D	B
MW-0105	19-Jul-88	0	0		0	0	0	0	0	D	B
MW-0105	13-Oct-88	0	0		0	0	0	0	0	D	B
MW-0105	17-Jan-89	0	0		0	0	0	0	0	D	B
MW-0105	10-Apr-89	0	0		0	0	0	0	0	D	B
MW-0105	31-Jul-89	0	0		0	0	0	0	0	D	B
MW-0105	14-Dec-89	0	0		0	0	0	0	0	D	B
MW-0105	12-Jan-90	0	0		0	0	0	0	0	D	B
MW-0105	01-May-90	0	0		0	0	0	0	0	D	B
MW-0105	29-Oct-90	0	0		0	0	0	0	1.04E-07	D	B
MW-0105	16-Jul-91	0	0		0	0	0	0	2.70E-07	D	B
MW-0105	19-Oct-92	0	0	0	0	0	0	0	0	D	B
MW-0106	21-Nov-85	0	0		0	0	0	0	0	D	A
MW-0106	13-Mar-86	0	0		0	0	0	0	0	D	A
MW-0106	05-Jan-87	0	0		0	0	0	0	0	D	A
MW-0106	21-Apr-87	0	0		0	0	0	0	0	D	A
MW-0106	28-Jul-87	0	0		0	0	0	0	0	D	A
MW-0106	09-Oct-87	0	0		0	0	0	0	0	D	A
MW-0106	25-Jan-88	0	0		0	0	0	0	0	D	A
MW-0106	18-Apr-88	0	0		0	0	0	0	0	D	A
MW-0106	13-Jul-88	0	0		0	0	0	0	0	D	A
MW-0106	05-Oct-88	0	0		0	0	0	0	0	D	A
MW-0106	27-Dec-89	0	0		0	0	0	0	0	D	A
MW-0107	07-Nov-85	0	0		0	0	0	0	0	C	A
MW-0107	01-Apr-86	0	0		0	0	0	0	0	C	A
MW-0107	07-Jan-87	0	0		0	0	0	0	0	C	A
MW-0107	23-Apr-87	0	0		0	0	0	0	0	C	A
MW-0107	30-Jul-87	0	0		0	0	0	0	1.12E-07	C	A
MW-0107	12-Oct-87	0	0		0	0	0	0	0	C	A
MW-0107	14-Jan-88	0	0		0	0	0	0	0	C	A
MW-0107	18-Apr-88	0	0		0	0	0	0	0	C	A
MW-0107	12-Jul-88	0	0		0	0	0	0	0	C	A
MW-0107	05-Oct-88	0	0		0	0	0	0	0	C	A
MW-0107	02-Jan-90	0	0		0	0	0	0	0	C	A
MW-0108	27-Dec-85	0	0		0	0	0	0	0	C	AB
MW-0108	01-Apr-86	0	0		0	0	0	0	0	C	AB
MW-0108	07-Jan-87	0	0		0	0	0	0	0	C	AB
MW-0108	22-Apr-87	0	0		0	0	0	0	0	C	AB
MW-0108	30-Jul-87	0	0		0	0	0	0	1.70E-07	C	AB
MW-0108	12-Oct-87	0	0		0	0	0	0	0	C	AB
MW-0108	14-Jan-88	0	0		0	0	0	0	0	C	AB
MW-0108	18-Apr-88	0	0		0	0	0	0	0	C	AB
MW-0108	12-Jul-88	0	0		0	0	0	0	0	C	AB
MW-0108	05-Oct-88	0	0		0	0	0	0	0	C	AB
MW-0108	06-Oct-89	0	0		0	0	0	0	0	C	AB
MW-0108	23-Jul-90	0	0		0	0	0.3	0	9.36E-08	C	AB
MW-0108	22-Jul-91	0	0		0	0	0	0	2.08E-07	C	AB
MW-0108	16-Oct-92	0	0	0	0	0	0	0	0	C	AB
MW-0109	06-Jan-87	0	0		0	0	0	0	0	C	B
MW-0109	22-Apr-87	0	0		0	0	0	0	0	C	B
MW-0109	30-Jul-87	0	0		0	0	0	0	2.70E-07	C	B

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0109	16-Oct-87	0	0		0	0	0	0	0	C	B
MW-0109	14-Jan-88	0	0		0	0	0	0	0	C	B
MW-0109	18-Apr-88	0	0		0	0	0	0	0	C	B
MW-0109	12-Jul-88	0	0		0	0	0	0	0	C	B
MW-0109	05-Oct-88	0	0		0	0	0	0	0	C	B
MW-0109	06-Oct-89	0	0		0	0.64	0	0	0	C	B
MW-0109	24-Jul-90	0	0		0.38	0	0	0	4.87E-07	C	B
MW-0109	22-Jul-91	0	0		0	0	0	0	9.34E-08	C	B
MW-0109	16-Oct-92	0	0	0	0	0	0	0	0	C	B
MW-0110	06-Nov-85	0	0		0	0	0	0	0	C	A
MW-0110	31-Mar-86	0	0		0	0	0	0	3.11E-06	C	A
MW-0110	05-Jan-87	0	0		0	0	0	0	0	C	A
MW-0110	23-Apr-87	0	0		0	0	0	0	0	C	A
MW-0110	29-Jul-87	0	0		0	0	0	0	4.36E-07	C	A
MW-0110	21-Oct-87	0	0		0	0	0	0	0	C	A
MW-0110	18-Jan-88	0	0		0	0	0	0	0	C	A
MW-0110	26-Apr-88	0	0		0	0	0	0	0	C	A
MW-0110	25-Jul-88	0	0		0	0	0	0	0	C	A
MW-0110	12-Oct-88	0	0		0	0	0	0	0	C	A
MW-0110	27-Dec-89	0	0		0	0	0	0	0	C	A
MW-0110	01-Aug-90	0	0		0	0	0	0	0	C	A
MW-0110	25-Jul-91	0	0		0	0	0	0	0	C	A
MW-0110	30-Jul-93	0	0	0	0	0	0	0	0	C	A
MW-0111	06-Nov-85	0	0		0	0	0	0	0	C	A
MW-0111	03-Apr-86	0	0		0	0	0.2	0	9.36E-08	C	A
MW-0111	03-Apr-86	0	0		0	0	0.3	0	9.36E-08	C	A
MW-0111	22-Sep-86	0	0		0	0	0.3	0	9.36E-08	C	A
MW-0111	09-Jan-87	0	0		0	0	0	0	0	C	A
MW-0111	23-Apr-87	0	0		0	0	1.1	0	3.43E-07	C	A
MW-0111	29-Jul-87	0	0		0	0	0	0	2.08E-07	C	A
MW-0111	19-Oct-87	0	0		0	0	0.39	0	1.22E-07	C	A
MW-0111	15-Jan-88	0.12	0		0	0	0.83	0	5.17E-07	C	A
MW-0111	26-Apr-88	0.1	0		0	0	1.1	0	5.59E-07	C	A
MW-0111	12-Jul-88	0.17	0		0	0	1.4	0	1.28E-06	C	A
MW-0111	15-Dec-89	0	0		0	0	3.8	0	2.19E-06	C	A
MW-0111	19-Apr-90	0.15	0		0	0	2.5	0	1.97E-06	C	A
MW-0111	19-Apr-90	0.19	0		0	0	2.8	0	1.97E-06	C	A
MW-0111	29-Oct-90	0.56	0		0	0	2.8	0	2.92E-06	C	A
MW-0111	19-Apr-91	0.6	0		0	0	4.5	0	3.99E-06	C	A
MW-0111	21-Apr-93	0	0	0.60	0	0	8.40	0	5.33E-06	C	A
MW-0111	21-Apr-93	0	0	0.80	0	0	1.30	0	5.33E-06	C	A
MW-0111	02-Aug-93	0	0	1.24	0	0	2.91	0	1.85E-06	C	A
MW-0112	20-Dec-85	0	0		0	0	0	0	5.40E-05	C	B
MW-0112	02-Apr-86	0	0		0	0	0	0	2.49E-06	C	B
MW-0112	22-Sep-86	0	0		0	0	0	0	4.35E-06	C	B
MW-0112	09-Jan-87	0	0		0	0	0	0	0	C	B
MW-0112	24-Apr-87	0	0		0	0	0	0	0	C	B
MW-0112	29-Jul-87	0	0		0	0	0	0	2.91E-07	C	B
MW-0112	19-Oct-87	0	0		0	0	0	0	0	C	B
MW-0112	15-Jan-88	0	0		0	0	0	0	0	C	B
MW-0112	26-Apr-88	0	0		0	0	0	0	0	C	B
MW-0112	11-Jul-88	0	0		0	0	0	0	0	C	B
MW-0112	15-Dec-89	0	0		0	0	0	0	0	C	B
MW-0112	18-Apr-90	0	0		0	0	0	0	8.72E-08	C	B
MW-0112	18-Jan-91								0	C	B
MW-0113	09-Jan-87	0	0		0	0	0	0	0	C	AB
MW-0113	24-Apr-87	0	0		0	0	0	0	0	C	AB
MW-0113	29-Jul-87	0	0		0	0	0	0	0	C	AB
MW-0113	19-Oct-87	0	0		0	0	0	0	0	C	AB
MW-0113	15-Jan-88	0	0		0	0	0	0	0	C	AB
MW-0113	26-Apr-88	0	0		0	0	0	0	0	C	AB

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0113	11-Jul-88	0	0		0	0	0	0	0	C	AB
MW-0113	18-Dec-89	0	0		0	0	0	0	0	C	AB
MW-0113	18-Apr-90	0	0		1	0	0.65	0	1.48E-06	C	AB
MW-0113	05-Nov-90	0	0		0	0	0	0	0	C	AB
MW-0113	26-Jul-91	0	0		0	0	0	0	0	C	AB
MW-0114	11-Nov-85	0	0		0	0	0	0	0	C	A
MW-0114	02-Oct-86	0	0		0	0	0.21	0	2.90E-06	C	A
MW-0114	13-Jan-87	0	0		0	0	0	0	0	C	A
MW-0114	21-Apr-87	0	0		0	0	0	0	0	C	A
MW-0114	12-Aug-87	0	0		0	0	0	0	0	C	A
MW-0114	15-Oct-87	0	0		0	0	0	0	2.70E-07	C	A
MW-0114	12-Jul-88	0	0		0	0	0	0	0	C	A
MW-0114	10-Oct-88	0	0		0	0	0	0	0	C	A
MW-0114	20-Apr-89	0	0		0	0	0	0	0	C	A
MW-0115	19-Dec-85	0	0		0	0	0	0	1.41E-04	C	A
MW-0115	06-Mar-86	0	0		0	0	0	0	2.42E-07	C	A
MW-0115	19-Jan-87	0	0		0	0	0	0	0	C	A
MW-0115	20-Apr-87	0	0		0	0	0	0	0	C	A
MW-0115	27-Jul-87	0	0		0	0	0	0	0	C	A
MW-0115	08-Oct-87	0	0		0	0	0	0	0	C	A
MW-0115	07-Jan-88	0	0		0	0	0	0	0	C	A
MW-0115	22-Apr-88	0	0		0	0	0	0	0	C	A
MW-0115	18-Jul-88	0	0		0	0	0	0	0	C	A
MW-0115	03-Oct-88	0	0		0	0	0	0	0	C	A
MW-0115	16-Jan-89	0	0		0	0	0	0	0	C	A
MW-0115	20-Apr-89	0	0		0	0	0	0	0	C	A
MW-0115	28-Jul-89	0	0		0	0	0	0	0	C	A
MW-0115	11-Oct-89	0	0		0	0	0.21	0	6.55E-08	C	A
MW-0115	18-Jan-90	0	0		0	0	0	0	0	C	A
MW-0115	29-Oct-90	0	0		0	0	0	0	0	C	A
MW-0116	11-Nov-85	0	0		0	0	0	0	0	B	A
MW-0116	28-Feb-86	0	0		0.2	0	0	0	4.98E-07	B	A
MW-0116	26-Sep-86	0	0		0.23	0	0	0	8.27E-07	B	A
MW-0116	14-Jan-87	0	0		0	0	0	0	0	B	A
MW-0116	27-Apr-87	0	0		0.47	0	0	0	6.02E-07	B	A
MW-0116	03-Aug-87	0	0		0.25	0	0	0	4.90E-07	B	A
MW-0116	09-Oct-87	0	0		0	0	0	0	0	B	A
MW-0116	13-Jan-88	0	0		0.12	0	0	0	1.54E-07	B	A
MW-0116	11-Apr-88	0	0		0.17	0	0	0	2.18E-07	B	A
MW-0116	06-Jul-88	0	0		0	0	0	0	0	B	A
MW-0116	10-Oct-88	0	0		0	0	0	0	0	B	A
MW-0116	11-Oct-89	0	0		0	0	0	0	0	B	A
MW-0117	04-Mar-86								0	B	A
MW-0117	20-Apr-86	0.2	0		0	0	17	0	6.53E-06	B	A
MW-0117	20-Oct-86	0	0		0	0	19	0	8.83E-06	B	A
MW-0117	20-Oct-86	1	0		0	0	21	0	8.83E-06	B	A
MW-0118	25-Mar-86	0	0		0	0	0	0	0	B	B
MW-0118	21-Oct-86	0	0		0	0	1	0	1.57E-06	B	B
MW-0119	05-Mar-86	0	0		0	0	0	0	0	B	C
MW-0120	04-Mar-86								0	B	A
MW-0120	20-Apr-86	0.2	0		0	0	24	0	9.51E-06	B	A
MW-0120	13-Oct-86	0	0		0	0	20	0	8.63E-06	B	A
MW-0120	20-Jan-87	0	0		0	0	17.35	0	7.22E-06	B	A
MW-0120	20-Jan-87	0	0		0	0	19.32	0	7.22E-06	B	A
MW-0120	20-Apr-87	0	0		0	0	25	0	8.82E-06	B	A
MW-0120	08-Aug-87	0	0		0	0	26	0	9.02E-06	B	A
MW-0120	22-Oct-87	0.29	0		0	0	9.3	0	4.19E-06	B	A
MW-0120	23-Jan-88	0.19	0		0	0	8.8	0	3.61E-06	B	A
MW-0120	13-Apr-88	0.24	0		0	0	12	0	5.00E-06	B	A
MW-0120	11-Jul-88	0	0		0	0	12	0	3.75E-06	B	A
MW-0120	11-Jul-88	0.15	0		0	0	9.1	0	3.75E-06	B	A

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0120	12-Oct-88	0	0		0	0	6.2	0	2.17E-06	B	A
MW-0120	10-Jan-89	0	0		0	0	5.1	0	2.24E-06	B	A
MW-0120	10-Jan-89	0.15	0		0	0	4.9	0	2.24E-06	B	A
MW-0120	14-Apr-89	0.15	0		0	0	4.5	0	2.23E-06	B	A
MW-0120	11-Jul-89	0	0		0	0	0	0	0	B	A
MW-0121	26-Feb-86	0	0		0	0	0.2	0	3.04E-07	B	AB
MW-0121	23-Jan-87	0	0		0	0	0	0	0	B	AB
MW-0121	25-Apr-87	0	0		0	0	0	0	0	B	AB
MW-0121	01-Aug-87	0	0		0	0	0	0	0	B	AB
MW-0121	22-Oct-87	0	0		0	0	0	0	0	B	AB
MW-0121	23-Jan-88	0	0		0	0	0	0	0	B	AB
MW-0121	20-Apr-88	0	0		0	0	0	0	0	B	AB
MW-0121	11-Jul-88	0	0		0	0	0	0	0	B	AB
MW-0121	19-Oct-88	0	0		0	0	0	0	0	B	AB
MW-0121	13-Jan-89	0	0		0	0	0	0	0	B	AB
MW-0121	20-Apr-89	0	0		0	0.22	0	0	9.96E-08	B	AB
MW-0121	07-Jul-89	0	0		0	0	0	0	0	B	AB
MW-0121	16-Oct-89	0	0		0	0	0	0	0	B	AB
MW-0121	15-Jan-90	0	0		0	0.47	0	0	0	B	AB
MW-0121	27-Apr-90	0	0		0	0	0	0	0	B	AB
MW-0121	06-Aug-90	0	0		0	0	0	0	2.08E-07	B	AB
MW-0121	05-Nov-90	0	0		0	0	0	0	1.99E-07	B	AB
MW-0121	30-Jan-91	0	0		0	0	0	0	0	B	AB
MW-0121	24-Jul-91	0	0		0	0	0	0	0	B	AB
MW-0122	26-Feb-86	0	0		0	0	0	0	2.42E-07	B	C
MW-0122	26-Jan-87	0	0		0	0	0	0	0	B	C
MW-0122	07-May-87	0	0		0	0	0	0	0	B	C
MW-0122	08-Aug-87	0	0		0	0	0	0	0	B	C
MW-0122	22-Oct-87	0	0		0	0	0	0	0	B	C
MW-0122	23-Jan-88	0	0		0	0	0	0	0	B	C
MW-0122	19-Apr-88	0	0		0	0	0	0	0	B	C
MW-0122	18-Jul-88	0	0		0	0	0	0	0	B	C
MW-0122	12-Oct-88	0	0		0	0	0	0	0	B	C
MW-0122	10-Jan-89	0	0		0	0	0	0	0	B	C
MW-0122	14-Apr-89	0	0		0	0	0	0	0	B	C
MW-0122	07-Jul-89	0	0		0	0	0	0	0	B	C
MW-0122	12-Dec-89	0	0		0	0	0	0	2.28E-07	B	C
MW-0123	25-Mar-86								0	B	A
MW-0123	04-Apr-86	0	0		0	0	3.1	0	2.50E-06	B	A
MW-0123	21-Oct-86	0	0		0	0	7.1	0	3.66E-06	B	A
MW-0124	25-Feb-86	0	0		0	0.5	0	0	7.95E-07	B	AB
MW-0125	25-Feb-86	0	0		0	0	0	0	2.42E-07	B	C
MW-0126	03-Mar-86	0	0		0	0	0	0	6.23E-07	B	AB
MW-0127	04-Mar-86	0	0		0	0	0	0	5.40E-07	B	C
MW-0127	24-Oct-86	0	0		0.15	0	1.3	0	5.98E-07	B	C
MW-0128	05-Dec-86	41	5.7		0	0	41000	0	1.29E-02	C	A
MW-0128	16-Jan-87	0	0		0	0	28200	0	8.78E-03	C	A
MW-0128	16-Apr-87	56	0		23	0	55000	0	8.66E-03	C	A
MW-0128	16-Apr-87	63	0		19	0	27000	0	8.66E-03	C	A
MW-0128	12-Aug-87	0	0		0	0	68000	0	2.11E-02	C	A
MW-0128	17-Sep-87	75	5.5		0	0	36000	1.2	1.15E-02	C	A
MW-0128	23-Oct-87	0	0		0	0	27000	0	8.41E-03	C	A
MW-0128	13-Jan-88	0	0		0	0	19000	0	5.92E-03	C	A
MW-0128	12-Apr-88	0	0		0	0	27000	0	8.41E-03	C	A
MW-0128	12-Jul-88	0	0		0	0	34000	0	1.40E-02	C	A
MW-0128	12-Jul-88	0	0		0	0	45000	0	1.40E-02	C	A
MW-0128	20-Oct-88	0	0		0	0	22000	0	6.86E-03	C	A
MW-0128	12-Jan-89	0	0		0	0	17000	0	5.47E-03	C	A
MW-0128	10-Apr-89	0	0		0	0	11000	0	3.74E-03	C	A
MW-0128	10-Apr-89	0	0		0	0	12000	0	3.74E-03	C	A
MW-0128	20-Jul-89	0	0		0	0	26000	0	8.10E-03	C	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0128	06-Oct-89	0	0		0	0	18000	0	5.61E-03	C	A
MW-0128	30-Jan-90	0	0		0	0	20000	0	6.23E-03	C	A
MW-0128	30-Jan-90	0	0		0	0	21000	0	6.23E-03	C	A
MW-0128	13-Apr-90	0	0		0	0		0	0	C	A
MW-0128	19-Jul-90	0	0		16000	0	42000	0	3.35E-02	C	A
MW-0128	04-Dec-90	0	0		0	0	12000	0	3.74E-03	C	A
MW-0128	07-Jan-91	0	0		0	0	33000	0	1.03E-02	C	A
MW-0128	26-Jul-91	0	0		0	0	15000	0	4.68E-03	C	A
MW-0128	26-Jul-91	0	0		0	0	16000	0	4.68E-03	C	A
MW-0128	15-Oct-92	0	0	0	0	0	11000	0	3.43E-03	C	A
MW-0129	05-Dec-86	0	0		0	0	130	0	4.06E-05	C	A
MW-0129	16-Jan-87	0	0		0	0	10	0	3.12E-06	C	A
MW-0129	15-Apr-87	0	0		0	0	48	0	1.50E-05	C	A
MW-0129	12-Aug-87	0	0		0	0	610	0	1.90E-04	C	A
MW-0129	23-Oct-87	0	0		0	0	45	0	1.40E-05	C	A
MW-0129	13-Jan-88	0	0		0	0	11	0	3.43E-06	C	A
MW-0129	12-Apr-88	0	0		0	0	27	0	8.43E-06	C	A
MW-0129	12-Jul-88	0	0		0	0	220	0	6.87E-05	C	A
MW-0129	10-Oct-88	0	0		0	0	93	0	2.90E-05	C	A
MW-0129	12-Jan-89	0	0		0	0	140	0	5.31E-05	C	A
MW-0129	12-Jan-89	0	0		0	2.3	170	0	5.31E-05	C	A
MW-0129	20-Apr-89	0	0		0	0	410	0	1.28E-04	C	A
MW-0129	20-Jul-89	0	0		0	0	140	0	4.37E-05	C	A
MW-0129	06-Oct-89	0	0		0	0	140	0	4.37E-05	C	A
MW-0129	19-Jan-90	0	0		0	0	290	0	9.05E-05	C	A
MW-0129	13-Apr-90	0	0		0	0	530	0	1.65E-04	C	A
MW-0129	20-Jul-90	0	0		86	0	680	0	3.22E-04	C	A
MW-0129	20-Jul-90	0	0		2500	0	560	0	3.22E-04	C	A
MW-0129	10-Oct-90	0	0		0	0	1500	0	4.68E-04	C	A
MW-0129	07-Jan-91	0	0		0	0	1400	0	4.37E-04	C	A
MW-0129	18-Apr-91	0	0		0	0	2400	0	7.49E-04	C	A
MW-0129	26-Jul-91	0	0		0	0	2800	0	8.74E-04	C	A
MW-0129	15-Oct-92	0	0	0	0	0	3800	0	1.19E-03	C	A
MW-0130	13-Nov-86	0	3.2		0	0.97	2.6	0	8.12E-07	C	B
MW-0130	16-Jan-87	0	4		0	0.8	1.9	0	5.93E-07	C	B
MW-0130	15-Apr-87	0	6.1		0	1.3	3.2	0	1.57E-06	C	B
MW-0130	29-Jul-87	0	7.8		0	0	4	0	1.25E-06	C	B
MW-0130	29-Jul-87	0	8.6		0	1.2	4	0	1.25E-06	C	B
MW-0130	27-Oct-87	0	2.3		0	0.93	1.1	0	6.53E-07	C	B
MW-0130	27-Oct-87	0	2.5		0	0.85	1.2	0	6.53E-07	C	B
MW-0130	13-Jan-88	0	2.9		0	0.61	2	0	1.01E-06	C	B
MW-0130	12-Apr-88	0	2.7		0	0.51	2.2	0	9.52E-07	C	B
MW-0130	12-Jul-88	0	2.7		0	0	1.5	0	4.68E-07	C	B
MW-0130	12-Jul-88	0	3		0	0.7	2.2	0	4.68E-07	C	B
MW-0130	10-Oct-88	0	1.9		0	0.61	1.5	0	7.20E-07	C	B
MW-0130	10-Oct-88	0	2		0	0.47	3.7	0	7.20E-07	C	B
MW-0130	12-Jan-89	0	2.8		0	0.78	2.7	0	1.37E-06	C	B
MW-0130	10-Apr-89	0	1		0	0.27	2.3	0	1.04E-06	C	B
MW-0130	20-Jul-89	0	1		0.18	0.22	2.6	0	1.40E-06	C	B
MW-0130	13-Dec-89	0	0		0	0	3.8	0	1.50E-06	C	B
MW-0130	13-Dec-89	0	0.57		0	0.24	4.1	0	1.50E-06	C	B
MW-0130	19-Jan-90	0	0		0.11	0.2	3.4	0	1.47E-06	C	B
MW-0130	12-Apr-90	0	0.33		0	0	1.8	0	5.62E-07	C	B
MW-0130	19-Jul-90	0	0		5.9	0	4.2	0	9.09E-06	C	B
MW-0130	09-Oct-90	0	0		0	0	1.5	0	4.68E-07	C	B
MW-0130	09-Jan-91	0	0.34		0	0	1.3	0	5.65E-07	C	B
MW-0130	09-Jan-91	0	0.5		0	0	1.6	0	5.65E-07	C	B
MW-0130	18-Apr-91	0	0		0	0	1	0	3.12E-07	C	B
MW-0130	29-Jul-91	0	0		0	0	1.6	0	4.99E-07	C	B
MW-0130	15-Oct-92	0	0	0.58	0	0	2.7	0	8.43E-07	C	B
MW-0131	19-Nov-86	0	0		0	0	27	0	8.65E-06	C	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0131	19-Nov-86	0	0		0	0.78	29	0	8.65E-06	C	A
MW-0131	19-Jan-87	0	0		0	0	19	0	5.93E-06	C	A
MW-0131	28-Apr-87	0	0		0	0.24	30	0	9.36E-06	C	A
MW-0131	07-Aug-87	0	0		0	0	120	0	3.75E-05	C	A
MW-0131	14-Oct-87	0	0		0	0	40	0	1.25E-05	C	A
MW-0131	14-Oct-87	0	0		0	0	55	0	1.25E-05	C	A
MW-0131	19-Jan-88	0.31	0		0	0	32	0	1.11E-05	C	A
MW-0131	13-Apr-88	0.45	0		0	0	52	0	1.78E-05	C	A
MW-0131	13-Jul-88	0	0		0	0	83	0	2.59E-05	C	A
MW-0131	13-Jul-88	1.1	0		0	0	99	0	2.59E-05	C	A
MW-0131	04-Oct-88	0	0		0	0	72	0	2.25E-05	C	A
MW-0131	12-Jan-89	0.82	0		0	0	90	0	3.25E-05	C	A
MW-0131	11-Apr-89	0	0		0	0	97	0	3.16E-05	C	A
MW-0131	14-Jul-89	0	0		0	0	27	0	9.22E-06	C	A
MW-0131	26-Jan-90	0	0		0	0	49	0	1.53E-05	C	A
MW-0131	26-Apr-90	0	0		0	0	50	0	1.70E-05	C	A
MW-0131	19-Jul-90	0	0		0	0	49	0	1.65E-05	C	A
MW-0131	16-Oct-90	0	0		0	0	16	0	4.99E-06	C	A
MW-0131	09-Jan-91	0	0		0	0	16	0	5.44E-06	C	A
MW-0131	23-Apr-91	0	0		0	0	25	0	8.72E-06	C	A
MW-0131	30-Jul-91	0	46		0	95	120	0	3.75E-05	C	A
MW-0132	24-Nov-86	0.7	0.33		0	0	90	0	3.03E-05	B	C
MW-0132	21-Jan-87	0	0		0	0	62	0	1.94E-05	B	C
MW-0132	15-May-87	0	0		0	0	100	0	3.12E-05	B	C
MW-0132	15-May-87	0	0		0	0	110	0	3.12E-05	B	C
MW-0132	29-Jul-87	0	0		0	0	110	0	3.43E-05	B	C
MW-0132	24-Oct-87	0	0		0	0	130	0	3.50E-05	B	C
MW-0132	24-Oct-87	0.3	0.32		0	0	110	0	3.50E-05	B	C
MW-0132	22-Jan-88	0.9	0.48		0	0	77	0	2.60E-05	B	C
MW-0132	20-Apr-88	0	0		0	0	47	0	1.60E-05	B	C
MW-0132	18-Jul-88	0	0		0	0	85	0	2.65E-05	B	C
MW-0132	18-Jul-88	0.87	0		0	0	87	0	2.65E-05	B	C
MW-0132	13-Oct-88	0.55	0		0	0	90	0	3.14E-05	B	C
MW-0132	13-Oct-88	0.79	0		0	0	95	0	3.14E-05	B	C
MW-0132	16-Jan-89	1.2	0		0	0	90	0	3.20E-05	B	C
MW-0132	17-Apr-89	2	0		0	0	62	0	3.21E-05	B	C
MW-0132	17-Apr-89	3	0		0	0	75	0	3.21E-05	B	C
MW-0132	06-Jul-89	0.75	0		0	0	55	0	1.95E-05	B	C
MW-0132	11-Oct-89	1.2	0		0	0	90	0	3.28E-05	B	C
MW-0132	17-Jan-90	0	0		0	0	130	0	4.51E-05	B	C
MW-0132	17-Jan-90	2	0		0	0	120	0	4.51E-05	B	C
MW-0132	25-Apr-90	0.68	0		3.2	0	130	0	4.61E-05	B	C
MW-0132	20-Jul-90	0	0		87	0	230	0	1.83E-04	B	C
MW-0132	01-Nov-90	0	0		0	0	91	0	2.84E-05	B	C
MW-0132	30-Jan-91	0	0		0	0	73	0	2.48E-05	B	C
MW-0132	06-May-91	0	0		0	0	59	0	1.84E-05	B	C
MW-0132	06-May-91	0	0		0	0	69	0	1.84E-05	B	C
MW-0132	17-Jul-91	1.3	0		0	0	86	0	3.34E-05	B	C
MW-0132	07-Oct-91	0	0		0	0	77	0	2.40E-05	B	C
MW-0132	05-Feb-92	0	0		0	0	87	0	3.39E-05	B	C
MW-0132	05-Feb-92	0	0		0	0	100	0	3.39E-05	B	C
MW-0132	22-Jul-92								0	B	C
MW-0132	19-Aug-92	0	0	23	0	0	36	0	1.18E-05	B	C
MW-0132	19-Oct-92	1.1	0	25	0	0	63	0	2.65E-05	B	C
MW-0132	27-Jan-93	0.51	0	16	0	0	48	0	1.78E-05	B	C
MW-0132	06-Aug-93	0	0	12.10	0	0	31	0	2.55E-05	B	C
MW-0132	06-Aug-93	0.65	0	9.76	0	1.31	35	0	2.55E-05	B	C
MW-0133	08-Feb-88	0	0		0	0	0	0	0	B	C
MW-0133	14-Apr-88	0	0		0	0	0	0	0	B	C
MW-0133	11-Jul-88	0	0		0	0	0	0	0	B	C
MW-0133	06-Oct-88	0	0		0	0	0	0	0	B	C

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0133	19-Jan-89	0	0		0	0	0	0	0	B	C
MW-0133	07-Apr-89	0	0		0	0	0	0	0	B	C
MW-0133	10-Jul-89	0	0		0	0	0	0	0	B	C
MW-0133	12-Oct-89	0	0		0	0	0	0	0	B	C
MW-0133	22-Jan-90	0	0		0	3.4	0	0	0	B	C
MW-0133	10-Apr-90	0	0		0	0	0	0	0	B	C
MW-0133	19-Jul-90	0	0		0.71	0	0	0	9.09E-07	B	C
MW-0133	08-Oct-90	0	0		0	0	0	0	0	B	C
MW-0133	16-Jan-91	0	0		0	0	0	0	0	B	C
MW-0133	15-Jul-91	0	0		0	0	0	0	0	B	C
MW-0133	14-Oct-92	0	0	0	0	0	0	0	0	B	C
MW-0134	08-Feb-88	0	0		0	0	0	0	0	B	B
MW-0134	14-Apr-88	0	0		0	0	0.75	0	2.34E-07	B	B
MW-0134	11-Jul-88	0	0		0	0	2.9	0	9.05E-07	B	B
MW-0134	06-Oct-88	0	0		0	0	2.5	0	7.80E-07	B	B
MW-0134	16-Jan-89	0	0		0	0	2.9	0	9.05E-07	B	B
MW-0134	07-Apr-89	0	0		0	0	3.3	0	1.03E-06	B	B
MW-0134	10-Jul-89	0	0		0	0	3.2	0	9.99E-07	B	B
MW-0134	12-Oct-89	0	0		0	0	4.5	0	1.40E-06	B	B
MW-0134	15-Jan-90	0	0		0	0	2.9	0	9.05E-07	B	B
MW-0134	11-Apr-90	0	0		0	0	2.8	0	8.74E-07	B	B
MW-0134	19-Jul-90	0	0		32	0	9.9	0	4.41E-05	B	B
MW-0134	09-Oct-90	0	0		0	0	3.9	0	1.37E-06	B	B
MW-0134	09-Oct-90	0	0		0	0	4.4	0	1.37E-06	B	B
MW-0134	16-Jan-91	0	0		0	0	2.8	0	8.74E-07	B	B
MW-0134	08-Apr-91	0	0		0	0	4.1	0	1.28E-06	B	B
MW-0134	15-Jul-91	0	0		0	0	1.9	0	5.93E-07	B	B
MW-0135	08-Feb-88	0.74	0		0	0	30	0	1.22E-05	B	A
MW-0135	14-Apr-88	0.95	0		0	0	26	0	1.18E-05	B	A
MW-0135	11-Jul-88	0.46	0		0	0	27	0	1.15E-05	B	A
MW-0135	08-Nov-88	0.39	0		0	0	25	0	1.02E-05	B	A
MW-0135	16-Jan-89	0.45	0		0	0	25	0	9.99E-06	B	A
MW-0135	07-Apr-89	0.3	0		0	0	15	0	6.37E-06	B	A
MW-0135	11-Jul-89	0.22	0		0	0	17	0	7.11E-06	B	A
MW-0135	11-Jul-89	0.24	0		0	0	19	0	7.11E-06	B	A
MW-0135	13-Oct-89	0.54	0		0	0	24	0	1.01E-05	B	A
MW-0135	22-Jan-90	1	0		0	0	19	0	9.29E-06	B	A
MW-0135	22-Jan-90	2.5	0		9.6	0	23	0	9.29E-06	B	A
MW-0135	10-Apr-90	0.49	0		0	0		0	2.51E-06	B	A
MW-0135	03-Jul-90	0.13	0		0	0	18	0	6.76E-06	B	A
MW-0135	08-Oct-90	0	0		0	0	18	0	5.62E-06	B	A
MW-0135	16-Jan-91	0.22	0		0	0	16	0	5.63E-06	B	A
MW-0135	16-Jan-91	0.25	0		0	0	15	0	5.63E-06	B	A
MW-0135	08-Apr-91	0.48	0		0	0	20	0	8.59E-06	B	A
MW-0135	15-Jul-91	0	0		0	0	11	0	3.43E-06	B	A
MW-0135	15-Jul-91	0	0		0	0	12	0	3.43E-06	B	A
MW-0135	13-Oct-92	0	0	1.6	0	0	8.7	0	2.72E-06	B	A
MW-0135	15-Apr-93	0	0	1.60	0	0	9.20	0	1.33E-05	B	A
MW-0135	15-Apr-93	0.27	0	1.90	0	0	12	0	1.33E-05	B	A
MW-0136	10-Mar-88	0	0		0	0	230	0	7.18E-05	C	C
MW-0136	25-Apr-88	0	0		0	0	230	0	7.18E-05	C	C
MW-0136	14-Jul-88	0	0		0	0	470	0	1.47E-04	C	C
MW-0136	10-Oct-88	0	0		0	0	260	0	8.12E-05	C	C
MW-0136	10-Oct-88	0	0		0	0	360	0	8.12E-05	C	C
MW-0136	26-Jan-89	0	0		0	0	230	0	7.18E-05	C	C
MW-0136	21-Apr-89	0	0		0	0	390	0	1.22E-04	C	C
MW-0136	25-Jul-89	0	0		0	0	130	0	4.06E-05	C	C
MW-0136	17-Oct-89	0	0		0	0	170	0	5.31E-05	C	C
MW-0136	30-Jan-90	0	0		0	0	690	0	2.15E-04	C	C
MW-0136	27-Apr-90	0	0		0	0	140	0	4.37E-05	C	C
MW-0136	06-Aug-90	0	0		0	0	100	0	3.93E-05	C	C

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0136	06-Aug-90	0	0		3.9	0	110	0	3.93E-05	C	C
MW-0136	02-Nov-90	0	0		0	0	72	0	2.25E-05	C	C
MW-0136	04-Feb-91	0	0		0	0	55	0	1.72E-05	C	C
MW-0136	17-May-91	0	0		0	0	31	0	9.68E-06	C	C
MW-0136	31-Jul-91	0	0		0	0	49	0	1.59E-05	C	C
MW-0136	14-Oct-92	0.28	0	1.5	0	0	38	0	1.25E-05	C	C
MW-0138	11-Mar-88	0	0		0	0	0	0	0	C	C
MW-0138	22-Apr-88	0	0		0	0	0	0	0	C	C
MW-0138	14-Jul-88	0	0		0	0	0	0	0	C	C
MW-0138	07-Oct-88	0	0		0	0	0	0	0	C	C
MW-0138	12-Jan-89	0	0		0	0	0	0	0	C	C
MW-0138	12-Apr-89	0	0		0	0	0	0	0	C	C
MW-0138	05-Jul-89	0	0		0	0	0	0	0	C	C
MW-0138	20-Dec-89	0	0		0	0.25	0	0	0	C	C
MW-0138	29-Jan-90	0	0		0	0	0	0	0	C	C
MW-0138	30-Apr-90	0	0		0	0	0	0	0	C	C
MW-0138	25-Jul-90	0	0		0.37	0	0	0	4.74E-07	C	C
MW-0138	05-Nov-90	0	0		0	0	0	0	0	C	C
MW-0138	24-Jan-91	0	0		0	0	0	0	0	C	C
MW-0138	31-Jul-91	0	0		0	0	0	0	0	C	C
MW-0138	14-Oct-92	0	0	0	0	0	0	0	0	C	C
MW-0139	09-Feb-88	1.8	1		0	0	89	0	3.31E-05	B	A
MW-0139	19-Apr-88	0	0		0	0	74	0	2.31E-05	B	A
MW-0139	08-Jul-88	0	0		0	0	83	0	2.59E-05	B	A
MW-0139	14-Oct-88	0	0		0	0	63	0	1.97E-05	B	A
MW-0139	16-Jan-89	1.9	0		0	2.2	100	0	3.74E-05	B	A
MW-0139	08-Apr-89	0	11		0	0	80	0	2.50E-05	B	A
MW-0139	18-Jul-89	1.7	0		0	0		0	6.44E-06	B	A
MW-0139	06-Oct-89	0	0		0	0	95	0	3.26E-05	B	A
MW-0139	06-Oct-89	1.7	0		0	0	92	0	3.26E-05	B	A
MW-0139	26-Jan-90	0	0		0	0	110	0	3.43E-05	B	A
MW-0139	26-Apr-90	0.89	0		0	0	130	0	4.33E-05	B	A
MW-0139	25-Jul-90	0	0		0	0	85	0	2.65E-05	B	A
MW-0139	02-Nov-90	0	0		0	0	100	0	3.12E-05	B	A
MW-0139	04-Dec-90								0	B	A
MW-0139	15-Jan-91	0	0		0	0	74	0	2.31E-05	B	A
MW-0139	22-Apr-91	0	0		0	0	86	0	2.68E-05	B	A
MW-0139	22-Apr-91	1.7	0		0	0	48	0	2.68E-05	B	A
MW-0139	16-Jul-91	0	0		0	0	83	0	2.59E-05	B	A
MW-0139	13-Oct-92	0	0	35	0	0	120	0	3.75E-05	B	A
MW-0139	29-Jul-93	0	0	32.5	0	0	130	0	1.03E-04	B	A
MW-0142	09-Feb-88	0	0		0	0	0	0	0	B	B
MW-0142	26-Apr-88	0	0		0	0	0	0	0	B	B
MW-0142	18-Oct-88	0	0		0	0	0	0	0	B	B
MW-0142	18-Jan-89	0	0		0	0	0	0	0	B	B
MW-0142	08-Apr-89	0	0		0	0	0	0	0	B	B
MW-0142	25-Jul-89	0	0		0	0	0	0	0	B	B
MW-0142	13-Dec-89	0	0		0	0	0	0	0	B	B
MW-0142	29-Jan-90	0	0		0	0	0	0	0	B	B
MW-0142	27-Apr-90	0	0		0	0	0	0	0	B	B
MW-0142	02-Aug-90	0	0		0	0	0	0	0	B	B
MW-0142	24-Jan-91	0	0		0	0	0	0	0	B	B
MW-0142	03-May-91	0	0		0	0	0	0	0	B	B
MW-0142	13-Jul-92	0	0	0	0	0	0	0	0	B	B
MW-0143	10-Feb-88	0	0		0	0	0	0	0	C	B
MW-0143	26-Apr-88	0	0		0	0	0	0	0	C	B
MW-0143	21-Jul-88	0	0		0	0	0	0	0	C	B
MW-0143	05-Oct-88	0	0		0	0	0	0	0	C	B
MW-0143	18-Jan-89	0	0		0	0	0	0	0	C	B
MW-0143	11-Apr-89	0	0		0	0	0	0	0	C	B
MW-0143	28-Jul-89	0	0		0	0	0	0	0	C	B

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0143	17-Oct-89	0	0		0	0	0	0	0	C	B
MW-0143	16-Jan-90	0	0		0	0	0	0	0	C	B
MW-0143	27-Apr-90	0	0		0	0	0	0	1.70E-07	C	B
MW-0143	08-Aug-90	0	0		0	0	0	0	0	C	B
MW-0143	28-Jan-91	0	0		0	0	0	0	0	C	B
MW-0143	07-May-91	0	0		0	0	0	0	0	C	B
MW-0143	17-Jul-92	0	0	0	0	0	0	0	0	C	B
MW-0143	19-Jul-93	0	0	0	0	0	0	0	0	C	B
MW-0145	24-Mar-89	0	0		0	0	1.3	0	4.06E-07	B	A
MW-0145	31-Jul-89	0	0		0	0	0	0	1.32E-07	B	A
MW-0145	02-Jan-90	0	0		0	0	2.1	0	6.55E-07	B	A
MW-0145	25-Jan-90	0	0		0	0	1.9	0	5.93E-07	B	A
MW-0145	25-Apr-90	0	0		0	0	1.8	0	5.62E-07	B	A
MW-0145	02-Aug-90	0	0		0	0	2.9	0	9.05E-07	B	A
MW-0145	02-Nov-90	0	0		0	0	1.5	0	4.68E-07	B	A
MW-0145	25-Jan-91	0	0		0	0	2.4	0	1.12E-06	B	A
MW-0145	03-May-91	0	0		0	0	2.2	0	6.87E-07	B	A
MW-0145	17-Jul-91	0	0		0	0	1.9	0	5.93E-07	B	A
MW-0145	08-Apr-93	0	0	0.31999999	0	0	1	0	6.35E-07	B	A
MW-0145	19-Jul-93	0.38600001	0	0.36199999	0	0	1.23000002	0	2.75E-06	B	A
MW-0146	24-Mar-89	0	0		0	0	0	0	0	B	B
MW-0146	11-Jul-89	0	0		0	0	0	0	0	B	B
MW-0146	21-Dec-89	0	0		0	0	0	0	0	B	B
MW-0146	06-Feb-90	0	0		0	0	0	0	0	B	B
MW-0146	08-May-90	0	0		0	0	0	0	0	B	B
MW-0146	30-Oct-90	0	0		0	0	0	0	0	B	B
MW-0146	03-May-91	0	0		0	0	0	0	0	B	B
MW-0146	21-Jul-93	0	0	0	0	0	0	0	0	B	B
MW-0147	20-Mar-89	0	0		0	0	0	0	0	B	C
MW-0147	11-Jul-89	0	0		0	0	0	0	0	B	C
MW-0147	21-Dec-89	0	0		0	0	0	0	0	B	C
MW-0147	06-Feb-90	0	0		0	0	0	0	0	B	C
MW-0147	09-May-90	0	0		0	0	0	0	0	B	C
MW-0147	23-Oct-90	0	0		0	0	0	0	0	B	C
MW-0147	03-May-91	0	0		0	0	0	0	0	B	C
MW-0148	30-Mar-89	0	0		0	0	8.7	0	3.21E-06	B	CD
MW-0148	06-Apr-89	0	0		0	0	7.2	0	2.25E-06	B	CD
MW-0148	07-Jul-89	0	0		0	0	5.3	0	1.87E-06	B	CD
MW-0148	07-Jul-89	0	0		0	0	6	0	1.87E-06	B	CD
MW-0148	19-Oct-89	0	0		0	0	7.6	0	2.77E-06	B	CD
MW-0148	22-Dec-89	0	0		0	0	6.8	0	2.12E-06	B	CD
MW-0148	07-Feb-90	0	0		0	0.39	7.2	0	2.40E-06	B	CD
MW-0148	01-May-90	0.14	0		0	0	8.6	0	3.28E-06	B	CD
MW-0148	30-Jul-90	0	0		0	0	0.65	0	2.03E-07	B	CD
MW-0148	08-Oct-90	0	0		0	0	6.8	0	2.28E-06	B	CD
MW-0148	08-Oct-90	0	0		0	0	7.3	0	2.28E-06	B	CD
MW-0148	23-Jan-91	0	0		0	0	7	0	2.29E-06	B	CD
MW-0148	01-May-91	0	0		0	0	14	0	4.37E-06	B	CD
MW-0148	01-Aug-91	0	0		0	0	11	0	4.74E-06	B	CD
MW-0148	04-Oct-91	0	0		0	0	12	0	3.75E-06	B	CD
MW-0148	27-Jan-92	0	0		0	0	15	0	4.68E-06	B	CD
MW-0148	27-Jan-92	0	0		0	3	15	0	4.68E-06	B	CD
MW-0148	14-Jul-92	0	0	4	0	0	13	0	4.06E-06	B	CD
MW-0148	08-Oct-92	0	0	4.7	0	0	8.8	0	2.75E-06	B	CD
MW-0148	12-Jan-93	0	0	2.3	0	0	9.1	0	2.84E-06	B	CD
MW-0148	21-Jul-93	0.37	0	2.65	0	0	9.73	0	8.06E-06	B	CD
MW-0149	25-Apr-89	0	0		0	0	0.23	0	7.18E-08	B	D
MW-0149	12-Jul-89	0	0		0	0	0.34	0	1.06E-07	B	D
MW-0149	22-Dec-89	0	0		0	0	0.71	0	2.22E-07	B	D
MW-0149	07-Feb-90	0	0		0	0	0.98	0	3.06E-07	B	D
MW-0149	10-May-90	0	0		0	0	1	0	3.12E-07	B	D

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0149	02-Jul-90	0	0		0	0	1.2	0	3.75E-07	B	D
MW-0149	22-Oct-90	0	0		0	0	0.83	0	9.85E-07	B	D
MW-0149	09-Jan-91	0	0		0	0	6.2	0	3.06E-06	B	D
MW-0149	09-Jan-91	0	0.24		0.13	0.48	7.3	0	3.06E-06	B	D
MW-0149	01-May-91	0	0		0	0	3.7	0	1.15E-06	B	D
MW-0149	01-Aug-91	0	0		0	0	1.4	0	4.37E-07	B	D
MW-0149	04-Oct-91	0	0		0	0	1.7	0	5.31E-07	B	D
MW-0149	27-Jan-92	0	0		0	0	0.54	0	1.69E-07	B	D
MW-0149	22-Jul-92	0	0	0	0	0	2.2	0	6.87E-07	B	D
MW-0149	09-Oct-92	0	0	0	0	0	0.73	0	2.28E-07	B	D
MW-0149	19-Jan-93	0	0	0	0	0	0.68	0	2.12E-07	B	D
MW-0149	08-Apr-93	0	0	0	0	0	0.38	0	2.48E-07	B	D
MW-0149	08-Apr-93	0	0	0	0	0	0.39	0	2.48E-07	B	D
MW-0150	24-Mar-89	0	0		0	0	0	0	0	B	A
MW-0150	14-Jul-89	0	0		18	0	0	0	2.30E-05	B	A
MW-0150	20-Dec-89	0	0		11	0.32	0	0	1.49E-05	B	A
MW-0150	22-Feb-90	0	0		2.5	0	0	0	3.20E-06	B	A
MW-0150	14-May-90	0	0		0.52	0	0	0	2.65E-06	B	A
MW-0150	14-May-90	0	0		0.54	0	0	0	2.65E-06	B	A
MW-0150	06-Jul-90	0	0		0	0	0.25	0	9.87E-07	B	A
MW-0150	11-Oct-90	0	0		0	0	0	0	0	B	A
MW-0150	31-Jan-91	0	0		1.6	0	0	0	3.16E-06	B	A
MW-0150	10-May-91	0	0		2.8	0	0.51	0	3.74E-06	B	A
MW-0150	11-Jul-91	0	0		2.6	0	0	0	6.60E-06	B	A
MW-0150	18-Oct-91	0	0		0	0	0	0	0	B	A
MW-0150	29-Jan-92	0	0		0.59	0	0	0	3.16E-06	B	A
MW-0150	20-Jul-92	0	0	0	0	0	0	0	1.85E-06	B	A
MW-0150	05-Oct-92								6.27E-07	B	A
MW-0150	05-Oct-92	0	0	0	0.49	0	0	0	6.27E-07	B	A
MW-0150	08-Jan-93	0	0	0	0.2	0	0	0	2.56E-07	B	A
MW-0150	08-Jan-93	0	0	0	0.43	0	0	0	2.56E-07	B	A
MW-0150	09-Apr-93	0	0	0	1.30	0.55	0	0	3.81E-06	B	A
MW-0150	02-Aug-93	0	0	0	0.14	0	0	0	4.67E-06	B	A
MW-0151	20-Mar-89	0	0		0	0	0	0	0	B	B
MW-0151	13-Jul-89	0	0		9.9	0	0	0	1.27E-05	B	B
MW-0151	19-Dec-89	0	0		0	0	0	0	0	B	B
MW-0151	08-Feb-90	0	0		6.1	0	0	0	7.81E-06	B	B
MW-0151	23-Apr-90	0	0			0	0	0	0	B	B
MW-0151	16-Jul-90	0	0		0.31	0	7.4	0	2.71E-06	B	B
MW-0151	15-Oct-90	0	0		0	0	0	0	0	B	B
MW-0151	31-Jan-91	0	0		0.83	0	0	0	1.06E-06	B	B
MW-0151	05-Apr-91	0	0		0.53	0	0	0	6.79E-07	B	B
MW-0151	10-Jul-91	0	0		0.47	0	0	0	6.02E-07	B	B
MW-0151	21-Oct-91	0	0		0	0	0	0	0	B	B
MW-0151	29-Jan-92	0	0		0	0	0	0	0	B	B
MW-0151	05-Oct-92	0	0	0	0	0	0	0	0	B	B
MW-0151	09-Apr-93	0	0	0	7.90	0	0	0	2.31E-05	B	B
MW-0152	17-Mar-89	0	0		0	0	0	0	0	B	C
MW-0152	14-Jul-89	0	0		1.2	0	0	0	1.54E-06	B	C
MW-0152	20-Dec-89	0	0		0	0	0	0	0	B	C
MW-0152	08-Feb-90	0	0		0	0	0	0	0	B	C
MW-0152	14-May-90	0	0		0	0	0.26	0	8.12E-08	B	C
MW-0152	13-Jul-90	0	0		0	0	18	0	5.62E-06	B	C
MW-0152	03-Oct-90	0	0		0	0	0	0	0	B	C
MW-0152	07-Jan-91	0	0		0	0	0	0	0	B	C
MW-0152	05-Apr-91	0	0		0	0	0	0	0	B	C
MW-0152	29-Jul-91	0	0		0	0	0	0	0	B	C
MW-0152	07-Oct-91	0	0		0	0	0	0	0	B	C
MW-0152	29-Jan-92	0	0		0	0	0	0	0	B	C
MW-0152	20-Jul-92	0.37	0	0	0	0	0	0	2.00E-05	B	C
MW-0152	05-Oct-92	0	0	0	0	0	0	0	0	B	C

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0152	08-Jan-93	0	0	0	0	0	0	0	0	B	C
MW-0152	09-Apr-93	0	0	0	0	0	0	0	0	B	C
MW-0152	27-Jul-93	0	0	0	0	0	0	0	0	B	C
MW-0153	05-May-89	0	0		0	0	12	0	4.80E-06	B	A
MW-0153	13-Jul-89	0	0		0.76	0	10	0	4.57E-06	B	A
MW-0153	20-Dec-89	0	0		4.4	0	43	0	2.22E-05	B	A
MW-0153	20-Dec-89	0	0		4.7	0	52	0	2.22E-05	B	A
MW-0153	21-Feb-90	0	0		6.5	0	150	0	5.51E-05	B	A
MW-0153	21-Feb-90	0	0		9.8	0	140	0	5.51E-05	B	A
MW-0153	02-May-90	0	0		3.8	0	62	0	2.54E-05	B	A
MW-0153	27-Jul-90	0	0		11	0	130	0	9.92E-05	B	A
MW-0153	27-Jul-90	0	0		53	0	97	0	9.92E-05	B	A
MW-0153	22-Oct-90	0	0		0	0	45	0	1.40E-05	B	A
MW-0153	22-Jan-91	0	0		3.7	0	70	0	2.66E-05	B	A
MW-0153	01-May-91	0	0		0.86	0	23	0	8.28E-06	B	A
MW-0153	06-Aug-91	0	0		4.3	0	97	0	3.70E-05	B	A
MW-0153	21-Oct-91	0	0		0.12	0	12	0	4.13E-06	B	A
MW-0153	21-Oct-91	0	0		0.74	0	14	0	4.13E-06	B	A
MW-0153	22-Jan-92	0	0		0.48	0	17	0	7.64E-06	B	A
MW-0153	14-Jul-92	0	0	6	7.1	0	110	0	5.65E-05	B	A
MW-0153	14-Jul-92	0	0	7.6	10	0	140	0	5.65E-05	B	A
MW-0153	21-Oct-92	0	0	13	21	0	170	0	8.26E-05	B	A
MW-0153	08-Jan-93	0	0	0	13	0	180	0	7.28E-05	B	A
MW-0153	08-Jan-93	0	0	0	17	0	220	0	7.28E-05	B	A
MW-0153	09-Apr-93	0	0	5.5	4.70	0	56	0	4.93E-05	B	A
MW-0153	29-Jul-93	0	0	6.39	15.90	0	155	0	1.46E-04	B	A
MW-0154	01-May-89	0	0		0	0	0	0	0	B	C
MW-0154	19-Jul-89	0	0		0	0	0.27	0	8.43E-08	B	C
MW-0154	20-Dec-89	0	0		0.72	0	0.89	0	1.37E-06	B	C
MW-0154	08-Feb-90	0	0		0	0	0.83	0	2.59E-07	B	C
MW-0154	08-May-90	0	0		1.7	0	0.57	0	2.35E-06	B	C
MW-0154	19-Jul-90	0	0		8.7	0	0.93	0	1.18E-05	B	C
MW-0154	03-Oct-90	0	0		0	0	0	0	0	B	C
MW-0154	23-Jan-91	0	0		0	0	0.56	0	8.04E-07	B	C
MW-0154	25-Apr-91	0	0		0	0	1.3	0	4.06E-07	B	C
MW-0154	05-Aug-91	0	0		0	0	2.4	0	7.49E-07	B	C
MW-0154	18-Oct-91	0	0		0	0	1.4	0	4.37E-07	B	C
MW-0154	30-Jan-92	0	0		0	0	4.1	0	3.93E-06	B	C
MW-0154	14-Jul-92	0	0	0.65	0	0	5.1	0	3.80E-06	B	C
MW-0154	20-Oct-92	0	0	1	0	0	3.8	0	4.70E-06	B	C
MW-0154	14-Jan-93	0	0	0	0	0	4.4	0	6.47E-06	B	C
MW-0154	29-Jul-93	0	0	0	0	0	3.17	0	2.01E-06	B	C
MW-0155	14-Sep-89	0	0		0	0	48	0	1.50E-05	B	A
MW-0155	10-Oct-89								0	B	A
MW-0155	07-Feb-90	0	0		0	0	0	0	1.12E-07	B	A
MW-0155	14-May-90	1.3	0		0	0		0	6.24E-06	B	A
MW-0155	06-Jul-90	0.24	0		0	0	22	0	8.36E-06	B	A
MW-0155	30-Oct-90	0	0		0	0	38	0	1.19E-05	B	A
MW-0155	30-Jan-91	0.28	0		0	0	28	0	1.01E-05	B	A
MW-0155	24-Apr-91	0.69	0		0	0	26	0	1.26E-05	B	A
MW-0155	01-Aug-91	0.95	0		0	0	32	0	1.78E-05	B	A
MW-0155	07-Oct-91	0.99	0		0	0	33	0	3.02E-05	B	A
MW-0155	24-Jan-92	0	0		0	0	36	0	1.76E-05	B	A
MW-0155	24-Jan-92	0.72	0		0	0	40	0	1.76E-05	B	A
MW-0155	20-Jul-92	0.74	0	18	0	0	18	0	9.20E-06	B	A
MW-0155	06-Oct-92	0.76	0	19	0	0	28	0	1.55E-05	B	A
MW-0155	12-Jan-93	0.61	0	13	0	0	19	0	1.12E-05	B	A
MW-0155	12-Jan-93	0.63	0	14	0	0	24	0	1.12E-05	B	A
MW-0155	09-Apr-93	0.44	0	15	0	0	25	0	2.48E-05	B	A
MW-0155	28-Jul-93	0	0	16.80	0	0	29.70	0	2.64E-05	B	A
MW-0156	14-Sep-89	0	0		0	0	78	0	2.43E-05	B	B

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0156	26-Feb-90	0	0		0	0	100	0	3.12E-05	B	B
MW-0156	14-May-90	1.2	0		0	0	92	0	3.13E-05	B	B
MW-0156	02-Aug-90	0	0		0	0	150	0	4.68E-05	B	B
MW-0156	29-Oct-90	0	0		0	0	94	0	2.93E-05	B	B
MW-0156	29-Oct-90	0	0		0	0	100	0	2.93E-05	B	B
MW-0156	15-Jan-91	0	0		0	0	120	0	3.75E-05	B	B
MW-0156	29-Apr-91	0	0		0	0	130	0	4.06E-05	B	B
MW-0156	29-Apr-91	0	0		0	0	250	0	4.06E-05	B	B
MW-0156	01-Aug-91	0	0		0	0	110	0	3.43E-05	B	B
MW-0156	09-Oct-91	0	0		0	0	110	0	6.09E-05	B	B
MW-0156	22-Jan-92	0	0		0	0	180	0	6.73E-05	B	B
MW-0156	08-Jul-92								0	B	B
MW-0156	08-Oct-92	0	0	64	0	0	81	0	2.53E-05	B	B
MW-0156	27-Jan-93	0.98	0	38	0	0	93	0	3.39E-05	B	B
MW-0156	19-Apr-93	0	0	25	0	0	85	0	6.29E-05	B	B
MW-0156	19-Apr-93	0	0	29	0	0	99	0	6.29E-05	B	B
MW-0156	29-Jul-93	0	0	38.10	0	0	114	0	7.38E-05	B	B
MW-0157	21-Sep-89	0	0		390	0	4800	0	2.00E-03	B	A
MW-0157	19-Feb-90	0	0		1400	0	5400	0	3.48E-03	B	A
MW-0157	19-Mar-90	0	0		1100	0	7700	0	3.83E-03	B	A
MW-0157	20-Apr-90	0	0		1400	0	8000	0	4.29E-03	B	A
MW-0157	05-Jul-90	0	0		740	0	7700	0	3.35E-03	B	A
MW-0157	05-Jul-90	0	170		580	0	5800	0	3.35E-03	B	A
MW-0157	30-Oct-90	0	0		700	0	6000	0	2.77E-03	B	A
MW-0157	07-Jan-91	0	0		700	0	6000	0	2.77E-03	B	A
MW-0157	08-May-91	0	0		0	0	30	0	9.36E-06	B	A
MW-0157	06-Aug-91	0	0		250	0	3900	0	1.54E-03	B	A
MW-0157	21-Oct-91	0	0		150	0	2500	0	9.72E-04	B	A
MW-0157	21-Oct-91	0	0		180	0	2300	0	9.72E-04	B	A
MW-0157	30-Jan-92	0	0		150	0	2300	0	9.10E-04	B	A
MW-0157	28-Jul-92	0	0	0	110	0	740	0	3.72E-04	B	A
MW-0157	22-Oct-92	0	0	0	70	0	650	0	2.93E-04	B	A
MW-0157	14-Jan-93	0	0	0	46	0	460	0	2.96E-04	B	A
MW-0157	14-Jan-93	0	0	0	68	0	670	0	2.96E-04	B	A
MW-0157	29-Jul-93	0	0	0	86.20	4.84	664	0	6.82E-04	B	A
MW-0158	05-Oct-89								4.15E-04	B	A
MW-0158	05-Oct-89	0	0		80	0	1000	0	4.15E-04	B	A
MW-0158	13-Feb-90	0	0		210	29	1500	0	7.42E-04	B	A
MW-0158	13-Apr-90	0	0		320	0		0	4.10E-04	B	A
MW-0158	12-Jul-90	0	0		0	0	7700	0	2.69E-03	B	A
MW-0158	23-Oct-90	0	0		60	0	6800	0	2.20E-03	B	A
MW-0158	22-Jan-91								0	B	A
MW-0158	08-May-91	0	0		890	0	8700	0	3.85E-03	B	A
MW-0158	11-Jul-91	0	0		1100	0	6900	0	3.56E-03	B	A
MW-0158	08-Oct-91	0	0		430	0	7300	0	4.00E-03	B	A
MW-0158	08-Oct-91	0	0		690	0	10000	0	4.00E-03	B	A
MW-0158	23-Jan-92								0	B	A
MW-0158	26-Feb-92	0	0		400	0	2700	0	1.35E-03	B	A
MW-0158	17-Jul-92	0	0	28	190	0	1300	0	6.49E-04	B	A
MW-0158	22-Oct-92	0	0	58	68	0	430	0	2.21E-04	B	A
MW-0158	14-Jan-93	0	0	18	110	0	950	0	4.37E-04	B	A
MW-0158	03-Aug-93	0	0	15.90	50.70	0	467	0	4.50E-04	B	A
MW-0159	28-Dec-89	0	0		1.3	0	85	0	3.34E-05	B	A
MW-0159	11-May-90	1.1	0		0	0	140	0	4.61E-05	B	A
MW-0159	05-Jul-90	0	55		29	0	940	0	4.59E-04	B	A
MW-0159	07-Nov-90	0	0		0	0	103	0	2.64E-05	B	A
MW-0159	07-Nov-90	2.7	0		0	0	66	0	2.64E-05	B	A
MW-0159	07-Jan-91	1.4	0		5	0	110	0	4.87E-05	B	A
MW-0159	05-Apr-91	1.6	0		3.9	0	35	0	3.10E-05	B	A
MW-0159	02-Aug-91	2.1	0		0.12	0	55	0	3.45E-05	B	A
MW-0159	25-Oct-91	2.2	0		1.2	0	67	0	4.11E-05	B	A

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0159	31-Jan-92	0	0		0	0	120	0	5.45E-05	B	A
MW-0159	31-Jan-92	2.1	0		2.9	0	110	0	5.45E-05	B	A
MW-0159	17-Jul-92	1.1	0	55	5	0	110	0	5.05E-05	B	A
MW-0159	09-Oct-92	2.6	0	77	10	0	110	0	6.41E-05	B	A
MW-0159	14-Jan-93								5.49E-05	B	A
MW-0159	14-Jan-93	0	0	42	6.3	0	150	0	5.49E-05	B	A
MW-0159	03-Aug-93	0	0	38.70	32.5	0	263	0	2.72E-04	B	A
MW-0160	11-Oct-89	0	0		0	0	3.6	0	5.64E-06	A	A
MW-0160	11-Oct-89	0	0		0	0	4	0	5.64E-06	A	A
MW-0160	16-Oct-89								0	A	A
MW-0160	17-Jan-90	0	0		0	0	13	0	1.15E-05	A	A
MW-0160	20-Mar-90	0	0		0	0	21	0	1.64E-05	A	A
MW-0160	12-May-90	0.34	0		0	0	27	0	2.22E-05	A	A
MW-0160	08-Aug-90	0	0		0	0	31	0	2.14E-05	A	A
MW-0160	08-Aug-90	1.1	0		0	0	29	0	2.14E-05	A	A
MW-0160	16-Oct-90	1.7	0		0	0	23	0	1.77E-05	A	A
MW-0160	08-Jan-91	2.3	0.85		2.4	0.58	56	0	3.57E-05	A	A
MW-0160	25-Apr-91	3.1	0		0	0	54	0	4.09E-05	A	A
MW-0160	25-Apr-91	3.4	0		0	0	61	0	4.09E-05	A	A
MW-0160	09-Jul-91	2.4	0		0	0	80	0	5.03E-05	A	A
MW-0160	21-Oct-92	6.5	6.6	48	0	0	72	0	4.34E-05	A	A
MW-0161	06-Oct-89	0	0		0	0	0	0	0	A	C
MW-0161	11-Oct-89	0	0		0	0	0	0	0	A	C
MW-0161	16-Oct-89								0	A	C
MW-0161	22-Dec-89	0	0		0	0	0	0	0	A	C
MW-0161	16-May-90	0	0		0	0	0	0	0	A	C
MW-0161	30-Jul-90	0	0		0	0	0	0	0	A	C
MW-0161	08-Jan-91	0	0		0	0	0.22	0	6.87E-08	A	C
MW-0161	06-Aug-91	0	0		0	0	0.26	0	8.12E-08	A	C
MW-0161	26-Jul-93	0	0	0	0	0	0.75	0	7.71E-07	A	C
MW-0161	26-Jul-93	0	0	0	0	0	0.97	0	7.71E-07	A	C
MW-0162	04-Dec-89	0	0		0	0.37	39	0	1.22E-05	B	D
MW-0162	04-Dec-89	0	0.39		0	0	26	0	1.22E-05	B	D
MW-0162	20-Mar-90	0	0		0	0.63	9.8	0	3.35E-06	B	D
MW-0162	20-Mar-90	0	0		0.48	0.79	6.5	0	3.35E-06	B	D
MW-0162	06-Aug-90	0	0.65		0	0.52	0	0	1.48E-06	B	D
MW-0162	06-Aug-90	0.74	0		0	0	27	0	1.48E-06	B	D
MW-0162	30-Oct-90	0	0		0	0	18	0	5.62E-06	B	D
MW-0162	08-May-91	0	0		0	0	9.1	0	2.84E-06	B	D
MW-0162	07-Jul-92	0	0	0.99	0	0	7.4	0	2.31E-06	B	D
MW-0162	27-Jul-93	0	0	0	3.18	0	18.30	0	2.13E-05	B	D
MW-0163	25-Jan-90	0	0		0	0	7.3	0	2.28E-06	B	D
MW-0163	24-Apr-90	0	0		0	0	6.5	0	3.09E-06	B	D
MW-0163	24-Apr-90	0	0		0	0	9.9	0	3.09E-06	B	D
MW-0163	07-Aug-90	0	0		0	0	7.4	0	2.31E-06	B	D
MW-0163	23-Oct-90	0	0		0	0	7	0	2.18E-06	B	D
MW-0163	23-Jan-91								0	B	D
MW-0163	22-Jul-91	0	0		0	0	8.4	0	2.62E-06	B	D
MW-0163	27-Jan-93	0	0	0.69	0	0	5.5	0	1.72E-06	B	D
MW-0164	07-Nov-89	0	0		0	0	25	0	9.79E-06	B	A
MW-0164	26-Jun-90	0.16	0		0	0	12	0	5.28E-06	B	A
MW-0164	30-Oct-90	0	0		0	4.5	14	0	4.37E-06	B	A
MW-0164	14-Jan-91	0.3	1.2		0.47	0.46	17	0	6.55E-06	B	A
MW-0164	09-Apr-91	0.45	1.7		0	0	13	0	6.62E-06	B	A
MW-0164	29-Jul-91	0	0		0	0	13	0	6.84E-06	B	A
MW-0164	29-Jul-91	0.47	0		0	0	13	0	6.84E-06	B	A
MW-0164	19-Apr-93	0.15	0.82	10	0	0	17	0	1.61E-05	B	A
MW-0164	19-Apr-93	0.31	1.30	10	0	0	16	0	1.61E-05	B	A
MW-0165	08-Nov-89	0	0		0	0	170	0	5.78E-05	B	B
MW-0165	26-Jun-90	0	0		0	0	61	0	2.16E-05	B	B
MW-0165	26-Jun-90	0	0		0	0	94	0	2.16E-05	B	B

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0165	18-Oct-90	0	0		0	0	140	0	5.36E-05	B	B
MW-0165	09-Apr-91	0	0		0	0	160	0	5.15E-05	B	B
MW-0166	06-Nov-89	0	0		0	0	100	0	3.12E-05	B	C
MW-0166	27-Jun-90	0	5.5		0	0	180	0	5.62E-05	B	C
MW-0166	25-Oct-90	0	0		0	0	130	0	4.06E-05	B	C
MW-0166	14-Jan-91	0	0		0	0	120	0	3.75E-05	B	C
MW-0166	09-Apr-91	0	0		0	0	120	0	3.75E-05	B	C
MW-0166	09-Apr-91	0	0		0	0	130	0	3.75E-05	B	C
MW-0166	30-Jul-91	1.1	0		0	0	100	0	3.56E-05	B	C
MW-0167	15-Dec-89	0	0		0	0	79	0	2.47E-05	B	D
MW-0167	11-Jul-90	0.73	0		0	0	82	0	2.72E-05	B	D
MW-0167	24-Oct-90	0	0		0	0	66	0	2.06E-05	B	D
MW-0167	18-Jan-91	0	0		0	0	53	0	1.65E-05	B	D
MW-0167	09-Apr-91	0	0		0	0	67	0	2.09E-05	B	D
MW-0167	30-Jul-91	0.77	0		0	0	57	0	1.94E-05	B	D
MW-0167	19-Apr-93	0.36	0	11	0	0	28	0	1.96E-05	B	D
MW-0168	19-Jan-90	0	0		0	0	70	0	1.96E-05	B	D
MW-0168	19-Jan-90	0.82	0		0	0	57	0	1.96E-05	B	D
MW-0168	10-Apr-90	0	0		0	0	52	0	1.62E-05	B	D
MW-0168	25-Oct-90	0	0		0	0	0.28	0	8.74E-08	B	D
MW-0169	03-Jan-90	0	0		0	0	1.5	0	4.68E-07	A	A
MW-0169	28-Sep-90	0	0		0	0	2.2	0	6.87E-07	A	A
MW-0169	08-Jan-91	0	0		0	0	9.3	0	3.61E-06	A	A
MW-0169	08-Apr-91	0	0		0	0	7.9	0	2.47E-06	A	A
MW-0169	05-Aug-91	0	0		0	0	5	0	1.56E-06	A	A
MW-0169	30-Jan-92								0	A	A
MW-0169	25-Feb-92	0	0		0	0	10	0	4.71E-06	A	A
MW-0169	20-Jul-92	0	0	0	0	0	2.7	0	8.43E-07	A	A
MW-0169	20-Jul-92	0	0	0	0	0	3.9	0	8.43E-07	A	A
MW-0169	12-Oct-92	0	0	0	0	0	3.3	0	1.03E-06	A	A
MW-0169	12-Oct-92	0	0	0	0	0	4.7	0	1.03E-06	A	A
MW-0169	19-Jan-93	0	0	0	0.25	0	7.3	0	2.60E-06	A	A
MW-0169	06-Apr-93	0	0	0	0	0	6.70	0	4.25E-06	A	A
MW-0169	06-Apr-93	0	0	0	0	0	6.80	0	4.25E-06	A	A
MW-0169	04-Aug-93	0	0	0	0	0	4.17	0	2.65E-06	A	A
MW-0170	05-Jan-90	0	0		0	0	0	0	0	A	B
MW-0170	11-May-90	0	0		0	0	0	0	0	A	B
MW-0170	23-Jul-90	0	0		0	0	0	0	0	A	B
MW-0170	08-Jan-91	0	0		0	0	0	0	8.30E-08	A	B
MW-0170	05-Aug-91	0	0		0	0	0	0	0	A	B
MW-0170	14-Oct-91	0	0		0	0	0	0	9.67E-07	A	B
MW-0170	30-Jan-92								0	A	B
MW-0170	25-Feb-92	0	0		0	0	0	0	0	A	B
MW-0170	08-Apr-93	0	0	0	0	0	0	0	0	A	B
MW-0171	22-Dec-89	0	0		0	0	0	0	0	A	C
MW-0171	14-May-90	0	0		0	0	0	0	0	A	C
MW-0171	27-Jul-90	0	0		0	0	0	0	0	A	C
MW-0171	08-Apr-91	0	0		0	0	0	0	0	A	C
MW-0171	03-Feb-92	0	0		0	0	0	0	0	A	C
MW-0171	12-Oct-92	0	0	0	0	0	0	0	0	A	C
MW-0172	09-Feb-90	0	600		0	0	15000	0	6.36E-03	A	A
MW-0172	30-Mar-90	0	0		0	0	20000	0	1.20E-02	A	A
MW-0172	30-Mar-90	0	0		0	0	21000	0	1.20E-02	A	A
MW-0172	13-Jul-90	0	0		0	0	14000	0	1.49E-02	A	A
MW-0172	13-Jul-90	0	2000		0	0	26000	0	1.49E-02	A	A
MW-0172	11-Jan-91	0	490		0	0	10000	0	7.07E-03	A	A
MW-0172	11-Jan-91	60	800		120	0	16000	0	7.07E-03	A	A
MW-0172	30-Apr-91	0	0		0	0	15000	0	8.30E-03	A	A
MW-0172	09-Aug-91	0	0		0	0	15000	0	7.33E-03	A	A
MW-0172	09-Aug-91	0	0		0	0	17000	0	7.33E-03	A	A
MW-0173	23-Jan-90	0	0		0	0	12	0	2.97E-05	A	B

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0173	09-May-90	0.14	0.44		0	0		0	3.70E-05	A	B
MW-0173	18-Jul-90	0.37	0		0	0	25	0	5.08E-05	A	B
MW-0173	16-Oct-90	0	0		0	0	52	0	6.35E-05	A	B
MW-0173	09-Jan-91	0	1.5		0	0	91	0	9.71E-05	A	B
MW-0173	09-Jan-91	0	1.8		0	0	99	0	9.71E-05	A	B
MW-0173	08-May-91	0	0		0	0	140	0	4.37E-05	A	B
MW-0173	06-Aug-91	0	0		0	0	48	0	4.61E-05	A	B
MW-0173	29-Jul-93	0	0	0	0	0	257	0	3.70E-04	A	B
MW-0174	19-Dec-89	0	0		0	0	0.7	0	2.18E-07	A	C
MW-0174	03-May-90	0	0		0	0	0	0	0	A	C
MW-0174	06-Aug-90	0	0		0	0	0	0	0	A	C
MW-0174	16-Oct-90	0	0		0	0	0	0	0	A	C
MW-0174	25-Jan-91								0	A	C
MW-0174	07-May-91	0	0		0	0	6.2	0	1.94E-06	A	C
MW-0174	06-Aug-91	0	0		0	0	2.1	0	1.38E-06	A	C
MW-0174	13-Apr-93	0	0	0	0	0	0.77	0	4.89E-07	A	C
MW-0175	26-Oct-89	0	0	0	0	0	0	0	0	A	A
MW-0175	01-May-90	0	0		0	0	0	0	0	A	A
MW-0175	12-Jul-90	0	0		0	0	0.45	0	1.40E-07	A	A
MW-0175	10-Oct-90	0	0		0	0	0	0	0	A	A
MW-0175	09-Jan-91	0	0		0	0	0	0	0	A	A
MW-0175	05-Apr-91	0	0		0	0	0	0	0	A	A
MW-0175	02-Aug-91	0	0		0	0	0	0	0	A	A
MW-0175	11-Oct-91	0	0		0	0	0	0	5.32E-06	A	A
MW-0175	28-Jan-92	0	0		1.3	0	3.2	0	2.66E-06	A	A
MW-0175	14-Oct-92	0	0	0	0	0	0	0	0	A	A
MW-0175	08-Apr-93	0	0	0	0	0	0	0	0	A	A
MW-0176	26-Oct-89								0	A	B
MW-0176	26-Oct-89	0	0	0	0	0	0	0	0	A	B
MW-0176	01-May-90	0	0		0	0	0	0	0	A	B
MW-0176	01-Aug-90	0	0		0	0	0	0	0	A	B
MW-0176	09-Jan-91	0	0		0	0	0	0	0	A	B
MW-0176	24-Jul-91	0	0		0	0	0	0	2.42E-07	A	B
MW-0176	11-Oct-91	0	0		0	0	0	0	2.42E-06	A	B
MW-0176	03-Feb-92	0	0		0	1.6	1.4	0	4.37E-07	A	B
MW-0176	17-Jul-92	0	0	0	0	0.94	0	0	0	A	B
MW-0176	14-Oct-92	0	0	0	0	0	0.89	0	2.78E-07	A	B
MW-0176	11-Jan-93	0	0	0	0	0	0	0	0	A	B
MW-0176	08-Apr-93	0	0	0	0	0	0.60	0	3.81E-07	A	B
MW-0177	26-Jan-90	0	0		0	0	0	0	0	A	C
MW-0177	27-Apr-90	0	0		0	0	0	0	0	A	C
MW-0177	10-Jul-90	0	0		0	0	4.7	0	1.47E-06	A	C
MW-0177	01-Aug-91	0	0		0	0	0	0	0	A	C
MW-0177	07-Oct-91	0	0		0	0	0.2	0	2.24E-06	A	C
MW-0177	29-Jan-92	0	0		0	0	0	0	0	A	C
MW-0177	24-Jul-92								0	A	C
MW-0177	24-Jul-92	0	0	0	0	0	0	0	0	A	C
MW-0177	14-Oct-92	0	0	0	0	0	0	0	0	A	C
MW-0177	19-Jan-93								0	A	C
MW-0177	19-Jan-93	0	0	0	0	0	0	0	0	A	C
MW-0178	17-Jan-90	0	0		0	0	60	0	4.56E-05	A	A
MW-0178	30-Mar-90	0	0		0	0	66	0	2.06E-05	A	A
MW-0178	16-Jul-90	0	0		0.78	0	91	0	7.22E-05	A	A
MW-0178	06-Nov-90	0	0		0	0	68	0	4.54E-05	A	A
MW-0178	06-Nov-90	0	0		0.55	0	85	0	4.54E-05	A	A
MW-0178	05-Feb-91	0	0		0	0	71	0	8.89E-05	A	A
MW-0178	23-Apr-91	0	0		[illegible]	0	76	0	8.63E-05	A	A
MW-0178	23-Apr-91	0	0		[illegible]	0	90	0	8.63E-05	A	A
MW-0178	07-Aug-91	0	0		[illegible]	0	130	0	1.48E-04	A	A
MW-0178	13-Apr-93	0	0	0	0	0	89	0	2.51E-04	A	A
MW-0179	09-Jan-90	0	0		0	0	0	0	0	A	B

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0179	02-May-90	0	0		0	0	0	0	0	A	B
MW-0179	06-Jul-90	0	0		0.21	0	0	0	2.69E-07	A	B
MW-0179	18-Oct-90	0	0		0	0	0	0	0	A	B
MW-0179	15-Jan-91	0	0		0	0	0.32	0	9.99E-08	A	B
MW-0179	07-May-91	0	0		0	0	0	0	0	A	B
MW-0179	07-Aug-91	0	0		0	0	2.5	0	7.80E-07	A	B
MW-0179	13-Apr-93	0	0	0	0	0	0	0	0	A	B
MW-0180	11-Jan-90	0	0		0	0	0	0	0	A	C
MW-0180	03-May-90	0	0		0	0	0	0	0	A	C
MW-0180	07-Nov-90	0	0		0	0	0	0	0	A	C
MW-0180	25-Jan-91	0	0		0	0	0	0	0	A	C
MW-0180	07-Aug-91	0	0		0	0	5.9	0	1.84E-06	A	C
MW-0181	20-Dec-89	0	0		0	0	0	0	0	B	C
MW-0181	28-Sep-90	0	0		0	0	0	0	0	B	C
MW-0181	09-Jan-91	0	0		0	0	0	0	0	B	C
MW-0181	25-Jul-91	0	0		0	0	0	0	0	B	C
MW-0181	28-Jan-93	0	0	0	0	0	0.63	0	1.97E-07	B	C
MW-0182	15-Feb-90	0	0		0	0	3.4	0	1.06E-06	B	A
MW-0182	23-Mar-90	0	0		0	0	3.1	0	1.58E-06	B	A
MW-0182	13-Jul-90	0.12	0		0	0	31	0	1.09E-05	B	A
MW-0182	09-Nov-90	0	0		0	0	3.1	0	9.68E-07	B	A
MW-0182	17-Jan-91	0.1	0		0	0	4.5	0	1.82E-06	B	A
MW-0182	19-Apr-91	0.42	0		0	0	4.4	0	2.28E-06	B	A
MW-0182	11-Jul-91	0	0		0	0	3.4	0	1.12E-06	B	A
MW-0182	11-Jul-91	0	0		0	0	3.6	0	1.12E-06	B	A
MW-0183	13-Feb-90	0	0		0	0.31	0	0	0	B	B
MW-0183	22-Mar-90	0	0		0	0	3.3	0	1.03E-06	B	B
MW-0183	19-Jul-90	0	0		3.8	0	2	0	5.49E-06	B	B
MW-0183	17-Oct-90	0	0		0	0	0	0	0	B	B
MW-0183	17-Jan-91	0	0.42		0	0.24	14	0	7.10E-06	B	B
MW-0183	19-Apr-91	0	0		0	0	0.68	0	2.12E-07	B	B
MW-0183	25-Jul-91								0	B	B
MW-0183	25-Jul-91	0	0		0	0	0	0	0	B	B
MW-0183	26-Jan-93	0	0	0	0	0	0	0	0	B	B
MW-0184	06-Feb-90	0	0		0	0	0	0	0	B	C
MW-0184	22-Mar-90	0	0		0	0	0	0	0	B	C
MW-0184	16-Jul-90	0	0		0	0	2	0	6.24E-07	B	C
MW-0184	17-Oct-90	0	[illegible]		0	0	0	0	0	B	C
MW-0184	28-Jan-91	0	[illegible]		0	0	0	0	1.55E-07	B	C
MW-0184	19-Apr-91	0	[illegible]		0	0	0	0	0	B	C
MW-0184	24-Jul-91	0	0		0	0	0	0	0	B	C
MW-0185	22-Feb-90	0	0		0	0	1.1	0	3.43E-07	H	A
MW-0185	12-Jun-90	0	0		0	0	6.5	0	2.17E-06	H	A
MW-0185	18-Oct-90	0	0		0	0	3.2	0	9.99E-07	H	A
MW-0185	05-Feb-91	0	0		0	0	3	0	9.36E-07	H	A
MW-0185	06-May-91	0	0		0	0	4.3	0	1.34E-06	H	A
MW-0185	20-Jul-92	0	0	4.3	0	0	2.3	0	7.18E-07	H	A
MW-0185	13-Apr-93	0	0	2.10	0	0	3.5	0	2.22E-06	H	A
MW-0186	09-Apr-90	0	0		0	0		0	2.21E-06	A	A
MW-0186	11-Jun-90	0	0		0	0	38	0	1.40E-05	A	A
MW-0186	04-Dec-90	0	0		0	0	29	0	1.08E-05	A	A
MW-0186	04-Dec-90	0	0		0	0	37	0	1.08E-05	A	A
MW-0186	05-Feb-91	0	0		0	0	24	0	1.27E-05	A	A
MW-0186	08-May-91	0	0		0	0	44	0	2.10E-05	A	A
MW-0186	05-Aug-91	0	0		0	0	43	0	2.22E-05	A	A
MW-0187	07-Mar-90	0	0		0	0.99	0	0	0	A	C
MW-0187	22-Jun-90	0	0		0	0	0	0	0	A	C
MW-0187	12-Oct-90	0	0		0	0	0	0	0	A	C
MW-0187	04-Feb-91	0	0		0	0	0	0	1.12E-07	A	C
MW-0187	03-May-91	0	0		0	0	0	0	0	A	C
MW-0187	05-Aug-91	0	0		0	0	0	0	0	A	C

Table K-6											
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0187	23-Apr-93	0	0	0	0.31999999	0	1.60000002	0	1.95E-06	A	C
MW-0188	23-Mar-90	0	0		0	0	0.3	0	2.00E-07	C	A
MW-0188	11-Jun-90	0	0		0	0	0.46	0	3.24E-06	C	A
MW-0188	12-Oct-90	0	0		0	0	0	0	0	C	A
MW-0188	23-Jan-91	0	0		0	0	0	0	8.91E-08	C	A
MW-0188	18-Apr-91	0	0		0	0	0	0	4.34E-07	C	A
MW-0188	30-Jul-91	0	0		0	2	2.6	0	8.12E-07	C	A
MW-0188	19-Jan-93	0	0	0	0	0	1	0	3.12E-07	C	A
MW-0189	17-Apr-90	0	0		0	0	0	0	0	C	B
MW-0189	21-Jun-90	0	0.37		0	0	0	0	0	C	B
MW-0189	22-Oct-90	0	0		0	0	0	0	0	C	B
MW-0189	16-Jan-91	0	0		0	0	0	0	1.05E-07	C	B
MW-0189	29-Jul-91	0	0		0	0	0	0	0	C	B
MW-0189	21-Apr-93	0	0	0	8.60000038	0	30	0	4.42E-05	C	B
MW-0190	19-Mar-90	0	0		0	0	0	0	1.57E-06	C	C
MW-0190	22-Oct-90	0	0		0	0	0	0	0	C	C
MW-0190	29-Jul-91	0	0		0	0	0	0	0	C	C
MW-0191	02-Mar-90	0	0		0	0	0	0	0	B	A
MW-0191	12-Jun-90	0	0		0	0	0	0	0	B	A
MW-0191	19-Oct-90	0	0		0	0	0	0	9.19E-07	B	A
MW-0191	15-Jan-91	0	0.41		0.76	0.23	5.3	0	2.63E-06	B	A
MW-0191	02-May-91	0	0		0	0	0	0	5.32E-07	B	A
MW-0191	05-Aug-91	0	0		0	0	3.7	0	3.07E-06	B	A
MW-0191	12-Apr-93	0	0	0	0.13	0	0.75	0	8.57E-07	B	A
MW-0192	27-Feb-90	0	0		0	0	0	0	0	B	B
MW-0192	18-Jun-90	0	0		0	0	0	0	0	B	B
MW-0192	19-Oct-90	0	0.34		0	0	0	0	9.19E-07	B	B
MW-0192	15-Jan-91								0	B	B
MW-0192	09-Apr-91	0	0		0	0	0.57	0	1.78E-07	B	B
MW-0192	05-Aug-91	0	0		0	0	0	0	0	B	B
MW-0192	15-Apr-93	0	0	0	0	0	0	0	0	B	B
MW-0193	20-Feb-90	0	0		0	0	0	0	0	B	C
MW-0193	18-Jun-90	0	0		0	0	0	0	0	B	C
MW-0193	22-Oct-90	0	0		0	0	0	0	9.43E-07	B	C
MW-0193	04-Feb-91								0	B	C
MW-0193	05-Aug-91	0	0		0	0	0	0	6.29E-07	B	C
MW-0193	21-Apr-93	0	0	0	0	0	0	0	0	B	C
MW-0194	29-Mar-90	0	0		0	0	0	0	0	G	A
MW-0194	27-Sep-90								0	G	A
MW-0194	12-Dec-90	0	0		0	0	0	0	0	G	A
MW-0194	24-Jan-91	0	0		0	0	0	0	1.44E-07	G	A
MW-0194	19-Apr-91	0	0		0	0	0	0	0	G	A
MW-0194	14-Apr-93	0	0	0	0.39	0	8.10	0	6.29E-06	G	A
MW-0195	28-Mar-90	0	0		0	0	0	0	0	G	B
MW-0195	15-Jun-90	0	0		0	0	0	0	0	G	B
MW-0195	18-Oct-90	0	0		0	0	0	0	0	G	B
MW-0195	22-Apr-93	0	0	0	1.40	0	1.80	0	5.24E-06	G	B
MW-0196	26-Mar-90	0	0		0	0	0	0	0	G	C
MW-0196	15-Jun-90	0	0		0	0	0	0	0	G	C
MW-0196	18-Oct-90	0	0		0	0	0	0	0	G	C
MW-0196	28-Jul-93	0	4.07	0	0	0.98	1.53	0	1.23E-06	G	C
MW-0197	05-Apr-90	0	0		0	0	0	0	0	A	A
MW-0197	13-Jun-90	0	0		0	0	0	0	0	A	A
MW-0197	01-Nov-90	0	0		0	0	0	0	0	A	A
MW-0197	18-Jan-91	0	13		0.3	2.8	6.8	0	3.09E-06	A	A
MW-0197	01-May-91								0	A	A
MW-0197	01-May-91	0	0		0	0	0	0	0	A	A
MW-0197	06-Aug-91	0	0		0	0	0	0	0	A	A
MW-0197	13-Oct-92	0	0	0	0	0	0	0	0	A	A
MW-0197	15-Apr-93	0	0	0	0.75	0	6.40	0	6.26E-06	A	A
MW-0197	04-Aug-93	0	0	0	0	0	0	0	0	A	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0198	16-Apr-90	0	0		0	0	0	0	0	A	B
MW-0198	13-Jun-90	0	0		0	0	0	0	0	A	B
MW-0198	02-Nov-90	0	0		0	0	0	0	0	A	B
MW-0198	18-Jan-91	0	3.8		0	1.7	1.8	0	5.62E-07	A	B
MW-0198	25-Apr-91	0	0		0	0	0.6	0	1.87E-07	A	B
MW-0198	09-Jul-91	0	0		0	0	0	0	0	A	B
MW-0198	09-Jul-91	0	0		0	0.96	0	0	0	A	B
MW-0198	15-Apr-93	0	0	0	0	0	1.30	0	8.26E-07	A	B
MW-0199	12-Apr-90	0	0		0	0	0	0	0	A	C
MW-0199	14-Jun-90	0	0		0	0	0	0	0	A	C
MW-0199	01-Nov-90	0	0		0	0	0	0	0	A	C
MW-0199	30-Jan-91	0	0		0	0	0	0	0	A	C
MW-0199	09-Aug-91	0	0		0	0	2.5	0	7.80E-07	A	C
MW-0199	20-Oct-92	0	0	0	0	0	0	0	0	A	C
MW-0199	15-Apr-93	0	0	0	0	0	0	0	0	A	C
MW-0200	19-Apr-90	0	0		0	0	2.4	0	7.491E-07	B	A
MW-0200	28-Jun-90	0.21	0		0	0	7.8	0	4.11E-06	B	A
MW-0200	02-Nov-90	0	0		0	0	4	0	1.25E-06	B	A
MW-0200	08-Jan-91	0.3	0		0.65	0	8.1	0	4.89E-06	B	A
MW-0200	22-Apr-91	0.63	0		0	0	12	0	7.62E-06	B	A
MW-0200	06-Aug-91	0	0		0	0	9.5	0	5.21E-06	B	A
MW-0200	10-Oct-91	1.2	0		0	0	6.7	0	6.31E-06	B	A
MW-0200	24-Jan-92	0.54	0		0	0	13	0	7.74E-06	B	A
MW-0200	21-Jul-92	0.78	0	19	0	0	9.1	0	7.04E-06	B	A
MW-0200	19-Oct-92	0.46	0	14	0	0	10	0	7.75E-06	B	A
MW-0200	19-Oct-92	0.59	0	13	0	0	9.3	0	7.75E-06	B	A
MW-0200	15-Jan-93	0.36	0	16	3.5	0	27	0	1.48E-05	B	A
MW-0200	06-Apr-93	0.33	0	10	0.48	0	11	0	1.56E-05	B	A
MW-0200	04-Aug-93	0.32	0	17.60	0	0	15.80	0	1.95E-05	B	A
MW-0201	09-Mar-90	0	0		0	0	0	0	1.16E-07	B	B
MW-0201	05-Feb-91	0	0		0	0	0	0	0	B	B
MW-0201	05-Aug-91	0	0		0	0	0	0	0	B	B
MW-0201	09-Apr-93	0	0	0	0	0	0.71	0	4.51E-07	B	B
MW-0202	08-Oct-90	0	0		0	0	0	0	0	A	A
MW-0202	08-Oct-90	0	0.28		0	0	0	0	0	A	A
MW-0202	19-Oct-90	0	0		0	0	0	0	0	A	A
MW-0202	02-May-91	0	0		0	0	0	0	0	A	A
MW-0203	02-Apr-90	0	0		0	0	13	0	4.37E-06	A	A
MW-0203	02-Apr-90	0	0		0	0	14	0	4.37E-06	A	A
MW-0203	12-Jun-90	0	0		0	0	36	0	1.12E-05	A	A
MW-0203	17-Oct-90	0	0		0	0	21	0	6.55E-06	A	A
MW-0203	16-Jan-91	0	0		0	0	26	0	8.12E-06	A	A
MW-0203	18-Apr-91	0	0		0	0	33	0	2.00E-05	A	A
MW-0203	18-Apr-91	0	0		0	0	64	0	2.00E-05	A	A
MW-0203	09-Jul-91	0	0		0	0	19	0	5.93E-06	A	A
MW-0204	06-Apr-90	0	0		0	0	0.39	0	1.22E-07	A	B
MW-0204	19-Jun-90	0	0		0	0	0.79	0	1.53E-06	A	B
MW-0204	17-Oct-90	0	0		0	0	0	0	0	A	B
MW-0204	16-Jan-91	0	0		0	0	1.6	0	6.11E-07	A	B
MW-0204	18-Apr-91	0	0		0	0	0.38	0	1.19E-07	A	B
MW-0204	09-Jul-91	0	0		0	0	0	0	0	A	B
MW-0204	24-Jul-92	0	0	0	0	0	0	0	0	A	B
MW-0204	21-Jan-93	0	0	0	0	0	0.65	0	2.03E-07	A	B
MW-0204	04-Aug-93	0	0	0	0	0	0.51	0	3.23E-07	A	B
MW-0205	03-Apr-90	0	0	0	0	0	0	0	0	A	C
MW-0205	19-Jun-90	0	0		0	0	1.9	0	3.01E-06	A	C
MW-0205	17-Oct-90	0	0		0	0	0	0	0	A	C
MW-0205	04-Feb-91	0	0		0	0	0	0	2.26E-07	A	C
MW-0205	18-Apr-91	0	0		0	0	0	0	1.14E-06	A	C
MW-0205	07-Aug-91	0	0		0	0	0	0	0	A	C
MW-0205	04-Aug-93	0	0	0	0	0	0	0	0	A	C

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0206	01-Feb-90	0	0		0	0	1.5	0	4.68E-07	C	A
MW-0206	21-Mar-90	0	0		0	0	6.3	0	2.58E-06	C	A
MW-0206	16-Jul-90	0	0		0	0	22	0	7.26E-06	C	A
MW-0206	26-Oct-90	0	0		0	0	4	0	1.25E-06	C	A
MW-0206	16-Jan-91	0.13	0		0	0	5.2	0	2.08E-06	C	A
MW-0206	16-Jan-91	0.14	0		0	0	5.3	0	2.08E-06	C	A
MW-0206	24-Apr-91	0	0		0	0	6.3	0	2.96E-06	C	A
MW-0206	09-Aug-91	0	0		0	0	7.5	0	2.34E-06	C	A
MW-0206	06-Feb-92	0.42	0		0	0	8.3	0	5.88E-06	C	A
MW-0206	27-Feb-92								0	C	A
MW-0206	10-Jul-92	0.23	0	3.6	0	0	4.7	0	1.96E-06	C	A
MW-0206	21-Jan-93	0	0	2.5	0	0	3.1	0	9.68E-07	C	A
MW-0206	03-Aug-93	0	0	1.43	0	0	2.01	0	2.52E-06	C	A
MW-0207	02-Feb-90	0	0		0	0	0	0	0	C	B
MW-0207	21-Mar-90	0	0		0	0	0.63	0	7.78E-07	C	B
MW-0207	06-Aug-90	0	0		0	0	0.95	0	3.12E-07	C	B
MW-0207	06-Aug-90	0	0		0	0	1	0	3.12E-07	C	B
MW-0207	25-Oct-90	0	0		0	0	0.63	0	1.97E-07	C	B
MW-0207	22-Jan-91	0	0		0	0	0	0	0	C	B
MW-0207	24-Apr-91	0	0		0	0	0	0	0	C	B
MW-0207	25-Jul-91	0	0		0	0	0	0	0	C	B
MW-0208	30-Jan-90	0	0		0	0	2	0	3.77E-06	C	C
MW-0208	21-Mar-90	0	0		0	0	2.6	0	8.12E-07	C	C
MW-0208	16-Jul-90	0	0		0	0	2.7	0	1.01E-06	C	C
MW-0208	26-Oct-90	0	0		0	0	2.8	0	8.74E-07	C	C
MW-0208	22-Jan-91	0	0		0	0	1.4	0	4.37E-07	C	C
MW-0208	25-Apr-91	0	0		0	0	2.2	0	2.57E-06	C	C
MW-0208	25-Jul-91	0	0		0	0	2.3	0	7.18E-07	C	C
MW-0208	02-Aug-93	0	0	0	0	0	1.63	0	1.94E-06	C	C
MW-0209	20-Sep-90	4	0		0	0		0	1.25E-04	A	A
MW-0209	30-Jan-91	0	0		0	0	2300	0	7.63E-04	A	A
MW-0209	23-Apr-91	0	0		0	0	2400	0	8.63E-04	A	A
MW-0209	09-Aug-91	0	0		0	0	3000	0	9.36E-04	A	A
MW-0210	06-Jun-90	0	0		0	0	3	0	1.92E-05	A	A
MW-0210	04-Sep-90								1.66E-05	A	A
MW-0210	04-Sep-90	0	0.54		0	0	0.75	0	1.66E-05	A	A
MW-0210	31-Jan-91	0	0		0	0	1.1	0	2.24E-05	A	A
MW-0210	02-May-91	0	0		0	0	3.7	0	1.75E-05	A	A
MW-0210	02-May-91	0	0.76		0	0	4.1	0	1.75E-05	A	A
MW-0210	07-Aug-91	0	0		0	0	7.6	0	3.51E-05	A	A
MW-0210	22-Apr-93	0	0	0	9	0	21	0	9.06E-05	A	A
MW-0210	06-Aug-93	0.68	0	0	0.64	0	6.85	0	4.50E-05	A	A
MW-0211	05-Jun-90	0	0		0	0	0	0	0	A	B
MW-0211	04-Sep-90	0	0		0	0	0	0	0	A	B
MW-0211	31-Jan-91	0	0		0	0	0.51	0	1.39E-06	A	B
MW-0211	02-May-91	0	0		0	0	1	0	1.28E-06	A	B
MW-0211	07-Aug-91	0	0		0	0	0	0	0	A	B
MW-0212	29-Aug-90	0	0		0.86	0	0	0	5.10E-06	A	A
MW-0212	12-Oct-90	0	0		0	0	0	0	0	A	A
MW-0212	05-Feb-91	0	0		0	0	0	0	9.62E-07	A	A
MW-0212	22-Apr-91	0	0		0.6	0.87	5.5	0	3.12E-06	A	A
MW-0212	07-Apr-93	0	0	0	0	0	0	0	3.47E-06	A	A
MW-0213	08-Jun-90	0	0		0	0	0	0	0	A	B
MW-0213	04-Sep-90	0	0		0	0	0	0	0	A	B
MW-0213	30-Jan-91	0	0		0	0	0	0	1.74E-07	A	B
MW-0213	23-Apr-91	0	0		0	0	0	0	0	A	B
MW-0213	10-Jul-92	0	0	0	0	0	0	0	0	A	B
MW-0213	22-Jul-93	0	0	0	0	0	0	0	0	A	B
MW-0214	30-May-90	0.15	0		0	0	7.4	0	3.81E-06	B	A
MW-0214	31-Aug-90	0	0		0	0	7.9	0	2.61E-06	B	A
MW-0214	31-Aug-90	0	0		0	0	8.1	0	2.61E-06	B	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0214	02-Nov-90	0	0		0	0.34	11	0	4.16E-06	B	A
MW-0214	24-Jan-91	0	0		0	0	6.6	0	3.31E-06	B	A
MW-0214	06-May-91	0	0		0	0	6.8	0	2.12E-06	B	A
MW-0214	06-May-91	0	0		0.23	0	6.6	0	2.12E-06	B	A
MW-0214	19-Jul-91	0.11	0		0	0	15	0	7.96E-06	B	A
MW-0214	13-Oct-92	0.18	0	12	0	0	8	0	2.88E-06	B	A
MW-0214	12-Apr-93	0	0	11	0.31	0	7.60	0	9.12E-06	B	A
MW-0217	25-May-90	0	0		0	0	54	0	2.18E-05	B	A
MW-0217	21-Aug-90	0.85	0		0	0	21	0	1.05E-05	B	A
MW-0217	01-Nov-90	0	0		0	0	35	0	1.09E-05	B	A
MW-0217	29-Jan-91	0.36	0		0	0	32	0	1.24E-05	B	A
MW-0217	29-Jan-91	0.36	0.49		0.1	0	25	0	1.24E-05	B	A
MW-0217	07-May-91	0	0		0	0	35	0	1.53E-05	B	A
MW-0217	10-Jul-91	1.1	0		0.17	0	50	0	2.34E-05	B	A
MW-0217	08-Oct-91	0	0		0	0	53	0	1.65E-05	B	A
MW-0217	08-Oct-91	0	0		0	0	56	0	1.65E-05	B	A
MW-0217	24-Jan-92								0	B	A
MW-0217	25-Feb-92	0	0		0	0	50	0	2.67E-05	B	A
MW-0217	22-Jul-92								0	B	A
MW-0217	20-Aug-92	1.9	0	37	2.4	0	57	0	2.50E-05	B	A
MW-0217	20-Oct-92	1.1	0	37	2.2	0	65	0	2.94E-05	B	A
MW-0217	15-Jan-93	0	0	25	0	0	47	0	2.42E-05	B	A
MW-0217	15-Jan-93	0.52	0	25	0.24	0	38	0	2.42E-05	B	A
MW-0217	21-Apr-93	0	0	17	0	0	33	0	3.36E-05	B	A
MW-0217	23-Jul-93	0.21	0	29.10	1.98	0	75.40	0	6.28E-05	B	A
MW-0218	23-May-90	0	0		0	0	1.6	0	4.99E-07	B	B
MW-0218	21-Aug-90								0	B	B
MW-0218	11-Sep-90	0	0		0	0	2	0	6.24E-07	B	B
MW-0218	09-Nov-90	0	0		0	0	1.3	0	4.06E-07	B	B
MW-0218	14-Jan-91	0	0		0	0	1.8	0	5.62E-07	B	B
MW-0218	19-Apr-91	0	0		0	0	2.8	0	8.74E-07	B	B
MW-0218	31-Jul-91	0	0		0	0	1.2	0	3.75E-07	B	B
MW-0218	14-Oct-91	0	0		0	1.4	1.6	0	4.99E-07	B	B
MW-0218	30-Jan-92	0	0		0	0	2.6	0	8.12E-07	B	B
MW-0218	20-Aug-92	0	0	2.8	0	0	1.4	0	2.95E-06	B	B
MW-0218	20-Oct-92	0	0	3	0	0	1.5	0	4.68E-07	B	B
MW-0218	15-Jan-93	0	0	1.5	0	0	2.5	0	7.80E-07	B	B
MW-0218	18-Jan-93								0	B	B
MW-0218	21-Apr-93	0	0	1.10	0	0	7	0	4.45E-06	B	B
MW-0218	23-Jul-93	0	0	0.62	0	0	1.5	0	7.49E-07	B	B
MW-0218	23-Jul-93	0	0	0.67	0	0	1.18	0	7.49E-07	B	B
MW-0219	22-May-90	0.32	0		0	0	54	0	1.75E-05	B	C
MW-0219	17-Aug-90	0	0		0	0	26	0	8.12E-06	B	C
MW-0219	08-Nov-90	0	0		0	0	26	0	8.12E-06	B	C
MW-0219	31-Jan-91	0.23	0		0	0	27	0	1.04E-05	B	C
MW-0219	31-Jan-91	0.25	0		0.12	0	29	0	1.04E-05	B	C
MW-0219	09-May-91	0	0		0	0	21	0	6.55E-06	B	C
MW-0219	31-Jul-91	0.47	0		0	0	20	0	7.25E-06	B	C
MW-0219	09-Oct-91	0	0		0	0	33	0	1.03E-05	B	C
MW-0219	30-Jan-92	0	0		0	0	19	0	5.93E-06	B	C
MW-0219	22-Jul-92								0	B	C
MW-0219	20-Aug-92	0.74	0	5.7	0.6	0	9.6	0	6.75E-06	B	C
MW-0219	20-Oct-92								3.03E-06	B	C
MW-0219	20-Oct-92	0.29	0	4.8	0	0	7.7	0	3.03E-06	B	C
MW-0219	15-Jan-93	0	0	1.5	0	0	5.5	0	1.72E-06	B	C
MW-0219	23-Jul-93	0	0	6.41	0	1.02	18	0	1.14E-05	B	C
MW-0220	26-Jul-90	0	0		0	0	0	0	1.14E-06	B	B
MW-0220	26-Jul-90	0	0		0.89	0	0	0	1.14E-06	B	B
MW-0220	13-Sep-90	0	0		0	0	0	0	0	B	B
MW-0220	31-Jan-91	0	0		0	0	5.4	0	1.82E-06	B	B
MW-0220	19-Apr-91	0	0		0	0	0	0	0	B	B

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0220	05-Aug-91	0	0		0	0	0	0	0	B	B
MW-0220	04-Aug-93	0	0	0	0	0	0	0	0	B	B
MW-0221	13-Nov-90	0	0		0	0	0	0	0	B	C
MW-0221	30-Nov-90	0	0		0	0	0	0	0	B	C
MW-0221	30-Jan-91	0	0		0	0	0	0	7.08E-08	B	C
MW-0221	06-Aug-91	0	0		0	0	0	0	0	B	C
MW-0221	12-Apr-93	0	0	0	0	0	0	0	0	B	C
MW-0222	29-Jun-90	0	0		0	0	0	0	6.74E-07	A	A
MW-0222	29-Jun-90	0	0		0	0	0.53	0	6.74E-07	A	A
MW-0222	31-Aug-90	0	0		0	0	0	0	0	A	A
MW-0222	09-Nov-90	0	0		0	0	0	0	0	A	A
MW-0222	23-Jan-91	0	0		0	0	0	0	0	A	A
MW-0222	10-May-91	0	0		0	0	2.5	0	3.12E-06	A	A
MW-0222	10-May-91	0	0		0	0	2.6	0	3.12E-06	A	A
MW-0222	06-Aug-91	0	0		0	0	13	0	1.61E-05	A	A
MW-0222	05-Feb-92	0	0		0	0	1.3	0	4.06E-07	A	A
MW-0222	12-Apr-93	0	0	0.5	0	0	3.70	0	1.14E-05	A	A
MW-0222	05-Aug-93	0	0	3.97	0	0	20.60	0	4.78E-05	A	A
MW-0223	27-Jun-90	0	0		0	0	0	0	0	A	B
MW-0223	31-Aug-90	0	0		0	0	0	0	0	A	B
MW-0223	08-Nov-90	0	0		0	0	0	0	0	A	B
MW-0223	10-Jul-91	0	0		0	0	0	0	0	A	B
MW-0223	08-Jul-92	0	0	0	0	0	0	0	0	A	B
MW-0223	05-Aug-93	0	0	0	0	0	0	0	2.61E-05	A	B
MW-0224	09-Jul-90	0	0		0	0	3400	0	1.42E-03	A	A
MW-0224	05-Sep-90	10	0.34		5.1	0	8100	0	2.96E-03	A	A
MW-0224	24-Jan-91	0	0		0	0	9300	0	3.17E-03	A	A
MW-0224	24-Apr-91	0	0		0	0	8200	0	3.13E-03	A	A
MW-0224	07-Aug-91	0	0		0	0	15000	0	4.68E-03	A	A
MW-0224	07-Aug-91	0	0		0	0	19000	0	4.68E-03	A	A
MW-0224	19-Aug-92	0	0	520	0	0	9600	0	3.09E-03	A	A
MW-0224	19-Aug-92	0	0	570	0	0	9900	0	3.09E-03	A	A
MW-0224	13-Apr-93	0	0	210	0	0	14000	0	8.87E-03	A	A
MW-0225	03-Jul-90	0	0		0	0	0	0	0	A	B
MW-0225	05-Sep-90	0	0		0.54	0	262	0	9.19E-05	A	B
MW-0225	29-Jan-91	0	0		0.17	0	11	0	5.59E-06	A	B
MW-0225	24-Apr-91	0	0		0	0	29	0	9.05E-06	A	B
MW-0225	07-Aug-91								3.36E-05	A	B
MW-0225	07-Aug-91	0	0		0	0	86	0	3.36E-05	A	B
MW-0225	08-Jul-92	0	0	0	0	0	32	0	9.99E-06	A	B
MW-0225	05-Aug-93	0	0	0	0	0	51.5	0	4.08E-05	A	B
MW-0226	10-Sep-90	0	0		0	0	0	0	0	H	A
MW-0226	08-Oct-90	0	0		0	0	0	0	0	H	A
MW-0226	15-Jan-91	0	0		0	0	0	0	0	H	A
MW-0226	22-Apr-91	0	0		0	0	0	0	0	H	A
MW-0226	22-Jul-92								0	H	A
MW-0226	19-Aug-92	0	0	0	0	0	7.3	0	2.96E-06	H	A
MW-0226	16-Apr-93	0	0	0	0.29	0	7.5	0	5.61E-06	H	A
MW-0227	18-Sep-90	0	0		0	0	0	0	0	H	B
MW-0227	09-Oct-90	0	0		0	0	0	0	8.10E-07	H	B
MW-0227	04-Feb-91	0	0		0	0	0	0	7.08E-08	H	B
MW-0227	01-May-91	0	0		0	0	0.33	0	1.03E-07	H	B
MW-0227	09-Jul-92	0	0	0	0	0	0	0	0	H	B
MW-0227	28-Jul-93	0	0	0	0	0	0	0	0	H	B
MW-0228	03-Oct-90	7.6	2.1		0	0	1.2	0	2.43E-05	A	A
MW-0228	19-Oct-90	17	11		0	0	6.9	0	5.75E-05	A	A
MW-0228	01-Feb-91	2.9	2		0	0	2.1	0	1.84E-05	A	A
MW-0228	22-Apr-91	4.4	4.7		0	0	4	0	1.81E-05	A	A
MW-0228	07-Aug-91	15	19		0	0	50	0	6.61E-05	A	A
MW-0228	28-Jul-92	42	4	0	0.94	0	5.2	0	1.00E-04	A	A
MW-0228	28-Jul-92	43	4.4	0	0.21	0	6.6	0	1.00E-04	A	A

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-0228	16-Apr-93	18	8.80	0.40	0.21	0	14	0	1.15E-04	A	A
MW-0228	05-Aug-93	30.10	2.80	0	0	0	1.74	0	1.72E-04	A	A
MW-0228	05-Aug-93	30.5	0	0	0	0	2.17	0	1.72E-04	A	A
MW-0229	26-Sep-90	0	0		0	0	0	0	0	A	B
MW-0229	04-Jan-91	0	0.43		0	0	0.68	0	2.12E-07	A	B
MW-0229	13-May-91	0	0		0.42	0	0	0	5.38E-07	A	B
MW-0229	07-Aug-91	0	0		0	0	30	0	1.07E-05	A	B
MW-0229	28-Jul-92	0	0	0	0	0	0.41	0	1.28E-07	A	B
MW-0229	16-Apr-93	0	0	0	0	0	0.46	0	2.92E-07	A	B
MW-0230	18-Oct-90	0	0		0	0	0	0	0	B	E
MW-0230	13-Nov-90	0	0		0	0	0	0	0	B	E
MW-0230	03-May-91	0	0		0	0	0	0	0	B	E
MW-0230	15-Jul-92	0	0	0	0	0	0	0	0	B	E
MW-0230	16-Apr-93	0	0	0	0	0	0	0	0	B	E
MW-0231	26-Jun-90	0	0		0	0	0.22	0	1.66E-07	B	E
MW-0231	05-Sep-90	0	0		0	0	1.1	0	3.43E-07	B	E
MW-0231	18-Jan-91	0	1.1		0	0	0.82	0	2.56E-07	B	E
MW-0231	09-Aug-91	0	0		0	0	1.7	0	5.31E-07	B	E
MW-0232	21-Jun-90	0	0		0	0	0	0	0	B	E
MW-0232	02-Oct-90	0	0		0	0	0	0	0	B	E
MW-0232	03-May-91	0	0		0	0	0	0	0	B	E
MW-0235	08-Aug-91	0	0		420	0	2900	0	1.44E-03	B	A
MW-0235	10-Oct-91	0	0		750	0	2800	0	1.83E-03	B	A
MW-0235	28-Jan-92	0	0		1800	0	9900	0	5.39E-03	B	A
MW-0235	21-Jul-92	0	0	0	1800	0	5500	0	4.02E-03	B	A
MW-0235	21-Apr-93	0	0	0	2100	0	9500	0	1.22E-02	B	A
MW-0236	08-Aug-91	0	0		33	0	2500	0	8.22E-04	B	A
MW-0236	10-Oct-91	0	0		47	0	830	0	5.06E-04	B	A
MW-0236	10-Oct-91	0	0		78	0	1300	0	5.06E-04	B	A
MW-0236	06-Feb-92	0	0		210	0	2300	0	9.87E-04	B	A
MW-0236	21-Jul-92	0	0	0	130	0	900	0	4.47E-04	B	A
MW-0236	21-Oct-92	0	0	0	87	0	840	0	3.81E-04	B	A
MW-0236	15-Jan-93	0	0	0	72	0	1100	0	4.36E-04	B	A
MW-0236	04-Aug-93	0	0	0	104	0	1120	0	1.02E-03	B	A
MW-1000	12-Dec-85	0	0		0	0	0	0	1.69E-06	B	AB
MW-1000	07-Mar-86	0	0		0	0	0	0	0	B	AB
MW-1000	03-Oct-86	0	0		0.11		0.3	0	2.34E-07	B	AB
MW-1000	13-Jan-87	0	0		0	0	0	0	0	B	AB
MW-1000	27-Apr-87	0	0		0	0	0.94	0	2.93E-07	B	AB
MW-1000	01-Aug-87	0	0		0	0	0.86	0	5.80E-07	B	AB
MW-1000	08-Oct-87	0	0		0	0	0	0	0	B	AB
MW-1000	13-Jan-88	0	0		0	0	0	0	0	B	AB
MW-1000	20-Apr-88	0	0		0	0	0	0	0	B	AB
MW-1000	04-Oct-88	0	0		0	0	0	0	0	B	AB
MW-1000	09-Jan-89	0	0		0	0	0	0	0	B	AB
MW-1000	12-Apr-89	0	0		0	0	0	0	0	B	AB
MW-1000	02-Aug-89	0	0		0	0	0	0	0	B	AB
MW-1000	13-Oct-89	0	0		0	0	0	0	0	B	AB
MW-1000	19-Feb-90	0	0		0	0	0	0	4.36E-07	B	AB
MW-1000	03-Aug-90	0	0		0	0	0	0	0	B	AB
MW-1000	23-Jan-91	0	0		0	0	0	0	9.82E-08	B	AB
MW-1000	09-Apr-91	0	0		0	0	0	0	0	B	AB
MW-1000	15-Oct-91	0	0		0	0	0	0	0	B	AB
MW-1000	13-Jul-92	0	0	0	0	0	0	0	0	B	AB
MW-1000	14-Jan-93	0	0	0	0	0	0	0	0	B	AB
MW-1000	06-Aug-93	0	0	0	0	0	0	0	0	B	AB
MW-1001	18-Dec-85	0	0		0	0	0	0	6.44E-05	D	B
MW-1001	04-Apr-86	0	0		0	0	0	0	3.74E-06	D	B
MW-1001	26-Jan-87	0	0		0	0	0	0	0	D	B
MW-1001	08-May-87	0	0		0	0	0	0	0	D	B
MW-1001	08-Aug-87	0	0		0	0	0	0	0	D	B

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1001	09-Oct-87	0	0		0	0	0	0	0	D	B
MW-1001	20-Jan-88	0	0		0	0	0	0	0	D	B
MW-1001	27-Apr-88	0	0		0	0	0	0	0	D	B
MW-1001	22-Jul-88	0	0		0	0	0	0	0	D	B
MW-1001	18-Oct-88	0	0		0	0	0	0	0	D	B
MW-1001	17-Jan-89	0	0		0	0	0	0	0	D	B
MW-1001	13-Apr-89	0	0		0	0	0	0	0	D	B
MW-1001	03-Aug-89	0	0		0	0	0	0	0	D	B
MW-1001	10-Oct-89	0	0		0	0	0	0	0	D	B
MW-1001	31-Jan-90	0	0		0	0	0	0	0	D	B
MW-1001	25-Jul-90	0	0		0	0	0	0	0	D	B
MW-1001	08-Jan-91	0	0		0	0	0	0	0	D	B
MW-1001	09-Jul-91	0	0		0	0	0	0	0	D	B
MW-1001	06-Oct-92	0	0	0	0	0	0	0	0	D	B
MW-1001	07-Apr-93	0	0	0	0	0	0	0	0	D	B
MW-1002	07-Nov-85	0	2.4		0	0	1.1	0	3.43E-07	D	A
MW-1002	02-Apr-86	0	0.9		0	0	0.9	0	5.46E-07	D	A
MW-1002	02-Apr-86	0	1		0	0	0.9	0	5.46E-07	D	A
MW-1002	25-Sep-86	0	3.3		0	0	1.7	0	1.59E-06	D	A
MW-1002	04-Feb-87	0	0		0	0	0	0	0	D	A
MW-1002	04-May-87	0	0		0	0	1.2	0	3.75E-07	D	A
MW-1002	08-Aug-87	0	1.8		0	0.42	0	0	0	D	A
MW-1002	15-Oct-87	0	0.98		0	0	0.32	0	4.80E-07	D	A
MW-1002	21-Jan-88	0	0.96		0	0	0.39	0	6.48E-07	D	A
MW-1002	27-Apr-88	0	0		0	0	0.31	0	2.29E-07	D	A
MW-1002	19-Jul-88	0	0.66		0	0	0.29	0	9.05E-08	D	A
MW-1002	17-Oct-88	0	0.4		0	0	0.25	0	7.80E-08	D	A
MW-1002	13-Jan-89	0	0.49		0	0	0.46	0	1.44E-07	D	A
MW-1002	19-Apr-89	0	0.16		0	0	0.22	0	6.87E-08	D	A
MW-1002	24-Jul-89	0	0.3		0	0	0	0	0	D	A
MW-1002	19-Dec-89	0	0		0	0	0	0	3.53E-07	D	A
MW-1002	17-Jan-90	0	0		0	0	0	0	0	D	A
MW-1002	10-Apr-90	0	0		0	0	0	0	0	D	A
MW-1002	02-Aug-90	0	0		0	0	0	0	0	D	A
MW-1003	18-Dec-85	0	0		0	0	0	0	0	D	AB
MW-1003	18-Mar-86	0	0		0	0	0	0	7.27E-07	D	AB
MW-1003	15-Oct-86	0	0.16		0	0	0	0	3.32E-06	D	AB
MW-1003	23-Jan-87	0	0		0	0	0	0	0	D	AB
MW-1003	08-May-87	0	0		0	0	0	0	0	D	AB
MW-1003	08-Aug-87	0	0		0	0	0	0	0	D	AB
MW-1003	09-Oct-87	0	0		0	0	0	0	0	D	AB
MW-1003	20-Jan-88	0	0		0	0	0	0	0	D	AB
MW-1003	27-Apr-88	0	0		0	0	0	0	0	D	AB
MW-1003	22-Jul-88	0	0		0	0	0	0	0	D	AB
MW-1003	18-Oct-88	0	0		0	0	0	0	0	D	AB
MW-1003	17-Jan-89	0	0		0	0	0	0	0	D	AB
MW-1003	13-Apr-89	0	0		0	0	0	0	0	D	AB
MW-1003	07-Aug-89	0	0		0	0	0	0	0	D	AB
MW-1003	10-Oct-89	0	0		0	0	0	0	0	D	AB
MW-1003	31-Jan-90	0	0		0	0	0	0	5.82E-07	D	AB
MW-1003	25-Jul-90	0	0		0	0	0	0	3.76E-06	D	AB
MW-1003	08-Jan-91	0	0		0	0	0	0	0	D	AB
MW-1003	09-Jul-91	0	0		0	0	0	0	0	D	AB
MW-1003	06-Oct-92	0	0	0	0	0	0	0	0	D	AB
MW-1004	18-Dec-85	0	120		0	2.1	14	0	4.49E-06	D	A
MW-1004	18-Mar-86	0.7	59		0	3.2	15	0	6.45E-06	D	A
MW-1004	29-Sep-86	0	91		0	1.5	23	0	1.22E-05	D	A
MW-1004	29-Sep-86	1.9	100		0	1.4	26	0	1.22E-05	D	A
MW-1004	26-Jan-87	0	62		0	1.7	18	0	6.10E-06	D	A
MW-1004	08-May-87	0	160		0	0	27	0	8.43E-06	D	A
MW-1004	08-Aug-87	0	150		0	0	24	0	7.49E-06	D	A

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1004	09-Oct-87	0.79	41		0	0.9	6.2	0	3.95E-06	D	A
MW-1004	09-Oct-87	0.88	40		0	1.1	7.2	0	3.95E-06	D	A
MW-1004	20-Jan-88	0.4	23		0	0.6	3.6	0	1.98E-06	D	A
MW-1004	27-Apr-88	0	15		0	0	3.2	0	9.99E-07	D	A
MW-1004	27-Apr-88	0.26	16		0	0	2.4	0	9.99E-07	D	A
MW-1004	22-Jul-88	0.25	12		0	0	2.2	0	1.23E-06	D	A
MW-1004	18-Oct-88	0.2	14		0	0	2.4	0	1.18E-06	D	A
MW-1004	17-Jan-89	0.22	7		0	0	1.3	0	8.80E-07	D	A
MW-1004	13-Apr-89	0			0	0.28	0.86	0	2.68E-07	D	A
MW-1004	02-Aug-89	0	5.3		0	0	0.74	0	2.31E-07	D	A
MW-1004	10-Oct-89	0	4.2		0	0	0.83	0	2.59E-07	D	A
MW-1004	31-Jan-90		0		0	0	0.43	0	1.34E-07	D	A
MW-1004	31-Jan-90	0	0		0	0	0.74	0	1.34E-07	D	A
MW-1004	09-Apr-90	0	1.3		0	0	0.3	0	9.36E-08	D	A
MW-1004	25-Jul-90	0	0		0	0	0.36	0	1.73E-06	D	A
MW-1004	17-Oct-90	0	0.79		0	0	0	0	0	D	A
MW-1004	08-Jan-91	0	0.78		0	0	0.52	0	1.62E-07	D	A
MW-1004	09-May-91	0	0		0	0	0	0	0	D	A
MW-1004	09-Jul-91	0	0		0	0	0	0	0	D	A
MW-1004	20-Jan-92	0	0		0	0	0	0	9.13E-08	D	A
MW-1004	06-Oct-92	0	0	0	0	0	0	0	0	D	A
MW-1005	17-Dec-85	5	160		0	16	100	0	4.60E-05	D	A
MW-1005	14-Mar-86	9.1	86		0.1	5.6	47	0	3.64E-05	D	A
MW-1005	25-Sep-86	13	110		0.33		76	0.43	7.34E-05	D	A
MW-1005	25-Sep-86	14	110		0.32		80	0.41	7.34E-05	D	A
MW-1005	09-Jan-87	5.7	100		0.21	2.6	59	0	3.30E-05	D	A
MW-1005	09-Jan-87	5.7	102		0.18	0	54	0	3.30E-05	D	A
MW-1005	16-Apr-87	6	160		0.26	3.3	53	0	2.98E-05	D	A
MW-1005	16-Apr-87	7.9	140		0.37	4.3	95	0	2.98E-05	D	A
MW-1005	31-Jul-87	0	270		0	2.3	77	0	2.40E-05	D	A
MW-1005	31-Jul-87	0	280		0	0	86	0	2.40E-05	D	A
MW-1005	15-Oct-87	3.8	77		0	0	22	0	1.[illegible]8E-05	D	A
MW-1005	15-Oct-87	5.1	79		0	0	22	0	1.78E-05	D	A
MW-1005	19-Jan-88	2	51		0	0	15	0	9.11E-06	D	A
MW-1005	19-Jan-88	2.2	58		0	0	14	0	9.11E-06	D	A
MW-1005	27-Apr-88	1.4	36		0	0	10	0	6.14E-06	D	A
MW-1005	19-Jul-88	1	33		0	5.1	9.7	0	7.36E-06	D	A
MW-1005	19-Jul-88	2.1	32		0	1.1	9.1	0	7.36E-06	D	A
MW-1005	17-Oct-88	0	32		0	0	9.7	0	3.43E-06	D	A
MW-1005	17-Oct-88	0	33		0	0	11	0	3.43E-06	D	A
MW-1005	13-Jan-89	0.64	21		0	0.29	5.2	0	3.00E-06	D	A
MW-1005	20-Apr-89	0.96	14.5		0	0.36	3.2	0	3.28E-06	D	A
MW-1005	20-Apr-89	1	13		0	0.27	3.6	0	3.28E-06	D	A
MW-1005	02-Aug-89	0	3.9		0	0	0.8	0	2.50E-07	D	A
MW-1005	19-Dec-89	0	11		0	0	3	0	9.36E-07	D	A
MW-1005	01-Feb-90	0.32	11		0	0	3.1	0	1.66E-06	D	A
MW-1005	24-Apr-90	0.37	28		0	0	5.8	0	2.61E-06	D	A
MW-1005	03-Aug-90	0	9.2		0	0	2.9	0	9.05E-07	D	A
MW-1005	24-Oct-90	0.26	6.9		0	0	1.7	0	1.09E-06	D	A
MW-1005	25-Jan-91	0	5.1		0	0	1.6	0	4.99E-07	D	A
MW-1005	25-Jan-91	0	5.2		0	0	1.8	0	4.99E-07	D	A
MW-1005	10-May-91	0.43	7.5		0	0	2.2	0	1.61E-06	D	A
MW-1005	29-Jul-91	0.25	3.5		0	0	1.2	0	9.13E-07	D	A
MW-1005	24-Jan-92	0	0		0	0	1.5	0	4.68E-07	D	A
MW-1005	24-Jan-92	0	6.6		0	2.5	1.9	0	4.68E-07	D	A
MW-1009	19-Dec-85	0	0		0	0	0	0	0	D	A
MW-1009	21-Mar-86	0	0		0	0	0	0	0	D	A
MW-1009	03-Feb-87	0	0		0	0	0	0	0	D	A
MW-1009	17-Apr-87	0	0		0	0	0	0	0	D	A
MW-1009	31-Jul-87	0	0		0	0	0	0	0	D	A
MW-1009	15-Oct-87	0	0		0	0	0	0	2.28E-07	D	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1009	18-Jan-88	0	0		0	0	0	0	0	D	A
MW-1009	19-Apr-88	0	0		0	0	0	0	0	D	A
MW-1009	26-Jul-88	0	0		0	0	0	0	0	D	A
MW-1009	12-Oct-88	0	0		0	0	0	0	0	D	A
MW-1009	03-Jan-90	0	0		0	0	0	0	0	D	A
MW-1009	07-May-91	0	0		0	0	0	0	0	D	A
MW-1009	15-Jul-92	0	0	0	0	0	0	0	0	D	A
MW-1010	08-Apr-86	0	0		0	0	0	0	2.49E-06	D	AB
MW-1010	13-Jan-87	0	0		0	0	0	0	0	D	AB
MW-1010	04-May-87	0	0		0	0	0	0	0	D	AB
MW-1010	31-Jul-87	0	0		0	0	0	0	0	D	AB
MW-1010	15-Oct-87	0	0		0	0	0	0	0	D	AB
MW-1010	18-Jan-88	0	0		0	0	0	0	0	D	AB
MW-1010	25-Apr-88	0	0		0	0	0	0	0	D	AB
MW-1010	19-Jul-88	0	0		0	0	0	0	0	D	AB
MW-1010	12-Oct-88	0	0		0	0	0	0	0	D	AB
MW-1010	03-Jan-90	0	0		0	0	0	0	0	D	AB
MW-1010	26-Oct-90	0	0		0	0	0	0	0	D	AB
MW-1010	16-Oct-91	0	0		0	0	0	0	0	D	AB
MW-1010	19-Jan-93	0	0	0	0	0	0	0	0	D	AB
MW-1011	05-Nov-85	0	0		0	0	0	0	0	B	A
MW-1011	27-Mar-86	0	0		0	0	0	0	1.64E-06	B	A
MW-1011	06-Oct-86	0	0		0	0	0	0	2.28E-06	B	A
MW-1011	06-Jan-87	0	0		0	0	0	0	0	B	A
MW-1011	27-Apr-87	0	0		0	0	0	0	0	B	A
MW-1011	05-Aug-87	0	0		0	0	0	0	0	B	A
MW-1011	22-Oct-87	0	0		0	0.25	0	0	0	B	A
MW-1011	25-Jan-88	0	0		0	0	0	0	0	B	A
MW-1011	22-Apr-88	0	0		0	0	0	0	0	B	A
MW-1011	15-Jul-88	0	0		0	0	0	0	0	B	A
MW-1011	04-Oct-88	0	0		0	0	0	0	0	B	A
MW-1011	02-Jan-90	0	0		0	0	0	0	0	B	A
MW-1012	15-Nov-85	0	0		0	0	0	0	0	F	A
MW-1012	06-Mar-86	0	0		0	0.2	0	0	0	F	A
MW-1012	23-Jan-87	0	0		0	0	0	0	0	F	A
MW-1012	05-May-87	0	0		0	0	0	0	0	F	A
MW-1012	27-Jul-87	0	0		0	0	0	0	0	F	A
MW-1012	26-Oct-87	0	0		0	0.28	0	0	0	F	A
MW-1012	21-Jan-88	0	0		0	0	0	0	0	F	A
MW-1012	20-Apr-88	0	0		0	0	0	0	0	F	A
MW-1012	26-Jul-88	0	0		0	0	0	0	0	F	A
MW-1012	17-Oct-88	0	0		0	0	0	0	0	F	A
MW-1012	09-Jan-90	0	0		0	0	0	0	0	F	A
MW-1012	26-Oct-90	0	0		0	0	0	0	0	F	A
MW-1012	23-Oct-91	0	0		0	0	0	0	0	F	A
MW-1013	12-Nov-85	0	0		0	0	0	0	0	B	A
MW-1013	11-Mar-86	0	0		0	0	0	0	0	B	A
MW-1013	07-Oct-86	0	0		0	0	0	0	4.77E-05	B	A
MW-1013	15-Jan-87	0	0		0	0	0	0	0	B	A
MW-1013	20-Apr-87	0	0		0	0	0	0	0	B	A
MW-1013	03-Aug-87	0	0		0	0	0	0	0	B	A
MW-1013	22-Oct-87	0	0		0	0	0	0	0	B	A
MW-1013	19-Jan-88	0	0		0	0	0	0	0	B	A
MW-1013	22-Apr-88	0	0		0	0	0	0	0	B	A
MW-1013	15-Jul-88	0	0		0	0	0	0	0	B	A
MW-1013	11-Oct-88	0	0		0	0	0	0	0	B	A
MW-1013	18-Jan-89	0	0		0	0	0	0	0	B	A
MW-1013	20-Apr-89	0	0		0	0	0	0	0	B	A
MW-1014	14-Nov-85	0	0		0	0	0	0	0	A	A
MW-1014	12-Mar-86	0	0		0	0	0	0	0	A	A
MW-1014	16-Jan-87	0	0		0	0	0	0	0	A	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1014	27-Apr-87	0	0		0	0	0	0	0	A	A
MW-1014	01-Aug-87	0	0		0	0	0	0	1.45E-07	A	A
MW-1014	26-Oct-87	0	0		0	0	0	0	0	A	A
MW-1014	25-Jan-88	0	0		0	0	0	0	0	A	A
MW-1014	27-Apr-88	0	0		0	0	0	0	0	A	A
MW-1014	19-Jul-88	0	0		0	0	0	0	0	A	A
MW-1014	27-Oct-88	0	0		0	0	0	0	0	A	A
MW-1014	24-Jan-89	0	0		0	0	0	0	0	A	A
MW-1014	27-Apr-89	0	0		0	0	0	0	0	A	A
MW-1015	14-Dec-85	0	0		0	0	0	0	2.18E-06	B	A
MW-1015	25-Mar-86	0	0		0	0	0	0	0	B	A
MW-1015	07-Oct-86	0	0		0.1	0	0	0	4.16E-06	B	A
MW-1015	14-Jan-87	0	0		0	0	0	0	0	B	A
MW-1015	04-May-87	0	0		0	0	0	0	0	B	A
MW-1015	01-Aug-87	0	0		0	0	0	0	0	B	A
MW-1015	17-Oct-87	0	0		0	0	0	0	0	B	A
MW-1015	19-Jan-88	0	0		0	0	0	0	0	B	A
MW-1015	22-Apr-88	0	0		0	0	0	0	0	B	A
MW-1015	15-Jul-88	0	0		0	0	0	0	0	B	A
MW-1015	11-Oct-88	0	0		0	0	0	0	0	B	A
MW-1015	10-Jan-89	0	0		0	0	0	0	0	B	A
MW-1015	06-Apr-89	0	0		0	0	0	0	0	B	A
MW-1015	31-Jul-89	0	0		0	0	0	0	0	B	A
MW-1015	16-Dec-89	0	0		0	0	0	0	0	B	A
MW-1015	26-Jan-90	0	0		0	0	0	0	0	B	A
MW-1015	23-Apr-90	0	0		0	0	0	0	0	B	A
MW-1015	01-Nov-90	0	0		0	0	0	0	0	B	A
MW-1015	28-Jan-91								0	B	A
MW-1015	10-May-91	0	0		0	0	0	0	0	B	A
MW-1015	21-Oct-91	0	0		0	0	0	0	0	B	A
MW-1015	21-Jan-92	0	0		0	0	0	0	0	B	A
MW-1015	05-Oct-92								0	B	A
MW-1015	05-Oct-92	0	0	0	0	0	0	0	0	B	A
MW-1015	30-Jul-93	0	0	0	0	0	0	0	0	B	A
MW-1016	14-Nov-85	0	0		0	0	0	0	0	B	A
MW-1016	12-Mar-86	0	0		0	0	0	0	0	B	A
MW-1016	07-Oct-86	0	0		0	0	0	0	1.46E-07	B	A
MW-1016	16-Jan-87	0	0		0	0	0	0	0	B	A
MW-1016	07-May-87	0	0		0	0	0	0	4.37E-07	B	A
MW-1016	01-Aug-87	0	0		0	0	0	0	2.28E-07	B	A
MW-1016	16-Oct-87	0	0		0	0	0	0	0	B	A
MW-1016	12-Jan-88	0	0		0	0	0	0	0	B	A
MW-1016	26-Apr-88	0	0		0	0	0	0	0	B	A
MW-1016	19-Jul-88	0	0		0	0	0	0	0	B	A
MW-1016	12-Oct-88	0	0		0	0	0	0	1.31E-06	B	A
MW-1016	11-Jan-89	0	0		0	0	0	0	1.93E-07	B	A
MW-1016	10-Apr-89	0	0		0	0	0	0	0	B	A
MW-1016	26-Jul-89	0	0		0	0	0	0	2.25E-07	B	A
MW-1016	13-Oct-89	0	0		0	0	0	0	9.82E-07	B	A
MW-1016	26-Jan-90	0	0		0	0	0	0	0	B	A
MW-1016	23-Apr-90	0	0		0.2	0	0	0	2.56E-07	B	A
MW-1016	02-Aug-90	0	0		0	0	0	0	2.65E-06	B	A
MW-1016	01-Nov-90	0	0		0	0	0	0	0	B	A
MW-1016	23-Jan-91	0	0		0	0	0	0	0	B	A
MW-1016	03-May-91	0	0		0	0	0	0	0	B	A
MW-1016	22-Jul-91	0	0		0	0	0	0	0	B	A
MW-1016	14-Oct-91	0	0		0	0	0	0	0	B	A
MW-1016	21-Jan-92	0	0		0	0	0	0	0	B	A
MW-1016	05-Oct-92	0	0	0	0	0	0	0	0	B	A
MW-1017	08-Nov-85	0	0		0	0	0	0	0	C	A
MW-1017	18-Mar-86	0	0		0	0	0	0	0	C	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1017	20-Jan-87	0	0		0	0	0	0	0	C	A
MW-1017	20-Apr-87	0	0		0	0	0	0	0	C	A
MW-1017	28-Jul-87	0	0		0	0	0	0	0	C	A
MW-1017	17-Oct-87	0	0		0	0	0	0	0	C	A
MW-1017	21-Jan-88	0	0		0	0	0	0	0	C	A
MW-1017	20-Apr-88	0	0		0	0	0	0	0	C	A
MW-1017	12-Jul-88	0	0		0	0	0	0	0	C	A
MW-1017	13-Oct-88	0	0		0	0	0	0	0	C	A
MW-1017	09-Jan-90	0	0		0	0	0	0	0	C	A
MW-1017	10-Apr-90	0	0		0	0	0	0	0	C	A
MW-1018	18-Nov-85	0	0		0	0	0.7	0	2.18E-07	C	A
MW-1018	12-Mar-86	0	0		0	0	0.7	0	3.51E-07	C	A
MW-1018	23-Sep-86	0	0		0	0	0.94	0	5.19E-07	C	A
MW-1018	04-Feb-87	0	0		0	0	0	0	0	C	A
MW-1018	01-May-87	0	0		0	0	1.7	0	5.31E-07	C	A
MW-1018	04-Aug-87	0	0		0	0	1.4	0	4.37E-07	C	A
MW-1018	08-Oct-87	0	0		0	0	0.57	0	3.50E-07	C	A
MW-1018	14-Jan-88	0	0		0	0	0.54	0	3.01E-07	C	A
MW-1018	13-Apr-88	0	0		0	0	0.6	0	1.87E-07	C	A
MW-1018	23-Jul-88	0	0		0	0	0.58	0	3.66E-07	C	A
MW-1018	20-Oct-88	0	0		0	0	0.56	0	1.75E-07	C	A
MW-1018	20-Oct-88	0	0		0	0	0.58	0	1.75E-07	C	A
MW-1018	03-Jan-90	0	0		0	0	0.64	0	2.00E-07	C	A
MW-1018	06-Apr-90	0	0		0	0	0.47	0	1.47E-07	C	A
MW-1018	17-Jan-91								0	C	A
MW-1018	09-Apr-91	0	0		0	0	0.66	0	2.06E-07	C	A
MW-1018	24-Jan-92								0	C	A
MW-1018	26-Feb-92	0	0		0	0	0	0	0	C	A
MW-1018	15-Apr-93	0	0	0	0	0	0	0	0	C	A
MW-1019	19-Dec-85	0	0		0	0	0.5	0	4.73E-06	D	A
MW-1019	08-Apr-86	0	0		0.4	0.2	2	0	1.89E-06	D	A
MW-1019	24-Sep-86	0	0		0	0	1.6	0	1.07E-04	D	A
MW-1019	09-Jan-87	0	0		0.22	0	1.3	0	9.13E-07	D	A
MW-1019	20-Apr-87	0	0		1.1	0	2.6	0	2.63E-06	D	A
MW-1019	20-Apr-87	0	0		1.1	0	3.7	0	2.63E-06	D	A
MW-1019	07-Aug-87	0	0		1.2	0.68	4	0	2.79E-06	D	A
MW-1019	21-Oct-87	0.13	0		1.1	0.26	1.5	0	2.51E-06	D	A
MW-1019	25-Jan-88	0	0.1		0.53	0	1.3	0	1.71E-06	D	A
MW-1019	25-Jan-88	0	0.11		0.61	0	1.7	0	1.71E-06	D	A
MW-1019	22-Apr-88	0	0		0.43	0	1.3	0	1.12E-06	D	A
MW-1019	11-Jul-88	0	0		0.5	0	1.3	0	1.26E-06	D	A
MW-1019	12-Oct-88	0	0		0.55	0	1.1	0	1.52E-06	D	A
MW-1019	18-Jan-89	0	0		0.5	0	1.2	0	1.17E-06	D	A
MW-1019	19-Apr-89	0	0		0.6	0	1.1	0	1.43E-06	D	A
MW-1019	19-Apr-89	0	0		0.64	0	1.2	0	1.43E-06	D	A
MW-1019	28-Jul-89	0	0		0	0	1.2	0	3.75E-07	D	A
MW-1019	21-Dec-89	0	0		0.83	0	1.5	0	1.88E-06	D	A
MW-1019	21-Dec-89	0	0		0.87	0	1.7	0	1.88E-06	D	A
MW-1019	01-Feb-90	0	0		1	0	2.1	0	1.94E-06	D	A
MW-1019	06-Apr-90	0	0		1.1	0	2.5	0	2.37E-06	D	A
MW-1019	03-Aug-90	0	0		0.6	0	1.3	0	1.17E-06	D	A
MW-1019	24-Oct-90	0	0		0	0	1.4	0	4.37E-07	D	A
MW-1019	22-Jan-91	0	0		0.52	0	1	0	9.78E-07	D	A
MW-1019	22-Jan-91	0	0		0.59	0	1.4	0	9.78E-07	D	A
MW-1019	08-Apr-91	0	0		0.49	0	2.6	0	1.44E-06	D	A
MW-1019	11-Jul-91	0	0		0.53	0	1.5	0	1.15E-06	D	A
MW-1019	04-Oct-91	0	0		0.32	0	1.2	0	7.84E-07	D	A
MW-1019	21-Jan-92	0	0		0.38	0	1.7	0	2.74E-06	D	A
MW-1019	20-Oct-92	0	0	0	0	0	0.24	0	7.80E-08	D	A
MW-1019	20-Oct-92	0	0	0	0	0	0.25	0	7.80E-08	D	A
MW-1019	18-Jan-93	0	0	0	0	0	0.54	0	1.69E-07	D	A

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1019	19-Apr-93	0	0	0	0	0	0.37	0	2.35E-07	D	A
MW-1019	20-Jul-93	0	0	0	0	0	0.58	0	3.71E-07	D	A
MW-1020	08-Nov-85	0	0		0	0	0	0	0	B	A
MW-1020	07-Mar-86	0	0		0	0	0	0	0	B	A
MW-1020	03-Oct-86	0	0		0.16		0	0	2.05E-07	B	A
MW-1020	13-Jan-87	0	0		0	0	0	0	0	B	A
MW-1020	30-Apr-87	0	0		0	0	0.3	0	9.36E-08	B	A
MW-1020	01-Aug-87	0	0		0	0	0	0	2.28E-07	B	A
MW-1020	08-Oct-87	0	0		0	0	0	0	0	B	A
MW-1020	13-Jan-88	0	0		0	0	0	0	0	B	A
MW-1020	18-Apr-88	0	0		0	0	0	0	0	B	A
MW-1020	15-Jul-88	0	0		0	0.26	0	0	0	B	A
MW-1020	18-Jan-89	0	0		0	0	0.32	0	9.99E-08	B	A
MW-1020	10-Apr-89	0	0		0	0	0.23	0	7.18E-08	B	A
MW-1020	26-Jul-89	0	0		0	0	0.31	0	9.68E-08	B	A
MW-1020	13-Oct-89	0	0		0	0	0	0	1.59E-07	B	A
MW-1020	01-Feb-90	0	0		0	0	0.43	0	1.34E-07	B	A
MW-1020	06-Apr-90	0	0		0	0	0	0	0	B	A
MW-1020	03-Aug-90	0	0		0	0	0	0	0	B	A
MW-1020	01-Nov-90	0	0		0	0	0	0	0	B	A
MW-1020	15-Jan-91	0	0		0	0	0	0	0	B	A
MW-1020	09-Apr-91	0	0		0	0	0	0	0	B	A
MW-1020	19-Jul-91	0	0		0	0	0	0	0	B	A
MW-1020	15-Oct-91	0	0		0	0	0	0	0	B	A
MW-1020	13-Jul-92	0	0	0	0	0	0	0	0	B	A
MW-1020	08-Jan-93	0	0	0	0	0	0	0	0	B	A
MW-1021	07-Nov-86	0	0		2.8	0	57	0	2.17E-05	B	A
MW-1021	26-Jan-87	0	0		0	0	32	0	1.29E-05	B	A
MW-1021	27-Apr-87	0	0		5.6	0	57	0	2.78E-05	B	A
MW-1021	03-Aug-87	0	0		2.7	0	46	0	1.78E-05	B	A
MW-1021	27-Oct-87	0	0		0.8	0	17	0	6.33E-06	B	A
MW-1021	19-Jan-88	0	0		1.3	0	11	0	5.35E-06	B	A
MW-1021	21-Apr-88	0	0		1.2	0	14	0	5.91E-06	B	A
MW-1021	19-Jul-88	0	0		1.8	0	18	0	8.19E-06	B	A
MW-1021	11-Oct-88	0	0		1.4	0	10	0	5.57E-06	B	A
MW-1021	11-Oct-88	0	0		1.5	0	11	0	5.57E-06	B	A
MW-1021	19-Jan-89	0	0		1.4	0	15	0	6.78E-06	B	A
MW-1021	10-Apr-89	0	0		1	0	8.5	0	4.58E-06	B	A
MW-1021	10-Apr-89	0	0		1.1	0	9.3	0	4.58E-06	B	A
MW-1021	25-Jul-89	0	0		2	0	14	0	7.13E-06	B	A
MW-1021	21-Dec-89	0	0		0	0	15	0	1.61E-05	B	A
MW-1021	01-Feb-90	0	0		0.77	0	12	0	5.69E-06	B	A
MW-1021	01-Feb-90	0	0		0.84	0	13	0	5.69E-06	B	A
MW-1021	24-Apr-90	0	0		1.4	0	18	0	7.68E-06	B	A
MW-1021	02-Aug-90	0	0		1.4	0	17	0	7.85E-06	B	A
MW-1021	23-Oct-90	0	0		1.3	0	13	0	5.72E-06	B	A
MW-1021	25-Jan-91	0	0		0.39	0	7.4	0	2.94E-06	B	A
MW-1021	25-Jan-91	0	0		0.41	0	10	0	2.94E-06	B	A
MW-1021	26-Apr-91	0	0		0.59	0	12	0	4.50E-06	B	A
MW-1021	01-Aug-91	0	0		0	0	11	0	3.43E-06	B	A
MW-1021	18-Oct-91	0	0		0	0	6.7	0	2.09E-06	B	A
MW-1021	18-Oct-91	0	0		0	0	7.1	0	2.09E-06	B	A
MW-1021	16-Jan-92	0	0		0.42	0	11	0	4.79E-06	B	A
MW-1021	14-Jul-92	0	0	2.5	0.45	0	9.3	0	3.48E-06	B	A
MW-1021	21-Jan-93	0	0	0	0	0	3.3	0	1.03E-06	B	A
MW-1021	20-Apr-93	0	0	1.90	0	0	6.20	0	6.34E-06	B	A
MW-1021	28-Jul-93	0	0	2.84	0	0.65	9.99	0	6.73E-06	B	A
MW-1022	07-Nov-86	0	0		0.54	0	13	0	5.40E-06	B	B
MW-1022	23-Jan-87	0	0		0.57	0	0	0	2.13E-05	B	B
MW-1022	27-Apr-87	0	0		1	0	20	0	7.65E-06	B	B
MW-1022	03-Aug-87	0	0		0.77	0	21	0	7.54E-06	B	B

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1022	20-Oct-87	0	0		0	0	9.4	0	2.93E-06	B	B
MW-1022	19-Jan-88	0	0		0.36	0	4.8	0	2.12E-06	B	B
MW-1022	21-Apr-88	0	0		0.56	0	12	0	4.46E-06	B	B
MW-1022	19-Jul-88	0	0		0	0	6.1	0	1.90E-06	B	B
MW-1022	19-Jul-88	0	0		0.64	0	9.7	0	1.90E-06	B	B
MW-1022	21-Oct-88	0	0		0.61	0	10	0	3.94E-06	B	B
MW-1022	21-Oct-88	0	0		0.64	0	10	0	3.94E-06	B	B
MW-1022	19-Jan-89	0	0		0.8	0	10	0	4.16E-06	B	B
MW-1022	19-Jan-89	0	0		0.81	0	9.1	0	4.16E-06	B	B
MW-1022	10-Apr-89	0	0		0.5	0	5.2	0	2.66E-06	B	B
MW-1022	25-Jul-89	0	0		1.2	0	8.8	0	4.43E-06	B	B
MW-1022	03-Jan-90	0	0		0.31	0	5.7	0	2.18E-06	B	B
MW-1022	01-Feb-90	0	0			0	5.9	0	1.84E-06	B	B
MW-1022	23-Apr-90	0	0		0.78	0	12	0	4.90E-06	B	B
MW-1022	02-Aug-90	0	0		0.92	0	16	0	6.17E-06	B	B
MW-1022	23-Oct-90	0	0		1.1	0	11	0	4.84E-06	B	B
MW-1022	25-Jan-91	0	0		0.44	0	9.4	0	3.68E-06	B	B
MW-1022	26-Apr-91	0	0		0.48	0	12	0	4.36E-06	B	B
MW-1022	01-Aug-91	0	0		0.27	0	9.8	0	3.40E-06	B	B
MW-1022	18-Oct-91	0	0		0	0	7.2	0	2.25E-06	B	B
MW-1022	21-Jan-92	0	0		0.36	0	13	0	5.84E-06	B	B
MW-1022	14-Jul-92	0	0	1.1	0.49	0	10	0	3.75E-06	B	B
MW-1022	08-Oct-92	0	0	1.8	0.51	0	7.3	0	2.98E-06	B	B
MW-1022	08-Oct-92	0	0	2	0.52	0	7.4	0	2.98E-06	B	B
MW-1022	21-Jan-93	0	0	0	0	0	8.5	0	2.65E-06	B	B
MW-1022	28-Jul-93	0	0	0.60	0	0	9.27	0	6.49E-06	B	B
MW-1023	04-Nov-86	0	0		0	0	0	0	0	B	A
MW-1023	19-Jan-87	0	0		0	0	0	0	0	B	A
MW-1023	15-Apr-87	0	0		0	0	0	0	0	B	A
MW-1023	11-Aug-87	0	0		0	0	0	0	0	B	A
MW-1023	22-Oct-87	0	0		0	0	0	0	0	B	A
MW-1023	13-Jan-88	0	0		0	0	0	0	0	B	A
MW-1023	15-Apr-88	0	0		0	0	0	0	0	B	A
MW-1023	08-Jul-88	0	0		0	0	0	0	0	B	A
MW-1023	05-Oct-88	0	0		0	0	0	0	0	B	A
MW-1023	11-Jan-89	0	0		0	0	0	0	0	B	A
MW-1023	07-Apr-89	0	0		0	0	0	0	0	B	A
MW-1023	03-Aug-89	0	0		0	0	0	0	0	B	A
MW-1023	22-Dec-89	0	0		0	0	0	0	2.28E-07	B	A
MW-1023	18-Jan-90	0	0		0		0	0	0	B	A
MW-1023	20-Apr-90	0	0		0	0	0	0	0	B	A
MW-1023	11-Oct-90	0	0		0	0	0	0	0	B	A
MW-1023	07-Jan-91								0	B	A
MW-1023	19-Jul-91	0	0		0	0	0	0	1.04E-07	B	A
MW-1023	17-Oct-91	0	0		0	0	0	0	0	B	A
MW-1023	14-Jan-92	0	0		0	0	0	0	0	B	A
MW-1023	09-Oct-92	0	0	0	0	0	0	0	0	B	A
MW-1024	04-Nov-86	0	0		0	0	0	0	0	B	A
MW-1024	19-Jan-87	0	0		0	0	0	0	0	B	A
MW-1024	15-Apr-87	0	0		0	0	0	0	0	B	A
MW-1024	11-Aug-87	0	0		0	0	0	0	0	B	A
MW-1024	15-Oct-87	0	0		0	0	0	0	0	B	A
MW-1024	12-Jan-88	0	0		0	0	0	0	0	B	A
MW-1024	15-Apr-88	0	0		0	0	0	0	0	B	A
MW-1024	08-Jul-88	0	0		0	0	0	0	0	B	A
MW-1024	05-Oct-88	0	0		0	0	0	0	0	B	A
MW-1024	10-Jan-89	0	0		0	0	0	0	0	B	A
MW-1024	07-Apr-89	0	0		0	0	0	0	0	B	A
MW-1024	21-Jul-89	0	0		0	0	0	0	0	B	A
MW-1024	12-Oct-89	0	0		0	0	0	0	0	B	A
MW-1024	18-Jan-90	0	0		0	0.84	0	0	0	B	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1024	19-Apr-90	0	0		0	0	0	0	0	B	A
MW-1024	03-Aug-90	0	0		0	0	0	0	0	B	A
MW-1024	11-Oct-90	0	0		0	0	0	0	0	B	A
MW-1024	07-Jan-91	0	0		0	0	0	0	1.41E-07	B	A
MW-1024	01-Feb-91								0	B	A
MW-1024	19-Jul-91	0	0		0	0	0	0	0	B	A
MW-1024	04-Oct-91	0	0		0	0	0	0	0	B	A
MW-1024	17-Jan-92	0	0		0	0	0	0	0	B	A
MW-1024	14-Jul-92	0	0	0	0	0	0	0	0	B	A
MW-1024	18-Jan-93	0	0	0	0	0	0	0	0	B	A
MW-1025	03-Nov-86	0	0		0	0	0	0	0	B	B
MW-1025	19-Jan-87	0	0		0	0	0	0	0	B	B
MW-1025	15-Apr-87	0	0		0	0	0	0	0	B	B
MW-1025	11-Aug-87	0	0		0	0	0	0	0	B	B
MW-1025	15-Oct-87	0	0		0	0	0	0	0	B	B
MW-1025	12-Jan-88	0	0		0	0	0	0	0	B	B
MW-1025	15-Apr-88	0	0		0	0	0	0	0	B	B
MW-1025	08-Jul-88	0	0		0	0	0	0	0	B	B
MW-1025	05-Oct-88	0	0		0	0	0	0	0	B	B
MW-1025	10-Jan-89	0	0		0	0	0	0	0	B	B
MW-1025	07-Apr-89	0	0		0	0	0	0	0	B	B
MW-1025	21-Jul-89	0	0		0	0	0	0	0	B	B
MW-1025	12-Oct-89	0	0		0	0.42	0	0	0	B	B
MW-1025	18-Jan-90	0	0		0	0.47	0	0	0	B	B
MW-1025	19-Apr-90	0	0		0	0	0	0	0	B	B
MW-1025	03-Aug-90	0	0		0	0	0	0	0	B	B
MW-1025	11-Oct-90	0	0		0	0	0	0	0	B	B
MW-1025	07-Jan-91								0	B	B
MW-1025	07-May-91	0	0		0	0	0	0	0	B	B
MW-1025	19-Jul-91	0	0		0	0	0	0	0	B	B
MW-1025	04-Oct-91	0	0		0	0	0	0	0	B	B
MW-1025	14-Jan-92	0	0		0	0	0	0	0	B	B
MW-1025	14-Jul-92	0	0	0	0	0	0	0	0	B	B
MW-1025	09-Oct-92	0	0	0	0	0	0	0	0	B	B
MW-1025	13-Jan-93	0	0	0	0	0	0	0	0	B	B
MW-1026	05-Nov-86	0	0		0	0	0	0	0	D	A
MW-1026	14-Jan-87	0	0		0	0	0	0	0	D	A
MW-1026	17-Apr-87	0	0		0	0	0	0	3.32E-07	D	A
MW-1026	05-Aug-87	0	0		0	0	0	0	0	D	A
MW-1026	14-Oct-87	0	0		0	0	0	0	0	D	A
MW-1026	15-Jan-88	0	0		0	0	0	0	0	D	A
MW-1026	18-Apr-88	0	0		0	0	0	0	0	D	A
MW-1026	13-Jul-88	0	0		0	0	0	0	0	D	A
MW-1026	10-Oct-88	0	0		0	0	0	0	0	D	A
MW-1026	04-Jan-90	0	0		0	0	0	0	0	D	A
MW-1026	18-Oct-90	0	0		0	0	0	0	0	D	A
MW-1026	22-Oct-91	0	0		0.54	0	8.1	0	3.22E-06	D	A
MW-1026	24-Jul-92	0	0	0	1.3	0	5.7	0	3.44E-06	D	A
MW-1026	21-Jan-93	0	0	0	0	0	0.34	0	1.06E-07	D	A
MW-1027	25-Nov-86	0	0		0	0	0	0	4.00E-06	D	B
MW-1027	14-Jan-87	0	0		0	0	0	0	0	D	B
MW-1027	17-Apr-87	0	0		0	0	0	0	0	D	B
MW-1027	05-Aug-87	0	0		0	0	0	0	0	D	B
MW-1027	14-Oct-87	0	0		0	0	0	0	0	D	B
MW-1027	15-Jan-88	0	0		0	0	0	0	0	D	B
MW-1027	18-Apr-88	0	0		0	0	0	0	0	D	B
MW-1027	13-Jul-88	0	0		0	0	0	0	0	D	B
MW-1027	10-Oct-88	0	0		0	0	0	0	0	D	B
MW-1027	13-Nov-89	0	0		0	0.3	0	0	0	D	B
MW-1027	18-Oct-90	0	0		0	0	0	0	0	D	B
MW-1027	23-Oct-91	0	0		0	0	0	0	0	D	B

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1027	21-Jan-93	0	0	0	0	0	0	0	0	D	B
MW-1028	07-Aug-87	0	0		0	0	0	0	8.30E-08	D	B
MW-1028	14-Oct-87	0	0		0	0	0	0	0	D	B
MW-1028	15-Jan-88	0	0		0	0	0	0	0	D	B
MW-1028	18-Apr-88	0	0		0	0	0	0	0	D	B
MW-1028	13-Jul-88	0	0		0	0	0	0	0	D	B
MW-1028	10-Oct-88	0	0		0	0	0	0	0	D	B
MW-1028	04-Jan-90	0	0		0	0	0	0	0	D	B
MW-1028	18-Oct-90	0	0		0	0	0	0	0	D	B
MW-1028	24-Oct-91	0	0		0	0	0	0	0	D	B
MW-1028	15-Jan-92	0	0		0	0	0	0	0	D	B
MW-1028	15-Jul-92	0	0	0	0	0	0	0	0	D	B
MW-1028	21-Jan-93	0	0	0	0	0	0	0	0	D	B
MW-1029	11-Nov-86	0	0.17		0	0	1.1	0	3.43E-07	D	A
MW-1029	11-Nov-86	0	0.19		0	0	1.1	0	3.43E-07	D	A
MW-1029	08-Jan-87	0	0		0	0	0.78	0	2.43E-07	D	A
MW-1029	08-Jan-87	0	0		0	0	0.85	0	2.43E-07	D	A
MW-1029	29-Apr-87	0	0		0	0	3	0	9.36E-07	D	A
MW-1029	07-Aug-87	0	0		0	0	4.3	0	1.43E-06	D	A
MW-1029	12-Oct-87	0	0		0	0	1.4	0	9.67E-07	D	A
MW-1029	12-Oct-87	0	0		0	0	1.8	0	9.67E-07	D	A
MW-1029	18-Jan-88	0	0		0	0	1.7	0	8.62E-07	D	A
MW-1029	14-Apr-88	0	0.1		0	0	1.8	0	7.34E-07	D	A
MW-1029	03-Oct-88	0	0		0	0.61	1.9	0	5.93E-07	D	A
MW-1029	16-Oct-89	0.13	0		0	0	4	0	1.94E-06	D	A
MW-1029	09-Apr-90	0	0		0	0	4.1	0	1.86E-06	D	A
MW-1029	09-Apr-90	0	0		0	0	4.6	0	1.86E-06	D	A
MW-1029	23-Oct-90	0	0		0	0	2.7	0	8.43E-07	D	A
MW-1029	05-Apr-91	0	0		0	0	1.8	0	5.62E-07	D	A
MW-1029	27-Jan-92	0	0		0	0.68	3.8	0	2.26E-06	D	A
MW-1030	08-Jan-87	0	0		0	0	0	0	0	D	B
MW-1030	29-Apr-87	0	0		0	0	0	0	0	D	B
MW-1030	07-Aug-87	0	0		0	0	0	0	3.39E-07	D	B
MW-1030	12-Oct-87	0	0		0	0	0	0	0	D	B
MW-1030	17-Jan-88	0	0		0	0	0	0	0	D	B
MW-1030	14-Apr-88	0	0		0	0	0	0	0	D	B
MW-1030	16-Oct-89	0	0		0	0	0	0	0	D	B
MW-1030	23-Oct-90	0	0		0	0	0	0	0	D	B
MW-1030	05-Apr-91	0	0		0	0	0	0	0	D	B
MW-1030	15-Jan-92	0	0		0	0	0	0	1.02E-07	D	B
MW-1031	18-Nov-86	0	0		0	0	0	0	0	D	B
MW-1031	08-Jan-87	0	0		0	0	0	0	0	D	B
MW-1031	29-Apr-87	0	0		0	0	0	0	0	D	B
MW-1031	10-Aug-87	0	0		0	0	0	0	0	D	B
MW-1031	12-Oct-87	0	0		0	0	0	0	0	D	B
MW-1031	17-Jan-88	0	0		0	0	0	0	0	D	B
MW-1031	14-Apr-88	0	0		0	0	0	0	0	D	B
MW-1031	04-Oct-88	0	0		0	0	0	0	0	D	B
MW-1031	16-Oct-89	0	0		0	0	0	0	0	D	B
MW-1031	23-Oct-90	0	0		0	0	0	0	0	D	B
MW-1031	17-Oct-91	0	0		0	0	0	0	0	D	B
MW-1032	19-Nov-86	0	0		0	0	0	0	0	C	B
MW-1032	13-Jan-87	0	0		0	0	0	0	0	C	B
MW-1032	01-May-87	0	0		0	0	0	0	0	C	B
MW-1032	04-Aug-87	0	0		0	0	0	0	1.89E-07	C	B
MW-1032	09-Oct-87	0	0		0	0	0	0	9.96E-08	C	B
MW-1032	14-Jan-88	0	0		0	0	0	0	0	C	B
MW-1032	13-Apr-88	0	0		0	0	0	0	0	C	B
MW-1032	14-Jul-88	0	0		0	0	0	0	0	C	B
MW-1032	20-Oct-88	0	0		0	0	0	0	0	C	B
MW-1032	03-Jan-90	0	0		0	0	0	0	0	C	B

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1032	10-Apr-90	0	0		0	0	0	0	0	C	B
MW-1032	29-Jan-91								0	C	B
MW-1032	13-May-91	0	0		0	0	0	0	0	C	B
MW-1032	17-Jan-92	0	0		0	0	0	0	0	C	B
MW-1032	17-Jul-92	0	0	0	0	0	0	0	1.58E-06	C	B
MW-1033	08-Jan-87	0	0		0	0	0	0	0	B	A
MW-1033	28-Apr-87	0	0		0	0	0	0	0	B	A
MW-1033	10-Aug-87	0	0		0	0	0	0	0	B	A
MW-1033	13-Oct-87	0	0		0	0	0	0	0	B	A
MW-1033	12-Jan-88	0	0		0	0	0	0	0	B	A
MW-1033	15-Apr-88	0	0		0	0	0	0	0	B	A
MW-1033	13-Jul-88	0	0		0	0	0	0	0	B	A
MW-1033	14-Oct-88	0	0		0	0	0	0	0	B	A
MW-1034	08-Jan-87	0	0		0	0	0	0	0	B	AB
MW-1034	28-Apr-87	0	0		0	0	0	0	0	B	AB
MW-1034	10-Aug-87	0	0		0	0	0	0	0	B	AB
MW-1034	13-Oct-87	0	0		0.2	0	0	0	2.56E-07	B	AB
MW-1034	12-Jan-88	0	0		0	0	0	0	0	B	AB
MW-1034	15-Apr-88	0	0		0	0	0	0	0	B	AB
MW-1034	13-Jul-88	0	0		0	0	0	0	0	B	AB
MW-1034	14-Oct-88	0	0		0	0	0	0	0	B	AB
MW-1034	04-Jan-90	0	0		0	0	0	0	0	B	AB
MW-1034	20-Apr-90	0	0		0.28	0	0	0	3.59E-07	B	AB
MW-1034	26-Apr-91	0	0		0	0	0	0	0	B	AB
MW-1035	08-Jan-87	0	0		0	0	0	0	0	B	B
MW-1035	28-Apr-87	0	0		0	0	0	0	0	B	B
MW-1035	10-Aug-87	0	0		0	0	0	0	0	B	B
MW-1035	13-Oct-87	0	0		0	0	0	0	0	B	B
MW-1035	12-Jan-88	0	0		0	0	0	0	0	B	B
MW-1035	15-Apr-88	0	0		0	0	0	0	0	B	B
MW-1035	13-Jul-88	0	0		0	0	0	0	0	B	B
MW-1035	14-Oct-88	0	0		0	0	0	0	0	B	B
MW-1035	13-Oct-89	0	0		0	0	0	0	0	B	B
MW-1035	09-Apr-90	0	0		0	0	0	0	0	B	B
MW-1035	26-Apr-91	0	0		0	0	0	0	0	B	B
MW-1035	28-Jul-92	0	0	0	0	0	0	0	0	B	B
MW-1036	19-Nov-86	0	0		0	0	0.86	0	4.67E-07	C	A
MW-1036	16-Jan-87	0	0		0	0	0.63	0	1.97E-07	C	A
MW-1036	23-Apr-87	0	0		0	0	1.2	0	3.75E-07	C	A
MW-1036	06-Aug-87	0	0		0	0	0	0	0	C	A
MW-1036	21-Oct-87	0.12	0		0	0	0.55	0	6.20E-07	C	A
MW-1036	21-Oct-87	0.14	0		0	0	0.51	0	6.20E-07	C	A
MW-1036	14-Jan-88	0	0		0	0	0.25	0	9.99E-08	C	A
MW-1036	14-Jan-88	0	0		0	0	0.32	0	9.99E-08	C	A
MW-1036	22-Apr-88	0	0		0	0	0.4	0	1.25E-07	C	A
MW-1036	22-Jul-88	0	0		0	0	0.36	0	1.12E-07	C	A
MW-1036	05-Jan-90	0	0		0	0	0	0	0	C	A
MW-1036	06-Apr-90	0	0		0	0	0	0	0	C	A
MW-1036	02-May-91	0	0		0	0	0	0	0	C	A
MW-1037	31-Oct-86	0	0		0	0	0	0	0	A	A
MW-1037	15-Jan-87	0	0		0	0	0	0	0	A	A
MW-1037	07-May-87	0	0		0	0	0	0	0	A	A
MW-1037	12-Aug-87	0	0		0	0	0	0	0	A	A
MW-1037	13-Oct-87	0	0		0	0	0	0	0	A	A
MW-1037	15-Jan-88	0	0		0	0	0	0	0	A	A
MW-1037	18-Apr-88	0	0		0	0	0	0	0	A	A
MW-1037	14-Jul-88	0	0		0	0	0	0	0	A	A
MW-1037	06-Oct-88	0	0		0	0	0	0	0	A	A
MW-1037	11-Jan-89	0	0		0	0	0	0	0	A	A
MW-1037	05-Apr-89	0	0		0	0	0	0	0	A	A
MW-1037	12-Jul-89	0	0		0	0	0	0	0	A	A

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1037	22-Dec-89	0	0		0	0	0	0	2.70E-07	A	A
MW-1037	19-Jan-90	0	0		0	0	0	0	0	A	A
MW-1037	31-Jul-90	0	0		0	0	0	0	0	A	A
MW-1037	01-May-91	0	0		0	0	0	0	0	A	A
MW-1037	14-Oct-91	0	0		0	0	0	0	0	A	A
MW-1037	21-Jul-92	0	0	0	0	0	0	0	0	A	A
MW-1037	20-Jan-93	0	0	0	0	0	0	0	0	A	A
MW-1037	30-Jul-93	0	0	0	0	0	0	0	0	A	A
MW-1038	20-Nov-86	0	0		0	0	1.4	0	1.07E-06	A	B
MW-1038	15-Jan-87	0	0		0	0	0	0	0	A	B
MW-1038	30-Apr-87	0	0		0	0	0	0	0	A	B
MW-1038	04-Aug-87	0	0		0	0	0	0	0	A	B
MW-1038	13-Oct-87	0	0		0	0	0	0	0	A	B
MW-1038	15-Jan-88	0	0		0	0	0	0	0	A	B
MW-1038	18-Apr-88	0	0		0	0	0	0	0	A	B
MW-1038	14-Jul-88	0	0		0	0	0	0	0	A	B
MW-1038	06-Oct-88	0	0		0	0	0	0	0	A	B
MW-1038	11-Jan-89	0	0		0	0	0	0	0	A	B
MW-1038	05-Apr-89	0	0		0	0	0	0	0	A	B
MW-1038	12-Jul-89	0	0		0	0	0	0	0	A	B
MW-1038	11-Oct-89	0	0		0	0	0	0	0	A	B
MW-1038	19-Jan-90	0	0		0	0	0	0	0	A	B
MW-1038	31-Jul-90	0	0		0	0	0	0	0	A	B
MW-1038	01-May-91	0	0		0	0	0	0	0	A	B
MW-1038	14-Oct-91	0	0		0	0	0	0	0	A	B
MW-1038	20-Jan-93	0	0	0	0	0	0	0	0	A	B
MW-1039	20-Nov-86	0	0		0	0	0	0	[illegible]	A	C
MW-1039	15-Jan-87	0	0		0	0	0	0	0	A	C
MW-1039	30-Apr-87	0	0		0	0	0	0	0	A	C
MW-1039	03-Aug-87	0	0		0	0	0	0	0	A	C
MW-1039	13-Oct-87	0	0		0	0	0	0	0	A	C
MW-1039	27-Jan-88	0	0.75		0	0	0	0	0	A	C
MW-1039	18-Apr-88	0	0		0	0	0	0	0	A	C
MW-1039	14-Jul-88	0	0		0	0	0	0	0	A	C
MW-1039	06-Oct-88	0	0		0	0	0	0	0	A	C
MW-1039	11-Jan-89	0	0		0	0	0	0	0	A	C
MW-1039	05-Apr-89	0	0		0	0	0	0	0	A	C
MW-1039	12-Jul-89	0	0		0	0	0	0	0	A	C
MW-1039	21-Dec-89	0	0		0	0	0	0	0	A	C
MW-1039	19-Jan-90	0	0		0		0	0	0	A	C
MW-1039	31-Jul-90	0	0		0	0	0	0	0	A	C
MW-1039	01-May-91	0	0		0	0	0	0	0	A	C
MW-1039	14-Oct-91	0	0		0	0	0	0	0	A	C
MW-1039	20-Jan-93	0	0	0	0	0	0	0	0	A	C
MW-1040	17-Nov-86	0	0		0	0	0	0	0	G	C
MW-1040	21-Jan-87	0	0		0	0	0	0	0	G	C
MW-1040	05-May-87	0	0		0	0	0	0	0	G	C
MW-1040	27-Jul-87	0	0		0	0	0	0	0	G	C
MW-1040	20-Oct-87	0	0		0	0	0	0	0	G	C
MW-1040	20-Jan-88	0	0		0	0	0	0	0	G	C
MW-1040	25-Apr-88	0	0		0	0	0	0	0	G	C
MW-1040	20-Jul-88	0	0		0	0	0	0	0	G	C
MW-1040	17-Oct-88	0	0		0	0	0	0	0	G	C
MW-1040	16-Dec-89	0	0		0	0	0	0	0	G	C
MW-1040	24-Oct-90	0	0		0	0	0	0	1.22E-07	G	C
MW-1040	22-Oct-91	0	0		0	0	0	0	0	G	C
MW-1041	14-Nov-86	0	0		0	0	1	0	4.99E-06	D	A
MW-1041	14-Nov-86	0	0		0	0	16	0	4.99E-06	D	A
MW-1041	22-Jan-87	0	0		0	0	0	0	0	D	A
MW-1041	06-May-87	0	0		0	0	0	0	0	D	A
MW-1041	06-Aug-87	0	0		0	0	0	0	0	D	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1041	14-Oct-87	0	0		0	0	0	0	0	D	A
MW-1041	18-Jan-88	0	0		0	0	0	0	0	D	A
MW-1041	19-Apr-88	0	0		0	0	0	0	0	D	A
MW-1041	15-Jul-88	0	0		0	0	0	0	0	D	A
MW-1041	19-Oct-88	0	0		0	0	0	0	0	D	A
MW-1041	03-Jan-90	0	0		0	0	0	0	0	D	A
MW-1041	22-Oct-90	0	0		0	0	0	0	0	D	A
MW-1041	15-Oct-91	0	0		0	0	0	0	0	D	A
MW-1041	11-Jan-93	0	0	0	0	0	0	0	0	D	A
MW-1042	21-Nov-86	0	0		0	0	0.41	0	1.28E-07	D	AB
MW-1042	22-Jan-87	0	0		0	0	0	0	0	D	AB
MW-1042	06-May-87	0	0		0	0	0	0	0	D	AB
MW-1042	06-Aug-87	0	0		0	0	0	0	0	D	AB
MW-1042	14-Oct-87	0	0		0	0	0	0	0	D	AB
MW-1042	18-Jan-88	0	0		0	0	0	0	0	D	AB
MW-1042	19-Apr-88	0	0		0	0	0	0	0	D	AB
MW-1042	15-Jul-88	0	0		0	0	0	0	0	D	AB
MW-1042	19-Oct-88	0	0		0	0	0	0	0	D	AB
MW-1042	16-Oct-89	0	0		0	0	0	0	0	D	AB
MW-1042	22-Oct-90	0	0		0	0	0	0	0	D	AB
MW-1042	16-Oct-91	0	0		0	0	0	0	0	D	AB
MW-1042	11-Jan-93	0	0	0	0	0	0	0	0	D	AB
MW-1043	21-Nov-86	0	0		0	0	0	0	0	D	B
MW-1043	22-Jan-87	0	0		0	0	0	0	0	D	B
MW-1043	06-May-87	0	0		0	0	0	0	0	D	B
MW-1043	06-Aug-87	0	0		0	0	0	0	0	D	B
MW-1043	14-Oct-87	0	0		0	0	0	0	0	D	B
MW-1043	18-Jan-88	0	0		0	0	0	0	0	D	B
MW-1043	19-Apr-88	0	0		0	0	0	0	0	D	B
MW-1043	15-Jul-88	0	0		0	0	0	0	0	D	B
MW-1043	19-Oct-88	0	0		0	0	0	0	0	D	B
MW-1043	16-Oct-89	0	0		0	0	0	0	0	D	B
MW-1043	22-Oct-90	0	0		0	0	0	0	0	D	B
MW-1043	16-Oct-91	0	0		0	0	0	0	0	D	B
MW-1043	11-Jan-93	0	0	0	0	0	0	0	0	D	B
MW-1044	08-Apr-89	0	0		0	0	3.2	0	9.78E-06	B	A
MW-1044	31-Jul-89	0	1.5		0.19	0	0	0	1.41E-05	B	A
MW-1044	18-Dec-89	0	0		0	0	4.1	0	1.78E-05	B	A
MW-1044	26-Jan-90	0	0		0	0	3.3	0	1.11E-05	B	A
MW-1044	26-Jan-90	0	0		0	0	3.7	0	1.11E-05	B	A
MW-1044	24-Apr-90	0	1.2		0.36	0	4.6	0	5.53E-05	B	A
MW-1044	17-Jul-90	0	0		0	0	2.9	0	1.96E-05	B	A
MW-1044	01-Nov-90	0	0		0	0	3.5	0	1.59E-05	B	A
MW-1044	28-Jan-91	0	0		0	0	2.1	0	2.27E-05	B	A
MW-1044	28-Jan-91	0	0		0	0	2.4	0	2.27E-05	B	A
MW-1044	10-May-91	0	0		0	0	3.6	0	3.58E-05	B	A
MW-1044	30-Jul-91	0	0		0	0	2.5	0	1.32E-05	B	A
MW-1044	18-Oct-91	0	0		0	0	3.4	0	8.61E-06	B	A
MW-1044	17-Jan-92	0	0		0	0	7.4	0	1.25E-05	B	A
MW-1044	08-Oct-92	0	0	4	0	0	4	0	6.02E-06	B	A
MW-1044	26-Jan-93	0	0	1.3	0	0	3.6	0	8.28E-06	B	A
MW-1044	19-Apr-93	0	0	0.93	0	0	4.30	0	1.26E-05	B	A
MW-1044	05-Aug-93	0	0	0.52	0	0	1.78	0	5.15E-06	B	A
MW-1045	06-Apr-89	0	0		0	0	3.4	0	1.06E-06	B	B
MW-1045	10-Jul-89	0	0		0	0	2.2	0	6.87E-07	B	B
MW-1045	12-Jul-89	0	0		0	0	2.3	0	7.18E-07	B	B
MW-1045	09-Oct-89	0	0		0	0	5	0	1.81E-06	B	B
MW-1045	09-Oct-89	0	0		0	0	5.8	0	1.81E-06	B	B
MW-1045	12-Feb-90	0	0		0	0	4	0	1.25E-06	B	B
MW-1045	10-May-90	0	0		0	0	8.4	0	2.62E-06	B	B
MW-1045	30-Oct-90	0	0		0	0	9.9	0	3.09E-06	B	B

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1045	11-Feb-91	0	0		0	0	9.2	0	2.87E-06	B	B
MW-1045	01-May-91	0	0		0	0	20	0	6.24E-06	B	B
MW-1045	24-Jul-91	0	0		0	0	27	0	8.43E-06	B	B
MW-1045	17-Oct-91	0.74	0		0	0	40	0	1.84E-05	B	B
MW-1045	04-Feb-92	0.47	0		0	0	36	0	1.40E-05	B	B
MW-1045	13-Jul-92	0.4	0	11	0	0	34	0	1.18E-05	B	B
MW-1045	07-Oct-92	0.43	0	13	0	0	32	0	1.41E-05	B	B
MW-1045	11-Jan-93	0	0	3.1	0	0	11	0	3.12E-06	B	B
MW-1045	11-Jan-93	0	0	3.2	0	0	10	0	3.12E-06	B	B
MW-1045	05-Aug-93	0	0	2.64	0	0	8.72	0	5.54E-06	B	B
MW-1046	30-Mar-89	0.25	0.26		0	0	21	0	7.82E-06	B	C
MW-1046	30-Mar-89	0.3	0.19		0	0	23	0	7.82E-06	B	C
MW-1046	06-Apr-89	0.33	0		0	0	30	0	1.01E-05	B	C
MW-1046	10-Jul-89	0	0.26		0	0	17	0	6.32E-06	B	C
MW-1046	10-Jul-89	0.18	0		0	0	18	0	6.32E-06	B	C
MW-1046	09-Oct-89	0.17	0.12		0	0	20	0	7.02E-06	B	C
MW-1046	14-Feb-90		0	0	0	0.35	20	0	6.81E-06	B	C
MW-1046	14-May-90	0	0		0	0	14	0	4.37E-06	B	C
MW-1046	31-Jul-90	0	0		0	0	19	0	5.93E-06	B	C
MW-1046	19-Oct-90	0	0		0	0	10	0	3.12E-06	B	C
MW-1046	01-Feb-91	0	0		0	0	8.3	0	2.59E-06	B	C
MW-1046	09-May-91	0	0		0	0	7.3	0	2.56E-06	B	C
MW-1046	09-May-91	0	0		0	0	8.2	0	2.56E-06	B	C
MW-1046	24-Jul-91	0	0		0	0	6.8	0	2.12E-06	B	C
MW-1046	24-Oct-91	0	0		0	0	7.6	0	2.37E-06	B	C
MW-1046	03-Feb-92	0	0		0	0	11	0	3.43E-06	B	C
MW-1046	03-Feb-92	0	0		0	0	12	0	3.43E-06	B	C
MW-1046	13-Jul-92	0	0	1.9	0	0	6.4	0	2.00E-06	B	C
MW-1046	07-Oct-92	0	0	1.8	0	0	6.2	0	1.94E-06	B	C
MW-1046	11-Jan-93	0	0	0	0	0	1.7	0	5.31E-07	B	C
MW-1046	05-Aug-93	0	0	1.23	0	0	4.06	0	2.58E-06	B	C
MW-1047	06-Apr-89	0	0		0	0	0	0	0	B	D
MW-1047	21-Apr-89	0	0		0	0	0.31	0	9.68E-08	B	D
MW-1047	19-Jul-89	0	0		0	0	[illegible]	0	0	B	D
MW-1047	06-Oct-89	0	0		0	0	[illegible]	0	0	B	D
MW-1047	14-Feb-90	0	0		0	0	[illegible]	0	0	B	D
MW-1047	09-May-90	0	0		0	0	0	0	0	B	D
MW-1047	05-Nov-90	0	0		0	0	0	0	0	B	D
MW-1047	16-Jan-91	0	0		0	0	0	0	0	B	D
MW-1047	02-May-91	0	0		0	0	0	0	7.68E-06	B	D
MW-1047	24-Jul-91	0	0		0	0	0	0	0	B	D
MW-1047	11-Oct-91	0	0		0	0	0	0	5.80E-06	B	D
MW-1047	31-Jan-92	0	0		0	0	0	0	0	B	D
MW-1047	13-Jul-92	0	0	0	0	0	0	0	0	B	D
MW-1047	07-Oct-92	0	0	0	0	0	0	0	0	B	D
MW-1047	11-Jan-93	0	0	0	0	0	0	0	0	B	D
MW-1047	03-Aug-93	0	0	0	0	0	0	0	0	B	D
MW-1048	19-Apr-89	0	0		0	0	0.36	0	1.12E-07	B	D
MW-1048	21-Apr-89	0	0		0	0	0	0	0	B	D
MW-1048	17-Jul-89	0	0		0	0	0	0	0	B	D
MW-1048	05-Oct-89	0	0		0	0	0	0	0	B	D
MW-1048	15-Feb-90	0	0		0	0	0	0	0	B	D
MW-1048	04-May-90	0	0		0	0	0	0	0	B	D
MW-1048	23-Oct-90	0	0		0	0	0	0	0	B	D
MW-1048	30-Apr-91	0	0		0	0	0	0	0	B	D
MW-1048	11-Oct-91	0	0		0	0	0	0	0	B	D
MW-1048	31-Jan-92	0	0		0	0	0	0	0	B	D
MW-1049	24-Apr-89	0.2	0		0	0	7	0	2.91E-06	B	A
MW-1049	20-Jul-89	0	0		0	0	7.5	0	2.49E-06	B	A
MW-1049	15-Dec-89	0	0		0	0	8.5	0	2.65E-06	B	A
MW-1049	09-Feb-90	0.14	0		0	0	13	0	4.44E-06	B	A

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1049	15-May-90	0.13	0		0.12	0	18	0	6.49E-06	B	A
MW-1049	03-Aug-90	0	0		0	0	12	0	3.75E-06	B	A
MW-1049	09-Nov-90	0	0		0	0	7.9	0	2.47E-06	B	A
MW-1049	10-Jan-91	0.13	0		0.17	0	9.6	0	3.72E-06	B	A
MW-1049	08-May-91	0	0		0	0	13	0	4.26E-06	B	A
MW-1049	08-May-91	0	0		0.26	0	12	0	4.26E-06	B	A
MW-1049	23-Jul-91	0.21	0		0	0	11	0	3.89E-06	B	A
MW-1049	08-Oct-91	0	0		0	0	11	0	3.25E-05	B	A
MW-1049	31-Jan-92	0	0		0	0	14	0	5.60E-06	B	A
MW-1049	28-Jul-92	0	0	4.6	0	0	11	0	3.43E-06	B	A
MW-1049	16-Oct-92	0	0	3.5	0	0	8.1	0	2.53E-06	B	A
MW-1049	16-Oct-92	0	0	3.6	0	0	8.6	0	2.53E-06	B	A
MW-1049	22-Jan-93	0	0	2.3	0	0	6.7	0	2.47E-06	B	A
MW-1049	22-Jan-93	0	0	2.6	0	0	7.9	0	2.47E-06	B	A
MW-1049	20-Apr-93	0	0	2.40	0	0	6.90	0	4.38E-06	B	A
MW-1049	02-Aug-93	0	0	3.44	0	0	10	0	6.35E-06	B	A
MW-1050	24-Apr-89	0	0		0	0	1	0	3.12E-07	B	B
MW-1050	26-Jul-89	0	0		0	0	1.6	0	4.99E-07	B	B
MW-1050	08-Nov-89	0	0		0	0	1.7	0	1.38E-06	B	B
MW-1050	27-Dec-89	0	0		0	0	1.1	0	3.43E-07	B	B
MW-1050	09-Feb-90	0	0		0	0.35		0	0	B	B
MW-1050	15-May-90	0	0		0	0	1.2	0	8.38E-07	B	B
MW-1050	15-May-90	0	0		0.24	0.26	1.7	0	8.38E-07	B	B
MW-1050	02-Aug-90	0	0		0	0	3	0	9.36E-07	B	B
MW-1050	04-Oct-90	0	0		0	0	0.54	0	1.69E-07	B	B
MW-1050	05-Nov-90								0	B	B
MW-1050	10-Jan-91	0	0		0	0	3.6	0	1.12E-06	B	B
MW-1050	29-Apr-91	0	0		0	0	1.8	0	5.62E-07	B	B
MW-1050	23-Jul-91	0	0		0	0	4.9	0	1.53E-06	B	B
MW-1050	09-Oct-91	0	0		0	0	4.9	0	7.09E-06	B	B
MW-1050	23-Jan-92	0	0		0	0	2.4	0	7.49E-07	B	B
MW-1050	09-Jul-92	0	0	1.4	0	0	4.4	0	1.37E-06	B	B
MW-1050	16-Oct-92	0	0	1.9	0	0	5.3	0	1.65E-06	B	B
MW-1050	22-Jan-93	0	0	0.47	0	0	2.6	0	8.12E-07	B	B
MW-1050	02-Aug-93	0	0	0.65	0	0	2.75	0	2.63E-06	B	B
MW-1050	02-Aug-93	0	0	0.80	0.123	0	2.94	0	2.63E-06	B	B
MW-1051	08-Apr-89	0	0		0	0	0	0	0	B	C
MW-1051	21-Jul-89	0	0		0	0	0	0	0	B	C
MW-1051	27-Dec-89	0	0		0	0	0.31	0	9.68E-08	B	C
MW-1051	09-Feb-90	0	0		0.41	0.47	2	0	1.15E-06	B	C
MW-1051	15-May-90	0	0		0.45	0	1.6	0	1.08E-06	B	C
MW-1051	08-Aug-90	0	0		0	0	1.5	0	4.68E-07	B	C
MW-1051	19-Oct-90	0	0		0	0	0	0	4.84E-07	B	C
MW-1051	14-Jan-91								2.56E-07	B	C
MW-1051	14-Jan-91	0	0		0	0	0.82	0	2.56E-07	B	C
MW-1051	06-May-91	0	0		0	0	0	0	0	B	C
MW-1051	23-Jul-91	0	0		0	0	4	0	3.67E-06	B	C
MW-1051	09-Oct-91								6.87E-07	B	C
MW-1051	09-Oct-91	0	0		0	0	2.2	0	6.87E-07	B	C
MW-1051	03-Feb-92	0	0		0	0	0.57	0	1.78E-07	B	C
MW-1051	23-Jul-92	0	0	2.2	0	0	1.9	0	5.93E-07	B	C
MW-1051	16-Oct-92	0	0	2	0	0	5.6	0	1.75E-06	B	C
MW-1051	22-Jan-93	0	0	0	0	0	0	0	0	B	C
MW-1051	20-Apr-93	0	0	0.52	0	0	1.60	0	1.02E-06	B	C
MW-1051	02-Aug-93	0	0	2.12	0	2.20	7.42	0	5.11E-06	B	C
MW-1052	17-Apr-89	0	0		0	0	0	0	0	B	D
MW-1052	21-Jul-89	0	0		0	0	0	0	0	B	D
MW-1052	21-Dec-89	0	0		0	0	0	0	0	B	D
MW-1052	12-Feb-90	0	0		0	0	0	0	0	B	D
MW-1052	08-Aug-90	0	0		0	0	0	0	0	B	D
MW-1052	14-Jan-91	0	0		0	0	0	0	0	B	D

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1052	23-Jul-91	0	0		0	0	0	0	0	B	D
MW-1052	09-Oct-91	0	0		0	0	0	0	0	B	D
MW-1052	04-Feb-92	0	0		0	0	0	0	0	B	D
MW-1052	23-Jul-92	0	0	0	0	0	0	0	0	B	D
MW-1052	16-Oct-92	0	0	0	0	0	0	0	0	B	D
MW-1052	22-Jan-93	0	0	0	0	0	0	0	0	B	D
MW-1052	02-Aug-93	0	0	0	0	0	0	0	0	B	D
MW-1053	15-Sep-89	0	0		0	0	0	0	0	B	A
MW-1053	23-Feb-90	0	0		0	0	0.66	0	2.06E-07	B	A
MW-1053	15-May-90	0	0		0	0	0.99	0	3.09E-07	B	A
MW-1053	18-Jul-90	0	0		0	0	1.7	0	5.31E-07	B	A
MW-1053	08-Nov-90	0	0		0	0	0	0	0	B	A
MW-1053	01-Feb-91	0	0		0	0	0.22	0	2.31E-07	B	A
MW-1053	10-May-91	0	0		0	0	1	0	3.12E-07	B	A
MW-1053	08-Aug-91	0	0		0	0	2.1	0	6.55E-07	B	A
MW-1053	04-Oct-91	0	0		0	0	0.68	0	2.12E-07	B	A
MW-1053	31-Jan-92	0	0		0	0	0.95	0	2.97E-07	B	A
MW-1053	27-Jul-92	0	0	0	0	0	0.43	0	1.34E-07	B	A
MW-1053	15-Oct-92	0	0	0	0	0	4.7	0	1.47E-06	B	A
MW-1053	25-Jan-93	0	0	0	0	0	0.23	0	7.18E-08	B	A
MW-1053	13-Apr-93	0	0	0	0	0	0	0	0	B	A
MW-1053	03-Aug-93	0	0	0	0	0	0	0	0	B	A
MW-1054	03-Oct-89	0	0		0.17	0	1.1	0	8.13E-07	B	A
MW-1054	16-May-90	0	0		0	0	0.98	0	3.06E-07	B	A
MW-1054	18-Jul-90	0	0		0	0	1.4	0	4.37E-07	B	A
MW-1054	07-Nov-90	0	0		0	0	0	0	7.01E-07	B	A
MW-1054	01-Feb-91								2.12E-07	B	A
MW-1054	01-Feb-91	0	0		0	0	0.68	0	2.12E-07	B	A
MW-1054	23-Apr-91	0	0		0	0	0.83	0	2.59E-07	B	A
MW-1054	17-Jul-91	0	0		0	0	0.96	0	3.00E-07	B	A
MW-1054	08-Oct-91	0	0		0	0	0.68	0	6.74E-06	B	A
MW-1054	04-Feb-92	0	0		0	0	1.5	0	1.38E-06	B	A
MW-1054	27-Jul-92	0	0	0	0	0	1.1	0	3.43E-07	B	A
MW-1054	15-Oct-92								2.93E-07	B	A
MW-1054	15-Oct-92	0	0	0	0	0	0.94	0	2.93E-07	B	A
MW-1054	20-Apr-93	0	0	0	0	0	0.32	0	2.03E-07	B	A
MW-1054	30-Jul-93	0	0	0	0	0	0.37	0	2.34E-07	B	A
MW-1055	06-Oct-89	0	0		0	0	0	0	0	B	B
MW-1055	16-May-90	0	0		0	0	0	0	0	B	B
MW-1055	03-Aug-90	0	0		0.5	0	0	0	6.40E-07	B	B
MW-1055	31-Oct-90	0	0		0	0	0	0	0	B	B
MW-1055	22-Jan-91	0	0		0	0	0	0	5.25E-07	B	B
MW-1055	23-Apr-91	0	0		0	0	0	0	0	B	B
MW-1055	31-Jul-91	0	0		0	0	0	0	1.69E-06	B	B
MW-1055	09-Oct-91								0	B	B
MW-1055	09-Oct-91	0	0		0	0	0	0	0	B	B
MW-1055	28-Jan-92	0	0		0	0	0	0	0	B	B
MW-1055	27-Jul-92	0	0	0	0	0	0	0	0	B	B
MW-1055	15-Oct-92	0	0	0	0	0	0	0	0	B	B
MW-1055	30-Jul-93	0	0	0	0	0	0	0	0	B	B
MW-1056	27-Dec-89	0	0		0	0	4.4	0	1.75E-06	B	C
MW-1056	27-Dec-89	0	0		0	0	4.6	0	1.75E-06	B	C
MW-1056	16-May-90	0	0		0	0	2	0	6.24E-07	B	C
MW-1056	07-Aug-90	0	0		0	0	2.7	0	8.43E-07	B	C
MW-1056	31-Oct-90	0	0		0	0	2.5	0	7.80E-07	B	C
MW-1056	21-Jan-91	0	0		0	0	3.8	0	1.19E-06	B	C
MW-1056	23-Apr-91	0	0		0	0	3.9	0	1.22E-06	B	C
MW-1056	31-Jul-91	0	0		0	0	2.7	0	1.83E-06	B	C
MW-1056	08-Oct-91	0	0		0	0	2.2	0	6.87E-07	B	C
MW-1056	28-Jan-92	0	0		0	0	2.6	0	8.12E-07	B	C
MW-1056	27-Jul-92	0	0	0	0	0	1.5	0	4.68E-07	B	C

Table K-6
VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1056	15-Oct-92	0	0	0	0	0	1.8	0	5.62E-07	B	C
MW-1056	30-Jul-93	0	0	0	0	0	0.74	0	4.69E-07	B	C
MW-1057	27-Sep-89	0	0		0	0	0	0	8.51E-08	B	D
MW-1057	10-May-90	0	0		0	0	0	0	0	B	D
MW-1057	08-Aug-90	0	0		0	0	0	0	0	B	D
MW-1057	21-Jan-91	0	0		0	0	0	0	0	B	D
MW-1057	18-Jul-91	0	0		0	0	0	0	1.98E-06	B	D
MW-1057	08-Oct-91	0	0		0	0	0	0	0	B	D
MW-1057	03-Feb-92	0	0		0	0	0	0	0	B	D
MW-1057	27-Jul-92	0	0	0	0	0	0.49	0	1.53E-07	B	D
MW-1057	15-Oct-92	0	0	0	0	0	0.79	0	2.47E-07	B	D
MW-1057	20-Apr-93	0	0	0	0	0	0	0	0	B	D
MW-1057	30-Jul-93	0	0	0	0	0	0	0	0	B	D
MW-1058	18-Oct-89	0	0	0	0	0	0	0	0	A	A
MW-1058	08-Feb-90	0	0		0	0	1.8	0	5.62E-07	A	A
MW-1058	19-Apr-90	0	0		0	0	0	0	1.76E-06	A	A
MW-1058	18-Jul-90	0	0		0	0	0	0	0	A	A
MW-1058	25-Oct-90	0	0		0	0	0	0	0	A	A
MW-1058	11-Jan-91	0	0		0.41	0.52	2.9	0	1.94E-06	A	A
MW-1058	10-May-91	0	0		0	0	0.51	0	1.59E-07	A	A
MW-1058	08-Aug-91	0	0		0	0	2.5	0	1.98E-06	A	A
MW-1058	16-Oct-91	0	0		0	0	0	0	0	A	A
MW-1058	31-Jan-92	0	0		0	0	0	0	0	A	A
MW-1058	23-Jul-92	0	0	0	0.44	0	1.2	0	9.38E-07	A	A
MW-1058	23-Jul-92	0	0	0	0.52	0	1.5	0	9.38E-07	A	A
MW-1058	06-Oct-92	0	0	0	0	0	0	0	0	A	A
MW-1058	25-Jan-93	0	0	0	0	0	0.26	0	8.12E-08	A	A
MW-1058	07-Apr-93	0	0	0	0	0	0	0	0	A	A
MW-1058	03-Aug-93	0	0	0	0	0	0.68	0	4.30E-07	A	A
MW-1059	17-Oct-89	0	0	0	0	0	0	0	0	A	B
MW-1059	23-Mar-90	0	0		0	0	0	0	0	A	B
MW-1059	17-Jul-90	0	0		0	0	0	0	0	A	B
MW-1059	11-Jan-91	0	0		0	0	0.94	0	2.93E-07	A	B
MW-1059	08-Aug-91	0	0		0	0	0.5	0	1.56E-07	A	B
MW-1059	15-Oct-91	0	0		0	0	0	0	0	A	B
MW-1059	28-Jan-92	0	0		0	0	0	0	0	A	B
MW-1059	09-Jul-92	0	0	0	0	0	0	0	0	A	B
MW-1059	06-Oct-92	0	0	0	0	0	0	0	0	A	B
MW-1059	25-Jan-93	0	0	0	0	0	0	0	0	A	B
MW-1059	03-Aug-93	0	0	0	0	0	0	0	0	A	B
MW-1060	16-Oct-89	0	0	0	0	0	0	0	0	A	C
MW-1060	15-Mar-90	0	0		0	0	0	0	0	A	C
MW-1060	17-Jul-90	0	0		0	0	0.29	0	9.05E-08	A	C
MW-1060	26-Oct-90	0	0		0	0	0	0	0	A	C
MW-1060	11-Jan-91	0	0		0.28	0	1.4	0	7.96E-07	A	C
MW-1060	02-May-91	0	0		0	0	0	0	0	A	C
MW-1060	08-Aug-91	0	0		0	0	1.5	0	4.68E-07	A	C
MW-1060	16-Oct-91	0	0		0	0	0	0	0	A	C
MW-1060	28-Jan-92	0	0		0	0	0	0	0	A	C
MW-1060	23-Jul-92	0	0	0	0	0	0	0	1.47E-07	A	C
MW-1060	23-Jul-92	0	0	0	0	0	0.47	0	1.47E-07	A	C
MW-1060	06-Oct-92	0	0	0	0	0	0	0	0	A	C
MW-1060	25-Jan-93	0	0	0	0	0	0	0	0	A	C
MW-1060	05-Apr-93	0	0	0	0	0	2.70	0	1.71E-06	A	C
MW-1060	03-Aug-93	0	0	0	0	0	0	0	0	A	C
MW-1061	16-Mar-90	0	0		0	0	0	0	0	A	A
MW-1061	14-Jun-90	0	0		0	0	0	0	0	A	A
MW-1061	26-Oct-90	0	0		0	0	0	0	0	A	A
MW-1061	29-Jan-91	0	0		0.13	0	0.25	0	1.02E-06	A	A
MW-1061	02-May-91	0	0		0	0	0	0	0	A	A
MW-1061	17-Oct-91	0	0		0	0	0	0	1.04E-06	A	A

Table K-6

VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period

Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1061	03-Feb-92	0	4.5		0	4.2	3	0	9.36E-07	A	A
MW-1061	23-Apr-93	0	0	0	0.85	0	0.68	0	2.92E-06	A	A
MW-1061	05-Aug-93	0	0	0	0	0	0	0	0	A	A
MW-1062	14-Mar-90	0	0		0	0	0	0	0	A	B
MW-1062	20-Jun-90	0	0		0	0	0	0	0	A	B
MW-1062	29-Oct-90	0	0		0	0	0	0	0	A	B
MW-1062	02-May-91	0	0		0	0	0	0	0	A	B
MW-1062	17-Oct-91	0	0		0	0	0	0	0	A	B
MW-1062	29-Jan-92	0	0		0	0.84	0.85	0	2.65E-07	A	B
MW-1062	12-Oct-92	0	0	0	0	0	0	0	0	A	B
MW-1062	05-Aug-93	0	0	0	0	0	0	0	0	A	B
MW-1063	13-Mar-90	0	0		0	0	0	0	0	A	C
MW-1063	20-Jun-90	0	0		0	0	0	0	0	A	C
MW-1063	29-Oct-90	0	0		0	0	0	0	0	A	C
MW-1063	02-May-91	0	0		0	0	0	0	0	A	C
MW-1063	17-Oct-91	0	0		0	0	0	0	0	A	C
MW-1063	31-Jan-92	0	0		0	0	0	0	0	A	C
MW-1063	22-Jul-92	0	0	0	0	0	0	0	0	A	C
MW-1063	12-Oct-92	0	0	0	0	0	0	0	0	A	C
MW-1063	26-Jan-93	0	0	0	0	0	0	0	0	A	C
MW-1064	08-May-90	0	0		0	0	0	0	0	D	A
MW-1064	28-Jun-90	0	0		0	0	0	0	0	D	A
MW-1064	09-Nov-90	0	1.3		0.26	1.5	2.2	0	1.67E-06	D	A
MW-1064	30-Jan-91	0	0		0	0	0	0	0	D	A
MW-1064	22-Apr-91								0	D	A
MW-1064	22-Apr-91	0	0		0	0	0	0	0	D	A
MW-1064	23-Oct-91	0	0		0	0	0	0	0	D	A
MW-1064	20-Jan-93	0	0	0	0	0	0	0	0	D	A
MW-1065	20-Aug-90	0	0		4	0	0.34	0	6.02E-06	A	B
MW-1065	11-Sep-90	0	0		2.6	0	0	0	3.67E-06	A	B
MW-1065	28-Jan-91	0	0		2.7	0	0	0	4.38E-06	A	B
MW-1065	29-Apr-91	0	0		3.7	0	0.99	0	6.37E-06	A	B
MW-1065	15-Jul-91								9.80E-07	A	B
MW-1065	15-Jul-91	0	0		0	0	0	0	9.80E-07	A	B
MW-1065	15-Oct-91	0	0		0.8	0	0	0	2.31E-06	A	B
MW-1065	15-Jul-92	0	0	1.3	2.2	0	0	0	3.94E-06	A	B
MW-1065	15-Jul-92	0	0	1.3	2.3	0	0	0	3.94E-06	A	B
MW-1065	20-Jan-93								2.05E-06	A	B
MW-1065	20-Jan-93	0	0	0.65	1.6	0	0	0	2.05E-06	A	B
MW-1065	04-Aug-93	0	0	0.92	1.59	0	0.463	0	6.25E-06	A	B
MW-1066	28-Aug-90	0	0		5	0	0	0	6.93E-06	A	B
MW-1066	28-Aug-90	0	0		6.1	0	0	0	6.93E-06	A	B
MW-1066	28-Sep-90	0	0		5.6	0	0	0	7.49E-06	A	B
MW-1066	01-Feb-91	0	0		3.9	0	0.26	0	5.40E-06	A	B
MW-1066	23-Apr-91	0	0		2.7	0	1.3	0	4.72E-06	A	B
MW-1066	15-Jul-91	0	0		5.7	0	0.43	0	8.37E-06	A	B
MW-1066	15-Oct-91	0	0		2.8	0	0	0	3.59E-06	A	B
MW-1066	15-Jul-92	0	0	4.1	4.8	0	0.5	0	7.32E-06	A	B
MW-1066	20-Jan-93	0	0	0.59	1.5	0	0	0	1.92E-06	A	B
MW-1067	14-Aug-90	0	0		0	0	0	0	0	A	A
MW-1067	13-Sep-90	0	0		0	0	0	0	6.18E-06	A	A
MW-1067	05-Feb-91	0	0		0	0	0	0	4.36E-06	A	A
MW-1067	23-Apr-91	0	0		0	0	0.85	0	5.36E-06	A	A
MW-1067	16-Jul-91	0	0		0	0	0	0	9.09E-06	A	A
MW-1067	15-Oct-91								6.66E-06	A	A
MW-1067	15-Oct-91	0	0		0	0	0.36	0	6.66E-06	A	A
MW-1067	28-Jan-92	0	0		0	0	0.93	0	8.29E-06	A	A
MW-1067	27-Jul-92	0	0	0	0	0	0	0	7.75E-06	A	A
MW-1067	27-Jul-92	0	0	0	0	0	0.36	0	7.75E-06	A	A
MW-1067	21-Oct-92	0	0	0	0	0	1.3	0	6.95E-06	A	A
MW-1067	20-Jan-93	0	0	0	0	0	0.48	0	6.69E-06	A	A

Table K-6 VOC GSAP Concentrations up to Third Quarter 1993 Sampling Period											
Location ID	Log Date	1,2-DCA	1,1-DCE	c-1,2-DCE	PCE	1,1,1-TCA	TCE	VC	Risk for Pathways	Operable Unit	Zone
MW-1067	13-Apr-93	0	0	0	0	0	0.33	0	1.21E-05	A	A
MW-1067	13-Apr-93	0	0	0	0	0	0.34	0	1.21E-05	A	A
MW-1067	04-Aug-93	0	0	0	0	0	1.43	0	1.38E-05	A	A
MW-1068	16-Aug-90	0	0		0	0	0	0	1.41E-07	A	B
MW-1068	13-Sep-90	0	0		0	0	0	0	0	A	B
MW-1068	05-Feb-91	0	0		0	0	0	0	0	A	B
MW-1068	29-Apr-91	0	0		0	0	2.4	0	7.49E-07	A	B
MW-1068	16-Jul-91	0	0		0	0	0	0	0	A	B
MW-1068	15-Oct-91	0	0		0	0	0	0	9.91E-07	A	B
MW-1068	03-Feb-92	0	0		0	0	0	0	0	A	B
MW-1068	27-Jul-92	0	0	0	0	0	0	0	0	A	B
MW-1068	21-Oct-92	0	0	0	0	0	0	0	0	A	B
MW-1068	20-Jan-93	0	0	0	0	0	1.5	0	4.68E-07	A	B
MW-1068	04-Aug-93	0	0	0	0	0	0	0	0	A	B
MW-1069	29-Aug-90	0	0		0	0	0	0	6.66E-07	B	A
MW-1069	29-Aug-90	0	0		0.52	0	0	0	6.66E-07	B	A
MW-1069	14-Sep-90	0	0		0	0	0	0	0	B	A
MW-1069	24-Jan-91	0	0		0	0	4	0	1.25E-06	B	A
MW-1069	25-Apr-91	0	0		0	0	1.2	0	3.75E-07	B	A
MW-1069	23-Jul-91	0	0		0	0	0.43	0	1.34E-07	B	A
MW-1069	09-Oct-91	0	0		0	0	0	0	0	B	A
MW-1069	27-Jul-92	0	0	0	0	0	0.5	0	1.56E-07	B	A
MW-1069	22-Jan-93	0	0	0	0	0	1.3	0	4.06E-07	B	A
MW-1069	13-Apr-93	0	0	0	0	0	0	0	0	B	A

Appendix L1

PREPARED FOR: McClellan Air Force Base

DATE: November 7, 1993

SUBJECT: Innovative Technologies Screening
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.NT

Overview and Approach

The scope of the Groundwater Operable Unit Feasibility Study at McClellan AFB includes the evaluation and screening of applicable innovative technologies to remediate contaminated groundwater. These technologies passed through a two-tiered screening process and the field was narrowed down to the most promising technologies. The screening process followed the sequence of steps:

1. Site Information Review
2. Kickoff Brainstorming Session
3. Primary Technology Information Review
4. Initial Technology Identification
5. Primary Technology Screening
6. Murder Board Meeting
7. Secondary Technology Information Review
8. Secondary Screening
9. Alternatives Development Update/Consensus Meeting
10. Screening Documentation

The primary literature review identified 37 technologies to be potentially applicable for groundwater remediation at McClellan AFB. The primary screening reduced this number to 16, and the secondary screening further reduced this list to 7 technologies. McClellan AFB and applicable agencies participated in the selection and screening process.

Three preliminary assumptions were made for technology screening. The first was that the innovative technologies initially would be implemented in Monitoring Zone A since the A zone reportedly contains greater than 90 percent of the contaminant mass in the groundwater at McClellan AFB. The second was that trichloroethene (TCE) would be the primary contaminant targeted for cleanup, although other important chemicals were also considered. The third was that innovative technologies initially would be implemented in contaminant hot spots to achieve the greatest remedial benefit. TCE "hot spots" were initially defined as 1,000 $\mu g/l$, though later changed to 500 $\mu g/l$.

Primary Technology Information Review

Identifying potentially applicable technologies and obtaining information for screening were the two objectives of the primary literature review. The list of information sources consulted is presented in Table L1-1. The information gathered from these sources is summarized in Tables L1-2 through L1-6.

Primary Screening

The potentially applicable technologies were organized into five categories:

- In Situ Biological Treatment
- In Situ Physical/Chemical Treatment
- Ex Situ Biological Groundwater Treatment
- Ex Situ Physical/Chemical Groundwater Treatment
- Offgas Treatment

Three primary screening criteria were established to evaluate the technologies:

- Potential effectiveness
- Development status
- Relative cost

Using the primary screening information summarized in Tables L1-2 through L1-6, five team members independently graded each treatment technology. The technologies were graded by assigning a score for each criterion based on a scale of 1 to 5, where 1 represented "least favorable" and 5 represented "most favorable." For development status, a more objective scale was used:

1 = sub-bench scale
2 = bench-scale
3 = pilot-scale
4 = demonstration scale
5 = full-scale

Each technology was scored relative to others within the same category. Each of the three criteria were weighted equally, so the maximum composite score was 15.

Table L1-1 Initial Innovative Technology Information Sources
Databases and Bulletin Boards
VISITT Database
ATTIC Database
CLU-IN Electronic Bulletin Board
RREL Database
ORD Electronic Bulletin Board
Reports and Programs
EPA Bioremediation Action Committee
EPA Bioremediation Field Initiative
EPA SITE Program (Site Technology Profiles: Fifth Edition, November 1992)
EPA Innovative Treatment Report
Literature and Proceedings
EPA Groundwater Currents
HazTec News
Hazardous Waste Consultant
Water Environment Research
Nineteenth Annual RREL Haz Waste Research Proceedings
Battelle's 1993 Bioreclamation Conference Abstracts
Hill AFB 1993 Environmental Restoration Technical Interchange Symposium
Other Sources
Internal experts
Subconsultants (Dr. Perry McCarty and Dr. Lewis Semprini)
Ciba-Geigy Corporation

The scores from each of the five team members were averaged. The average scores were reviewed by the team and modified by eliminating outlying values that disproportionately skewed the results. The average composite scores were plotted (Figures L1-1 through L1-5), and the primary technology screening was performed by arbitrarily selecting a cutoff score for retaining/eliminating technologies. No statistical analysis was conducted to evaluate significant differences between scores. The objective of the primary screening process was to reduce the list of technologies to a manageable size for further development. The scoring process made the screening somewhat quantitative, but professional judgment was the ultimate basis used to develop the list of technologies retained after primary screening (Table L1-7).

Murder Board Meeting

The Murder Board Meeting was held on July 21, 1993, to present the primary screening results to McClellan AFB staff, regulatory agencies, and other interested parties. Participation was encouraged at this meeting, and feedback was requested on the screening process. Screening criteria, scoring tables, and bar charts were presented, and consensus was reached on the retained technology list. However, three action items to be addressed resulted from this meeting:

Table L1-2
Primary Screening Information
In Situ Biological Groundwater Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Aerobic	Bioremediation (SVSS remediation technology) Billings & Associates Rick M. Billings (505)345-1116	In situ technology consists of three stages: air injection below water table, vapor withdrawal above water table, and stimulation of microbial community to increase bioremediation of less volatile compounds.		Claimed to be significantly cheaper than conventional pump-and-treat systems. Claimed to breakdown anything that is biodegradable.	Adequate information on the success of treatment of halogenated VOCs is not available
	In situ bioremediation Ground Water Technology Inc. Ron Hicks (510)671-2387	In situ technology stimulates natural biodegradation systems by supplying nutrients and oxygen to contaminated groundwater.	Full-scale.	Destructive natural process cheaper than alternatives such as SVE and incineration.	Performance limited for heavily chlorinated water.
	Augmented in situ subsurface bioremediation process BIO-REM Inc David Mann 800-428-4626	Uses proprietary blend of microaerophilic bacteria and micronutrients to treat hydrocarbons and chlorinated compounds.	Accepted into SITE in 1991. Is being demonstrated at Williams AFB in AZ.	Process does not require additional oxygen or oxygen-producing compounds. Bacteria can operate in a wide temperature range.	May be more applicable to hydrocarbons than chlorinated solvents. Very little information available in SITE.
Cometabolic	In situ biodegradation ECOVA Corp John Kinsella 206-883-1900	Proprietary process uses a nontoxic inducer to stimulate microbial activity.	Pilot demonstration completed and ECOVA awaiting authorization for full-scale testing.	Pilot demonstration was successful, as TCE went from 3,000 ppb to less than 100 ppb.	How does it work with other chlorinated solvents? Is it cometabolic?
	Chlorinated hydrocarbon bioremediation Groundwater Technology Inc Ronald Hicks 510-671-2387	Cometabolic process to treat PCE, TCE, and vinyl chloride.	Pilot study conducted in 1989 and 1990. Full design has now begun.	Pilot study was successful.	Cost unknown.
	Perry McCarty Western Region Hazardous Substance Research Center				

Table L1-2
Primary Screening Information
In Situ Biological Groundwater Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Anaerobic	Biocat II (bioremediation) process Mary Hunter YellowStone Env. Sc.Inc (406) 586 3905	This in situ bioremediation process entails addition of sulfate, nitrate, or equivalent electron acceptors into the subsurface. Methane-producing microorganisms may be added to accomplish dehalogenation reactions.	Demonstrated on laboratory scale to remove 1,1,1-TCA and TCE.	Claimed to have several advantages over other bioremediation technologies including natural pH control, immobilization of metals to protect methanogens and conversion of breakdown products to methane.	Applicable only in situations in which a sequence of environments (denitrifying and/or sulfate-reducing and then methane-producing) can be induced to occur in a zone of contaminated water.
Sequential Anaerobic - Aerobic	Two-zone plume interception ABB Environmental Services Inc Sam Fogel 617-245-6606	First zone is anaerobic and partially dechlorinates highly chlorinated solvents, such as PCE. Second zone is immediately downgradient, is aerobic, and encourages oxidation of the partially chlorinated products.	Accepted into SITE in July 1989. Bench-scale testing is 75% complete as of September 1992.	Uses dechlorinating bacteria specially adapted to high concentration of chlorinated solvents.	Results and effectiveness are unknown at this time.
Enzyme Treatment	US EPA Dave Wolfe Athens, GA	Dehalogenase enzyme used (e.g., in permeable reaction wall) to dehalogenate chlorinated organics.	Laboratory development.		Results and effectiveness are unknown at this time.
Natural Attenuation					
In Situ Recirculation Unit	1 EG (UVB)	An immobilized-cell bioremediator is constructed inside a groundwater recirculation unit (well). Groundwater is circulated through the unit, achieving in situ treatment.	At initial development stages.	The treatment control achievable with an engineered reactor can be achieved without groundwater withdrawal to the surface.	No sufficiently developed to understand potential and limitations.
Permeable Reaction Wall	Robert Taylor Lawrence Livermore National Laboratory	A biologically active zone is constructed in the path of groundwater flow.	Conceptual development.	Groundwater control is not necessary.	Treatment duration could be quite lengthy.

Table L1-3
Primary Screening Information
In Situ Physical/Chemical Groundwater Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Sparging/SVE	Subsurface Volatilization and Ventilation System (SVVS) Billings and Associates. Gale Billings 505-345-1116	Network of injection and extraction wells to treat contamination via SVE combined with in situ biodegradation.	Accepted into SITE program in 1991. A site in Michigan selected to demonstrate SVVS for remediation of BTEX, TCE, PCE and DCE.	Technology designed specifically to enhance bioremediation.	Microbiological effectiveness unproven, especially chlorinated solvents.
	In situ air sparging (Sparge Vac) Terra Vac Inc.	Vapor extraction wells are installed and manifolded to a knock-out pot. A vacuum is induced to extract the soil vapors for offgas treatment. In addition to extraction wells, sparging wells are used to sparge air or nitrogen into groundwater. Volatile organics in the groundwater volatilize and diffuse into the air bubbles created by sparging. When the bubbles reach the vadose zone, the SVE system removes them.	Full-scale; successful remediation demonstrated.	Well proven technology; several vendors have the same or similar technology.	Contaminants that form complexes with soil matrix are not applicable.
Steam Injection/ Vapor Extraction	In Situ Steam-Enhanced Extraction (ISSE) Udell Technologies Inc Lloyd Stewart 510-653-9477	Steam is forced through soil by injection wells, while extraction wells pump water and move steam and vaporized contaminants.	Part of SITE demonstration at McClellan AFB.	CH2M HILL familiar with technology.	Really is a soil treatment, though vendor claims both above and below water table. Cost could be high.
Steam Injection Vapor Extraction (SIVE)	Hughes Environmental Systems John Dablow 213-536-6548	Steam is forced through soil by injection wells, while extraction wells pump water and move steam and vaporized contaminants.	Site demonstration in Huntington Beach, California.	CH2M HILL familiar with technology.	Really is a soil treatment, though vendor claims both above and below water table. Cost could be high.
Soil Heating/ Vapor Extraction	ERACE (Electrical Remediation at Contaminated Environment) Battelle	Electrodes are planted in a 100-foot-diameter circle, applying current to the soil. Water and volatile organics form a steam-contaminant mixture which is vacuum stripped.	Field tests planned at Savannah River, summer 1993.	Mass transfer limitations of hot air or steam injection are available.	Primarily a soil treatment process.
Chemical Oxidation	"Oxy-Vac" Terra Vac	Injection of hydrogen peroxide into DNAPL zone oxidizes contaminants and reportedly helps stimulate aerobic degradation.	At development stage.		
	Waterloo Centre for Groundwater Research Graham Farquar	Permanganate injection/extraction oxides contaminants.	At development stage.		

Table L1-3
Primary Screening Information
In Situ Physical/Chemical Groundwater Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Metal-Catalyzed Dehalogenation	Metal-enhanced degradation EnviroMetal Technologies Inc. John Quayle (519) 824-0432	In situ treatment technology that involves constructing an iron based permeable catalyst wall across the path of the contaminated groundwater plume. The metal catalyst degrades (dehalogenates) at rates 3 to 6 orders of magnitude greater than natural rates. Source Haz Waste Cons, Page 1.18, May/June 1993.	Laboratory and field demonstrations are being conducted.	Claimed to be cheaper than conventional pump-and-treat technologies. TCE and PCE destruction rates of 95% and 91%, respectively, have been achieved in the demonstrations.	Long-term integrity and effectiveness in a range of hydrogeological environments is yet to be determined. Presence of and potential for formation of breakdown products has not been tested.
Surfactant Flushing	State University of New York at Buffalo John Fountain 716-645-3996	Surfactant flushing process capable of removing DNAPLs from aquifer. A surfactant-containing solution is injected into the subsurface, then contaminants are recovered from withdrawn groundwater.	Bench-scale successful. Pilot field test underway.	Was successful at removing free phase PCE.	Unknown costs and effectiveness at other compound DNAPLs.
Solvent Flushing					
Hydrofracturing					
Pneumatic Fracturing					

In Situ Treatment of Contaminated Ground Water: An Inventory of Research and Field Demonstrations and Strategies for Improving Ground Water Remediation Technologies.

Table L1-4
Primary Screening Information
Ex Situ Biological Groundwater Treatment Technologies

Technology	Example Vendors/Contacts	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Aerobic	Immobilized Cell Bioreactor Allied-Signal, Inc. (ICB Biotreatment System) Ralph Nussbaum or Timothy Love (201-455-3190)	Fixed-film biotreatment system designed to maximize biological activity and contact between biofilm and contaminants. Applicable to a wide range of organic contaminants (for aerobic system) and chlorinated solvents (with anaerobic system).	Treatability and demonstration testing has been conducted (G&H Landfill in Utica, MI).	Likely to have high treatment capacity, compact design, reduced O&M costs, and low sludge production.	Effectiveness and robustness not demonstrated. Advantage over standard fixed-film biological system not demonstrated. Unknown extent of air emissions. Aerobic rector not expected to be effective in achieving chlorinated VOC reduction.
	Biological Aqueous Treatment System (BATS) Biotrol, Inc. Dennis Chilcote (612-448-2515)	Patented biological treatment system using heated influent in an immobilized-biomass, multiple cell reactor. Can be operated under aerobic (fine bubble membrane diffusers) or anaerobic conditions.	Performed pilot test in 1986-87. Since then has installed more than 20 full-scale systems and performed several other pilot tests.	Likely to have reduced O&M costs and low sludge production. Appears to require minimal operator attention.	Effectiveness and robustness not demonstrated. Advantage over standard fixed-film biological system not demonstrated. Unknown extent of air emissions. Aerobic reactor not expected to be effective in achieving chlorinated VOC reduction.
	ZenoGem Process Zenon Environmental Systems, Inc. Tony Tenelli (416-639-6320)	Process consists of a bioreactor combined with an ultrafiltration membrane system to recover and recycle biological solids and high molecular weight organics. Results in a system that can treat high BOD wastes at a long sludge retention time but short HRT.	No demonstration yet conducted.	System is compact.	May not be able to handle high flow rates. Treatment effectiveness not yet demonstrated. Bioreactor is aerobic and not expected to achieve chlorinated VOC reduction.
	Cognis, Inc. Kieth Weerts (707-576-6200)	Proprietary technology uses fixed-film bioreactors under anaerobic conditions to achieve degradation of halogenated solvents.	This emerging technology has been tested at the bench-scale. Pilot-scale equipment is available for use.	Anaerobic treatment could be effective and inexpensive compared to other technologies.	Throughput rate may be limited by reactor(s) size. Robustness and cost-effectiveness of technology not yet demonstrated.

Table L1-4
Primary Screening Information
Ex Situ Biological Groundwater Treatment Technologies

Technology	Example Vendors/Contacts	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Aerobic Cometabolic	Methanotrophic Bioreactor System Biotrol, Inc. Durell Dobbins (612-448-2515)	Process utilizes cometabolism and the methane monooxygenase enzyme to achieve TCE reduction.	Bench- and pilot-scale testing has been completed. Final report from testing was scheduled to be submitted to EPA in January 1993. Much literature is available on this technology, and one good paper (Radian) has been obtained.	Appears to achieve very high rates of reduction of TCE. Appears to be less expensive than GAC and competitive with stripping.	Robustness and capability of handling a variety of constituents is not demonstrated.
	Radian Corp (Michigan Biotechnology Institute) R. Legrande (512-454-4797)				
	Envirogen				
	Gerald Speitel Univ. of Texas at Austin				
Anaerobic	Immobilized Cell Bioreactor Allied-Signal, Inc. (ICB Biotreatment System) Ralph Nussbaum or Timothy Love (201-455-3190)	Fixed-film biotreatment system designed with (1) a unique reactor medium that maximizes biological activity, and (2) a reactor design which maximizes contact between biofilm and contaminants. Applicable to a wide range of organic contaminants (for aerobic system) and chlorinated solvents (with anaerobic system).	Treatability and demonstration testing (G&H Landfill in Utica, MI).	Likely to have high treatment capacity, compact design, reduced O&M costs, and low sludge production.	Effectiveness and robustness not demonstrated. Advantage over standard fixed-film biological system not demonstrated. Unknown extent of air emissions.
Anaerobic	Biological Aqueous Treatment System (BATS) Biotrol, Inc. Dennis Chilcote (612-448-2515)	Patented biological treatment system using heated influent in an immobilized-biomass, multiple cell reactor. Can be operated under aerobic (fine bubble membrane diffusers) or anaerobic conditions.	Performed pilot test in 1986-87. Since then has installed more than 20 full-scale systems and performed several other pilot tests.	Likely to have reduced O&M costs and low sludge production. Appears to require minimal operator attention.	Effectiveness and robustness not demonstrated. Advantage over standard fixed-film biological system not demonstrated. Unknown extent of air emissions.

Table L1-4
Primary Screening Information
Ex Situ Biological Groundwater Treatment Technologies

Technology	Example Vendors/Contacts	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Anaerobic (continued)	Cognis, Inc. Kieth Weerts (707-576-6200)	Proprietary technology uses fixed-film bioreactors under anaerobic conditions to achieve degradation of halogenated solvents.	This emerging technology has been tested at the bench-scale. Pilot-scale equipment is available for use.	Anaerobic treatment could be effective and inexpensive compared to other technologies.	Throughput rate may be limited by reactor(s) size. Robustness and cost-effectiveness of technology not yet demonstrated.
Sequential Anaerobic - Aerobic	David Stensel Univ. of Washington				
PACT	Zimpro Passivant William Copa (715-359-7211)	Biological treatment and powdered activated carbon are combined to achieve treatment standards which cannot be met by biological treatment alone. Contact-aeration tanks are followed by clarifiers to achieve carbon and biosolids recycle similar to activated sludge.			

Table L1-5
Primary Screening Information
Ex Situ Physical/Chemical Groundwater Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Evaporation w/ Catalytic Oxidation	PO*WW*ER Chemical Waste Management, Inc. Erick Neuman or Matt Husain (708-513-4500)	Proprietary technology combines evaporation with catalytic oxidation to concentrate and destroy contaminants. Achieves volume reduction by concentration of nonvolatile constituents in a waste stream (requiring further treatment).	One demonstration test at developer's pilot plant in Lake Charles, LA. A commercial system (50 gpm capacity) was nearing completion in Hong Kong at the end of 1992.	Treats a wide spectrum of contaminants, produces a high quality effluent, destroys volatile pollutants.	Produces a brine which would require further treatment (unless it could be recombined with effluent stream). Appears to be fairly energy-intensive, and not practical at very high flow rates.
Chemical Oxidation	ClO_2 Chemical Oxidation EXXON Chemical Company and RIO Linda Chemical Company Brent Bourland (713-460-6822)	Utilizes an onsite ClO_2 generator to oxidize contaminants.	No demonstration reported to date.	Will not form THMs.	Not expected to be effective against this waste stream in reducing VOCs. Operating costs are anticipated to be high.
Photolytic Oxidation	CAV-OX Process Magnum Water Technology	Uses a combination of hydrodynamic cavitation and UV radiation to oxidize contaminants in water. UV lamp output can be varied from 60 watts to over 15,000 watts depending on contaminant stream.	Has been tested several times at private and public sites. Was tentatively scheduled for demonstration at Edwards AFB in February 1993.	Doesn't release air emissions, treatment costs estimated at half the cost of advanced UV oxidation systems and substantially less than GAC. Maintenance costs are minimal.	Cannot handle free product or highly turbid waste streams. No results available on success of treating TCE, DCE, etc. (Achieved >95% R.E. for 1,1-DCA)
	Laser-Induced Photochemical Oxidative Destruction Energy and Environmental Engineering, Inc. James Porter (617-666-5500)	Technology photochemically oxidizes organic compounds using an oxidant (H_2O_2) and UV radiation from an Excimer laser. Process can be used as a final treatment step for reducing organic contamination to acceptable discharge limits.	This is an emerging technology which has been accepted into the SITE Demonstration Program. Pilot-scale system of 1 gpm.	Vendor claims cost competitiveness with AOP and GAC.	Robustness and cost-effectiveness of technology not yet demonstrated. Reaction times on order of 100 hours. Appears expensive at $30 to $70 per 1,000 gallons.

Table L1-5
Primary Screening Information
Ex Situ Physical/Chemical Groundwater Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Photolytic Oxidation (continued)	Light Activated Reduction of Chemicals (LARC) Arctech, Inc. Donald Shilesky (703-642-4189)	Patented photochemical process which uses UV light and an optimized reducing environment to dehalogenate organic compounds.	This emerging technology has been evaluated at the bench-scale. Mobile pilot-testing unit should be available.	Vendor claims cost-competitiveness with existing technologies for treatment of PCBs.	Vendor has not yet demonstrated cost-effective treatment of halogenated VOCs (but claims they will demonstrate effectiveness).
	Photothermal Detoxification Unit University of Dayto Datona? Dayton? Research Institute				
	Pulsed UV Continuum Ultraviolet Energy Generators Inc Alex Wekhof 510-272-0547	Wekhof flashlamp similar to xenon, but operates under parameters and high current density to produce pulsing continuum.	Tests conducted at Lawrence Livermore	Xenon lamp can also achieve this, but conditions greatly shorten its life.	Unknown how much more effective continuum is than standard UV. Still most effective when used with peroxide and catalyst (titanium dioxide).
	Photolytic oxidation Purus, Inc Paul Blystone 408-453-7804	Uses xenon pulsed plasma flashlamp that emits short wavelength ultraviolet (UV) light.	Accepted into SITE Emerging technologies program in March 1991.	Well documented success. Full-scale prototype began in October 1991.	Standard technology by definition.
	TiO_2 Photocatalytic Water Treatment Matrix Photocatalytic, Inc. Brian Butters (Ontario, Canada) (519-457-2963)	Removes and destroys organic contaminants from water through use of a TiO_2 semiconductor which is excited by UV-A light and produces hydroxyl radicals. For more refractive contaminants, oxidants are added in small quantities (0.0003 mol/l) to enhance the process. Direct operating cost for mini pilot-scale system was reported to be $1 to $2 per 1,000 gallons.	This is an emerging technology which has been taken to the pilot plant (5 gpm) stage.	Can treat a wide range of contaminants down to the very low ppb range.	Potentially high cost, especially with chemical usage.

Table L1-5
Primary Screening Information
Ex Situ Physical/Chemical Groundwater Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Membrane Separation	Cross-Flow Pervaporation System Wastewater Technology Centre Rob Booth (Ontario, Canada) (416-336-4689) Ron Turner, EPA	Permeable membranes that preferentially adsorb VOCs are used to partition them from contaminated water. The VOCs diffuse from the membrane-water interface through the membrane and are drawn under a vacuum. Upstream of the vacuum pump, a condenser traps and contains the permeating vapors, condensing all the vapor to avoid fugitive emissions. The VOC-rich condensate is recovered for further treatment/disposal. For low concentrations of VOCs vendor claims cost to be competitive with air stripping and GAC.	This is an emerging technology that has been developed to the pilot-plant stage.	Appears to have a high removal capacity with no fugitive emissions.	A VOC-rich condensate is produced which requires further treatment. Unknown performance with mixed waste streams and high concentrations of VOCs.
Membrane Separation (continued)	Rochem Disc Tube Module System Rochem Separation Systems, Inc. David LaMonica (310-370-3160)	Uses a reverse osmosis/ultrafiltration system to achieve separation of pure water from contaminated liquids.	A demonstration was planned for fall 1992. No results reported.		Probably not cost-effective for chlorinated VOC removal when compared with other technologies. Produces brine which requires further treatment/ disposal.
	VaporSep Membrane Technology and Research	VOC-laden air stream is passed through a compressor/ condenser. Liquids are stored, and the remaining vapors are passed through the VaporSep membrane modules. The membranes are permeable to organics and separate the organics from the air. The membrane-concentrated organics are recycled to the condenser.	Units installed in 17 locations, 10 of which are full-scale.	Can achieve concentration of most CVOCs. More cost-effective than condensation alone.	Optimal for high concentration low flow air streams. Potentially costly due to energy requirements.
	Membrane Separation and Biological Treatment SBP Technologies, Inc.	System is composed of a hyperfiltration unit to concentrate organic contaminants. The concentrate is then treated biologically.	Demonstrated under SITE program October 1991; scale unknown.	Vendor claims to be able to treat TCE.	May not be cost-effective for removal of low molecular weight compounds.
Photolytic Reduction	Reductive Photo-Dechlorination M.L. Energia Inc Moshe Lavid 609-799-7970	Reducing atmosphere and UV light are used to remove chlorine atoms.	Site emerging technologies in summer 1992.	Well documented technology for treatment of water and gas.	Unknown what distinguishes this from other UV/oxidation.
Resin Adsorption	PADRE Purus, Inc.				

Table L1-5
Primary Screening Information
Ex Situ Physical/Chemical Groundwater Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Surfactant Separation	GHEA Associates Process New Jersey Institute of Technology Itzhak Gotlieb (201-802-1946)	Contaminated water is treated with a dose of surfactant. The surfactant sorbs the contaminants, then is separated from the water phase. The water phase undergoes ultrafiltration then air flotation prior to discharge. The contaminant undergoes desorption from the surfactant and is recovered. The surfactant is recycled in the process.	This is an emerging technology which has undergone treatability testing at bench-scale and in a 25-gallon pilot plant. Final report on the pilot plant was due in June 1993.	Vendor claims very high removal rates and no emissions.	Potentially high cost and not demonstrated to be effective over a wide range of contaminant types and concentrations.
Metal-Catalyzed Dehalogenation	Environmental Technologies, Inc.		Emerging technology currently developed to bench-scale.	Technology has some potential.	Not sufficiently developed.
High-Energy Electron Irradiation	Electron Beam Research Facility, Florida International University and University of Miami William Cooper (305-348-3049) High Voltage Environmental Applications Thomas Waite (305-253-9143)	High energy electron irradiation produces the aqueous electron (e^-_{aq}), the hydrogen radical, and the hydroxyl radical, which transform organic contaminants.	This is an emerging technology which has been accepted into the SITE Demonstration Program. Pilot-scale studies conducted at 100 gpm.	System has been found to be effective on VOCs and BTEX.	Robustness and cost-effectiveness of technology not yet demonstrated.
	ZAPIT				
	X-Ray Treatment Pulse-Sciences, Inc. Randy Curry (510-632-5100)	Ionizing radiation causes the generation of electrons which generate the hydroxyl radical and break up contaminant molecules. A linear induction accelerator generates the X-rays used in the process.	This is an emerging technology which has only been tested at the bench-scale. The vendor is in the process of designing a 5 MeV plant.	Vendor claims technology to be effective for a wide range of contaminants (especially TCA, TCE, and benzene), safe, and comparable with respect to costs of alternative processes.	Not as effective for some compounds (such as CCl_4) which require greater energy and slower flow rates.
Wet Air Oxidation	Zimpro/Passavant Wietox Kenox Corp.	An aqueous waste stream is heated to 350° to 650°F at high pressure, oxidizing the organics and inorganics in groundwater.	This is an established technology for other (non-hazardous) treatment processes.		Technology is more appropriate for more highly concentrated waste streams. No likely to be cost-effective.

Table L1-5
Primary Screening Information
Ex Situ Physical/Chemical Groundwater Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Supercritical Water Oxidation	MODAR Sandia National Laboratories	Similar to wet oxidation except that higher temperatures and pressures are employed.	Some bench-scale and demonstration testing has been conducted.		Has not gained wide acceptance. Perceived to be more appropriate for mixed hazardous/ radioactive waste streams.

Table L1-6
Primary Screening Information
Offgas Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Photolytic Oxidation	TiO2 Photocatalytic Air Treatment Matrix Photocatalytic, Inc. Brian Butters 519-457-2963	Contaminated air flows through a fixed TiO2 catalyst bed activated by UV-A light.	Accepted into SITE Emerging Technology Program in 1992.	Testing has included TCE and PCE.	Potentially high cost.
	Solaire Process Solarchem Environmental Systems Peter O'Connor 702-255-7055	Contaminated air is passed through a chamber with a UV lamp. A proprietary adsorber is used to increase effectiveness.	Bench-scale tests are being completed. Field demonstration scheduled for fall 1993.	Higher efficiencies than TiD_2 systems are claimed by vendor.	Potentially high cost for complete mineralization of contaminants.
	Photolytic Oxidation Process Purus, Inc. Paul Blystone (408-453-7804)	The system uses a xenon pulsed-plasma flashlamp that emits short wavelength UV light at very high intensities to treat vapor-phase VOCs. UV treatment converts the VOCs into *less hazardous compounds.*	Field tested at air flows up to 500 cfm and TCE = 500 ppm.		Undesirable intermediates are formed (chloroacetyl chloride and *dichlorocarbonyl*).
Membrane Separation	VaporSep Vicki Simmons Membrane Technology (415) 328 2228	The VaporSep process removes and condenses organic vapors from off-gas produced by innovative remediation technologies such as SVE, thermal desorption, etc. Organics pass through a membrane which is impermeable to air.	Full-scale demonstrations completed successfully.	Removals of 90 to 99% have been achieved. Since the volume of recovered solvent condensate is small, ultimate disposal of the same is substantially cheaper.	At vapor concentrations below 1,000 ppm, other conventional technologies may be more cost effective.
Biotreatment/ Aerobic	Biofiltration		Pilot- and full-scale units in operation for numerous applications.	Generally good for high flow rates and low concentrations.	Success treating chlorinated VOCs w/ conventional aerobic biofilter not established.
	Bioscrubber Aluminum Company of America Paul Liu 412-826-3711	Bioscrubber contains activated carbon medium to support microbial growth.	SITE Emerging Technology Program in 1990. Bench-scale complete, pilot-scale scheduled for November 1992.	High efficiency removal of hazardous organics in lab scale tests.	Effective for BTEX, unproven for chlorinated solvents.

Table L1-6
Primary Screening Information
Offgas Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Biotreatment/ Cometabolic	Gas Phase Methanotrophic Bioreactor Remediation Technologies (ReTeC) Dr. Hans F. Stroo 206-624-9349	Upflow methanotrophic biofilm reactor for gas streams cometabolizes volatile chlorinated solvents. Three designs: compost biofilter, fluidized bed biofilter, and a stacked/staged activated carbon biofilter.	Emerging Technology Program (ETP) of SITE.	Flexible design alternatives. Staged/stacked biofilter also adsorbs VOCs.	Biofilter susceptible to flooding and rapid biogrowth.
	Envirogen Bill Guarini 609-936-9300 Fred Bishop EPA RREL 513-569-7629				
Adsorption	PADRE Purus Inc	Simultaneous destruction of VOCs from vapor extraction wells and a groundwater air stripper. Process involves adsorbing air-phase contaminants on a resin and then desorbing and recovering them as a liquid.	Trying to locate a site for demonstration.	Reportedly more cost-effective than vapor-phase GAC.	Condensate stream from resin regeneration must be treated.
Scrubbing	Chemtact Gaseous Waste Treatment QUAD Environmental Technologies Corp Robert Rafson 708-564-5070	Atomizing nozzles within scrubber chamber disperse droplets of controlled chemical solution. This is essentially a concentration process.	Accepted into SITE demonstration Program in 1989.	Units are mobile. Can be used with air strippers. Is best suited for VOCs.	Has been demonstrated with BTEX, but not chlorinated solvents.
Photolytic Reduction	M.L. Energia, Inc				
High Energy Electron Irradiation	ERACE				
	ZAPPIT				
High Temperature Steam Destruction	Synthetica Terry Galloway 510-525-3000	A contaminated vapor stream which has been concentrated (such as from the regeneration of a GAC bed) is fed into a detoxification reactor which oxidizes organics in a flameless heater, forming CO, CH_4, and H_2O (syngas). A catalytic converter oxidizes offgases to CO_2 and H_2O. An adsorber bed collects any trace organics and metals, and Selexsorb removes any trace halogens.	Full-scale units are now being constructed.	Disposal volumes are almost eliminated. Can regenerate GAC beds with offgas from unit. Syngas can be recycled as an energy source.	Solvent wastes are destroyed rather than recovered.

Table L1-6
Primary Screening Information
Offgas Treatment Technologies

Technology	Vendor/Contact	Technology Description	Current Status	Perceived Highlights	Perceived Lowlights
Flameless (Catalyzed) Thermal Oxidation	TherMatrix	Information not yet available.			

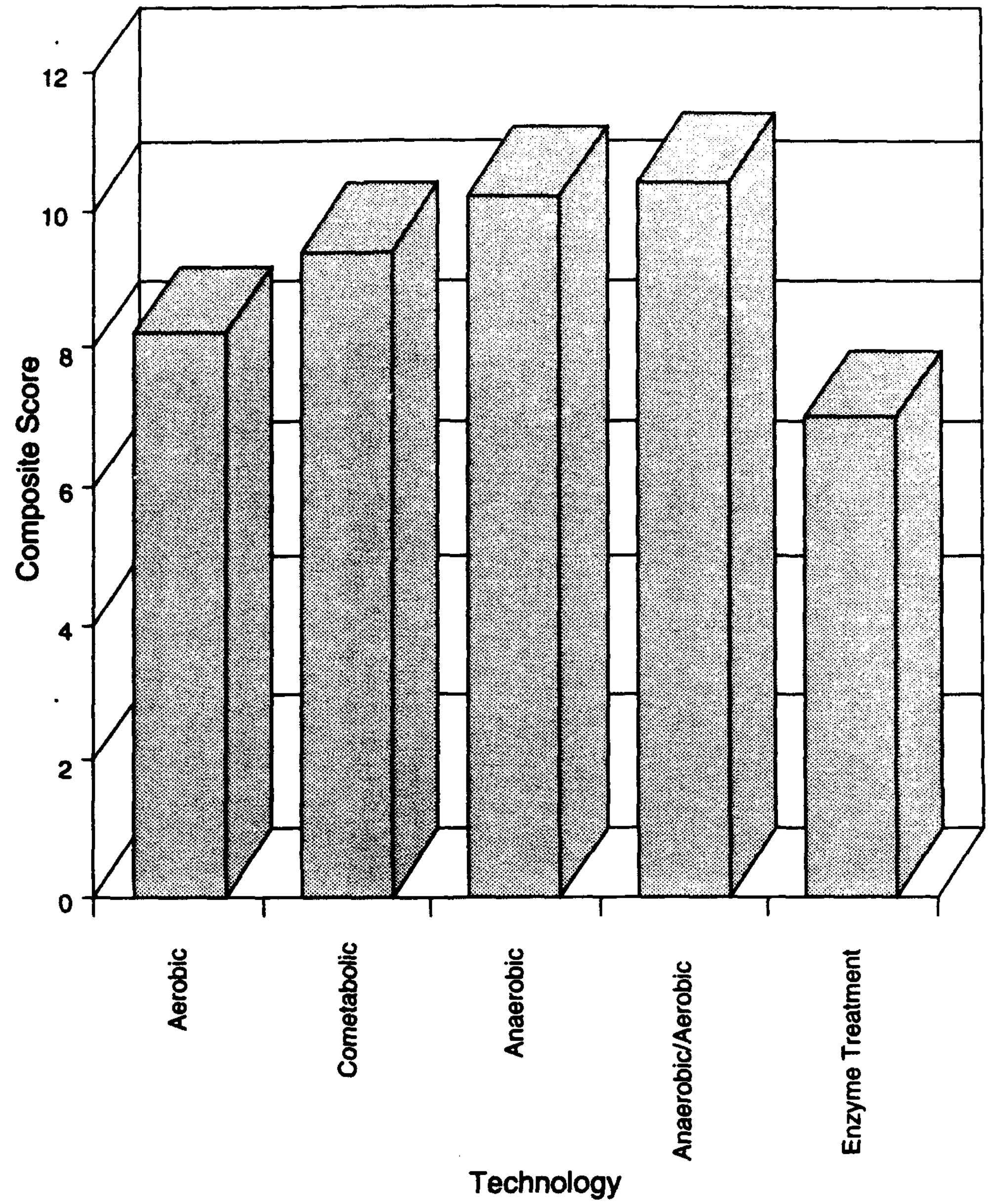

FIGURE L1-1
PRIMARY SCORING SUMMARY IN SITU BIOLOGICAL TREATMENT TECHNOLOGIES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_170

CH2MHILL

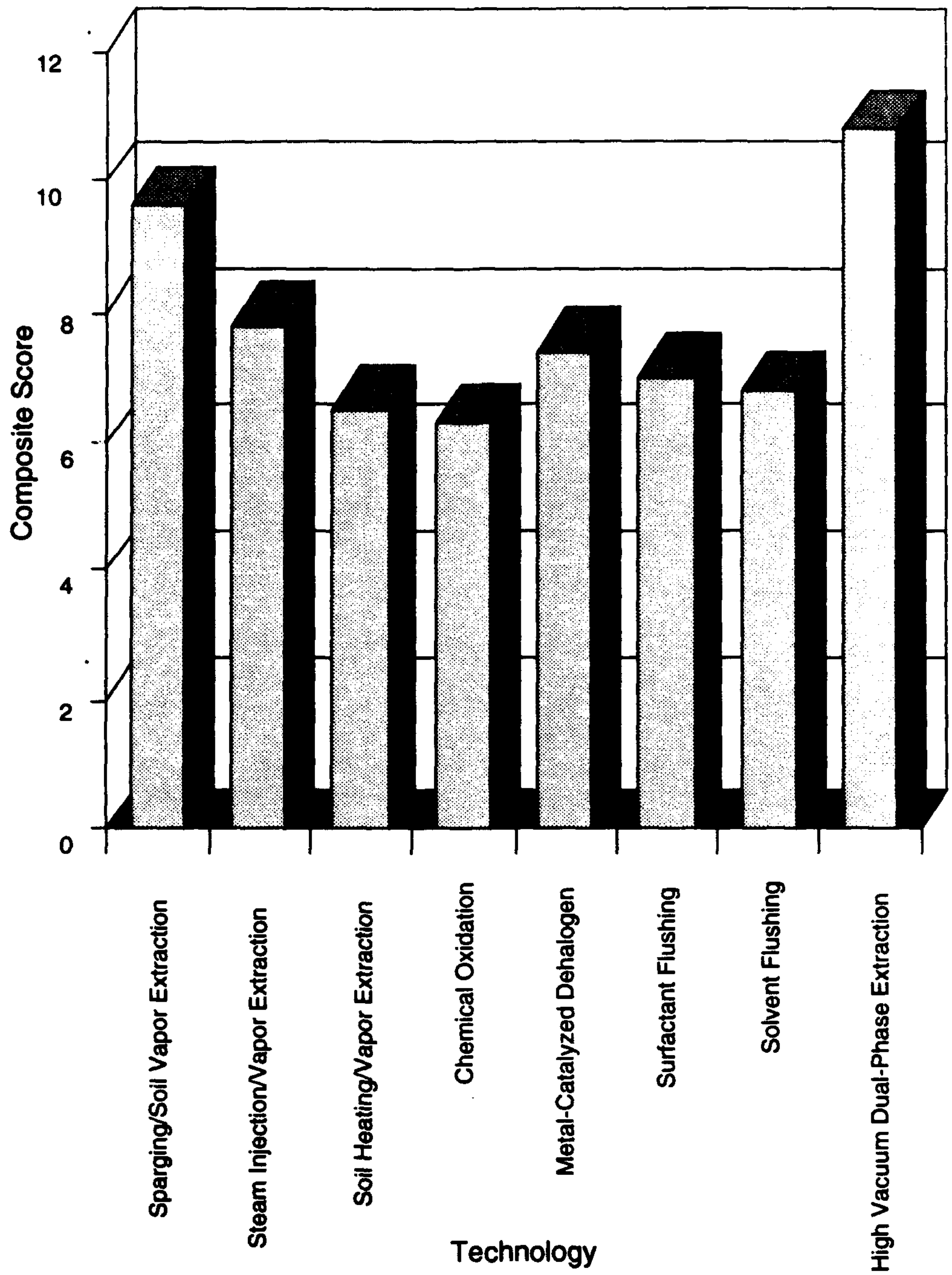

FIGURE L1-2
PRIMARY SCORING SUMMARY
IN SITU PHYSICAL/CHEMICAL
TREATMENT TECHNOLOGIES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1464_171

CH2M HILL

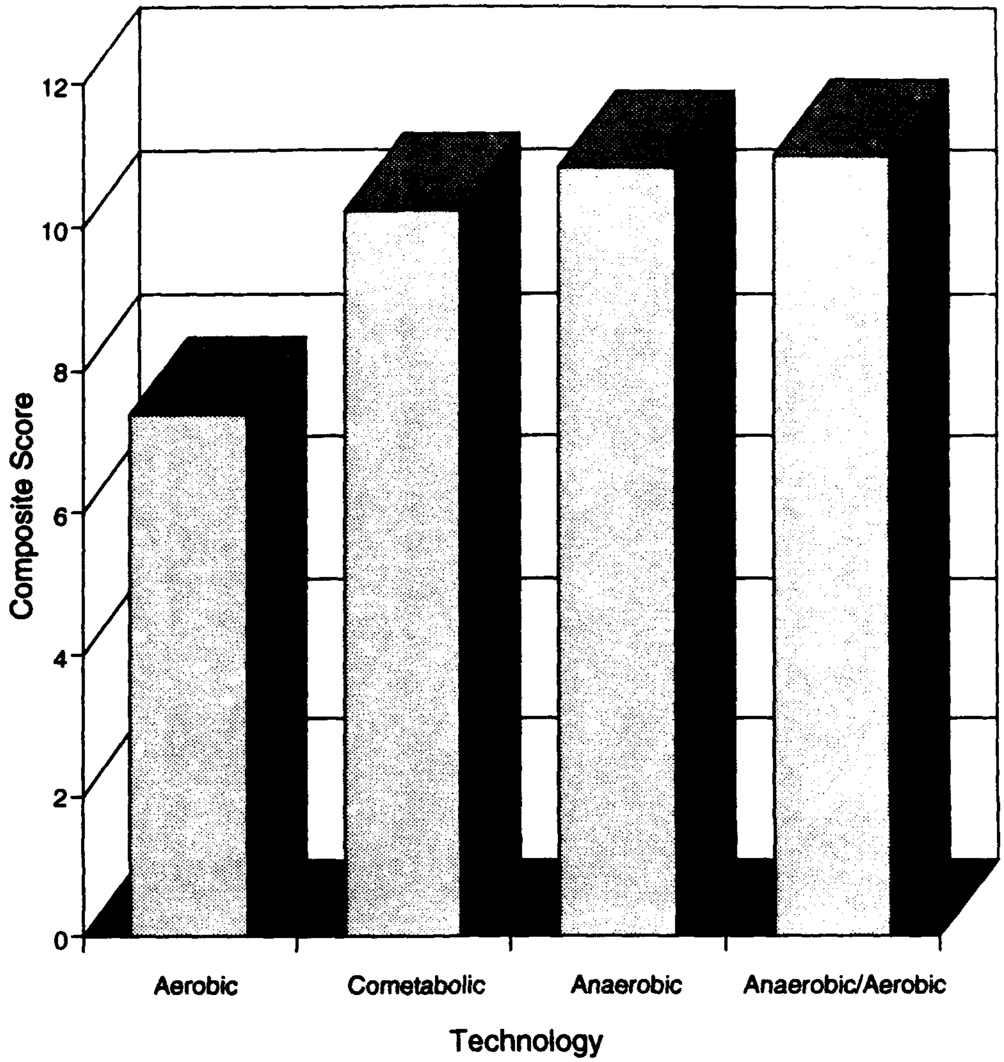

FIGURE L1-3
PRIMARY SCORING SUMMARY
EX SITU BIOLOGICAL GROUNDWATER TREATMENT TECHNOLOGIES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1484_172

CH2M HILL

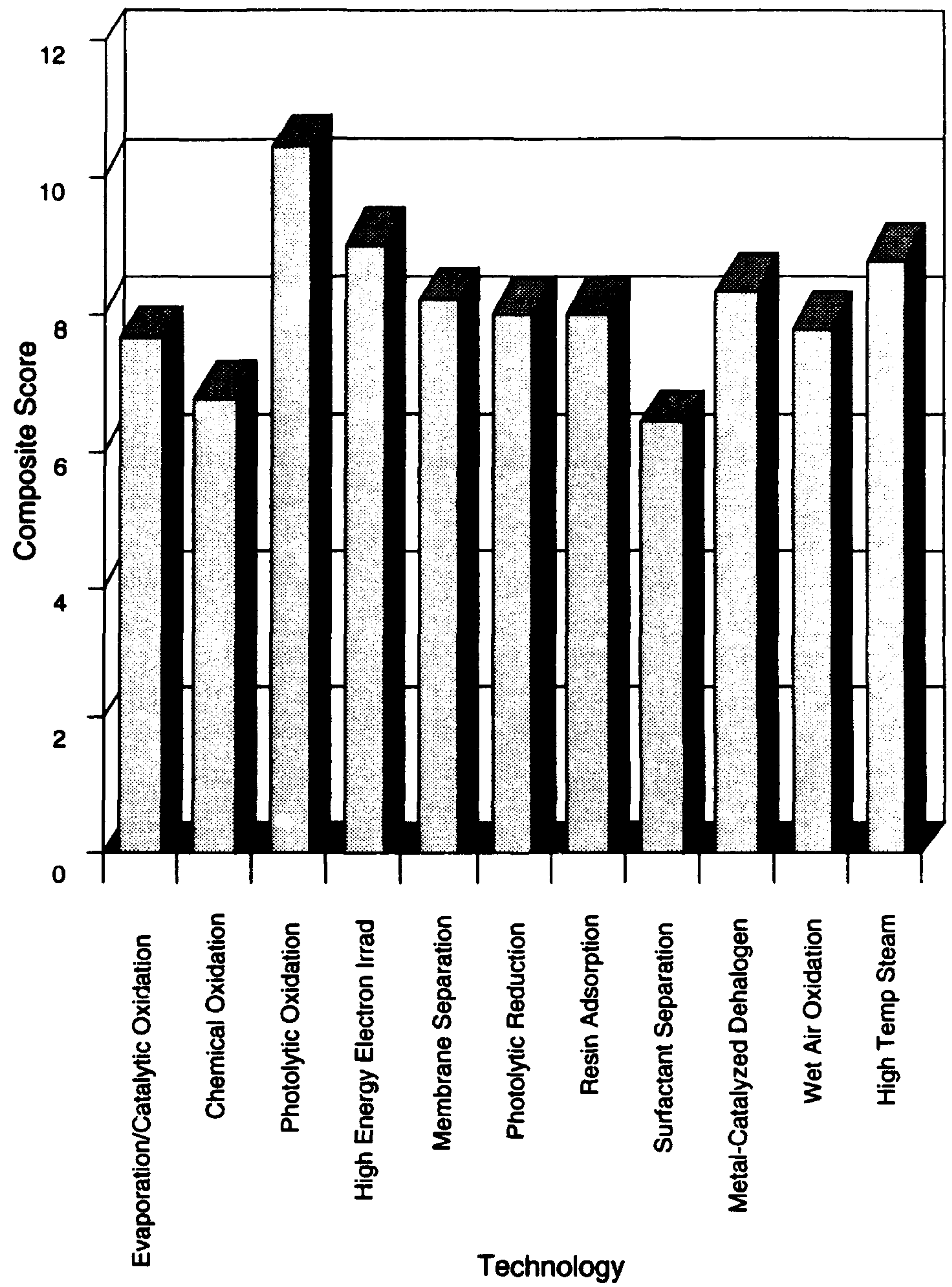

FIGURE L1-4
PRIMARY SCORING SUMMARY
EX SITU PHYSICAL/CHEMICAL
GROUNDWATER TREATMENT TECHNOLOGIES
GROUNDWATWER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1312_173

CH2M HILL

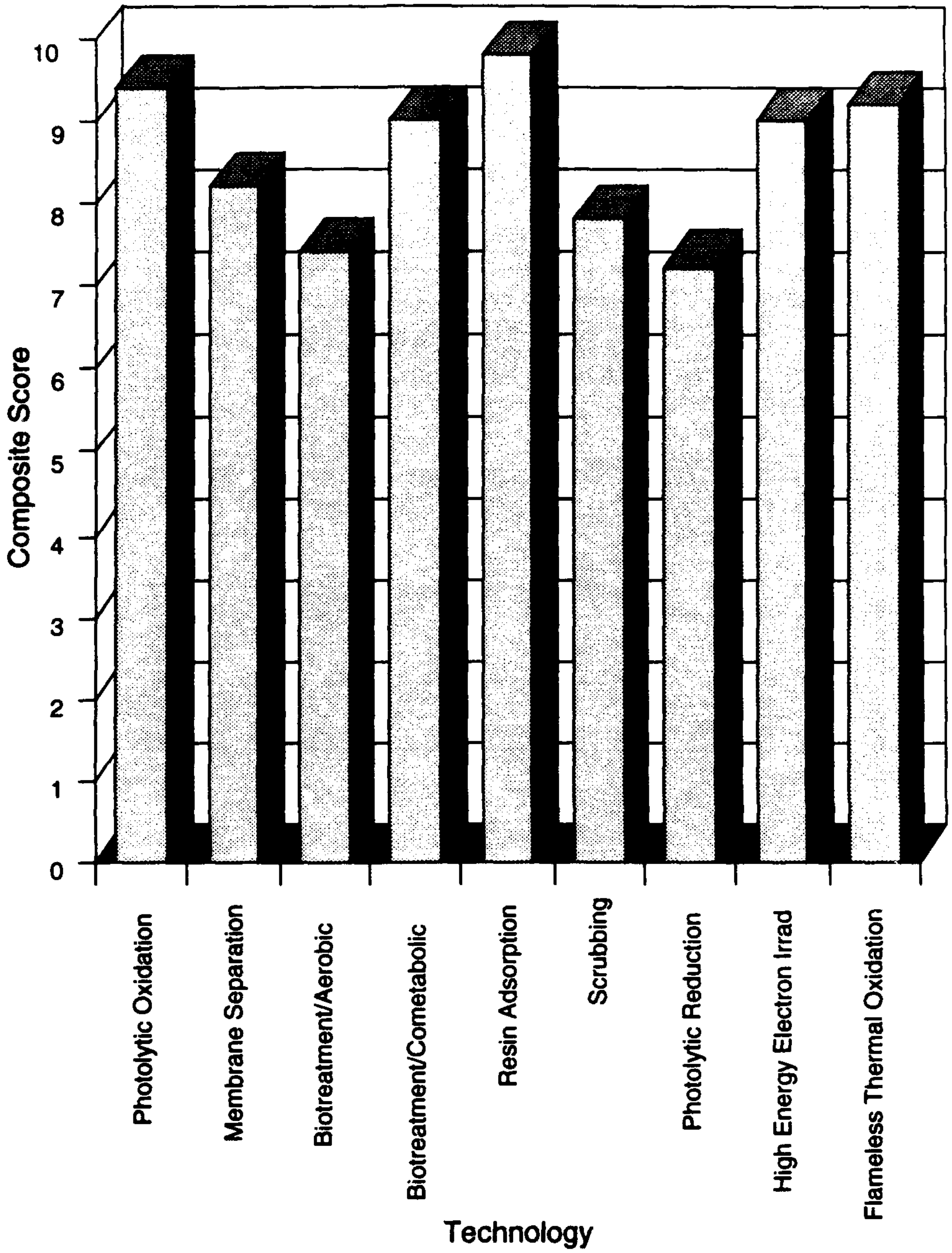

FIGURE L1-5
PRIMARY SCORING SUMMARY
OFFGAS TREATMENT TECHNOLOGIES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454_174

CH2M HILL

Table L1-7 Retained Technologies After Primary Screening (Preliminary)
In Situ Biological Treatment Cometabolic Anaerobic Anaerobic/Aerobic
In Situ Physical/Chemical Treatment Sparging/Soil Vapor Extraction
Ex Situ Biological Groundwater Treatment Cometabolic Anaerobic Anaerobic/Aerobic
Ex Situ Physical/Chemical Groundwater Treatment Photolytic Oxidation High Energy Electron Irradiation
Offgas Treatment Photolytic Oxidation Biotreatment/Cometabolic Resin Adsorption High Energy Electron Irradiation
Miscellaneous Natural Attenuation Implementation Methods In Situ Recirculation Unit

1. To contact additional sources of information:

- DOD/DOE: Savannah River, Hanford
- Tyndall AFB: Catherine Vogel
- AFCEE: Colonel Miller
- EPA: Terry Vandall, Terry Lyons

2. To reconsider three technologies that were initially screened out:

- Steam Injection/Vapor Extraction (SIVE)
- Metal-Catalyzed Dehalogenation
- Resin Adsorption (Ex Situ Groundwater Treatment)

3. To add four technologies that had not been included into the primary round:

- Dual Phase High Vacuum Extraction (In situ Physical/Chemical)
- High Temperature Steam Destruction (Ex Situ Physical/Chemical)
- Flameless Thermal Oxidation (Offgas)
- Wet Oxidation (Ex Situ Physical/Chemical)

Secondary Technology Information Review

This task included addressing the action items from the Murder Board Meeting, as well as preparing for the secondary screening. The first action item was to contact additional sources of information. A list of contacts and subjects discussed is presented in Table L1-8.

The second action item was to add several technologies to the screening process. Dual Phase High Vacuum Extraction was a technology being considered, but the appropriateness of including it in the screening was unclear because it is currently being tested at McClellan AFB by Radian Corporation. McClellan AFB staff assured the group that it is appropriate to include in this study. Further research and contacting of vendors provided information to screen the other three additional technologies. All four of these were subjected to the primary screening process. Dual Phase High Vacuum Extraction and Flameless Thermal Oxidation both scored high enough to be retained, while High Temperature Steam Destruction and Wet Oxidation were eliminated from consideration at the primary level.

The final action item was to reconsider several technologies that did not score well enough to be retained to the secondary round. McClellan AFB staff wanted steam injection/vapor extraction (SI/VE) reconsidered since it scored relatively low in the primary screening, even though this technology is proposed for pilot testing at the Base. It was pointed out that if SI/VE were retained through primary screening, Metal-Catalyzed Dehalogenation and Resin Adsorption (for groundwater treatment) should also be reconsidered, since those technologies scored higher than SI/VE.

Upon reconsideration and further research, SI/VE was retained, but not the other two, into the secondary screening. Metal-Catalyzed Dehalogenation is relatively undeveloped; the developer gave a reserved endorsement of the technology. Consultation with resin manufacturers did not reveal any significant advancements in the development of resins for removing chlorinated solvents from groundwater, so that technology was eliminated from further consideration.

The revised list of retained technologies from primary screening is shown as Table L1-9. Further research (literature review, vendor contracts, consultation with internal and external consultants) was conducted to obtain more detailed information on these retained technologies.

Table L1-8 Additional Information Sources	
Contact	**Technologies/Projects Discussed**
Sara Madearis Clean Sites	Air sparging Resin adsorption
Terry Lyons EPA	Emerging technologies
Ron Lewis EPA	Biological, physical/chemical processes
Kim Kreiton EPA	Biological processes
Franklin Alvarez EPA	Savannah River projects
Catherine Vogel Tyndall AFB	Bioremediation
Kumar Topudurti PRC Environmental Management Inc	Savannah River projects
Patrick Haas AFCEE	Surfactants, natural attenuation, cometabolic reactors, reductive dehalogenation.
Scott Vance Battelle (Hanford)	General DOE projects
Terry Walton Battelle (Hanford)	General DOE projects
Brian Looney Savannah River	General DOE work, E-Beam (groundwater)
John Haslow Savannah River	E-Beam (vapor)
Jane Bibler Savannah River	E-Beam (groundwater)
Dolloff Bishop, Jr. EPA	Biofiltration

Table L1-9 Retained Technologies from Primary Screening (Final)
In Situ Treatment • Anaerobic Biotreatment • Cometabolic Biotreatment • Anaerobic/Aerobic Biotreatment • Sparging/Soil Vapor Extraction (SVE) • Steam Injection/Vapor Extraction (SIVE) • High Vacuum Dual Phase Extraction
Ex Situ Groundwater Treatment • Anaerobic Biotreatment • Cometabolic Biotreatment • Anaerobic/Aerobic Biotreatment • Photolytic Oxidation • High Energy Electron Irradiation
Offgas Treatment • Cometabolic Biofiltration • Resin Adsorption • Photolytic Oxidation • High Energy Electron Irradiation • Flameless Thermal Oxidation

Secondary Screening

In this round of screening, the number of categories was reduced from five to three:

- In Situ Treatment
- Ex Situ Groundwater Treatment
- Offgas Treatment

All in situ processes were grouped together and all ex situ groundwater processes were grouped together. Technologies were again screened only against the others within a given category. In other words, in situ biological processes were now grouped together with and scored against in situ physical/chemical processes.

The secondary screening criteria and subcriteria are shown in Table L1-10.

For each technology, all subcriteria were assigned a score from 1 to 3, with 1 representing "least favorable" and 3 representing "most favorable." Some semiobjective guidelines were provided to aid scoring:

Table L1-10 Secondary Screening Criteria
Effectiveness Achievable Level of Treatment Treatment Consistency Advantages over Standard Technology
Robustness Range of Compounds Turnup/Turndown Capability Susceptibility to Upsets
Implementability Vendor Availability State of Development Patent Issues Permitting Issues
Relative Cost

For *Achievable Level of Treatment*:

- 3 = greater than 90 percent
- 2 = 80 to 90 percent
- 1 = less than 80 percent

For *Vendor Availability* (including in-house capabilities):

- 3 = many
- 2 = some
- 1 = few

For *State of Development*:

- 3 = Full-scale
- 2 = Pilot-scale
- 1 = Bench-scale

For *Patent Issues*:

- 3 = Not applicable
- 2 = Unknown
- 1 = Applicable

For *Permitting Issues*:

- 3 = Not applicable
- 2 = Unknown
- 1 = Applicable

For secondary screening, technology scoring was performed by a panel of six team members. These scores were compiled by criteria and averaged. In order to arrive at the most feasible alternatives for McClellan AFB, a weighting system was used to score the technologies. Effectiveness and implementability were determined to be more important criteria; therefore, they received a weighting factor of 30 percent each. Robustness and relative cost received a 20 percent weighting factor. The scores were comparatively examined, and isolated high and low values were eliminated. Composite average scores were computed and plotted (Figures L1-6 through L1-8).

Based on the secondary scoring results, seven technologies were tecommended to be retained for further development:

In Situ Treatment

- Sparging/Soil Vapor Extraction
- Dual Phase High Vacuum Extraction
- Anaerobic Biotreatment
- Cometabolic Biotreatment

Ex Situ Groundwater Treatment

- High Energy Electron Irradiation

Offgas Treatment

- Resin Adsorption
- Cometabolic Biofiltration

The justification for retaining a disproportionately large number of in situ technologies, compared to ex situ technologies, is that in situ treatment has the potential to provide a greater benefit to the overall Base remediation program. It is possible that in situ technologies will be capable of reducing the mass of contaminants more quickly than pump-and-treat alone, and thereby reduce the overall remedial duration. In contrast, the best that can possibly achieved by ex situ technologies is treatment effectiveness comparable to standard technologies (because proven standard technologies exist that are demonstrated effective), at a lower cost or providing some other benefit such as public perception.

Two possible applications exist for the offgas treatment technologies: treatment of air stripper offgas or treatment of offgas from an in situ soil venting technology.

Alternatives Development Update/Consensus Meeting

The secondary screening and scoring process were presented to McClellan AFB staff, regulatory agencies, and other interested parties on August 25, 1993, at the Alternatives Development Update/Consensus Meeting. Comments were solicited and received from the attendees on the screening process and results. Consensus was reached on the seven recommended technologies. Implementation plans will be developed for those technologies.

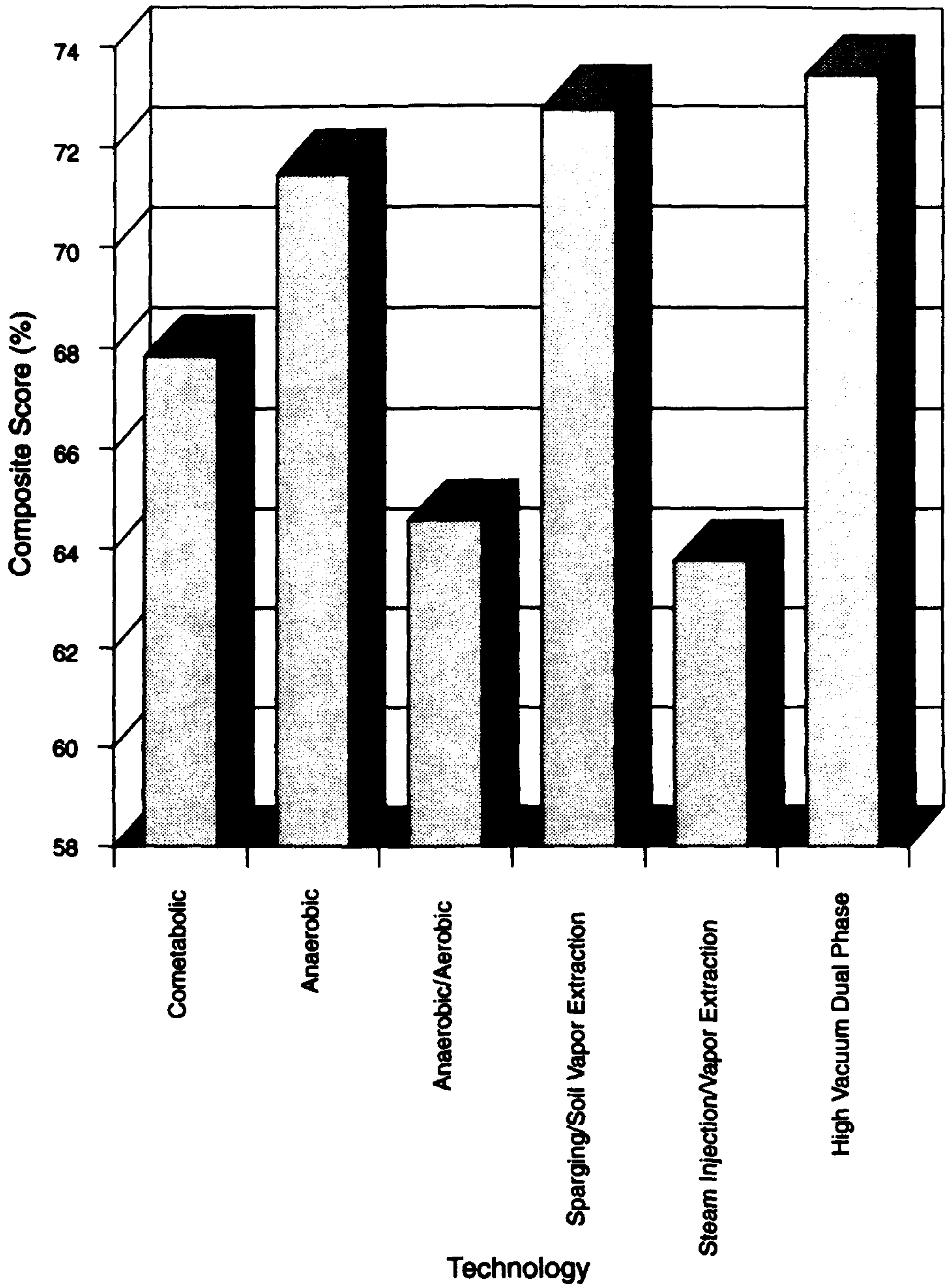

FIGURE L1-6
SECONDARY SCREENING SUMMARY IN SITU TREATMENT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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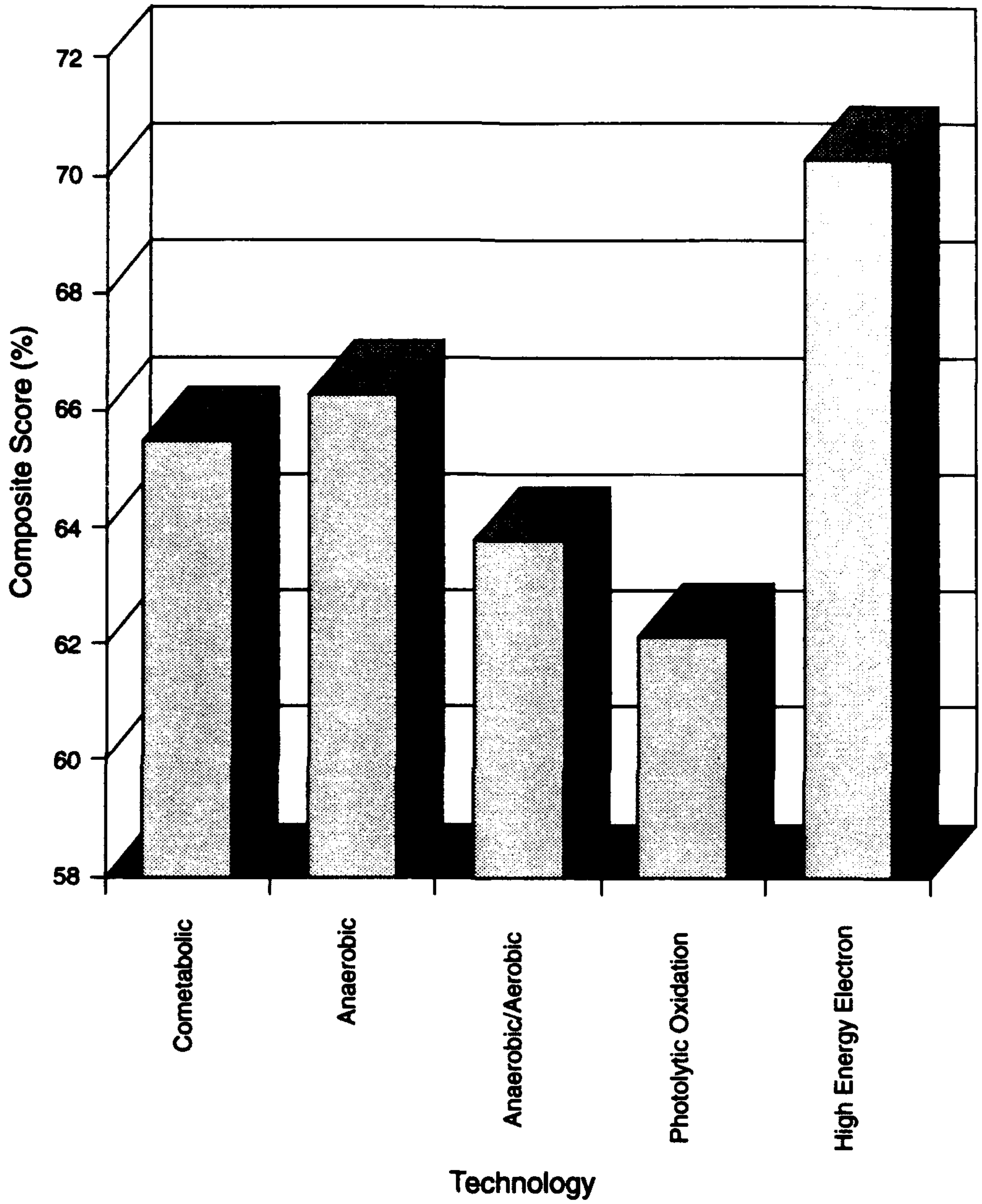

FIGURE L1-7
SECONDARY SCREENING SUMMARY
EX SITU GROUNDWATER TREATMENT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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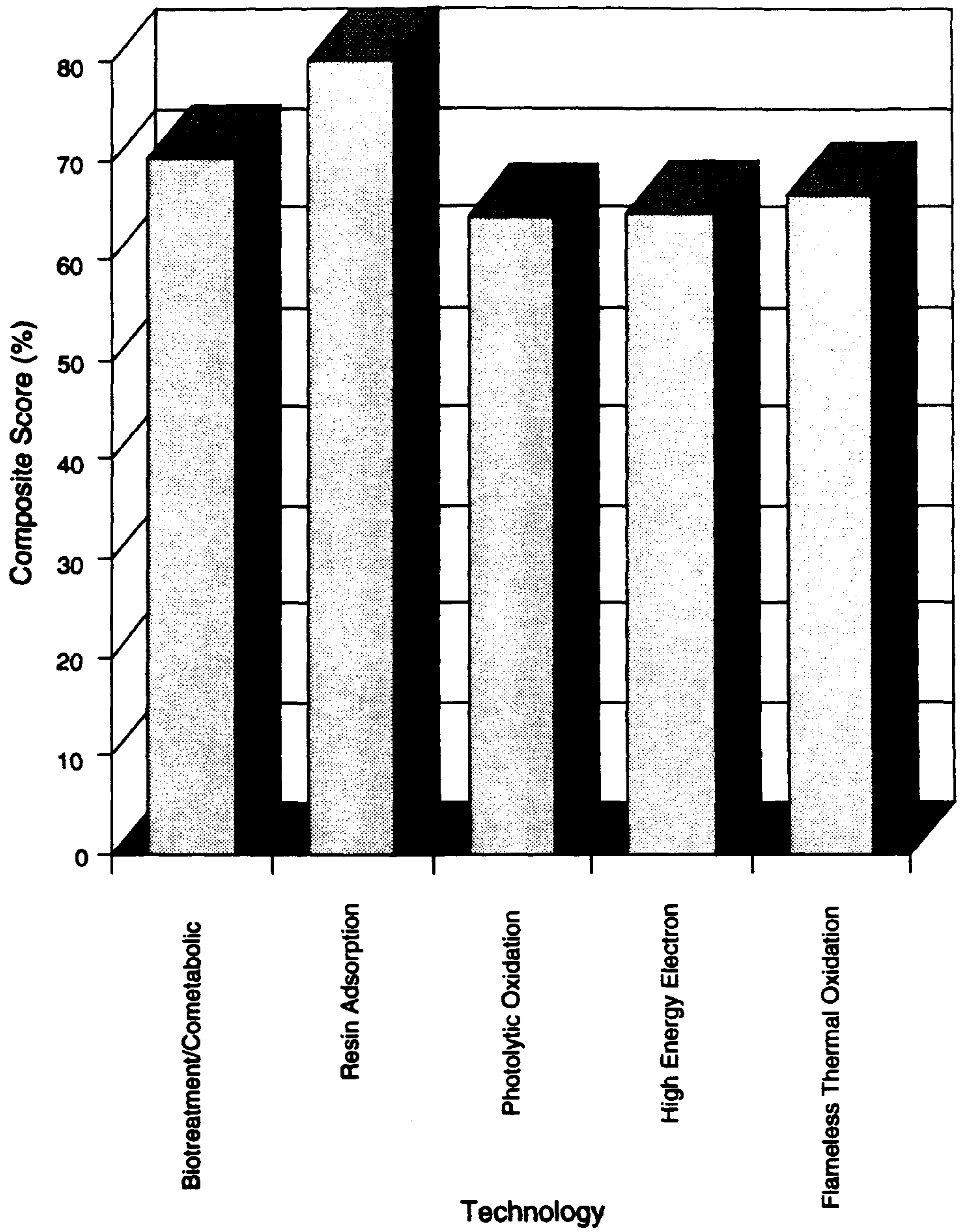

FIGURE L1-8
SECONDARY SCREENING
SUMMARY OFFGAS TREATMENT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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Appendix L2

PREPARED FOR: McClellan Air Force Base

DATE: November 7, 1993

SUBJECT: In Situ Anaerobic Biotreatment Implementation Plan
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.NT

Technology Overview

Description

In situ anaerobic biotreatment is an emerging technology for remediating groundwater contaminated with chlorinated VOCs. It uses anaerobic microbial metabolism to transform chlorinated VOCs to less chlorinated or nonchlorinated products. In situ anaerobic biotreatment refers to the process of adding chemical amendments (such as a readily degradable organic substrate, and inorganic nutrients) to the groundwater to stimulate anaerobic biodegradation.

Anaerobic biodegradation of chlorinated organics occurs by reductive dehalogenation, in which chlorine atoms are removed from the contaminant molecule one at a time and replaced with hydrogen. Current evidence indicates that microorganisms can use halogenated organics as the electron acceptor in biological reactions (Semprini, 1993). An organic substrate (for example, benzoate, acetate, formate, and lactate) is normally added to provide a readily available source of carbon and energy. The organic substrate donates electrons to drive the transformation reaction. Nitrogen and phosphorus are essential nutrients that can also be added to the groundwater, if needed.

Chlorinated aliphatic hydrocarbons (CAHs) are the principal organic contaminants in groundwater at McClellan AFB. Four of the groundwater CAH contaminants are common industrial solvents: trichloroethene (TCE), tetrachloroethene (PCE), carbon tetrachloride (CT), and 1,1,1-trichlorethane (1,1,1-TCA). All four of these contaminants are amenable to anaerobic biodegradation. Other important CAHs found in groundwater at the Base include 1,1-dichloroethene (1,1-DCE), 1,1-dichloroethane (1,1-DCA), chloroform (CF), cis- or trans-1,2-dichloroethene (1,2-DCE), methylene chloride (MC), and vinyl chloride (VC). These compounds either may have been used at McClellan AFB for some purpose or may have appeared in groundwater as a result of anaerobic biodegradation of parent CAH solvents. According to McCarty, 1993, some anaerobic transformation products are:

Parent Compound	Transformation Products
CT	CF, MC
1,1,1-TCA	1,1-DCA
TCE	1,2-DCE, VC, ethene, ethane
PCE	TCE, 1,2-DCE, VC, ethene, ethane

In addition to these intermediate transformation products, end-products of anaerobic treatment include methane, carbon dioxide, and inorganic compounds. Under the best conditions, reductive dehalogenation would be complete, and the remaining non-chlorinated compounds, which have significantly reduced associated health risks, would slowly degrade aerobically when ambient conditions are reestablished at the conclusion of anaerobic treatment system operation. Many of the transformation products are also amenable to aerobic treatment. For example, vinyl chloride transfonns rapidly in aerobic conditions.

Implementation Methods

There are four basic configurations for implementing in situ anaerobic biotreatment:

- In situ recirculation wells
- Vertical injection and extraction wells
- Horizontal injection and extraction wells
- Reactive walls

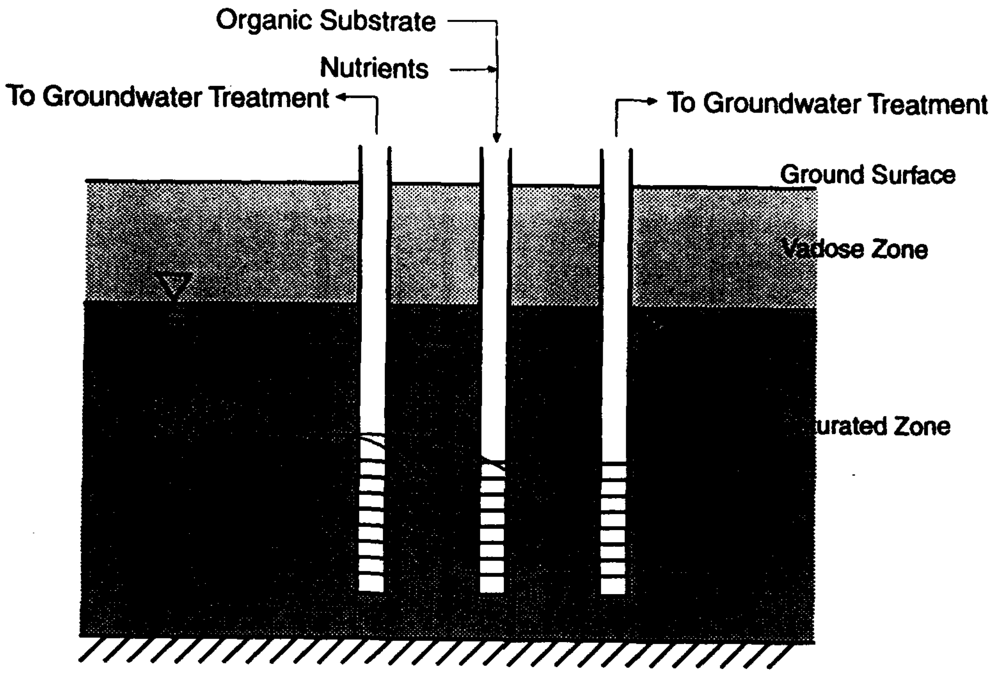
These four alternatives are depicted schematically in Figure L2-1, and are described below. Additional configurations are possible, including combinations of the systems described.

An in situ recirculation well consists of a vertical well that has two separate screened intervals in the saturated zone and a seal in the well above the upper screen. A submersible pump is positioned between the screens to force water out the bottom screen while drawing water in through the top screen (or vice versa). Pumping groundwater in this fashion results in flow paths like those depicted in Figure L2-1. Chemical amendments are added to the groundwater within the well.

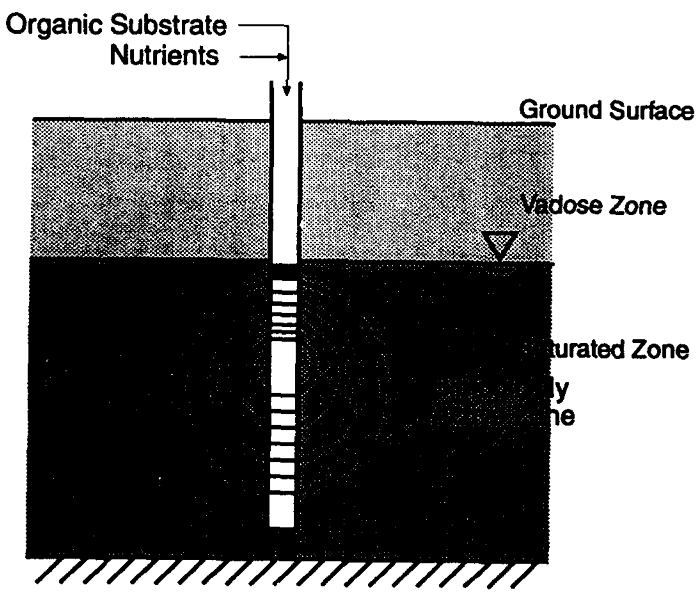
A combination of vertical injection and extraction wells is the traditional system used for in situ groundwater bioremediation. Substrate and nutrients are injected and pumped through the contaminated groundwater zone between injection and extraction wells to create a biologically active zone where treatment occurs. Horizontal injection and extraction wells function similarly to vertical wells except that the wells are oriented horizontally in the contaminated zone and therefore can influence a larger lateral area.

Reactive walls are either trenches or a linear array of wells designed to create a curtain through which groundwater passes under ambient gradients and in which the desired biological reactions occur.

VERTICAL INJECTION/EXTRACTION WELLS



IN SITU RECIRCULATION WELL



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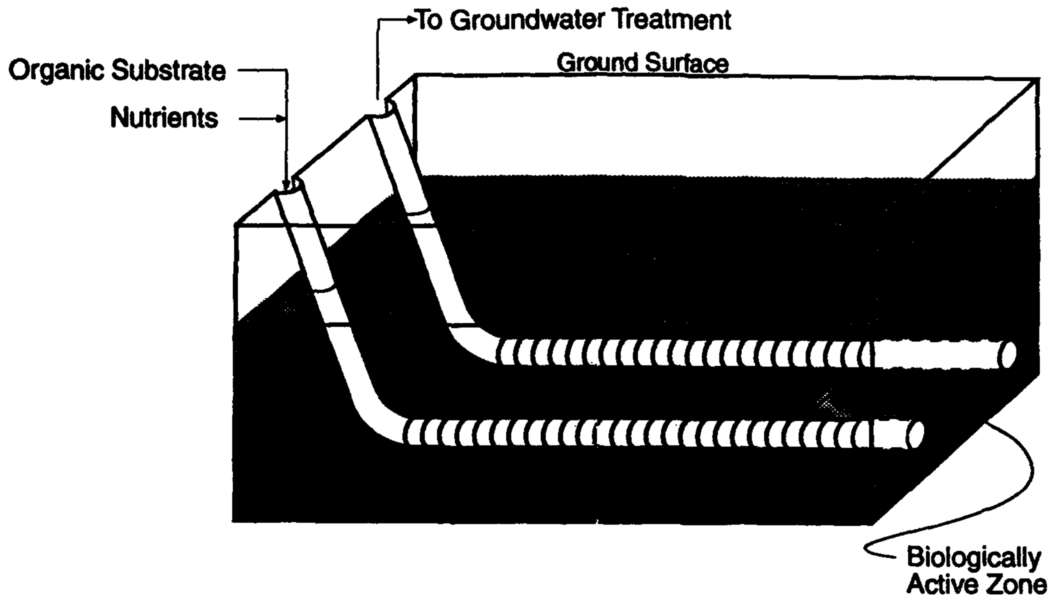
HORIZONTAL INJECTION/EXTRACTION WELLS



PERMEABLE REACTION WALL

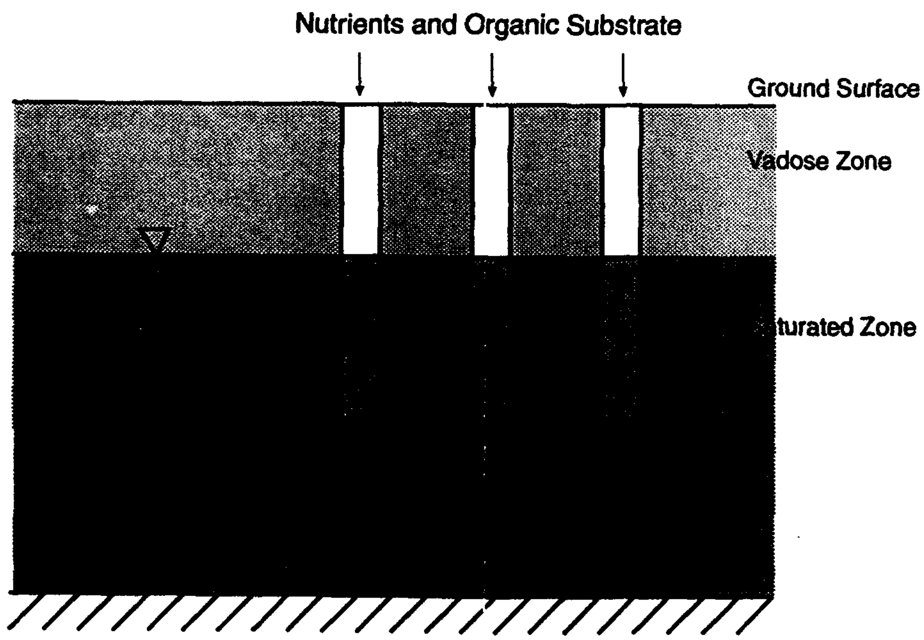


FIGURE L2-1
IN SITU ANAEROBIC BIOTREATMENT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

(2)

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The four basic implementation alternatives have different applicabilities and advantages and disadvantages with respect to site and contaminant distribution conditions. Because of the great depth to groundwater at McClellan AFB, vertical wells and in situ recirculation units are probably the two most feasible implementation alternatives for in situ anaerobic biotreatment at the Base.

Development Status

Extensive bench-scale research on anaerobic biotreatment of contaminated groundwater has been conducted at universities and by vendors. Effective anaerobic treatment of CAHs is well documented.

One full-scale application of in situ anaerobic biotreatment of CAH-contaminated groundwater has been performed at DuPont's Victoria, Texas, site. Complete dehalogenation of PCE to ethene was demonstrated. Because of these promising results, DuPont is actively looking for other sites at which to implement this technology.

Field pilot testing of in situ anaerobic biotreatment of CAHs in groundwater is reportedly planned for next year at the Moffett Naval Air Station site by Stanford University researchers.

Potential Benefits

This section describes the performance, advantages and disadvantages, and cost benefits associated with in situ anaerobic biotreatment. This information is intended to provide a basis for evaluating the potential benefits of implementing the technology as part of the overall McClellan AFB groundwater cleanup program.

General Performance

Effectiveness

- The ability of aquifer microorganisms to effectively biodegrade under anaerobic conditions is well demonstrated.
- CAHs can be completely biodegraded to nonchlorinated end products.
- In situ biotreatment effectively degraded PCE to ethene at a full-scale groundwater remediation project in Victoria, Texas.

Robustness

- Anaerobic biotreatment is effective, to some degree, at degrading all of the CAHs present in McClellan AFB groundwater.

- Relatively minor contaminants in Base groundwater, such as benzene, toluene, ethylbenzene, and xylene (BTEX) compounds and ketones, may be degraded more slowly under anaerobic conditions than aerobic conditions.

- In situ anaerobic biotreatment is subject to inhibitory effects.

- As with all in situ technologies, control over subsurface conditions is critical to treatment performance, as heterogeneities and mass transfer requirements limit effectiveness.

Potential Risk Reduction

In situ anaerobic treatment has the potential to reduce risk by biodegrading groundwater contaminants and thereby reducing the contaminant mass in the subsurface. By accelerating contaminant removal, the time to achieve remedial goals may be shortened. Injection of chemicals into groundwater and formation of intermediate transformation products could constitute new, albeit temporary, sources of risk, but adequate hydrologic control would be maintained to mitigate these risks during system operation.

Advantages Compared to Other Technologies

- Destruction of contaminants occurs in-place. Because treatment occurs in situ, contaminant desorption is accelerated.

- High concentrations of contaminants (tens of mg/l) can be treated.

- This technology may be effective at treating contaminant mixtures.

- This technology is capable of treating highly halogenated solvents such as PCE, CT, and freons, which are not degradable under anaerobic conditions.

- In general, as more highly halogenated contaminants are biodegraded, the transformation products become more mobile, which may enhance their removal via groundwater pumping.

- If groundwater extracted in conjunction with implementation of in situ anaerobic biotreatment could be reinjected without aboveground treatment (e.g., during implementation using vertical injection and extraction wells), the cost of this technology would be significantly reduced relative to other technologies requiring aboveground treatment. EPA has prepared a position statement allowing for reinjection of contaminated water when appropriate for such a treatment scheme.

- The difficulty and expense of supplying oxygen to groundwater, as required for in situ aerobic biotreatment, is avoided with anaerobic treatment.

- Anaerobes are slow growing, so biofouling problems should be minimal.

- Complete biodegradation of CAHs to nontoxic end products is possible with this technology. Even if dechlorination is incomplete, transformation byproducts are more amenable to aerobic treatment (following operation of the in situ anaerobic biotreatment system) than the parent compounds.

Disadvantages Compared to Other Technologies

- If adequate populations of anaerobic bacteria capable of degrading CAHs are not present, bioaugmentation may be necessary, though added microbes may not thrive in the subsurface environment. However, contaminant data indicate that anaerobic biodegradation of CAHs is already occurring at certain locations in McClellan AFB groundwater, indicating the presence of the necessary microorganisms.

- If electron acceptors such as oxygen, nitrate, sulfate, or ferric iron are present in Base groundwater, they must first be depleted before reductive dehalogenation of target contaminants will occur. This is achieved by adding sufficient organic substrate to allow biological utilization of those electron acceptors.

- Vinyl chloride is a toxic transformation product of anaerobic biodegradation of PCE, TCE, and DCE. It has a higher risk factor than the parent compounds and can be difficult to treat by some aboveground treatment processes.

- If required, aboveground water treatment will significantly increase the cost of the technology and will have permitting requirements.

- Reinjection of groundwater (with or without treatment) and injection of chemical amendments will require regulatory approval.

- Water quality problems, such as reduced iron and manganese, methane, fermentation products, and sulfide can result from anaerobic conditions.

Relative Cost Benefit

The cost benefits of in situ anaerobic biotreatment would result from increased rates of contaminant removal that could shorten the pump-and-treat remediation time. Cost benefits should be evaluated through an analysis of savings associated with the reduced operation time of pump-and-treat after accounting for the capital and operating costs of the in situ anaerobic biotreatment system.

Potential Locations

In situ anaerobic biotreatment is potentially applicable at many locations on the Base where groundwater is contaminated with halogenated solvents. Implementation of the technology in hot spot areas is likely to provide the most benefit to the groundwater cleanup program. Moderate to high permeability areas and relatively homogeneous conditions in the saturated zone are most favorable for effective treatment.

Hot spot locations in OUs C and D are potentially most suitable because of the generally higher subsurface permeabilities in those areas. OU D is an especially likely location because contaminant data indicate that anaerobic treatment is occurring naturally around some OU D wells.

The contaminants in OUs A and B are also amenable to anaerobic biodegradation, but those sites are potentially less favorable because of generally lower permeabilities.

Approach

Information Needs and Sources

Table L2-1 lists information requirements and the sources for implementation of in situ anaerobic biotreatment.

Information Gathering and Review

Information gathering to date has included the review of published and available unpublished technology information, vendor interviews, consultation with subcontracted experts, and an overview of McClellan AFB subsurface characteristics and groundwater contaminant data. Expert consultants for this technology are Dr. Lewis Semprini of the Department of Civil Engineering, Oregon State University, and Dr. Perry McCarty of the Department of Civil Engineering, Stanford University. Drs. McCarty and Semprini are considered to be leading experts on in situ biological treatment processes.

The first step for implementation of this technology should be a detailed review of the existing literature on anaerobic biotreatment of CAHs, paying particular attention to field data, and of the groundwater contaminant data for the Base. New information should be reviewed as it becomes available.

Table L2-1
In Situ Anaerobic Biotreatment
Information Needs and Sources

Information Needs for Pilot and Full-Scale Tests	Info Source		
	Bench	Pilot	Full
Contaminant Characterization			
• Contaminant Types	S	S	S
• Concentrations	S	S	S
• Treatment Goals	L	L	L
• Inhibitory/Toxicity Factors	L	B,L	P,L
• Contaminant Geometry	S	S,L	S,L
Subsurface Characterization			
• Environmental Factors (pH, temp)	S	S	P,S
• Water/soil chemistry parameters	S	B,S	P,S
• Flow	L	M	M
• Static Water Levels over time	--	S,L	S,L
• Soil Type	S	S,L	S,L
• Soil Heterogeneity	S	S,L	S,L
• Sorption/Retardation	M	M	M
• Microorganisms present	S	B,S	P,S
• Electron Acceptors	S	B,S	P,S
System Design: Physical Configuration			
• Number of wells, type	--	B,L,M	P,L,M
• Well spacing	--	B,L,M	P,L,M
• Residence Time (zone)	L	B,L,M	P,L,M
• Well Diameter	--	B,L	P,L
• Screen depth, length	--	L	P,L
• Patent Requirements	--	V	V
System Design: Treatment Requirements			
• Nutrient Additions	L	B,L	P,L
• Inducer Addition	L	B,L	P,L
• Microorganism Addition	L	B,L	P,L
• Permitting Requirements	--	L	L
System Design: Equipment Requirements			
• Equipment Requirements	L	L,V	P,V
• O & M Requirements	L	L,V	P,V
Performance Capabilities			
• Monitoring (Sampling and Analysis Requirements)	L	L	L
• Byproduct formation	S	B,L,S	P,L,S

Notes:
L = Literature/Experts
P = Pilot Scale
V = Vendor
B = Bench Scale
S = Sampling Results
M = Modeling/Other Technology Evaluations

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A detailed analysis of chemical distribution in three dimensions is needed to identify target volumes for treatment. After the existing chemical data have been thoroughly reviewed and analyzed and potential target areas have been roughly identified, it is likely that some additional site characterization data will be needed to fine-tune the selection of target zones, evaluate chemical amendment requirements, and collect samples of aquifer material for bench-scale testing. Samples for analysis and testing could be collected through the use of boreholes or cone penetrometers. Analytical parameters should include organic contaminants, possible anaerobic transformation products (ethenes, ethane, methane), potential electron acceptors (DO, nitrate, sulfate, ferric iron), and water quality parameters (Eh, pH, metals, COD, and/or TOC).

Implementation Issues

- Potential permitting/regulatory approval issues associated with in situ anaerobic biotreatment include:
    - Reinjection or discharge of extracted groundwater
    - The need for aboveground treatment of extracted groundwater if it is to be reinjected within a contained plume
    - Treatment requirements for groundwater and offgas if aboveground treatment of extracted groundwater is required
    - Injection of organic substrates and nutrients into groundwater
    - Formation of transformation products, particularly vinyl chloride
- Potential patent issues include the patent held by DuPont on the in situ anaerobic treatment process and the patent held by IEG Technologies, Inc., on the in situ recirculation unit. The applicability of these patents is currently unclear and would need to be resolved by patent attorneys.
- Other issues that could affect implementation are associated with newly generated site characterization data that may influence technology effectiveness or cost (and therefore feasibility) at target areas, including permeability, heterogeneity, contaminant distribution, and anaerobic biological activity information.

Bench-Scale Testing

Objectives

Bench-scale testing would consist of microcosm studies using aquifer material collected from target zones. The microcosm studies will help determine:

- Whether the desired anaerobes are present in the subsurface

- Whether they can be stimulated through the addition of an appropriate growth substrate
- Whether they can degrade the target contaminants and, if so, what transformation products are formed
- The concentration range over which effective transformation can be achieved
- The optimal organic substrate (the literature suggests that benzoate, methanol, and formate are some of the best substrates to drive anaerobic transformations)
- The benefit of adding an electron acceptor such as sulfate
- Whether high concentrations of electron donors should be added initially, or lower concentrations pulse-fed

Approach

Different types of microcosms might be employed, including batch reactors, batch-fed soil columns, and continuous-flow soil columns. Anaerobic bacteria have slow growth rates so several months may be required to achieve effective transformation, particularly if the necessary microbes are absent or present in low numbers. If core samples are taken from an active anaerobic zone, the anaerobic population should begin treatment more quickly. Bench-scale testing is likely to require 6 months to compare.

If indigenous anaerobic microorganisms are not present or are not capable of transforming the contaminants of concern, it may be possible to introduce anaerobes to the subsurface. In this event, microcosm studies could be used to determine if the introduced strain would survive and flourish under field conditions.

Pilot-Scale Testing

Objectives

Pilot-scale tests would be necessary to develop information for designing and operating a full-scale treatment system. Data would be obtained on the effectiveness of treatment, areal extent of treatment, and optimal methods of chemical addition. A probable duration for pilot testing is 6 months to 1 year.

Pilot-scale testing objectives include the evaluation of:

- Proper well spacing and number of wells required for full-scale implementation

- Required organic substrate and nutrient addition rates, and optimal pattern of delivery
- Characteristics of extracted groundwater
- Transformation product formation and disappearance rates
- Contaminant reduction rates and estimated treatment duration
- Estimated contaminant mass reductions achievable during treatment
- Estimated full-scale capital and operating costs
- Cost benefits associated with implementing the technology

Approach

Pilot-scale testing would involve the installation of one or two injection wells and two to four extraction wells, and operation of the system for a sufficiently long duration to obtain data needed to develop design and operating parameters for full-scale implementation. (For the purpose of this Implementation Plan, the use of vertical injection and extraction wells is assumed for pilot testing, but in situ recirculation units should also be considered.) The specific objectives and approach of the pilot testing program would be refined and detailed following the information gathering and review and bench-scale testing tasks. The general approach to pilot testing is outlined below.

1. Confirm appropriateness of target location selected for pilot testing.
2. Conduct modeling to support pilot system design. This work would include hydrodynamic modeling, advective transport modeling, and possibly, modeling of mass transfer and biological processes.
3. Prepare system installation and operation work plan.
4. Install injection, extraction, and groundwater monitoring wells. Set up aboveground nutrient delivery system.
5. Operate the system at different rates and patterns of substrate/nutrient delivery, holding each amendment condition constant for sufficient time to evaluate treatment performance (determined by groundwater sampling and analysis).
6. Analyze data to evaluate the performance under different testing conditions and evaluate potential benefits of in situ anaerobic biotreatment to the overall Base groundwater remediation program.
7. Decide whether to proceed with implementation at full scale.

Full-Scale Implementation

Pilot-scale results are necessary to develop a full-scale system design. However, an example conceptual design is outlined below to illustrate the major elements of a full-scale system and to provide a basis for a rough order-of-magnitude cost estimate. Rather than developing a conceptual design for a particular location, a modular approach was used to develop an estimated range of costs per unit acre for full-scale implementation.

The example conceptual design is based on the following key assumptions:

- Each module consists of nine injection and nine extraction wells, a piping system from the extraction wells to a groundwater treatment unit, a substrate feed system, and piping from the substrate feed system to the injection well (Figure L2-2).

- The spacing of wells varies from 30 to 60 feet based on initial modeling estimates.

- Approximate coverage by one module ranges from 8,100 ft^2 (5.4 modules/acre) to 32,400 ft^2 (1.3 modules/acre), depending on well spacing.

- Groundwater extraction and injection rate is 3 gpm per well.

- There will be one groundwater monitoring well per every 10 extraction/ injection wells.

- Electron donor is sodium benzoate applied at a rate of 10 grams per gram of contaminants. Sulfate addition would be added at the same mass ratio. Nutrient addition in the form of diammonium phosphate would occur at a ratio of 1 gram per gram of contaminants.

- The extracted groundwater is treated to MCLs at a single treatment system at the target location. This system consists of air stripping with vapor-phase GAC adsorption. Most ($\geq$90 percent) of the treated groundwater is chemically amended and reinjected, and a small blow-down stream ($\leq$10 percent) is discharged to maintain a net ground-water withdrawal (for containment).

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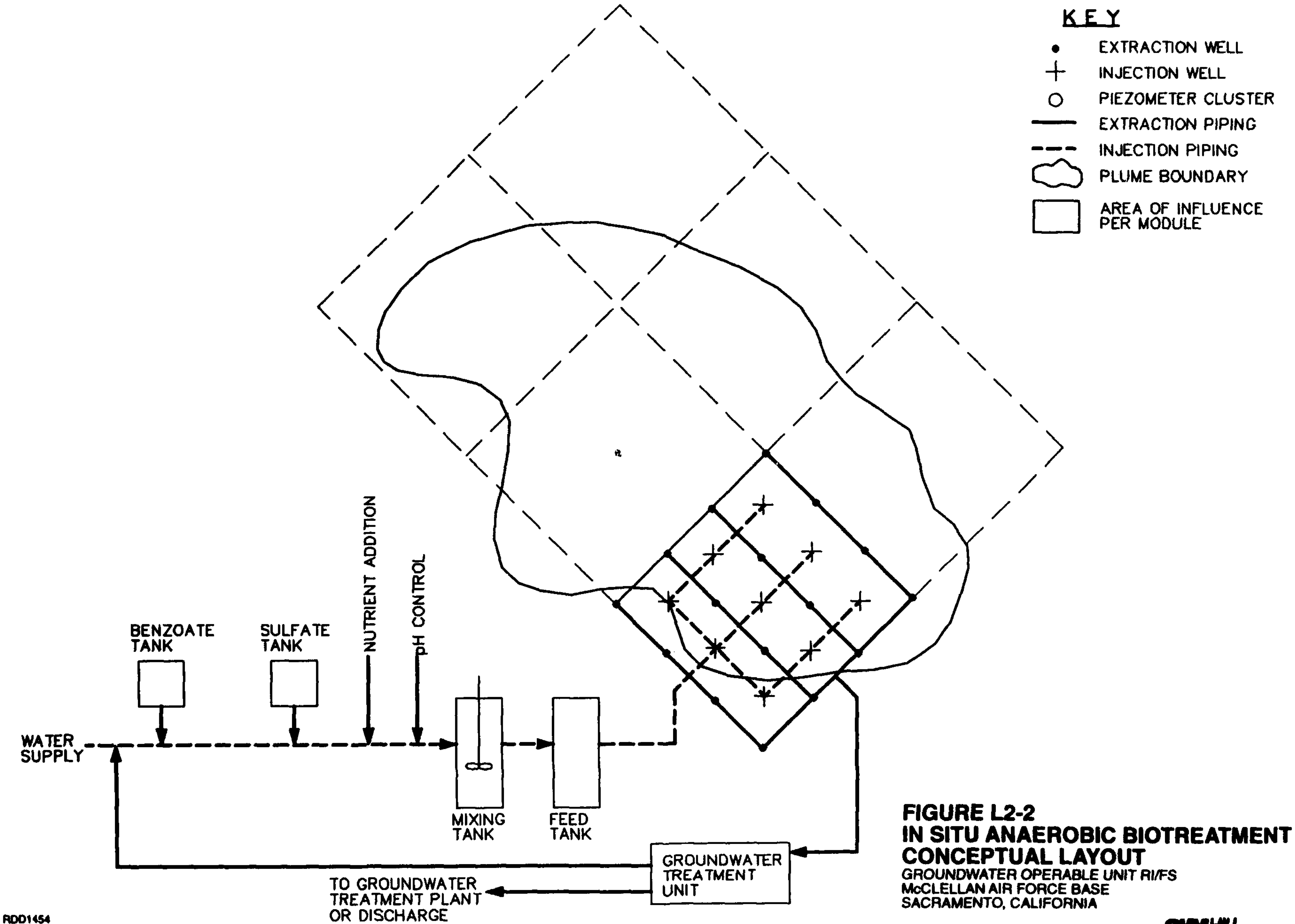

FIGURE L2-2
IN SITU ANAEROBIC BIOTREATMENT CONCEPTUAL LAYOUT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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- A single chemical feed system—including chemical storage, mixing, and feed tanks, mixers, pumps, and controls—services the entire in situ treatment system (Figure L2-3).

Technology Limitations and Uncertainties

The critical limitations and uncertainties of technology implementation are listed below.

- The suitability of hot spot areas at the Base for application of in situ anaerobic biotreatment will depend on subsurface characteristics such as soil permeabilities, heterogeneities, and contaminant distribution.

- It is unknown whether aboveground treatment of extracted groundwater will be required prior to reinjection. If so, it will significantly increase cost and permitting requirements.

- Other potential permitting issues are associated with reinjection of groundwater and injection of chemical amendments. Patent issues that must be resolved are associated with the use of the in situ anaerobic biotreatment process and the use of in situ recirculation units.

- Achievable contaminant treatment rates are unknown and must be determined through testing.

- The formation of toxic transformation products such as vinyl chloride could affect the risk associated with Base groundwater.

- The presence of natural anaerobic biological activity is only indicated at a few Base locations, based on existing groundwater contaminant data. The necessary microorganisms may or may not be present at potential target areas for implementation of the technology. The success of bioaugmentation is uncertain.

Schedule

A possible implementation schedule is provided in Figure L2-4.

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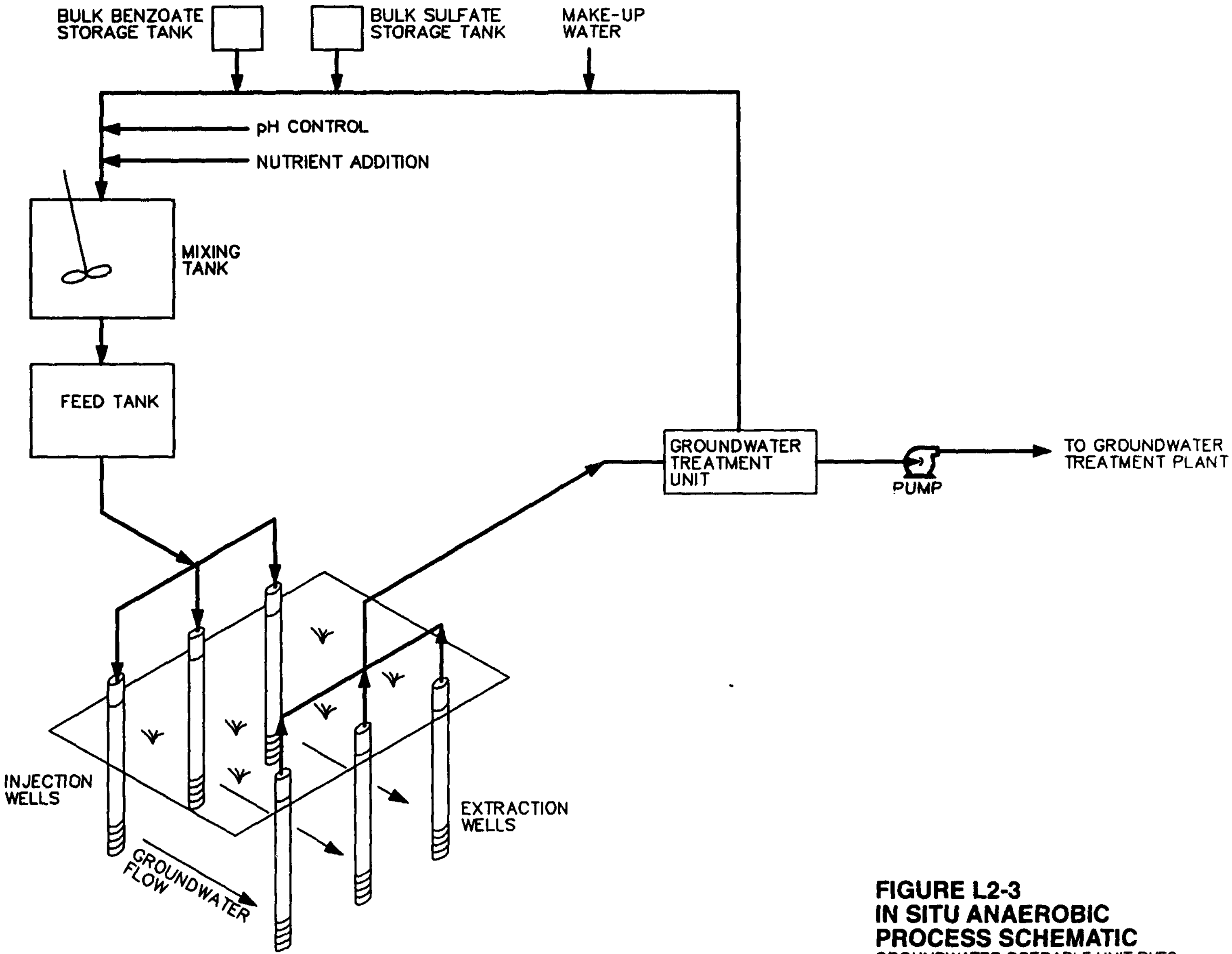

FIGURE L2-3
IN SITU ANAEROBIC PROCESS SCHEMATIC
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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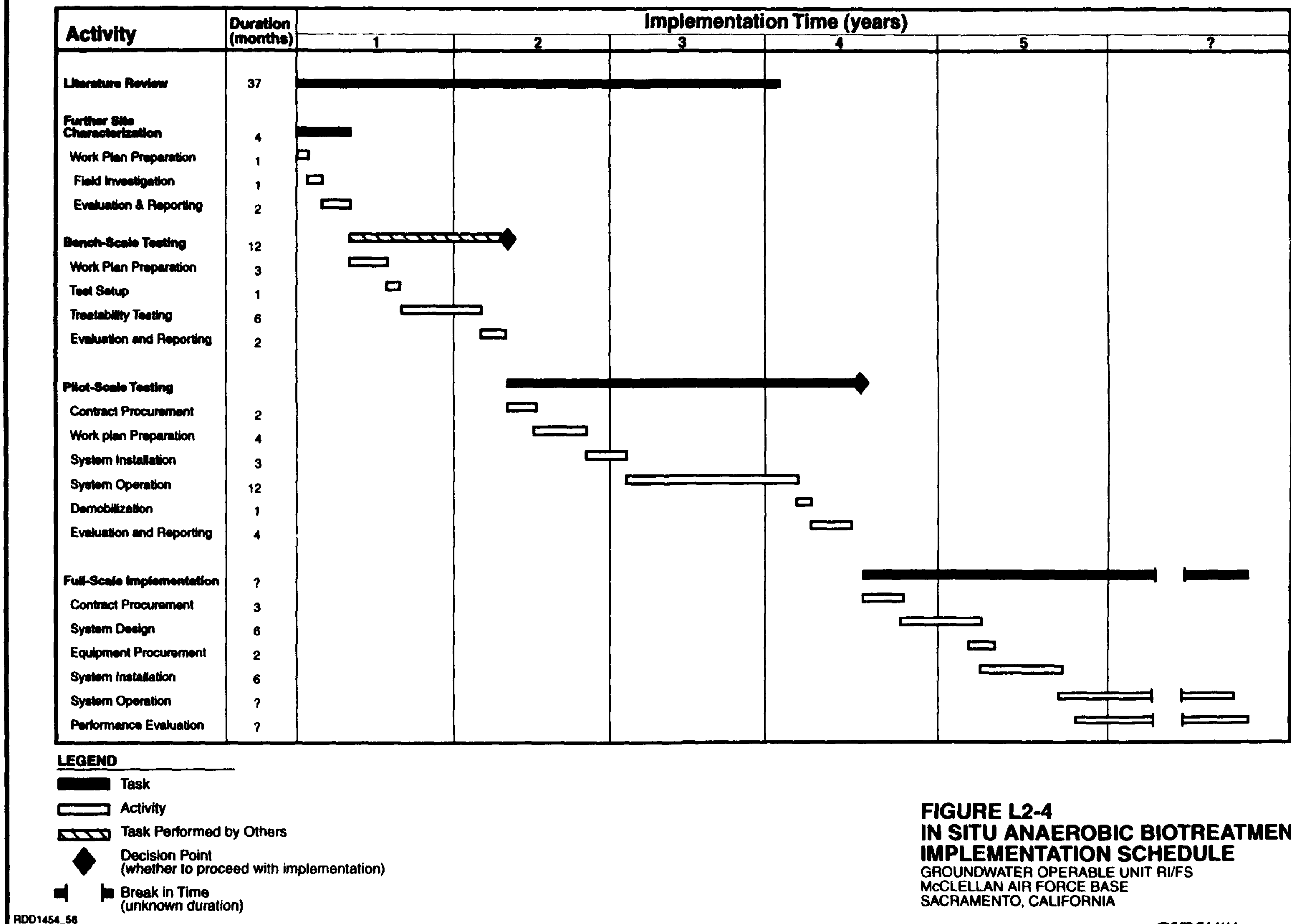

FIGURE L2-4
IN SITU ANAEROBIC BIOTREATMENT IMPLEMENTATION SCHEDULE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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Cost

This section presents an estimated range for order-of magnitude implementation costs based on the conceptual design. Implementation costs include costs associated with ongoing literature review, further site characterization, bench-scale testing, pilot-scale testing, and full-scale capital and annual operations and maintenance. The scope of each of these cost-related activities is summarized below:

- **Literature Review.** Technology researchers (i.e., universities, industry, consultants) are likely to further develop the technology such that enhancements (optimization) and limitations will be better understood. The decision to proceed with further implementation of in situ anaerobic biotreatment requires ongoing assessment and review of these research results. While this activity is not a significant cost factor of implementation, it is an important implementation activity.

- **Further Site Characterization.** This activity is necessary to confirm the location of a proposed implementation site and to provide the necessary soil cores for bench-scale microcosm studies. Associated costs are related to fieldwork (streamlined SAP, QAPP, sampling labor and expenses, analytical expenses, report, etc.) designed to identify site subsurface characteristics and collect and analyze samples for bench-scale testing.

- **Bench-Scale Testing.** This activity includes scope and workplan development, contract procurement, and the cost of conducting and overseeing soil microcosm studies.

- **Pilot-Scale Testing.** This activity includes costs associated with scope and workplan development, contract procurement, equipment procurement, system installation, system operation, demobilization, sampling and analysis (system monitoring), evaluation of system performance, and reporting.

- **Full-Scale Capital.** Capital costs are direct and indirect costs required to initiate and install the technology system components, including (but not limited to) engineering design, mobilization and demobilization of equipment and people, site construction activities (i.e., well installation), contractor bonding and insurance, equipment procurement and installation, licensing and permitting, health and safety, and supervision during construction.

- **Full-Scale Operation and Maintenance.** Operation and maintenance (O&M) costs represent those costs which would be incurred during each year of operation from initial startup to final shutdown of the full-scale system. O&M costs include operations and maintenance labor, sampling and analysis, power, and (optionally) groundwater treatment prior to reinjection. Since annual O&M costs occur over a period of years, future costs have been discounted to the present year's equivalent value (i.e., the present value cost) using 5 percent interest, so that annual costs remain comparable. Actual annual costs are likely to be much higher during the first year(s) of operation as the system is commissioned and optimized for operation, and due to higher chemical usage rates and associated labor required for treating higher initial concentrations. Therefore, the annual costs are intended to represent the anticipated average yearly cost of operation over the life of the system.

A contingency of 30 percent has been applied to the full-scale implementation cost to account for possible project cost increases due to scope and bid variations that typically occur with hazardous waste remediation projects. These increases are typically caused by the changes which normally occur as part of final design and implementation, based on observation of actual field conditions/contamination, and factors which affect the cost of subcontracted services, such as labor and material shortages. Not included in the estimates are any agency or Air Force administrative costs, nor any costs associated with modifications of the existing groundwater treatment system(s).

Typically, order-of-magnitude cost estimates for general construction projects are intended to reflect an accuracy of within 50 percent greater to 30 percent less than actual costs. The estimates summarized below are expected to be within these ranges; however, there is greater uncertainty of accuracy as a result of the lesser degree of development associated with this innovative technology compared to general construction technologies. Current pricing data based on quoted equipment costs, construction cost data (e.g., Means, 1993), previous local project experience, and engineering judgment have been used to generate the estimates, using adjustments for local McClellan AFB costs when available. Final project costs will depend on actual labor and material costs, actual site conditions at the time of implementation, productivity, competitive market conditions, final project scope and schedule, contractors selected to perform activities, and many other variables. As a result, the final project costs will differ from the exact value of any estimates presented here, but should still remain within the estimated range.

The following order-of-magnitude implementation costs are estimated for in situ anaerobic biotreatment:

- Literature review will require approximately $14,000 over a period of two years.
- It is estimated that further site characterization could be completed for approximately $50,000.
- It is estimated that bench-scale testing could be completed for approximately $68,000.
- Pilot-scale testing is estimated to cost approximately $345,000.

Full-scale implementation costs on a per acre basis are summarized in Table L2-2. The estimated costs for construction and operation of a full-scale system range from approximately $1.2 M/acre (for 60 feet well spacing, 2 years operation, and no groundwater treatment prior to reinjection) to $7.5 M/acre (for 30 feet well spacing, 5 years operation, and groundwater treatment prior to reinjection). The added cost of groundwater treatment prior to reinjection is estimated to be approximately $100,000/acre. Key assumptions associated with the implementation cost estimate, in addition to those previously described, include:

Table L2-2
In Situ Anaerobic Biotreatment
Order-of-Magnitude Implementation Cost Summary

Activity	Range of Costs ($/acre)			
	Low[1]	Low - Intermediate[2]	Intermediate - High[3]	High[4]
Full-Scale Capital	900,000	900,000	3,900,000	3,900,000
Full-Scale O&M (Present Worth for All Years)	300,000	400,000	1,600,000	3,700,000
Full-Scale Implementation Cost	1,200,000	1,300,000	5,500,000	7,600,000

Notes:
[1]Based on 60 feet well spacing, 2 years of operation, and no groundwater treatment prior to reinjection.
[2]Based on 60 feet well spacing, 2 years of operation, and groundwater treatment prior to reinjection.
[3]Based on 30 feet well spacing, 2 years of operation, and groundwater treatment prior to reinjection.
[4]Based on 30 feet well spacing, 5 years of operation, and groundwater treatment prior to reinjection.
Other significant assumptions include: 100 percent system on-time; annual sampling and analysis costs, and performance evaluations included in operational cost; 30 percent contingency factor applied.

- Full-scale costs are reported on a per-acre basis. Costs were estimated for a five-module (45 extraction well) system and converted to per-acre costs.
- Nine man-days/well plus drilling costs are needed to install wells. This includes drilling, well completion and development, and surface plumbing.
- Groundwater treatment unit operational costs are $200/lb VOCs, and approximately 600 lb of contaminants will require aboveground removal per year.
- Average groundwater concentration is 5 mg/l total chlorinated VOCs.
- System monitoring includes 240 man-days/year for system operation and maintenance, and the collection of nine samples per module.

- The substrate feed system is constructed inside a corrugated metal roof-covered building.

Works Cited

Semprini, Lewis. Oregon State University, Memo to CH2M HILL, September 24, 1993.

Semprini, Lewis. Oregon State University, Memo to CH2M HILL, August 13, 1993.

McCarty, Perry. Stanford University, Memo to CH2M HILL, August 15, 1993.

Appendix L3

PREPARED FOR: McClellan Air Force Base

DATE: March 24, 1994

SUBJECT: In Situ Cometabolic Biotreatment Implementation Plan
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.NT

Technology Overview

Description

In situ (aerobic) cometabolic biotreatment is an emerging technology for remediating groundwater contaminated with chlorinated aliphatic hydrocarbons (CAHs). In situ cometabolic biotreatment refers to the process of adding a primary organic substrate to groundwater to induce production of nonspecific enzymes by a certain group of microorganisms under aerobic conditions. These enzymes fortuitously degrade CAHs, which are otherwise resistant to aerobic biodegradation. For purposes of this report, the term cometabolic biotreatment is used to describe only aerobic cometabolism, so oxygen is added along with the primary organic substrate. The most promising substrates are methane, phenol, and toluene. Inorganic nutrients (primarily nitrogen and phosphorus) may also be added to the groundwater if needed.

CAHs are the principal organic contaminants in groundwater at McClellan AFB. The CAHs of interest at the Base include: trichloroethene (TCE), tetrachloroethene (PCE), carbon tetrachloride (CT), 1,1,1-trichloroethane (1,1,1-TCA), cis- and trans-1,2-dichloroethene (1,2-DCE), vinyl chloride (VC), 1,1-dichloroethene (1,1-DCE), 1,1-dichloroethane (1,1-DCA), chloroform (CF), and methylene chloride (MC). TCE, 1,2-DCE, and VC can be effectively treated by aerobic cometabolism; 1,1-DCE, 1,1,1-TCA and 1,1-DCA are not effectively treated by this method; and PCE and CT are recalcitrant. In this process, TCE and other chlorinated organics can be completely oxidized to carbon dioxide, water, and inorganic salts.

Implementation Methods

There are four basic configurations for implementing in situ cometabolic biotreatment:

- In situ recirculation wells
- Vertical injection and extraction wells
- Horizontal injection and extraction wells
- Reactive walls

These four alternatives are depicted schematically in Figure L3-1, and are described below. Additional configurations are possible, including combinations of the systems described.

An in situ recirculation well consists of a vertical well that has two separate screened intervals in the saturated zone and a seal in the well above the upper screen. A submersible pump is positioned between the screens to force water out the bottom screen while drawing water in through the top screen (or vice versa). Pumping groundwater in this fashion results in flow paths like those depicted in Figure L3-1. Chemical amendments are added to the groundwater within the well.

A combination of vertical injection and extraction wells is the traditional system used for in-situ groundwater bioremediation. Substrate and nutrients are injected and pumped through the contaminated groundwater zone between injection and extraction wells to create a biologically active zone where treatment occurs. Horizontal injection and extraction wells function similarly to vertical wells except that the wells are oriented horizontally in the contaminated zone and, therefore, can influence a larger lateral area.

Reactive walls are either trenches or a linear array of wells designed to create a curtain through which groundwater passes under ambient gradients and in which the desired biological reactions occur.

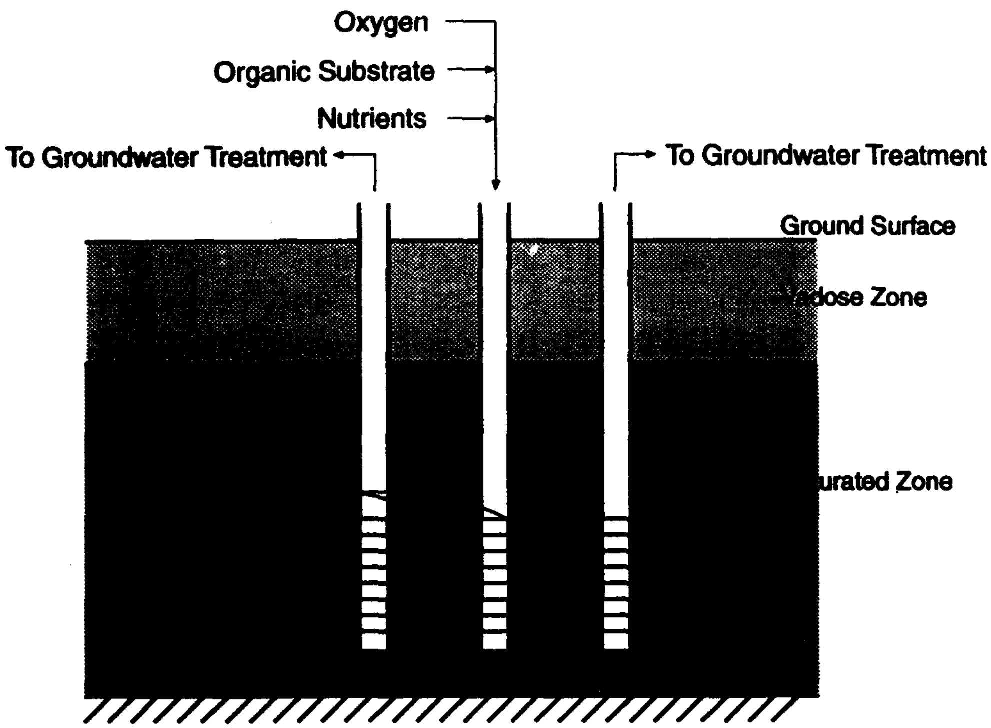
The four basic implementation alternatives have different applicabilities and advantages and disadvantages with respect to site and contaminant distribution conditions. Because of the great depth to groundwater at McClellan AFB, vertical wells and in situ recirculation units are probably the two most feasible implementation alternatives for in situ cometabolic biotreatment at the Base.

Development Status

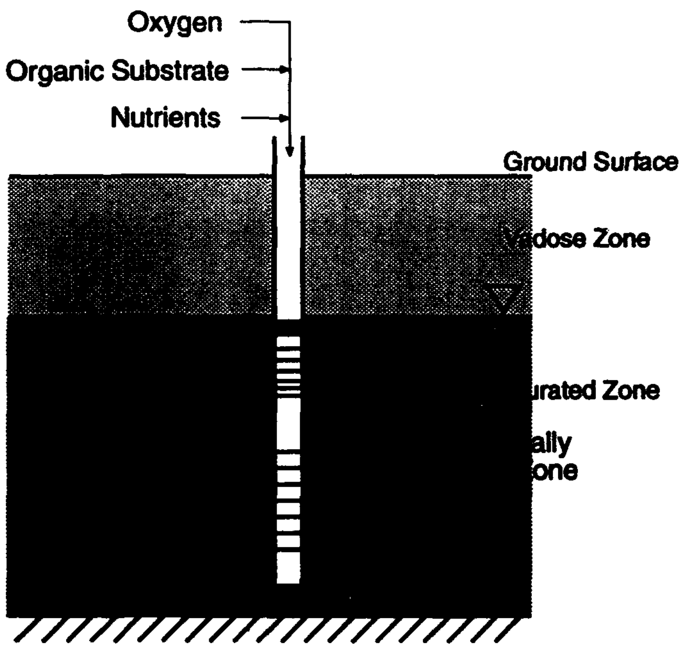
The capability of cometabolic biotreatment to degrade CAHs in aquifer material has been well established in bench-scale studies. Considerable laboratory work on this technology has been conducted by university researchers and vendors over the past several years.

Stanford University researchers have conducted a multi-year, small-scale, field pilot study of in situ cometabolic biodegradation of CAHs in a shallow water table aquifer at Moffett Naval Air Station. These studies have yielded very favorable results, but they were conducted using simple combinations of (approximately four) contaminants at a time.

VERTICAL INJECTION/EXTRACTION WELLS



IN SITU RECIRCULATION WELL



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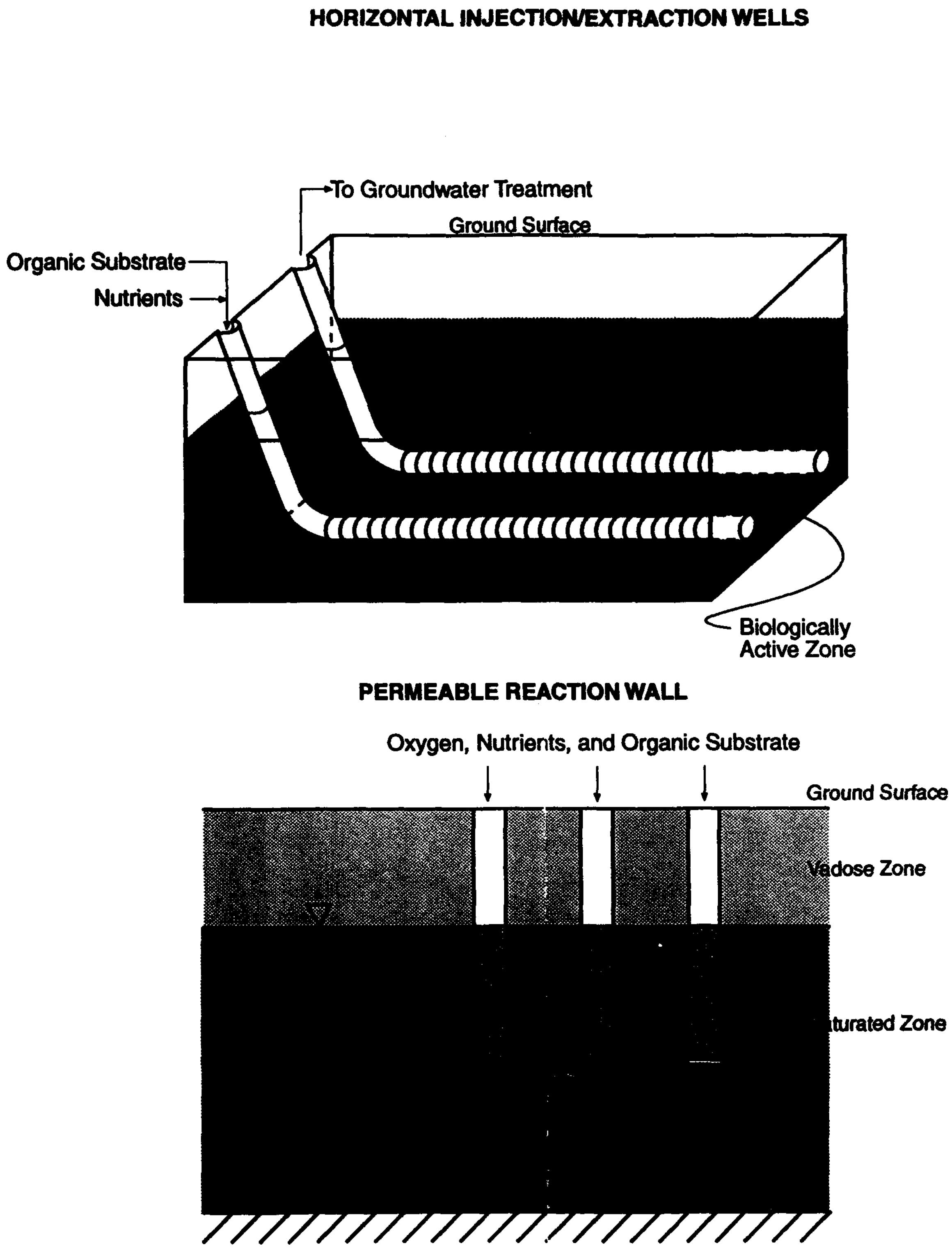

FIGURE L3-1
IN SITU COMETABOLIC BIOTREATMENT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

(2)

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The technology has been developed to the point where it is ready to be implemented in an appropriate full-scale application, but has not yet been applied for full-scale groundwater remediation to-date.

Potential Benefits

This section describes the performance, advantages and disadvantages, and cost benefits associated with in situ cometabolic biotreatment. This information is intended to provide a basis for evaluating the potential benefits of implementing the technology as part of the overall McClellan AFB groundwater cleanup program.

General Performance

Effectiveness

- Field pilot testing has demonstrated that removal efficiencies on the order of 90 percent can be achieved for TCE, 1,2-DCE, and VC for initial concentrations up to 1,000 μg/l.

- CAHs that are amenable to cometabolic treatment can be completely mineralized to CO_2, water, and chloride.

Robustness

- TCE, 1,2-DCE, VC, and possibly other prevalent CAHs are treatable by cometabolic biotreatment.

- Cometabolic biotreatment is not effective for CT, PCE, 1,1-DCE, 1,1-DCA, 1,1,1-TCA, or Freons.

- The technology is sensitive to toxic and inhibitory effects.

- High TCE concentrations (up to 10 mg/l) are not expected to be inhibitory.

- BTEX compounds, acetones, and other relatively minor nonhalogenated contaminants in Base groundwater are readily biodegradable under aerobic conditions.

- As with all in situ technologies, control over subsurface conditions is critical to treatment performance, as heterogeneities and mass transfer requirements limit effectiveness.

Potential Risk Reduction

In situ cometabolic biotreatment has the potential to reduce risk by biodegrading groundwater contaminants and thereby reducing the contaminant mass in the subsurface. By accelerating contaminant removal, the time to achieve remedial goals may be shortened. Injection of chemicals into groundwater and formation of intermediate transformation products could constitute new, albeit temporary, sources of risk, but adequate hydrologic control would be maintained to mitigate these risks during system operation.

Advantages Compared to Other Technologies

- Destruction of contaminants occurs in-place. Because treatment occurs in situ, contaminant desorption is accelerated.

- May treat high concentrations of amenable CAHs (tens of mg/l).

- Aerobic conditions are maintained, promoting better water quality (compared to naturally occurring or induced anaerobic conditions).

- The fast growth rates typical of aerobic microorganisms may allow rapid development of a contaminant-degrading culture.

- This technology is effective at degrading some anaerobic transformation products of PCE and TCE. The transformation products, which the cometabolic process would be effective on, are: cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride.

- At least simple contaminant mixtures are treatable using this technology.

- Complete degradation of TCE to nontoxic end products is possible.

- No significant transformation products are formed during treatment of CAHs that have higher associated risks than the parent compounds (e.g., VC).

- If groundwater extracted in conjunction with implementation of in situ cometabolic biotreatment could be reinjected without aboveground treatment (e.g., during implementation using vertical injection and extraction wells), the cost of this technology would be significantly reduced relative to other technologies requiring aboveground treatment. EPA has prepared a position statement allowing for reinjection of contaminated water when appropriate for such a treatment scheme.

Disadvantages Compared to Other Technologies

- Does not effectively degrade PCE, CT, 1,1-DCE, 1,1-DCA, 1,1,1-TCA, or Freons.
- Competitive inhibition occurs between the added organic substrate and some target CAHs.
- Because microorganisms are fast growing, it may be difficult to achieve distributed growth in subsurface. Biofouling is also a potential problem.
- This technology requires oxygenation of groundwater, which is expensive and can be difficult to achieve over extended volumes.
- Groundwater oxygenation can cause iron precipitation and plugging.
- If adequate populations of bacteria capable of producing CAH-degrading enzymes are not present, bioaugmentation may be necessary, but added microbes may not thrive in the subsurface environment. However, these microorganisms have been found to be fairly widespread in the environment.
- If required, aboveground water treatment will significantly increase the cost of the technology and will have permitting requirements.
- Reinjection of groundwater (with or without treatment) and injection of chemical amendments will require regulatory approval.

Relative Cost Benefit

The cost benefits of in situ cometabolic biotreatment would result from increased rates of contaminant removal that could shorten the pump-and-treat remediation time. Cost benefits should be evaluated through an analysis of savings associated with the reduced operation time of pump-and-treat after accounting for the capital and operating costs of the in situ anaerobic biotreatment system.

Potential Locations

Cometabolic biotreatment is potentially applicable at locations on the Base where TCE, 1,2-DCE, and/or VC are the predominant groundwater contaminants. Implementation of the technology in hot spot areas is likely to provide the greatest benefit to the overall groundwater cleanup program. Moderate to high permeabilities and relatively homogeneous conditions in the saturated zone are most favorable for effective treatment.

Hot spot locations in OU C are potentially most suitable because of the relatively high permeabilities found in that area and because TCE is the predominant CAH present.

Approach

Information Needs and Sources

Table L3-1 lists information requirements and sources for implementation of in situ cometabolic biotreatment.

Information Gathering and Review

Information gathering to date has included the review of published and available unpublished technology information, vendor interviews, consultation with subcontracted experts, and an overview of McClellan AFB subsurface characteristics and groundwater contaminant data. Expert consultants for this technology are Dr. Lewis Semprini of the Department of Civil Engineering, Oregon State University, and Dr. Perry McCarty of the Department of Civil Engineering, Stanford University. Drs. McCarty and Semprini are considered to be leading experts on in situ biological treatment processes

The first step for implementation of this technology should be a detailed review of the existing literature on cometabolic biotreatment of CAHs, paying particular attention to field data, and of the groundwater contaminant data for the Base. New information should be reviewed as it becomes available.

A detailed analysis of chemical distribution in three dimensions is needed to identify target volumes for treatment. After the existing chemical data have been thoroughly reviewed and analyzed and potential target areas have been roughly identified, it is likely that some additional site characterization data will be needed to fine-tune the selection of target zones, evaluate chemical amendment requirements, and collect samples of aquifer material for bench-scale testing. Samples for analysis and testing could be collected through the use of boreholes or cone penetrometers. Analytical parameters should include organic contaminants, major anions and cations, metals (iron), Eh, pH, DO, sulfide, methane, ethane, and COD, or TOC.

Implementation Issues

- Potential permitting/regulatory approval issues associated with in situ cometabolic biotreatment include:

  - Reinjection or discharge of extracted groundwater

Table L3-1 In Situ Cometabolic Biotreatment Information Needs and Sources			
	Test Scale		
Information Need	**Bench**	**Pilot**	**Full**
Contaminant Characterization			
• Contaminant Types	S	S	S
• Concentrations	S	S	S
• Treatment Goals	L	L	L
• Inhibitory/Toxicity Factors	L	B,L	P,L
• Contaminant Geometry	--	S,L	S,L
Subsurface Characterization			
• Environmental Factors (pH, temp)	S	S	P,S
• Water/soil chemistry parameters	S	B,S	P,S
• Flow	L	M	M
• Water Levels over time	--	S,L	S,L
• Soil type	S	S,L	S,L
• Soil heterogeneity	S	S,L	S,L
• Sorption/Retardation	L	M	M
• Microorganisms present	S	B,S	P,S
• Electron Acceptors	S	B,S	P,S
System Design: Physical Configuration			
• Number of wells, type	--	B,L,M	P,L,M
• Well spacing	--	B,L,M	P,L,M
• Residence Time (zone)	L	B,L,M	P,L,M
• Well Diameter	--	B,L	P,L
• Screen depth, length	--	L,V	P,L,V
System Design: Treatment Requirements			
• Nutrient Additions	L	B,L	P,L
• Metabolite Addition	L	B,L	P,L
• Microorganism Addition	L	B,L	P,L
• Oxygen Additions	L	B,L	P,L
• Permitting Requirements	--	L	L
System Design: Equipment Requirements			
• Equipment Requirements	L	L,V	P,V
• O&M Requirements	L	L,V	P,V
Performance Capabilities			
• Monitoring (Sampling and Analysis Requirements)	L	L	L
• By-product formation	S	B,L,S	P,L,S

Notes:
L = Literature/Experts
B = Bench Scale
P = Pilot Scale
S = Sampling Results
V = Vendor
M = Modeling/Other Technology Evaluations

- The need for aboveground treatment of extracted groundwater if it is to be reinjected within a contained plume

- Treatment requirements for groundwater and offgas if aboveground treatment of extracted groundwater is required

- Injection of organic substrates and nutrients into groundwater

- Formation of transformation products

• A potential patent issue pertains to the patent held by IEG Technologies, Inc., on the in situ recirculation unit. The applicability of this patent is currently unclear and would need to be resolved by patent attorneys.

• Other issues that could affect implementation are associated with newly generated site characterization data that may influence technology effectiveness or cost (and therefore feasibility) at target areas, including permeability, heterogeneity, contaminant distribution, and cometabolic biological activity information.

Bench-Scale Testing

Objectives

Bench-scale testing would consist of microcosm studies using aquifer material collected from target zones. The microcosm studies will help determine:

• What growth substrate is most effective (phenol, toluene, or methane)

• Whether the necessary microbial cultures are present in the subsurface and can be stimulated to degrade the target contaminants

• Whether they can degrade the target contaminants and how efficiently

• The concentration range over which effective transformation can be achieved

• The best method and rate for the addition of organic growth substrate

Approach

Different types of microcosms might be employed, including batch reactors, batch-fed soil columns, and continuous-flow soil columns. Bench-scale tests may take up to 6 months to complete.

If indigenous microorganisms are not present or they are not capable of mineralizing the contaminants of concern, it may be possible to introduce microbes to the subsurface. In this event, microcosm studies could be used to determine if the introduced strain would survive and flourish under field conditions.

Pilot-Scale Testing

Objectives

Pilot-scale tests would be necessary to develop information for designing and operating a full-scale treatment system. Data would be obtained on the effectiveness of treatment, areal extent of treatment, and optimal methods of chemical addition. A probable duration for pilot testing is 6 months to 1 year.

Pilot-scale testing objectives include the evaluation of:

- Proper well spacing and number of wells required for full-scale implementation
- Required organic substrate and nutrient addition rates, and optimal pattern of delivery
- Characteristics of extracted groundwater
- Transformation product formation, if any of significance, and disappearance rates
- Contaminant reduction rates and estimated treatment duration
- Estimated contaminant mass reductions achievable during treatment
- Estimated full-scale capital and operating costs
- Cost benefits associated with implementing the technology

Approach

Pilot-scale testing would involve the installation of one or two injection wells and two to four extraction wells, and operation of the system for a sufficiently long duration to obtain data needed to develop design and operating parameters for full-scale implementation. (For the purpose of this Implementation Plan, the use of vertical injection and extraction wells is assumed for pilot testing, but in situ recirculation units should also be considered.) The specific objectives and approach of the pilot testing program would be refined and detailed following the information gathering and review and bench-scale testi- ; tasks. The general approach to pilot testing is outlined below.

1. Confirm appropriateness of target location selected for pilot testing.

2. Conduct modeling to support pilot system design. This work would include hydrodynamic modeling, advective transport modeling, and possibly, modeling of mass transfer and biological processes.

3. Prepare system installation and operation work plan.

4. Install injection, extraction, and groundwater monitoring wells, and set up aboveground chemical delivery system.

5. Operate the system at different rates and patterns of substrate/nutrient delivery, holding each amendment condition constant for sufficient time to evaluate treatment performance (determined by groundwater sampling and analysis).

6. Analyze data to evaluate the performance under different testing conditions and evaluate potential benefits of in situ cometabolic biotreatment to the overall Base groundwater remediation program.

7. Decide whether to proceed with implementation at full scale.

Full-Scale Implementation

Pilot-scale results are necessary to develop a full-scale system design. However, an example conceptual design is outlined below to illustrate the major elements of a full-scale system and to provide a basis for a rough order-of-magnitude cost estimate. Rather than developing a conceptual design for a particular location, a modular approach was used to develop an estimated range of costs per unit acre for full-scale implementation.

The example conceptual design is based on the following key assumptions:

- Each module consists of nine injection and nine extraction wells, a piping system from the extraction wells to a groundwater treatment unit, a substrate feed system, and piping from the substrate feed system to the injection well (Figure L3-2).

- The spacing of wells varies from 30 to 60 feet based on initial modeling estimates.

- Approximate coverage by one module ranges from 8,100 ft^2 (5.4 modules/acre) to 32,400 ft^2 (1.3 modules/acre), depending on well spacing.

- Groundwater extraction and injection rate is 3 gpm per well.

- There will be one groundwater monitoring well per every 10 extraction/ injection wells.

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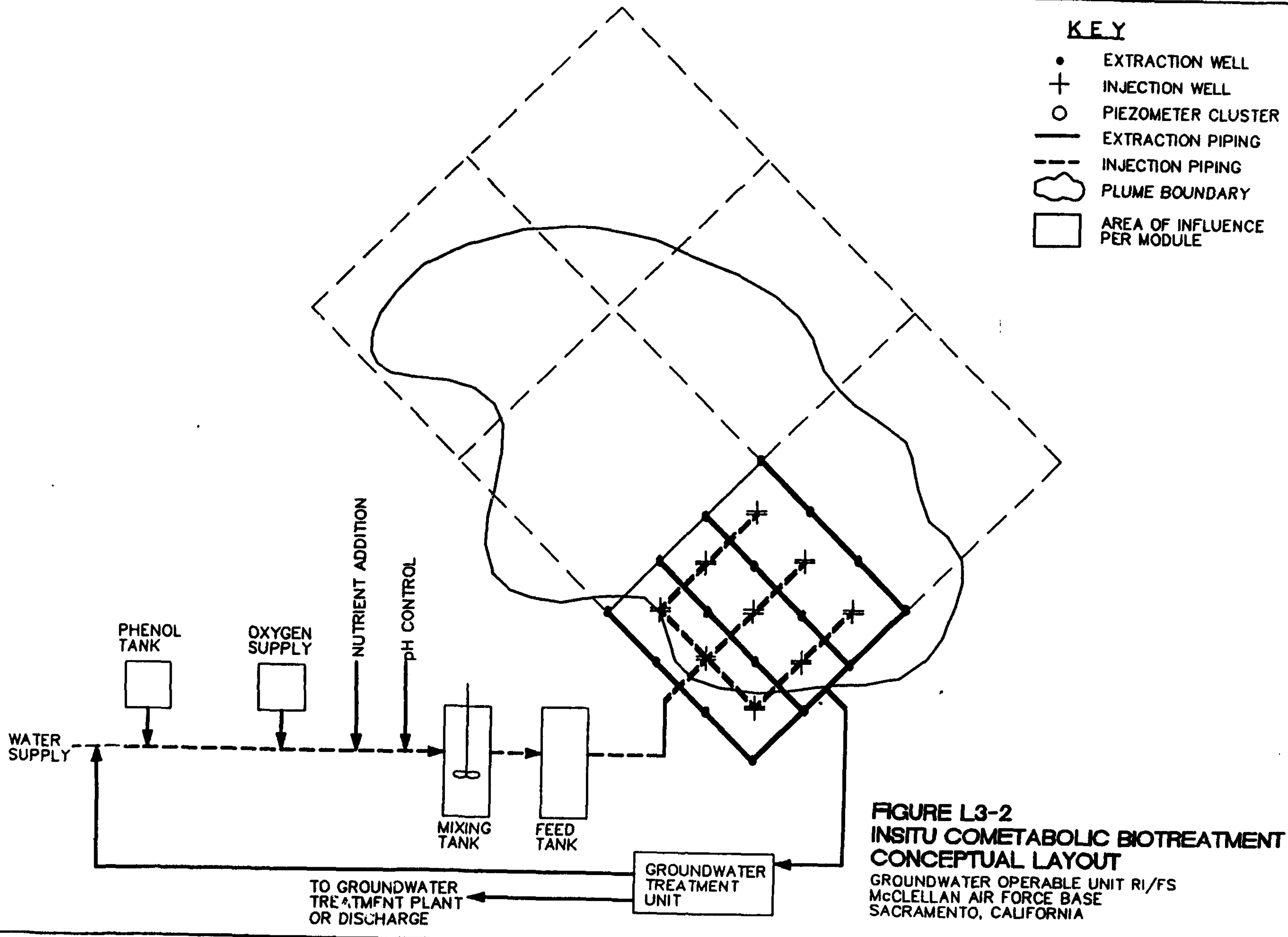

FIGURE L3-2
INSITU COMETABOLIC BIOTREATMENT CONCEPTUAL LAYOUT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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- The organic growth substrate is toluene, added at a ratio of 25 grams per gram of TCE. Oxygen is added to the groundwater using H_2O_2 at a ratio of 100 grams per gram of TCE. Inorganic nutrients are added as diammonium phosphate at a ratio of 1 gram per gram of TCE.

- The extracted groundwater is treated to MCLs at a single treatment system at the target location. This system consists of air stripping with vapor-phase GAC adsorption. Most ($\geq$90 percent) of the treated groundwater is chemically amended and reinjected, and a small blowdown stream ($\leq$10 percent) is discharged to maintain a net groundwater withdrawal (for containment).

- A single chemical feed system—including chemical storage, mixing, and feed tanks, mixers, pumps, and controls—services the entire in situ treatment system (Figure L3-3).

Technology Limitations and Uncertainties

The critical limitations and uncertainties of technology implementation are listed below.

- The suitability of hot spot areas at the Base for application of in situ cometabolic biotreatment will depend on subsurface characteristics such as soil permeabilities, heterogeneities, and contaminant types and distribution.

- It is unknown whether aboveground treatment of extracted groundwater will be required prior to reinjection. If so, it will significantly increase cost and permitting requirements.

- Other potential permitting issues are associated with reinjection of groundwater and injection of chemical amendments. Patent issues that must be resolved are associated with the use of in situ recirculation units.

- Achievable contaminant treatment rates are unknown and must be determined through testing.

- The presence of naturally occurring microorganisms capable of initiating transformation of CAHs is unknown. The necessary microorganisms may or may not be present at potential target areas for implementation of the technology, but they have been found to be widespread in the environment. The success of bioaugmentation is uncertain.

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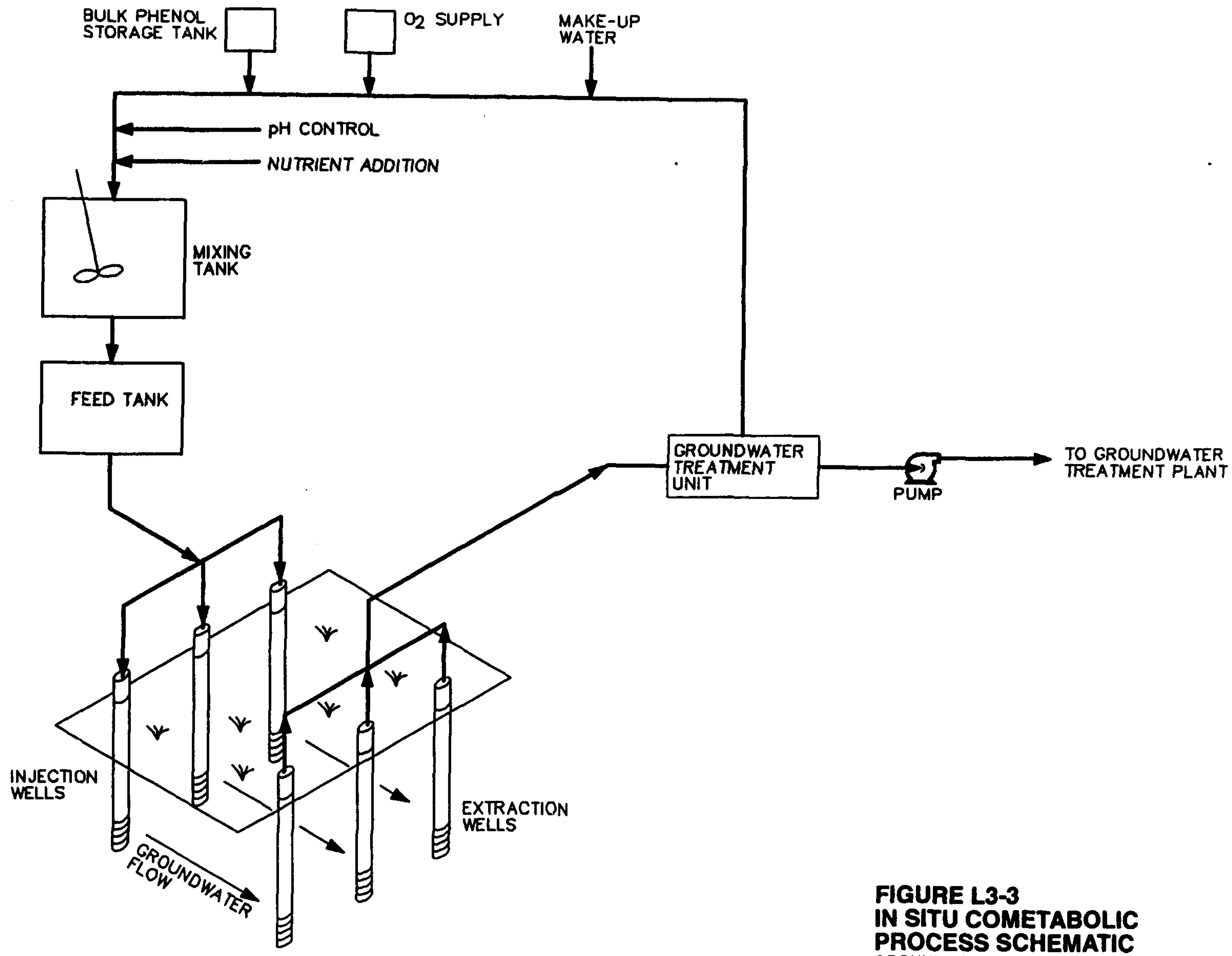

FIGURE L3-3
IN SITU COMETABOLIC PROCESS SCHEMATIC
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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- Complete utilization/biodegradation and/or recovery of injected organic substrate must be accomplished to avoid adding contaminants (and associated risk) to the groundwater.

Schedule

A possible implementation schedule is provided in Figure L3-4.

Cost

This section presents an estimated range of order-of magnitude implementation costs based on the conceptual design. Implementation costs include costs associated with: ongoing literature review, further site characterization, bench-scale testing, pilot-scale testing, and full-scale capital and annual operations and maintenance. The scope of each of these cost-related activities is summarized below:

- **Literature Review.** Technology researchers (i.e., universities, industry, consultants) are likely to further develop the technology such that enhancements (optimization) and limitations will be better understood. The decision to proceed with further implementation of in situ cometabolic biotreatment requires ongoing assessment and review of these research results. While this activity is not a significant cost factor of implementation, it is an important implementation activity.

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- **Bench-Scale Testing.** This activity includes scope and work plan development, contract procurement, and the cost of conducting and overseeing the soil microcosm studies previously described.

- **Pilot-Scale Testing.** This activity includes costs associated with scope and work plan development, contract procurement, equipment procurement, system installation, system operation, demobilization, sampling and analysis (system monitoring), evaluation of system performance, and reporting.

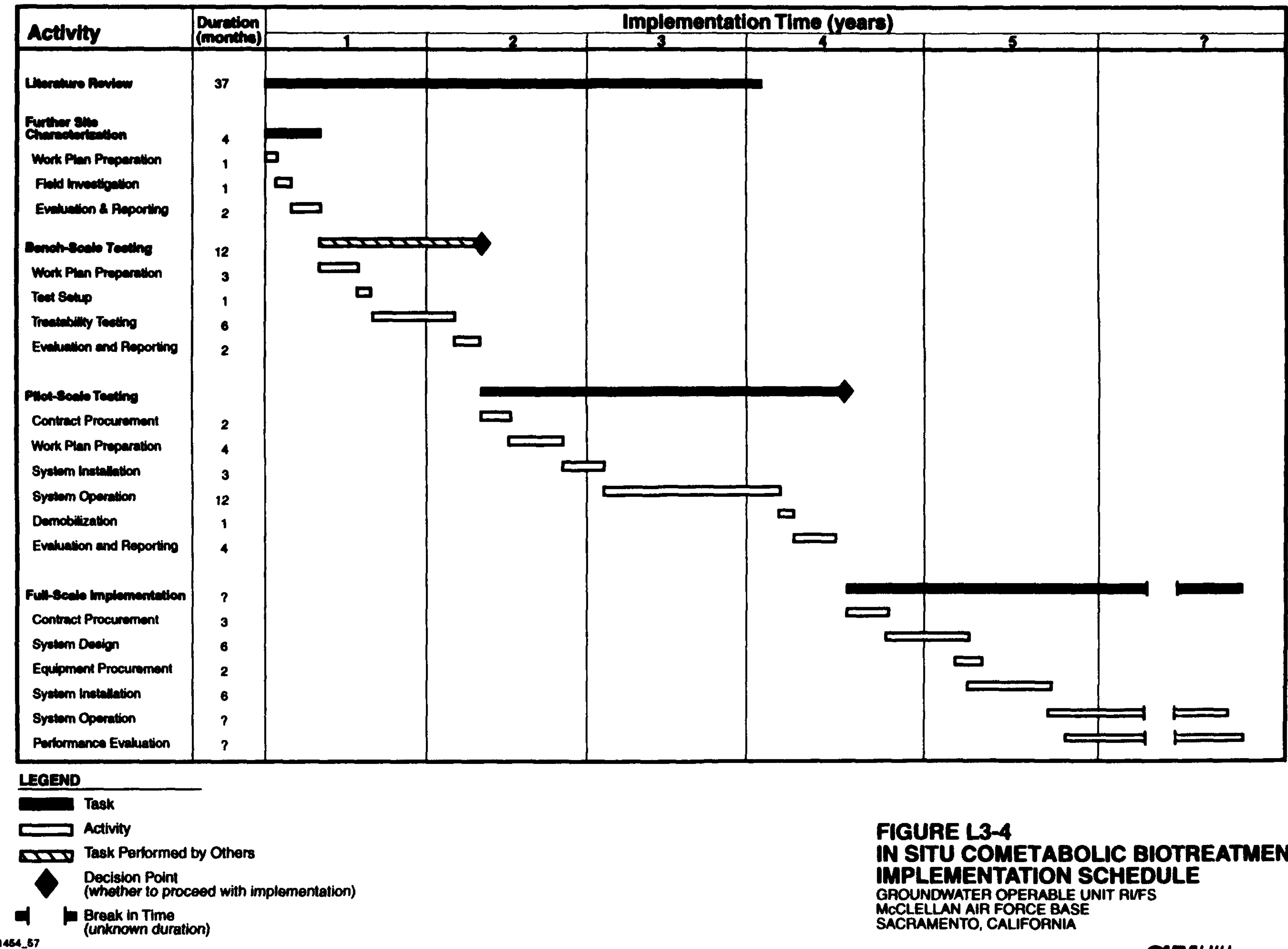

FIGURE L3-4
IN SITU COMETABOLIC BIOTREATMENT IMPLEMENTATION SCHEDULE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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- **Full-Scale Capital.** Capital costs are direct and indirect costs required to initiate and install the technology system components, including (but not limited to) engineering design, mobilization and demobilization of equipment and people, site construction activities (i.e., well installation), contractor bonding and insurance, equipment procurement and installation, licensing and permitting, health and safety, and supervision during construction.

- **Full-Scale Operation and Maintenance.** Operation and maintenance (O&M) costs represent those costs that would be incurred during each year of operation from initial startup to final shutdown of the full-scale system. Since annual O&M costs occur over a period of years, future costs have been discounted to the present year's equivalent value (i.e., the present value cost) using 5 percent interest, so that annual costs remain comparable. Actual annual costs are likely to be much higher during the first year(s) of operation as the system is commissioned and optimized for operation, and due to higher chemical usage rates and associated labor required for treating higher initial concentrations. Therefore, the annual costs are intended to represent the anticipated average yearly cost of operation over the life of the system.

A contingency of 30 percent has been applied to the full-scale implementation cost to account for possible project cost increases due to scope and bid variations that typically occur with hazardous waste remediation projects. These increases are typically caused by the changes that normally occur as part of final design and implementation, based on observation of actual field conditions/contamination, and factors, which affect the cost of subcontracted services, such as labor and material shortages. Not included in the estimates are any agency or Air Force administrative costs, nor any costs associated with modifications of the existing groundwater treatment system(s).

Typically, order-of-magnitude cost estimates for general construction projects are intended to reflect an accuracy of within 50 percent greater to 30 percent less than actual costs. The estimates summarized below are expected to be within these ranges; however, there is greater uncertainty of accuracy as a result of the lesser degree of development associated with this innovative technology compared to general construction technologies. Current pricing data based on quoted equipment costs, construction cost data (e.g., Means, 1993), previous local project experience, and engineering judgment have been used to generate the estimates, using adjustments for local McClellan AFB costs when available. Final project costs will depend on actual labor and material costs, actual site conditions at the time of implementation, productivity, competitive market conditions, final project scope and schedule, contractors selected to perform activities, and many other variables. As a result, the final project costs will differ from the exact value of any estimates presented here.

The following order-of-magnitude implementation costs are estimated for in situ cometabolic biotreatment:

- Literature review will require approximately $14,000 over a period of 2 years.
- It is estimated that further site characterization could be completed for approximately $50,000.
- It is estimated that bench-scale testing could be completed for approximately $68,000.
- Pilot-scale testing is estimated to cost approximately $355,000.

Full-scale implementation costs on a per acre basis are summarized in Table L3-2. The estimated costs for construction and operation of a full-scale system range from approximately $1.9M/acre (for 60-foot well spacing, 2 years' operation, and no groundwater treatment prior to reinjection) to $14.7M/acre (for 30-foot well spacing, 5 years' operation, and groundwater treatment prior to reinjection). The added cost of groundwater treatment prior to reinjection is estimated to be approximately $100,000/acre. Key assumptions associated with the implementation cost estimate, in addition to those previously described, include:

- Full-scale costs are reported on a per acre basis. Costs were estimated for a five-module (45 extraction wells) system and converted to per acre costs.
- Nine man-days/well plus drilling costs are needed to install wells. This includes drilling, well completion and development, and surface plumbing.
- Groundwater treatment unit operational costs are $200/lb VOCs, and approximately 600 lb of contaminants will require aboveground removal per year.
- Average groundwater concentration is 5 mg/l total chlorinated VOCs.
- System monitoring includes 240 man-days/year for system operation and maintenance, and the collection of nine samples per module.
- The substrate feed system is constructed inside a corrugated metal roof-covered building.
- Toluene is added at a rate of 15,000 lb/module per year at a cost of $4/lb; hydrogen peroxide is the oxygen source and is added at a rate of 59,000 lb/module per year at a cost of $3.50/lb. Chemical costs include shipping and handling.

- Each module consists of four extraction wells piped to a DPE skid. The skid contains an air/water separator; a high vacuum, continuous-duty

Table L3-2 In Situ Cometabolic Biotreatment Order-of-Magnitude Implementation Cost Summary				
	Range of Costs ($/acre)			
Activity	**Low[a]**	**Low - Intermediate[b]**	**Intermediate - High[c]**	**High[d]**
Full-Scale Capital	900,000	900,000	3,900,000	3,900,000
Full-Scale O&M (Present Worth for All Years)	1,000,000	1,100,000	4,600,000	10,800,000
Full-Scale Implementation Cost	1,900,000	2,000,000	8,500,000	14,700,000

Notes:
[a]Based on 60 feet well spacing, 2 years of operation, and no groundwater treatment prior to reinjection.
[b]Based on 60 feet well spacing, 5 years of operation, and groundwater treatment prior to reinjection.
[c]Based on 15 feet well spacing, 2 years of operation, and groundwater treatment prior to reinjection.
[d]Based on 15 feet well spacing, 5 years of operation, and groundwater treatment prior to reinjection.
Other significant assumptions include: 100 percent system on-time; annual sampling and analysis costs, and performance evaluations included in operational cost; 30 percent contingency factor applied.

Works Cited

Semprini, Lewis. Oregon State University, Memo to CH2M HILL, September 24, 1993.

Semprini, Lewis. Oregon State University, Memo to CH2M HILL, August 13, 1993.

McCarty, Perry. Stanford University, Memo to CH2M HILL, August 15, 1993.

Appendix L4

PREPARED FOR: McClellan Air Force Base

DATE: November 7, 1993

SUBJECT: Dual Phase Extraction (DPE) Implementation Plan
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.NT

Technology Overview

Description

Dual Phase Extraction (DPE) is a groundwater remediation technology that simultaneously extracts contaminants from the vadose, capillary fringe, and saturated zones. While conventional soil vapor extraction (SVE) systems and conventional pump-and-treat systems address only the zones above and below the water table, respectively, neither one directly addresses the capillary fringe. Insoluble contaminants tend to collect in the capillary fringe or "smear" zone due to low air flow and low water flows. This tends to represent one of the most difficult zones to remediate. DPE potentially can remediate all three zones at the same time.

There are two primary approaches for extracting water and soil vapors simultaneously from a single well. The first, known as DPE, uses pumping equipment located at the surface and an aspiration "straw" to remove groundwater and air in a common extraction stream. The other, known as Dual Extraction (DE), consists of a combination of conventional SVE and pump-and-treat systems in a single well. DE has been employed as an enhancement in settings conducive to conventional pump-and-treat (higher relative permeabilities), while DPE was developed specifically for very low permeability sites for which conventional pump-and-treat has been considered difficult or infeasible. The case histories for both systems include applications with groundwater depths that are much shallower than is typical at McClellan AFB. This Implementation Plan has been developed for DPE, as opposed to DE, because of the direct applicability of the DPE technology to very fine-grained, saturated zones of contamination, and, therefore, its potential applicability at McClellan AFB. However, this discussion of DPE is based on prior experience at groundwater depths of 10 to 30 feet, and whether its applicability holds true at groundwater depths of 100 feet remains to be demonstrated.

The DPE system consists of one or more wells, screened over a depth approximately 5 to 10 feet above the water table to a depth of about 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 injection wells screened above the equilibrium water table surface established during system operation.

High vacuum conditions are essential for DPE to be fully utilized. Also referred to as Two-Phase Extraction and High Vacuum Extraction, the process uses high vacuum (18 to 29 inches of mercury) at the smear zone/capillary fringe to remove soil vapor and groundwater by entrainment. The system extracts the groundwater and soil vapors using a central lift pipe, or "straw," as shown in Figure L4-1. In deep groundwater settings, the diameter of this straw can be a critical design parameter, since it directly influences the blower power requirements, the total flow rates, and the vacuum at the bottom of the straw. One of the side benefits is that volatiles present in the aqueous phase are stripped during transport up the straw, transferring as much as 95 percent by weight of the VOCs to the vapor phase (Radian, 1993).

DPE enhances groundwater removal rates and volatilizes contaminants from the sorbed and free-product phases. The high vacuum exerted by DPE increases the hydraulic gradient toward an extraction well, increasing well yield and extraction of dissolved contaminants. A dewatered zone is created in the vicinity of the well by pumping and is enhanced by the high vacuum applied. Air is drawn toward the well in the vadose and dewatered zones, and is extracted simultaneously with the water. The dewatering of the soil is vital for DPE to mobilize contaminants. The dewatered effect is maximized in fine-grained soils, where high vacuums can be maintained. Vapor-phase contaminants are entrained in the extracted air and removed from the subsurface; this effect is highest for contaminants with high Henry's constants, such as TCE and PCE. Contaminants that are sorbed onto the soil matrix may also be effectively removed in the air flow. A key benefit of the high vacuum employed by DPE is the ability to mobilize and remove NAPLs that are located in otherwise diffusion-limited formations such as moist clay.

The process can simplify remedial actions by eliminating the need for groundwater recovery pumps within individual wells. DPE also reduces water treatment requirements by volatilizing most of the aqueous phase contaminants during entrainment in the straw, resulting in lower concentrations in the aqueous phase requiring treatment. (Figure L4-1 shows a simplified schematic of DPE.)

Development Status

Full-scale field demonstrations have been performed at Xerox Corporation sites in New York, California, Illinois, and Canada (H&A). Multiple-well systems have been used in shallow applications (less than 30 feet) at sites in Webster, New York, and Irvine, California. Only one pilot test has occurred at depths of around 100 feet. Radian performed this single-well test for a confidential client in California.

Xerox Corporation is the developer of the DPE technology and holds the patent for all dual-phase systems that utilize a straw. H&A and Xerox have developed a pre-wired, skid-mounted system that can be purchased commercially. Use of the Xerox system/approach involves the payment of licensing and patent fees.

Radian is scheduled to conduct a DPE pilot test at three locations at McClellan AFB in the fall of 1993.

Potential Benefits

This subsection describes the performance, advantages and disadvantages, and cost benefits associated with DPE. This information is intended to provide a basis for evaluating the potential benefits of implementing the technology as part of the overall McClellan AFB groundwater cleanup program.

General Performance

The performance of DPE is measured by its ability to enhance contaminant mass removal rates from the subsurface.

Effectiveness

- Expected to be effective for removal of VOCs with Henry's constants greater than or equal to about 10^{-3} atm-m^3/mol.

- VOCs are removed from both the vadose zone and groundwater. This includes removal of persistent NAPLs that are otherwise difficult to remediate.

- According to Radian, achievable groundwater extraction rates can be increased 5 to 10 times compared to conventional pumping systems, and 95 percent of VOCs in extracted groundwater are transferred to the vapor phase in the straw.

- Deep groundwater at the Base could necessitate greater power requirements or alternative straw design relative to documented applications to achieve effective treatment.

Robustness

- The consistency of treatment is largely based on the ability to maintain high vacuum conditions. Layered strata at McClellan AFB could inhibit consistent and effective treatment.

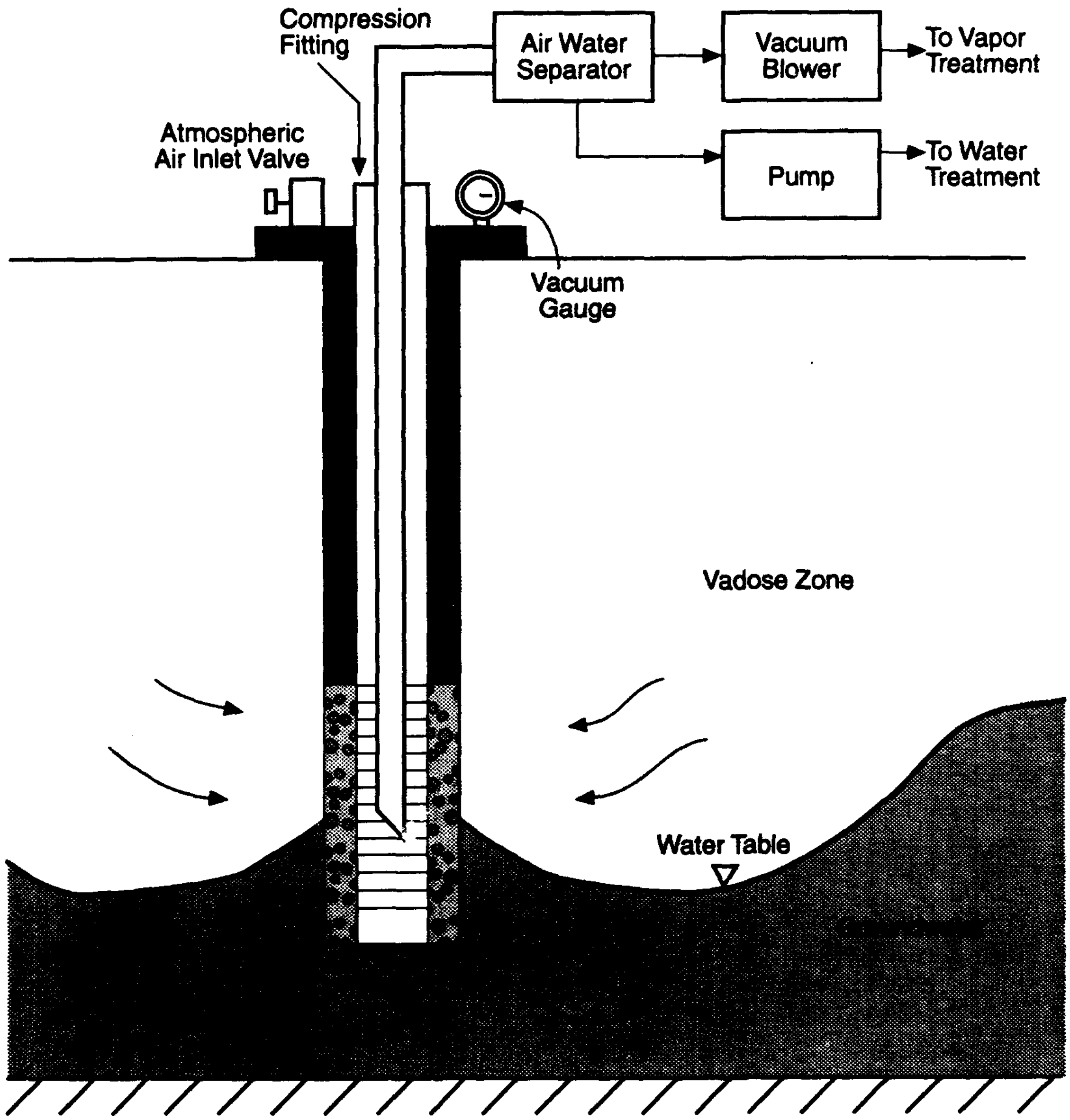

FIGURE L4-1
DUAL-PHASE EXTRACTION
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD 1454_66

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- The DPE system possesses a low to moderate turnup/turndown capability, and is fairly inflexible with respect to changes in flow rate of vapor and groundwater extraction systems. However, modular units could be operated in clusters to increase turnup capacity.

Potential Risk Reduction

DPE has the potential for removing contaminants from the zones that are otherwise difficult to remediate. NAPLs and sorbed sources in the capillary fringe can potentially be removed by this technology. Thus, some incremental risk reduction might be achieved through source removal.

  - Contaminant mass reduction in the vadose zone and capillary fringe may reduce the risk of continuing groundwater contamination.
  - Contaminant mass reduction in groundwater may reduce the risk of residual groundwater contamination.
  - Enhancement of contaminant removal may shorten the overall groundwater remediation time, and thus, risk.

Advantages Compared to Other Technologies

- Enhances removal of contaminants and NAPLs in the capillary fringe, which is otherwise difficult to treat.
- Effective contaminant removal has been demonstrated from low permeability soils (e.g., clays, silts) that are otherwise difficult to remediate.
- Enhancement of contaminant removal from the subsurface may reduce the overall groundwater remediation time.
- Groundwater and soil vapors are extracted from the same well by the same surface pump resulting in a decrease in equipment complexity.
- 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.
- Groundwater mounding is less than that which is normally encountered during conventional soil vapor extraction due to the simultaneous water extraction.
- As much as 95 percent of the VOCs in extracted groundwater is transferred to the vapor phase, which is more cost-efficient to treat.

Disadvantages Compared to Other Technologies

- DPE has been demonstrated to be effective at depths that are much shallower than will be necessary at McClellan AFB. At depths of about 100 feet, the advantage over conventional technologies may be reduced because of frictional losses in the aspiration straw. This uncertainty necessitates feasibility screening and design work efforts, which are not required for other technologies.

- The most successful demonstrations of DPE, compared to conventional technologies, have been in formations with very low hydraulic conductivities (e.g., silty clay). It is not yet clear that the low-to-moderate hydraulic conductivities more characteristic of McClellan AFB represent the same potential relative advantage for DPE. To resolve this uncertainty and verify the relative advantage of DPE at the Base will require pilot testing and/or extended operation, above and beyond that required by conventional technologies.

- The advantages (effectiveness and cost) of DPE over conventional DE systems are uncertain for sites with insufficiently low permeabilities to maintain high vacuum conditions.

- Application of the DPE technology is covered by patents held by the Xerox Corporation. The license fees are currently $5,000 per well used for more than pilot test purposes (more than 14 days). This represents an additional cost relative to other, non-patented technologies.

- Application of the technology in multiple-well configurations is not well documented in available case histories, and design guidance is not available for the well configurations expected to be needed at McClellan AFB. Relative to other technologies, this suggests an additional cost will be necessary to develop criteria for well spacing, optimum flows and vacuums, and other design parameters.

Relative Cost Benefit

To evaluate the overall potential effectiveness of DPE, one must look at each of the phases involved. In the vadose zone, DPE provides essentially no benefit over conventional soil vapor extraction systems. Below the water table, the groundwater pumping rate can be increased due to the high vacuum applied near the water table. More significantly, the upper portions of formerly submerged soil may be exposed to the air stream.

The greatest benefit of DPE applies to the capillary fringe that exists between the two zones. In this stasis zone, where air and water flows are very low, contaminants tend to be held in place. The soil is typically at least 60 to 80 percent saturated, a factor which significantly limits air permeability. This zone also retains insoluble contaminants. By lowering the water table, DPE reduces the moisture content of the capillary fringe and increases air permeability. The result is a change from a diffusion-limited condition to one in which removal is governed by the air flow rate.

The cost benefit of DPE would result from the increased rates of contaminant removal that could shorten the pump-and-treat operation time. Although a quantitative cost benefit cannot yet be accurately determined, it should be evaluated through an analysis of estimated savings associated with the reduced operation time of the pump-and-treat system compared with the capital and operating costs of the DPE system.

Potential Locations

Application of this technology should occur in regions of fine-grained, low permeability soils to support high vacuum conditions and maximize water drawdown and exposure of the capillary fringe. DPE systems should be located within hot spot plumes that have significant contamination in the smear zone at the surface of the water table, to maximize the potential contaminant mass removal.

The use of existing wells is limited to those that are screened over both the vadose and saturated zones. The screen would need to span about 5 feet above and 10 feet below the water table.

Locations on the east side of the base are, in general, less permeable than those on the west side. For this reason, Radian is performing DPE pilot testing in OU A and OU B. Hot spot areas in OUs A and B with appropriately low permeabilities are potentially suitable locations for full-scale implementation of DPE. However, specific location recommendations should be deferred until the pilot testing performance is evaluated.

Approach

Information Needs and Sources

Table L4-1 lists information requirements and sources for implementation of DPE.

Information Gathering and Review

Preliminary information gathering has consisted of a review of available reports, including the Radian Work Plan for the Fall 1993 pilot test, and conversations with Xerox representatives about the modular treatment units. Further information gathering should focus on the results of the McClellan AFB pilot test. Radian will perform that study in two stages at three locations. The first stage will consist of short-term tests of approximately 1 to 2 days duration per well (Radian, 1993). The second stage will consist of either additional short-term tests at alternate test wells or long-term tests of greater than 100 hours duration. How well the technology performs will influence the implementation program and design. Analysis of the results will indicate whether additional pilot testing is needed, what refinements are necessary, and what locations are potentially applicable. Alternately, the pilot testing results may indicate that the technology is not applicable or cost-effective at McClellan AFB and that implementation should be halted for DPE, and possibly transferred to a DE-based program.

Implementation Issues

- For DPE, both the extracted groundwater and the offgas stream will require treatment and discharge, resulting in the need for permits.

- The DPE system is patented and costs $20,000 per site for the licensing fee, plus $5000 per well where DPE is applied for more than 14 days.

- Other issues that could affect implementation include the generation of additional data suggesting that DPE could not be cost-effectively implemented in the target locations. For example, contaminant distributions or zones of higher permeability soils in hot spot areas may make DPE impractical.

Bench-Scale Testing

Bench-scale testing is not needed for the implementation of DPE at McClellan AFB.

Pilot-Scale Testing

Objectives

The two primary goals of pilot-scale testing are to evaluate the feasibility of DPE at McClellan AFB, and, if feasible, to determine critical full-scale design and operating parameters. The feasibility evaluation includes the following objectives:

- Evaluate contaminant removal rates achieved by DPE compared to conventional groundwater extraction.

- Characterize the aquifer response (drawdown) created by a network of DPE wells.

- Measure the air flow rate achievable and water the yield compared to conventional pumping.

- Evaluate the ability to establish and maintain target vacuum levels at the capillary fringe (i.e., at the bottom of the straw) in a deep well.

Table L4-1
Dual Phase Extraction
Information Requirements and Sources

Information Needed for Pilot and Full-Scale Implementations	Info Source	
	Pilot	Full
Contaminant Characterization		
• Contaminant Types	S	S
• Soil Gas Concentrations	S	S,P
• Aqueous Concentrations	S	S,P
• Treatment Requirements	L	L
• Contaminant Geometry	S,L	S,L
Subsurface Characterization: Hydrogeology		
• Flows	M	M
• Static Water Levels over time	S,L	S,L
• Water Chemistry Parameters	S	S
Subsurface Characterization: Geology		
• Soil Types	S	S
• Soil Heterogeneity	S,M	P,S
• Air Permeability	S,L	P
System Design: Physical Configuration		
• Number of wells	L,M	P,L,M
• Well spacing	L,M	P,L,M
• Screened Intervals	L	P,L
• Straw Diameter	L,V	P,L,V
• Straw Depth	L,M,V	P,L,V
System Design: Equipment Requirements		
• Number of Modular Units	L,V	P,V
• Patent Requirements	V	V
• O & M Requirements	L,V	P,V
• Blower Size	L,V	P,L
Performance Capabilities		
• Air Flow Rates, Concentrations	L,S	P,S
• Water Flow Rates, Concentrations	L,S	P,S
• Mass Removal Rates	L,M	P,M
• Vacuum applied/received ratio	L	P
• Monitoring (Sampling & Analysis Requirements)	L	L,P
• Response to Waste Stream Variabilities	L,V	P,V
Residuals Management		
• Physical Configuration (inlet separators, piping)	L,V	P,V
• Vapor flows, concentrations	S,L	P
• Aqueous flows, concentrations	S,L	P
• Permitting Requirements	L	L

Notes:
L = Literature/Experts — B = Bench Scale
P = Pilot Scale — S = Sampling Results
V = Vendor — M = Modeling/Other Evaluations

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- Establish preliminary ranges of geologic, engineering, and economic parameters for selection of DPE over conventional groundwater extraction.

- Evaluate the cost-effectiveness of DPE compared to a conventional groundwater pump-and-treat system. Develop order-of-magnitude cost estimates and schedule for full-scale remediation.

If DPE appears feasible, the second objective of pilot-scale testing would be to determine the following design and operating parameters:

- Optimum straw depth and diameter
- Determine adjacent site response
- Effect of a central, passive injection well in a multiple well setting
- Radius of influence and well spacing in a multiple well application
- Effect of different applied vacuums and injection well flow rates

Approach

It is presumed that a multiple-well, modular system will be required to treat hot spot plumes at McClellan AFB. Multiple-well pilot-scale testing would involve the installation of up to three DPE wells and one injection well that would be used to collect design and operation parameters necessary for full-scale implementation. In order to compare DPE with conventional pump-and-treat, a standard 24-hour aquifer test would be performed prior to DPE operation. Evaluation of multiple-well spacing and zone of influence, optimal straw diameter, and the benefits of a passive injection well would be the major parameters evaluated in a second phase of pilot testing. The specific objectives and approach of the pilot-testing program would be refined and detailed following additional information gathering and review. The general approach to pilot-scale testing is outlined below.

1. Prepare system installation and operation work plan.

2. Select an appropriate hot spot for test site. The areas of the existing DPE pilot testing could be considered for possible modification and use as the test site.

3. Conduct modeling using conventional groundwater and soil vapor extraction approaches to estimate the radius of influence for DPE wells and target extraction vacuum.

4. Perform a 24-hour conventional aquifer test.

5. Initially, install one DPE well within the hot spot, screened over an interval approximately 5 feet above and 10 feet below the water table.

6. Install nested piezometers at radial distances from the extraction/ injection wells in two directions, separated by an angle of 90 degrees. Nested piezometers should be screened at a minimum of two depths in the vadose zone and in the saturated zone.

7. Bring the first DPE well online. Once performance has been established, additional DPE wells would be constructed and brought online. The piezometers would be monitored to determine radius of influence of each DPE well and, possibly, to characterize the effects of heterogeneities with respect to depth in the subsurface between the DPE wells and piezometer nests.

8. Install one passive injection well within the radius of influence of the extraction well screened such that the screened interval is in the vadose zone, within 20 feet of the top of the saturated zone. The well would have flow control achieved through a valve and flowmeter placed at the top of the well.

9. After the multiple-well system reaches equilibrium, additional adjustments to vacuum and flows would be made to determine optimal performance and test multiple well systemic effects.

10. The system would be operated for a period sufficient for the system to reach equilibrium between adjustments.

11. The pilot system would require an offgas treatment system such as GAC, and extracted groundwater would be transported or piped directly to the existing groundwater treatment plant.

12. Analyze data to evaluate performance of each test condition and assess the potential benefit of DPE to the overall groundwater remediation program.

13. Decide whether to proceed with full-scale implementation.

Full-Scale Implementation

Pilot-scale results are necessary to complete a full-scale system design. However, an example conceptual design is outlined below to illustrate the major elements of a full-scale system and to provide a basis for a rough order-of-magnitude cost estimate. Rather than developing a conceptual design for a particular location, a modular approach was used to develop an estimated range of costs per unit acre for full-scale implementation.

The example conceptual design is based on the following key assumptions:

- Each module consists of four extraction wells piped to a DPE skid. The skid contains an air/water separator; a high vacuum, continuous-duty blower; and piping connections to the offgas and groundwater treatment systems. A process schematic is provided in Figure L4-2. A conceptual layout of modules at a hypothetical hot spot is depicted in Figure L4-3.

- The spacing of the DPE wells varies from 30 to 50 feet on center, based on initial calculations of radius of influence. These calculations presumed the following generic conditions:

    - Water transmissivities of 10 ft^2/day and 100 ft^2/day to provide range

    - Well efficiency is 100 percent

    - Groundwater extraction from DPE is approximately 5 to 10 times greater than under ambient conditions

    - Well screen length is 15 feet, from 10 feet below and 5 feet above the water table prior to extraction

- Approximate coverage by one module ranges from 3,600 ft^2 (12.1 modules per acre) to 10,000 ft^2 (4.4 modules per acre), depending on well spacing.

- Approximate ranges of flows from each module are 50 to 250 cfm vapor and 2 to 10 gpm water.

- Each DPE conceptual module includes two injection wells. For every ten extraction and injection wells, there will be one groundwater monitoring well.

- Offgas treatment is localized at the hot spot, and shared by all modules.

Technology Limitations and Uncertainties

The critical limitations and uncertainties of technology implementation are listed below.

- Subsurface heterogeneities are expected to significantly influence DPE effectiveness. Zones of low-to-moderate permeability will result in difficulty maintaining sufficiently high vacuums. Careful site characterization during well installation should identify these zones prior to completion of the well.

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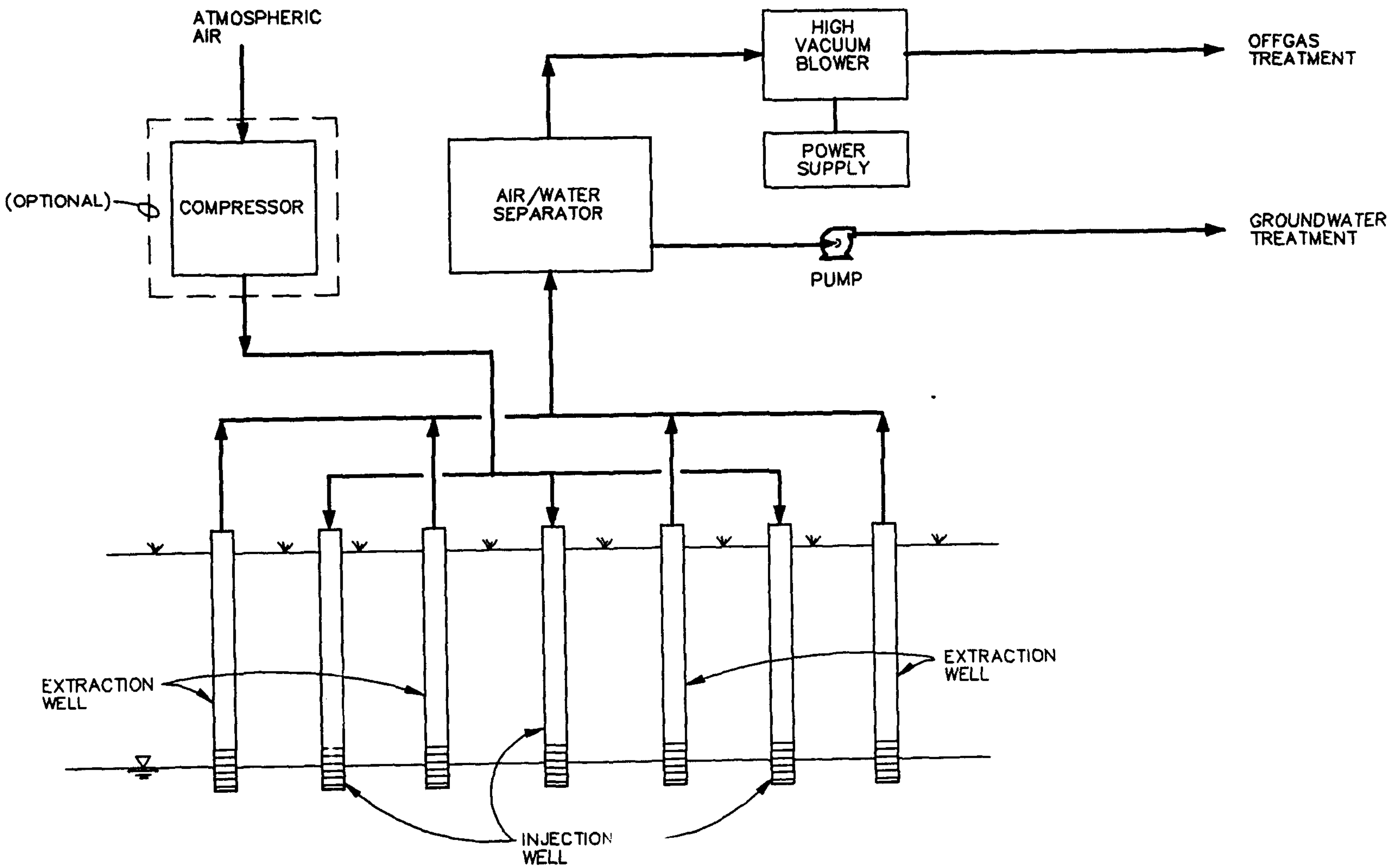

FIGURE L4-2
DPE CONCEPTUAL PROCESS SCHEMATIC
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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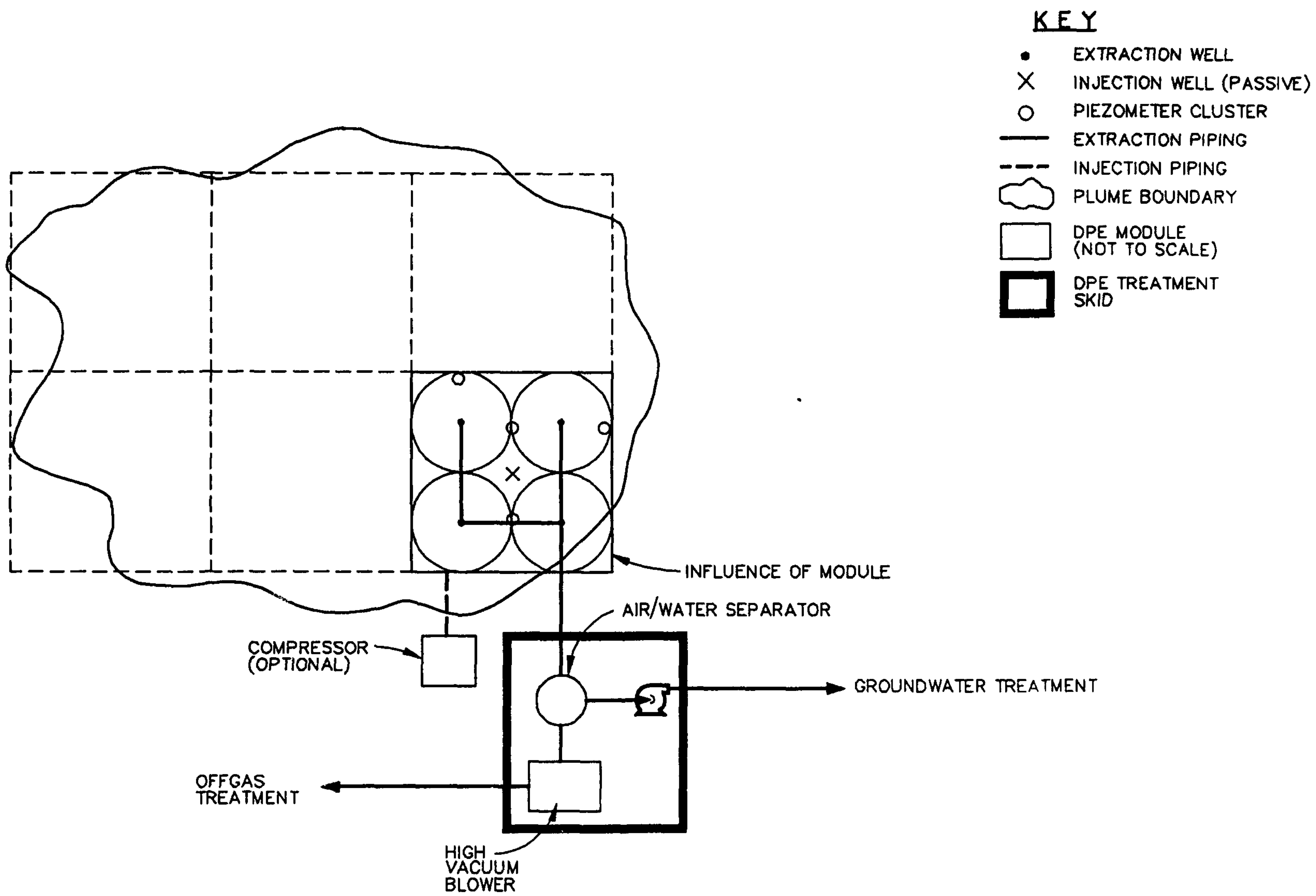

FIGURE L4-3
DPE CONCEPTUAL LAYOUT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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- The operational parameters and design requirements for deep well systems have not been defined. There is warranted concern that frictional forces in a small-diameter straw will impose head loss, which prevents reaching the target vacuum of 20 inches of mercury at the base of the well. Modifications to the DPE system may be necessary to correct this problem.

- The effect of repeated startup/shutdown periods on the movement of contaminants is uncertain.

- The interactions of DPE wells in a multiple-well setting have not been well documented. The above approach to pilot-scale testing attempts to investigate these interactions. Of particular concern is the behavior of groundwater and the capillary fringe in the area between DPE wells.

Schedule

An implementation schedule is shown in Figure L4-4.

Cost

This section presents an estimated range for order-of magnitude implementation costs based on the conceptual design. Implementation costs include costs associated with: ongoing literature review, pilot-scale testing, and full-scale capital expenses and annual operations and maintenance. The scope of eac' of these cost-related activities is summarized below:

- **Literature Review.** Technology researchers are likely to further develop the technology such that enhancements (optimization) and limitations will be better understood. The decision to proceed with further implementation of DPE requires ongoing assessment and review of these research results. While this activity is not a significant cost factor of implementation, it is an important implementation activity.

- **Pilot-Scale Testing.** This activity includes costs associated with scope and work plan development, contract procurement, equipment procurement, system installation, system operation, demobilization, sampling and analysis (system monitoring), evaluation of system performance, and reporting.

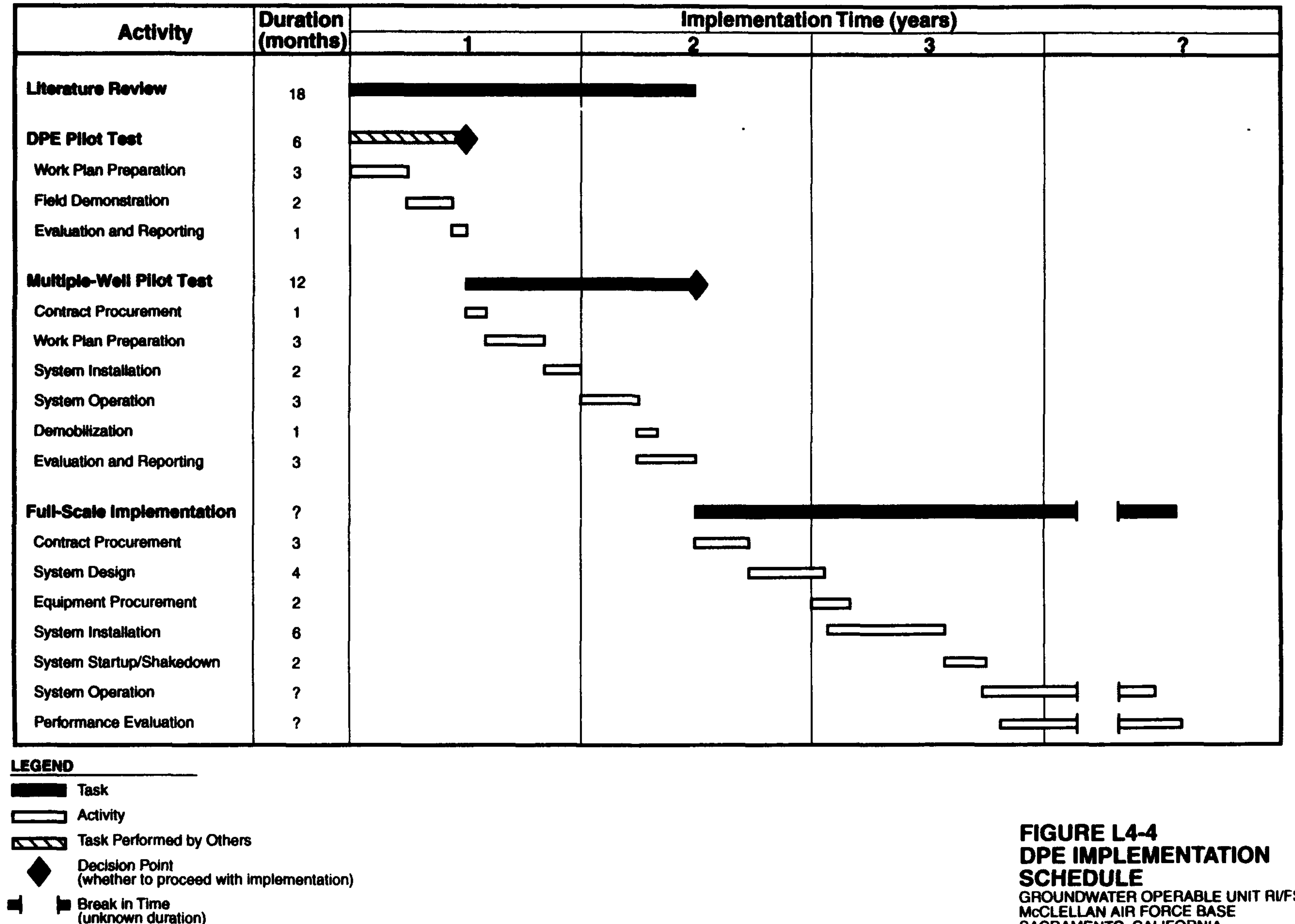

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FIGURE L4-4
DPE IMPLEMENTATION SCHEDULE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

- **Full-Scale Capital.** Capital costs are direct and indirect costs required to initiate and install the technology system components, including (but not limited to) engineering design, mobilization and demobilization of equipment and people, site construction (i.e., well installation) activities, contractor bonding and insurance, equipment procurement and installation, licensing and permitting, health and safety, and supervision during construction.

- **Full-Scale Operation and Maintenance.** Operation and maintenance (O&M) costs represent those costs which would be incurred during each year of operation from initial startup to final shutdown of the full-scale system. O&M costs include operations and maintenance labor, power, sampling and analysis, and residual waste stream treatment. Since annual O&M costs occur over a period of years, future costs have been discounted to the present year's equivalent value (i.e., the present value cost) using 5 percent interest, so that annual costs remain comparable. Actual annual costs are likely to be much higher during the first year(s) of operation as the system is commissioned and optimized for operation, and due to higher chemical usage rates and associated labor required for treating higher initial concentrations. Therefore, the annual costs are intended to represent the anticipated average yearly cost of operation over the life of the system.

A contingency of 30 percent has been applied to the full-scale implementation cost to account for possible project cost increases due to scope and bid variations that typically occur with hazardous waste remediation projects. These increases are typically caused by the changes which normally occur as part of final design and implementation, based on observation of actual field conditions, and factors which affect the cost of subcontracted services, such as labor and material shortages. Not included in the estimates are any agency or Air Force administrative costs, nor any costs associated with modifications of the existing groundwater treatment system(s).

Typically, order-of-magnitude cost estimates for general construction projects are intended to reflect an accuracy of within 50 percent greater to 30 percent less than actual costs. The estimates summarized below are expected to be within these ranges; however, there is greater uncertainty of accuracy as a result of the lesser degree of development associated with this innovative technology compared to general construction technologies. Current pricing data based on quoted equipment costs, construction cost data (e.g., Means, 1993), previous local project experience, and engineering judgment have been used to generate the estimates, using adjustments for local McClellan AFB costs when available. Final project costs will depend on actual labor and material costs, actual site conditions at the time of implementation, productivity, competitive market conditions, final project scope and schedule, contractors selected to perform activities, and many other variables. As a result, the final project costs will differ from the exact value of any estimates presented here.

The following order-of-magnitude implementation costs are estimated for DPE:

- Literature review will require approximately $24,000 over a period of 2 years.

- Multiple-well pilot-scale testing is estimated to cost approximately $340,000.

Full-scale implementation costs on a per acre basis are summarized in Table L4-2. The estimated costs for construction and operation of a full-scale system range from approximately $5.9 M/acre (for 50-foot well spacing and 3 years' operation) to $22.6 M/acre (for 30-foot well spacing and 5 years' operation). Key assumptions associated with the implementation cost estimate, in addition to those previously described, include:

- Full-scale costs are reported on a per acre basis. Costs were estimated for a five-module (20 DPE wells) system and converted to per acre costs.

- Licensing costs are a one-time $20,000 site fee, plus $5,000 per well in which DPE is utilized for more than 14 days.

- DPE skid-mounted units (from H&A of New York) can be purchased for approximately $50,000. These units include a 50 hp high vacuum blower, an air water separator, and piping connections for offgas and groundwater treatment systems.

- Twelve man-days per well are assumed to install a DPE well. This includes drilling, well completion and well development, straw installation, and all surface plumbing. Nine man-days per well are assumed for a passive injection wells, and nine man-days per well for groundwater monitoring wells.

- VOCs are removed at an average rate of 100 lb/day per module in the vapor phase over the operational period of the system. Assumed cost for offgas treatment is $5/lb VOCs, and is a significant cost factor.

- It is assumed that one 30 hp offgas blower rated at 900 cfm at 2-inch of mecury can service five modules for offgas collection for onsite treatment.

- It is assumed that one pump, rated at 5 to 50 gpm, can service ten modules for groundwater transport to the existing groundwater treatment plant. Additional costs for groundwater treatment are included in the estimate.

- Each module contains 500-foot PVC pipe.

Table L4-2 Dual Phase Extraction Order-of-Magnitude Implementation Cost Summary				
	Range of Costs ($/acre)			
Activity	Low[a]	Low - Intermediate[b]	Intermediate - High[c]	High[d]
Full-Scale Capital	1,960,000	1,960,000	5,390,000	5,390,000
Full-Scale O&M (Present Worth for All Years)	3,930,000	6,250,000	10,810,000	17,190,000
Full-Scale Implementation Cost	5,890,000	8,210,000	16,200,000	22,580,000

Notes:
[a]Based on 50 feet well spacing and 3 years of operation.
[b]Based on 50 feet well spacing and 5 years of operation.
[c]Based on 30 feet well spacing and 3 years of operation.
[d]Based on 30 feet well spacing and 5 years of operation.

Other significant assumptions include:

- $5/lb VOCs offgas treatment cost
- 100 lbs/day per module average removal rate
- 90 percent system on-time
- Annual sampling and analysis, and performance evaluations included in operational cost
- 30 percent contingency factor applied

- System operational time is assumed 90 percent, or 7,884 hours per year per well.

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H&A, New York, New York. Conversations with representatives during October 1993.

Radian Corporation, Operable Units A & B Dual Phase Extraction Pilot Testing, Draft Work Plan, September 1993.

Two-Phase Vacuum Extraction, "Business Confidential" Enclosures, McClellan AFB Private-Public Partnership Meeting, Alexandria, Virginia, December 1992.

Appendix L5

PREPARED FOR: McClellan Air Force Base

DATE: November 7, 1993

SUBJECT: SVE/Sparging Implementation Plan
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.NT

Technology Overview

Description

Soil vapor extraction/sparging, also referred to as "groundwater aeration" or "sparging," is sometimes used as 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. The sparged air travels upward into the vadose zone through buoyant forces, and the contaminants are withdrawn through standard vapor extraction wells installed in the vadose zone. Air sparging may enhance biodegradation of contaminants amenable to aerobic degradation through the increased supply of oxygen to the subsurface; and, conversely, may inhibit biodegradation of compounds by anaerobic mechanisms. The most likely niche for SVE/sparging is at sites with readily (aerobically) biodegradable contaminants in or near the smear zone immediately above the groundwater surface (capillary fringe) and/or floating light nonaqueous phase liquid (LNAPL).

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, the slow transport rates of dissolved contaminants in the aqueous phase to the air-water interface limit removal effectiveness. Air sparging is expected to significantly increase this rate of contaminant transport within soil macropores that are developed (Noonan et al., 1993), especially in the smear zone/capillary fringe.

Schematics showing the two most common configurations of an SVE/sparging system are depicted in Figure L5-1. Figure L5-1 shows vertical and horizontal well configurations; other configurations such as a combination of vertical and horizontal wells, are also possible. The optimal configuration for implementation of SVE/sparging at a given site at McClellan AFB will depend on the lithology, contaminant distribution, and size of the targeted treatment area.

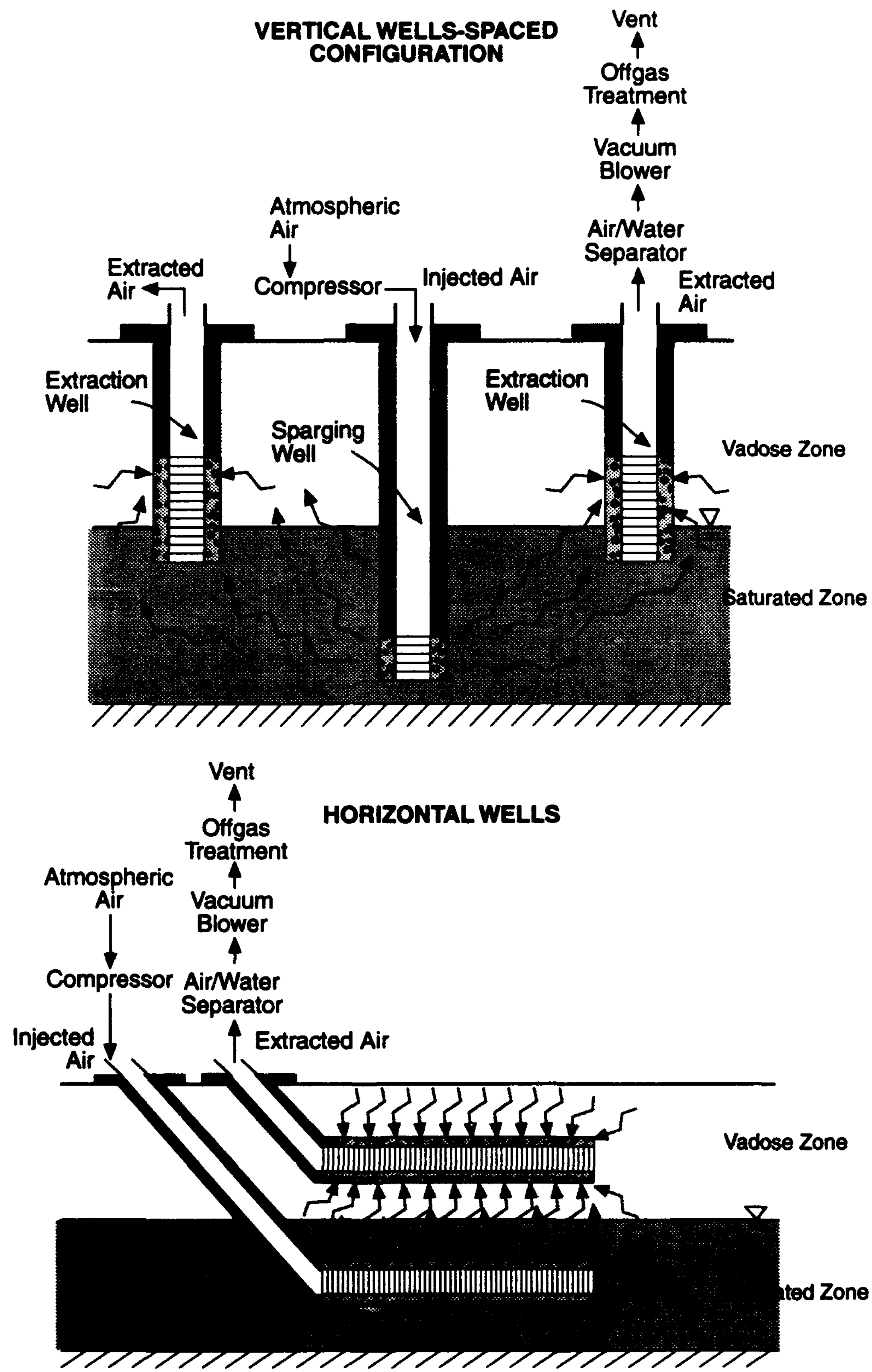

FIGURE L5-1
SVE/AIR SPARGING CONFIGURATIONS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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CH2MHILL

SVE wells are installed in the vadose zone, generally in close proximity to the groundwater table. Vapor extraction and contaminant removal is achieved with an aboveground system consisting of an air/water separator, vacuum blower, and offgas treatment system. An air sparging system consists of a well screened only in the saturated zone and an aboveground, oil-free compressor that is used to inject air into the well. Under certain circumstances an alternative injection gas, such as nitrogen, can be injected. For example, nitrogen sparging could be employed to avoid disruption of natural anaerobic biodegradation of contaminants.

The design of an air sparging system requires: the knowledge of subsurface properties such as air permeability, soil particle size, soil stratification, soil classification, and groundwater behavior; identification of injection and extraction well locations and design; desired air flows and expected SVE offgas contaminant concentrations; and the selection and sizing of aboveground equipment.

Development Status

A recent review (Camp, Dresser and McKee, Inc., 1992) listed 20 sites that have been remediated using SVE/sparging. In approximately half of those sites, chlorinated VOCs (PCE, TCE, TCA, etc.) were the primary contaminants. The technology has primarily been applied at sites with fairly homogeneous, permeable soils or highly fractured rock formations. Of the 20 sites identified, only two had depths to groundwater of roughly 100 feet bgs (90 and 135 feet bgs).

There are a number of companies that claim to have air sparging experience. The most aggressive promoters of the technology are Groundwater Technology and Vapex Environmental Technologies, Inc. (VAPEX). CH2M HILL has had mixed success with sparging. In some cases sparging has been very successful, but on other projects the results have been less conclusive. A perceived limitation of air sparging is that much of the published literature has not received peer review, and many of the failures of sparging are not reported. Therefore the applications and potential benefits may sometimes be overstated. However, this limitation is beginning to change as consultants and university researchers have begun to provide a more critical analysis of air sparging.

Potential Benefits

This subsection describes the performance, advantages and disadvantages, and cost benefits associated with SVE/sparging. This information is intended to provide a basis for evaluating the potential benefits of implementing the technology as part of the overall McClellan AFB groundwater cleanup program.

General Performance

The performance of SVE/sparging is measured by its ability to enhance contaminant mass removal from the subsurface.

Effectiveness

- Expected to be effective for removal of prevalent VOCs in subsurface at McClellan AFB. Contaminant removal will be most effective in the smear zone/capillary fringe, but removal effectiveness in saturated zone is uncertain.

- Contaminant removal efficiency will depend on soil stratigraphy, soil air permeability, aquifer characteristics, well layout, and process control.

Robustness

- VOCs are amenable to removal by SVE/sparging.

- Semi-VOCs and nonvolatile organics are not physically removed by stripping but may be biodegraded.

- Potentially effective over a wide range of concentrations. In general, mass removal rates are higher when contaminant concentrations are greater.

- System efficiency may be reduced by chemical or biological fouling of well screens.

- A properly designed monitoring and control system is required to maintain operational consistency and identify process upsets.

Potential Risk Reduction

- Removing contaminant mass from the vadose zone and smear zone reduces the risk of continuing groundwater contamination.

- Enhancing contaminant mass removal rates may reduce the time required to reach groundwater remediation goals.

Advantages Compared to Other Technologies

- SVE/sparging can potentially enhance removal of contaminants from the smear zone, which is otherwise difficult to treat.

- Contaminant desorption from soils in the saturated zone may be enhanced through the induced mixing and turbulence at soil-air-water interfaces, primarily in macropores.

- VOCs removed in the vapor phase are generally less expensive to treat than those removed in the liquid phase.

- Treatment of aerobically biodegradable organics may be promoted.

- SVE/sparging in conjunction with pump-and-treat can potentially reduce remediation time compared to pump-and-treat alone.

Disadvantages Compared to Other Technologies

- SVE/sparging may not effectively remove contaminants from groundwater. Air channeling is likely to occur, resulting in poor treatment in saturated zone.

- Horizontal channeling can reduce effectiveness and result in the uncontrolled migration of contaminants.

- Biological fouling and metals precipitation on well screens can occur, reducing effectiveness.

- Naturally occurring anaerobic degradation of some chlorinated organics may be inhibited.

- Air bubbles can become trapped in saturated macropores limiting overall contaminant removal and oxygen transfer.

Relative Cost Benefit

The cost benefit of SVE/sparging would result from increased rates of contaminant removal that could shorten the pump-and-treat operation time. Cost benefit should be evaluated through an analysis of estimated savings associated with the reduced operation time of the pump-and-treat system compared to the capital and operation costs of the SVE/sparging system.

Potential Locations

SVE/sparging is most effective when applied to the removal of contaminants from the smear zone in highly permeable soils with relatively low heterogeneity. Implementation of this technology at McClellan AFB would be most effective when applied in areas with high contaminant levels in the smear zone/capillary fringe subsurface hot spots. This type of application would provide source reduction in the smear zone, reducing the potential for long-term contamination of groundwater.

Because moderate-to-high permeabilities are required, hotspot locations in OU C and OU D are potentially suitable for SVE/sparging application at the Base. However, a thorough review of subsurface characterization data would be needed to select an exact location with the appropriate conditions (with respect to permeability, heterogeneity, and contaminant distribution) for implementation.

Approach

Information Needs and Sources

Table L5-1 provides a summary of the information needs and sources for implementation of SVE/sparging.

Information Gathering and Review

Information on SVE/sparging collected to date includes published literature, conference presentations, vendor literature and interviews, and consultations with CH2M HILL experts (see Works Cited section). The first step for implementation of this technology should be a detailed review of case studies of actual applications of the technology and of McClellan AFB subsurface characterization data. The intent of this review would be to evaluate the feasibility and potential effectiveness of SVE/sparging at the Base and to identify appropriate location(s) for implementation. If the existing site characterization data are not entirely sufficient to determine implementation locations, collection of additional field data, such as soil boring data and/or soil gas measurements may be needed.

Implementation Issues

- The SVE offgas would have to be treated to reduce VOC concentrations to levels compatible with the Basewide air emissions permit.
- Environmental Improvement Technologies (Billings and Associates, Albuquerque, New Mexico) has been awarded a patent that covers the broad application of air sparging. The applicability of the patent to implementation of SVE/sparging at the Base would need to be investigated.
- The potential for lateral migration of contaminants resulting from horizontal channeling of injected air would have to be minimized through proper location selection and system design and operation. Control of any horizontal migration would be demonstrated during startup of system operation.

Bench-Scale Testing

No bench-scale testing is needed for the implementation of SVE/sparging at McClellan AFB.

Table L5-1
SVE/Air Sparging
Information Needs and Sources

Information Needs	Project Scale	
	Pilot	**Full**
Contaminant Characteristics		
• Contaminant Types	S	S
• Soil Gas Concentrations	S	S
• Aqueous Concentrations	O,S	P
• Treatment Requirements	S	S
Subsurface Characterization		
• Soil Types and Stratigraphy	S	S
• Air Permeability	S	P
• Groundwater Behavior	S	P,S
• Water Chemistry Parameters	S	S
System Design		
• Number and Location of Wells	L,O	P,O
• Well Configuration (Diameters and Screened Depth)	L,O	P,O
• Injection/Extraction Flow Rates and Pressures	L,O	P,O
• Offgas Treatment Requirements	L	L
• Piping and Control Systems	L	P
• Permitting Requirements	L	L,P
• Patent Requirements	L	L
Performance Capabilities		
• Mass Removal Rates	L,O	P
• Monitoring (Sampling and Analysis Requirements)	L	L,P
• Response to Waste Stream Variability	L	P
Operations & Maintenance		
• Utility Connections/Installation Requirements	L	P
• Preventative Maintenance Requirements	L	L,P
• Safety	L	L,P

Notes:
L = Literature/Experts
O = Other Technology Evaluations, Modeling
P = Pilot Scale
S = Sampling Results

Pilot-Scale Testing

Objectives

- Determine air permeability of vadose zone soils and evaluate heterogeneities in the saturated and unsaturated zones in the target area.
- Determine mass removal rates for each contaminant by SVE, and the net increase in the removal rate by sparging.
- Establish a radius of influence for the sparging and vapor extraction wells at varying flow rates and pressures.
- Provide a basis for the determination of number and location of wells.
- Determine the offgas characteristics in order to identify offgas treatment system details.
- Develop design and operating criteria for aboveground equipment for a full-scale system.
- Evaluate the efficacy of sparging at >100-foot bgs depth and assess operational problems associated with depth.

Approach

Pilot-scale testing would involve the installation of one or more extraction and sparging wells that would be used to develop design and operation parameters necessary for full-scale implementation. The specific objectives and approach of the pilot-testing program would be refined and detailed following additional information gathering and review. The general approach to pilot-scale testing is outlined below.

An economical location for conducting a SVE/sparging test would be Site S in OU D. Significant cost savings could be achieved because vapor extraction wells/equipment, piezometers, and an offgas treatment system are installed and operational. Also, site characterization, air permeability, and SVE performance data exists for that location. New equipment required for the SVE/sparging pilot test would be limited to one or more injection wells and associated aboveground compressors for air injection.

1. Confirm appropriateness of Site S for SVE/sparging pilot test.
2. Prepare system installation and operation workplan.
3. Estimate required sparging pressure based on soil permeability, depth below groundwater table, and expected friction loses.

4. Install one or more injection wells.

5. With the extraction wells at equilibrium, begin air injection at a target pressure.

6. Operate the system until pressure at piezometers and offgas contaminant concentrations stabilize.

7. Operate the system at different pressures and/or flow rates, and evaluate effects of intermittent blowers and compressors.

8. Analyze data to evaluate performance, incremental contaminant removal due to sparging, and potential benefit of the SVE/sparging technology to the overall groundwater remediation program.

9. Decide whether to proceed with implementation at full-scale.

Full-Scale Implementation

Pilot-scale results are necessary to complete a full-scale system design. However, an example conceptual design is outlined below to illustrate the major elements of a full-scale system and to provide a basis for a rough order-of-magnitude cost estimate. Rather than developing a conceptual design for a particular location, a modular approach was used to develop an estimated range of costs per unit acre for full-scale implementation.

The example conceptual design is based on the following key assumptions:

- Each module consists of four vertical extraction and four vertical sparging wells piped to a skid containing an air/water separator, continuous-duty vacuum blower, oil-free air compressor, and piping connections to the offgas and groundwater treatment systems. A process schematic is provided in Figure L5-2. A conceptual layout of modules at a hypothetical hotspot is depicted in Figure L5-3.

- The spacing of the extraction wells varies from 40 to 70 feet on center, based on initial estimates of radius of influence. This range is based on:

  - A soil permeability of 0.1 to 1.0 darcy
  - An extraction vacuum applied to the subsurface of 40 inches of H_2O

- Approximate coverage by one module ranges from 6,400 ft^2 (6.8 modules/acre) to 19,600 ft^2 (2.2 modules/acre), depending on well spacing.

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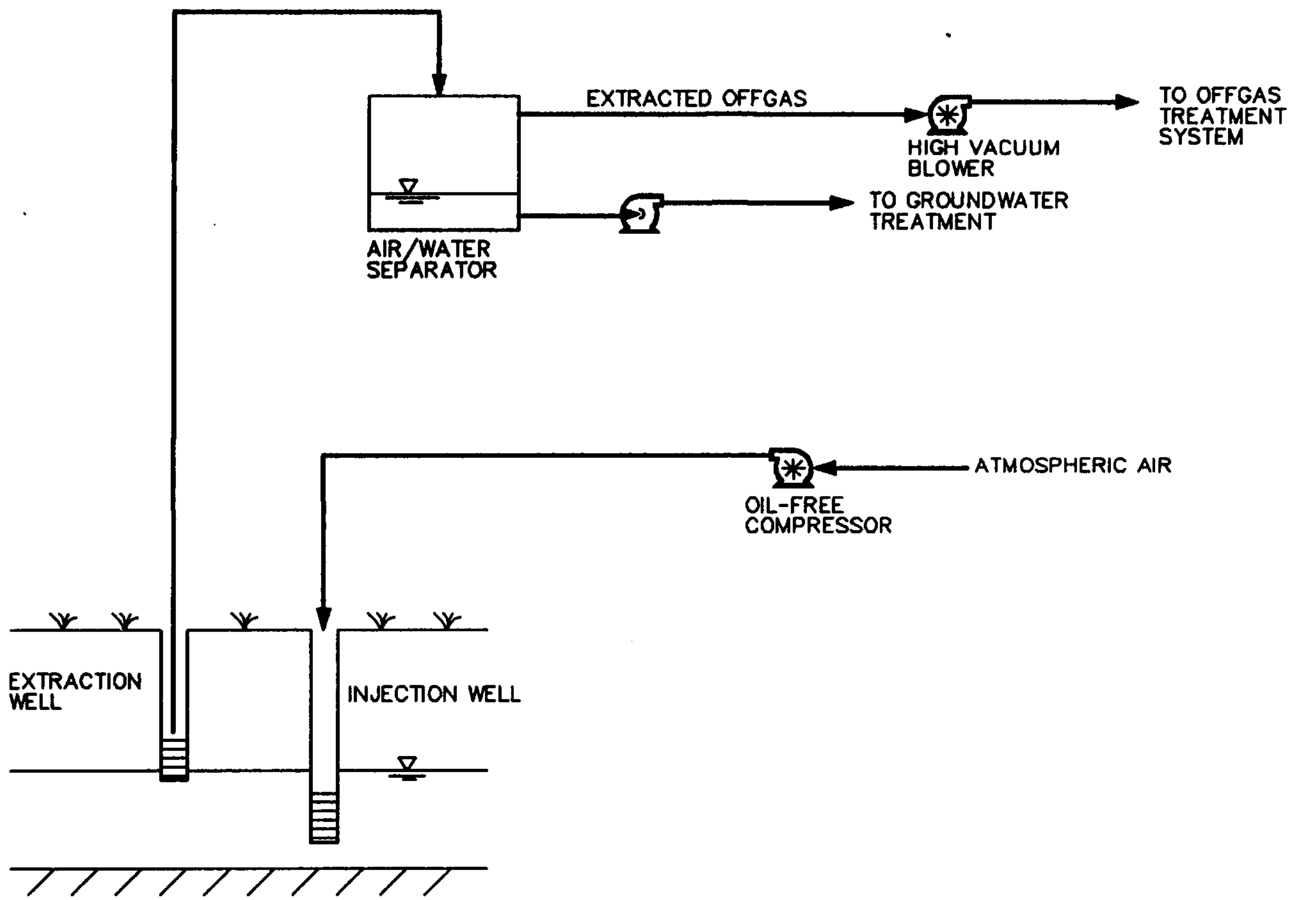

FIGURE L5-2
SVE/AIR SPARGING
CONCEPTUAL PROCESS SCHEMATIC
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

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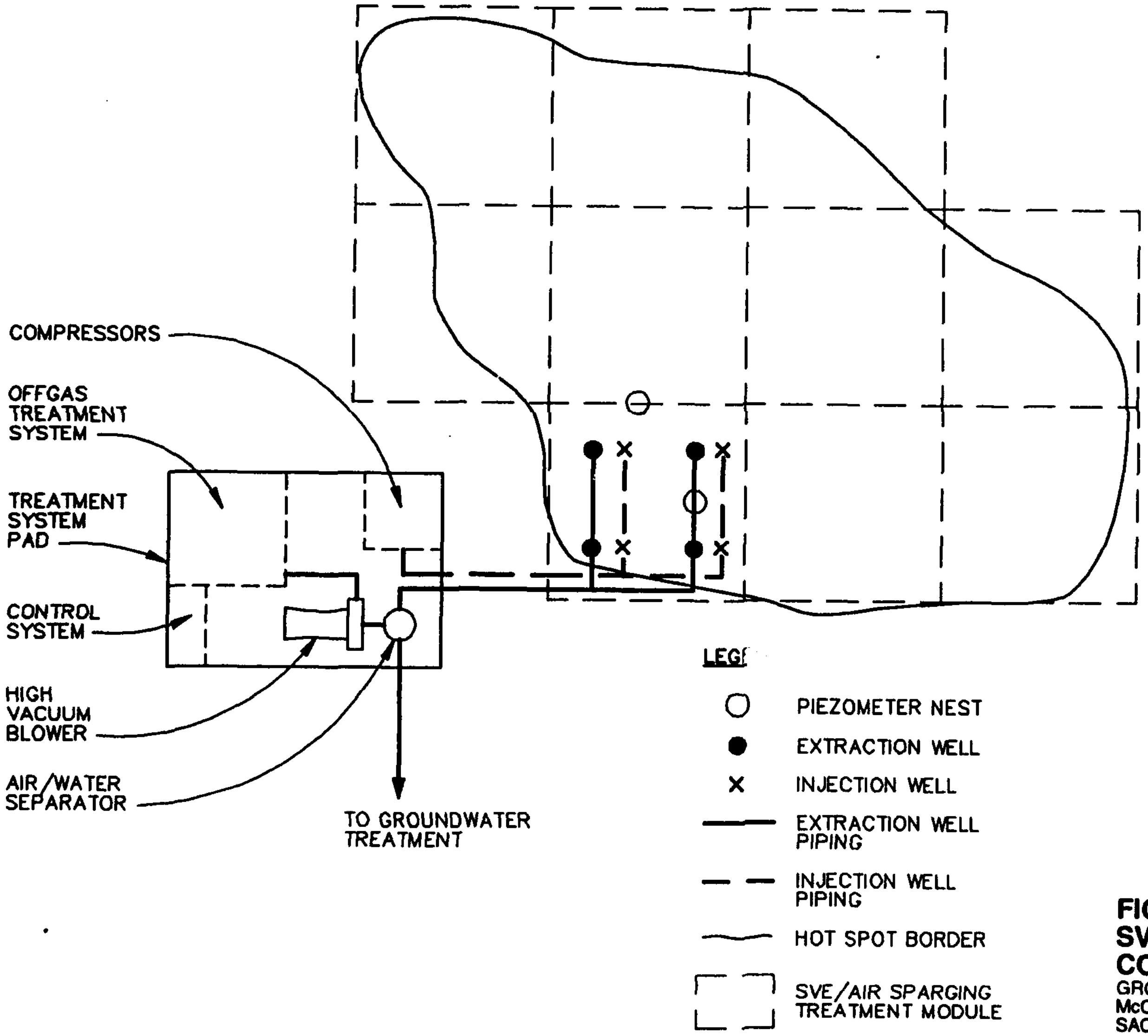

FIGURE L5-3
SVE/AIR SPARGING SYSTEM CONCEPTUAL LAYOUT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

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- Approximate ranges of flows from each module are 10 to 100 cfm.
- For every 10 extraction and injection wells there will be 1 groundwater monitoring well.
- Offgas treatment is localized at the hotspot, and shared by all modules.
- Sparging flow rates are 5 to 50 cfm per module at an injection pressure of 10 to 15 psi.

Technology Limitations and Uncertainties

The critical limitations and uncertainties of technology implementation are listed below.

- The extent to which subsurface heterogeneities will decrease the effectiveness of sparging or will lead to uncontrolled lateral movement of contaminants cannot be verified until the full-scale system begins operation.
- Researchers have observed that air sparging may create relatively few, small, widely spaced, and stationary air channels in the saturated zone. Under these conditions mass transfer requirements may significantly limit contaminant removal, particularly from the saturated zone (Johnson, 1993).
- Low soil permeabilities (<0.1 darcy) can significantly reduce the radius of influence of extraction and sparging wells. Because the number of wells required to treat a given area increases as the radius of influence decreases, technology application in areas of relatively low permeability will result in significantly higher costs, and may decrease or eliminate the cost benefits of implementation.
- There is limited previous experience with sparging at depths >100 feet, but no theoretical limitations prevent deep applications. This lack of deep application experience creates the need for more extensive monitoring than that typically employed for near-surface applications, especially during pilot-scale testing.
- Verification of acceptable site characteristics (such as air permeability, subsurface heterogeneities, and contaminant distribution) at target hot spots is required prior to technology implementation.

Schedule

A possible implementation schedule is shown in Figure L5-4.

Cost

This section presents an estimated range for order-of-magnitude implementation costs based on the conceptual design. Implementation costs include costs associated with: ongoing literature review, pilot-scale testing, and full-scale capital expenses and annual operations and maintenance. The scope of each of these cost-related activities is summarized below:

- **Literature Review.** Technology researchers are likely to further develop the technology such that enhancements (optimization) and limitations will be better understood. The decision to proceed with further implementation of SVE/sparging requires ongoing assessment and review of these research results. While this activity is not a significant cost factor of implementation, it is an important implementation activity.

- **Pilot-Scale Testing.** This activity includes costs associated with scope and workplan development, contract procurement, equipment procurement, system installation, system operation, demobilization, sampling and analysis (system monitoring), evaluation of system performance, and reporting.

- **Full-Scale Capital.** Capital costs are direct and indirect costs required to initiate and install the technology system components, including (but not limited to) engineering design, mobilization and demobilization of equipment and people, site construction (i.e., well installation) activities, contractor bonding and insurance, equipment procurement and installation, licensing and permitting, health and safety, and supervision during construction.

- **Full-Scale Operation and Maintenance.** Operation and maintenance (O&M) costs represent those costs which would be incurred during each year of operation from initial startup to final shutdown of the full-scale system. O&M costs include operation and maintenance labor, power, sampling and analysis, and residual waste stream treatment. Since annual O&M costs occur over a period of years, future costs have been discounted to the present year's equivalent value (i.e., the present value cost) using 5 percent interest, so that annual costs remain comparable. Actual annual costs are likely to be much higher during the first year(s)

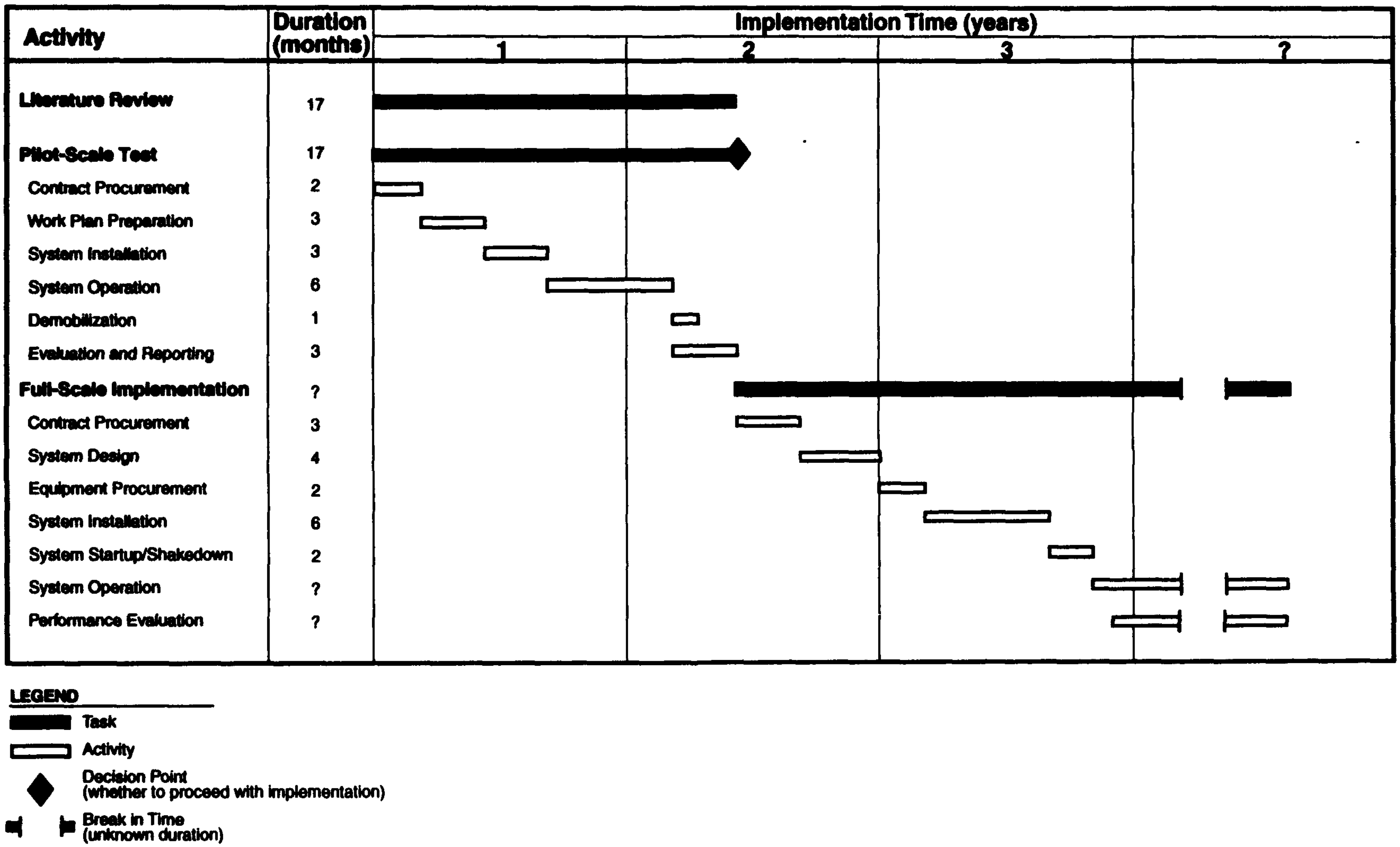

FIGURE L5-4
SVE/AIR SPARGING IMPLEMENTATION SCHEDULE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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of operation as the system is commissioned and optimized for operation, and due to higher chemical usage rates and associated labor required for treating higher initial concentrations. Therefore, the annual costs are intended to represent the anticipated average yearly cost of operation over the life of the system.

A contingency of 30 percent has been applied to the full-scale implementation cost to account for possible project cost increases due to scope and bid variations that typically occur with hazardous waste remediation projects. These increases are typically caused by the changes which normally occur as part of final design and implementation, based on observation of actual field conditions/contamination, and factors which affect the cost of subcontracted services, such as labor and material shortages. Not included in the estimates are any agency or Air Force administrative costs, nor any costs associated with modifications of the existing groundwater treatment system(s).

Typically, order-of-magnitude cost estimates for general construction projects are intended to reflect an accuracy of within 50 percent greater to 30 percent less than actual costs. The estimates summarized below are expected to be within these ranges; however, there is greater uncertainty of accuracy as a result of the lesser degree of development associated with this innovative technology compared to general construction technologies. Current pricing data based on quoted equipment costs, construction cost data (e.g., Means, 1993), previous local project experience, and engineering judgment have been used to generate the estimates, using adjustments for local McClellan AFB costs when available. Final project costs will depend on actual labor and material costs, actual site conditions at the time of implementation, productivity, competitive market conditions, final project scope and schedule, contractors selected to perform activities, and many other variables. As a result, the final project costs will differ from the exact value of any estimates presented here.

The following order-of-magnitude implementation costs are estimated for SVE/sparging:

- Literature review will require approximately $12,000 over a period of one year.

- Pilot-scale testing is estimated to cost approximately $135,000 if conducted using the existing SVE pilot system at Site S in OU D.

Full-scale implementation costs on a per acre basis are summarized in Table L5-2. The estimated costs for construction and operation of a full-scale system range from approximately $2M/acre (for 70-foot well spacing and 3 years' operation) to $10.6M/acre (for 40-foot well spacing and 8 years' operation). Key assumptions associated with the implementation cost estimate, in addition to those previously described, include:

- Full-scale costs are reported on a per acre basis; costs were estimated using a system comprised for a five-module (20 extraction wells) system and converted to per acre costs.

- Nine man-days/well plus drilling costs are needed to install wells and piezometer nests. This includes drilling, well completion and development, and surface plumbing.

- Offgas treatment cost is $5/lb VOCs, and is a significant O&M cost factor.

- Each module contains 500 feet of PVC pipe.

- Contaminants are removed at an average rate of 50 lbs/day per module over the operational period of the system.

- System operational time is assumed 50 percent, or 4,380 hours/year/well.

- System monitoring includes 45 man-days per year for system operation and maintenance, and the collection of five samples per module for laboratory analysis, quarterly.

Table L5-2 SVE/Sparging Order-of-Magnitude Implementation Cost Summary				
	Range of Costs ($/acre)			
Activity	Low[a]	Low - Intermediate[b]	Intermediate - High[c]	High[d]
Full-Scale Capital	920,000	920,000	2,850,000	2,850,000
Full-Scale O&M (Present Worth for All Years)	1,060,000	2,520,000	3,290,000	7,800,000
Full-Scale Implementation Cost	1,980,000	3,440,000	6,140,000	10,650,000

Notes:
[a]Based on 70 feet well spacing and 3 years of operation.
[b]Based on 70 feet well spacing and 8 years of operation.
[c]Based on 40 feet well spacing and 3 years of operation.
[d]Based on 40 feet well spacing and 8 years of operation.

Other significant assumptions include:

- $5/lb VOCs offgas treatment cost
- 50 lbs/day per module average removal rate
- 50 percent system on-time (to allow for cyclical operation)
- Annual sampling and analysis, and performance evaluations included in operational cost
- 30 percent contingency factor applied

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Appendix L6

PREPARED FOR: McClellan Air Force Base

DATE: November 7, 1993

SUBJECT: Electron Beam Treatment Implementation Plan
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.NT

Technology Overview

Description

Electron Beam (E-Beam) Treatment is a developing technology that can be used to treat either liquid waste streams, such as contaminated groundwater, or gaseous waste streams. This Implementation Plan has been developed for groundwater treatment applications.

Electron Beam Treatment is an innovative advanced oxidation process (AOP) that can destroy organic compounds in aqueous solution. Known generally as High Energy Electron Irradiation, the process involves the irradiation of a thin aqueous stream with high-energy electrons. This results in the formation of highly reactive, short-lived chemical species. These transient reactive species initiate chemical reactions with dissolved organic compounds. In most cases these compounds are oxidized to carbon dioxide, water, and inorganic species, although organic byproducts of transformation can also be formed (EPA SITE, 1992).

High energy electron accelerators have been used for years in industry for the cross-linking of polyethylene, the polymerization of lubricants, and the vulcanization of rubber (Nickelsen et al., 1992). Electron accelerators function by using a current to produce a stream of electrons which are accelerated by applying an electric field generated at a given voltage. The number of electrons generated per unit time is proportional to the beam current and thus the beam power. The amount of energy from the beam that is absorbed by an irradiated material per unit time is called dose. The absorbed dose depends on the type and thickness of the material, the beam power, and the length of time the material is exposed to the electron beam (Westinghouse, 1993). The dose is determined by measuring the temperature increase of the aqueous stream as a result of beam contact.

In all E-Beam accelerators, electrons are formed in a high vacuum by thermal emission from a hot surface, usually a tungsten filament or oxide coated surface. The electrons are focused into a beam and accelerated through a DC voltage potential, typically 300 kV to 5 MV. In E-Beam treatment, a liquid waste stream either passes through a slit or flows over a weir that forms a continuous sheet of liquid that is directed across a window, as shown in Figure L6-1. The flow over the window is intended to maintain a uniform thickness of the liquid.

The irradiation of aqueous streams by an electron beam results in the formation of highly energized species, the most reactive of which are aqueous electrons (e_{aq}) hydrogen radicals (H•) and hydroxyl radicals (OH•) (Nickelsen et al., 1992). These species are short-lived as they either quickly recombine or transfer their energy into other compounds present in solution. The subsequent mechanisms of reaction with hazardous compounds, such as chlorinated and nonchlorinated hydrocarbons, are understood to be similar to those of other AOPs; however, the proportions of the individual reactive species generated by E-Beam differ significantly from other AOPs, which may result in increased effectiveness for chlorinated hydrocarbons.

The treatment efficiency of the process is related to three major parameters: contaminant concentrations, irradiation dose, and water quality. Nickelsen et al. (1992) report that experimental data collected during the irradiation of potable water and wastewater containing BTEX compounds indicate that solute destruction is first order with respect to dose. Water chemistry can seriously affect removal efficiencies due to both scavenging effects and the formation of by-products. The presence of scavengers in the aqueous treatment stream causes the reactive species to be consumed before initiating the desired destruction reactions. Principal scavengers include dissolved oxygen, bicarbonate/carbonate, nitrate, and dissolved organic carbon.

Development Status

- The technology has been in existence for 30 years for applications such as sterilization of medical supplies, disinfection of wastewater, and food preservation.

- A full-scale plant (120 gpm) is in operation at the Miami-Dade Central Water District wastewater treatment Plant in Miami, Florida. It is known as the Electron Beam Research Facility (EBRF), and can be used for pilot testing (but requires a tanker truck volume of the sample to be tested).

- Two technology vendors have been identified: High Voltage Environmental Applications (HVEA) and Raychem Corporation. Each has mobile units under construction. Raychem appears to be further along in equipment development, though HVEA, which is associated with the EBRF, appears to have further developed E-Beam theory. (Zappit Technology has developed an E-Beam system for treating contaminated gas streams, but not liquid waste steams.)

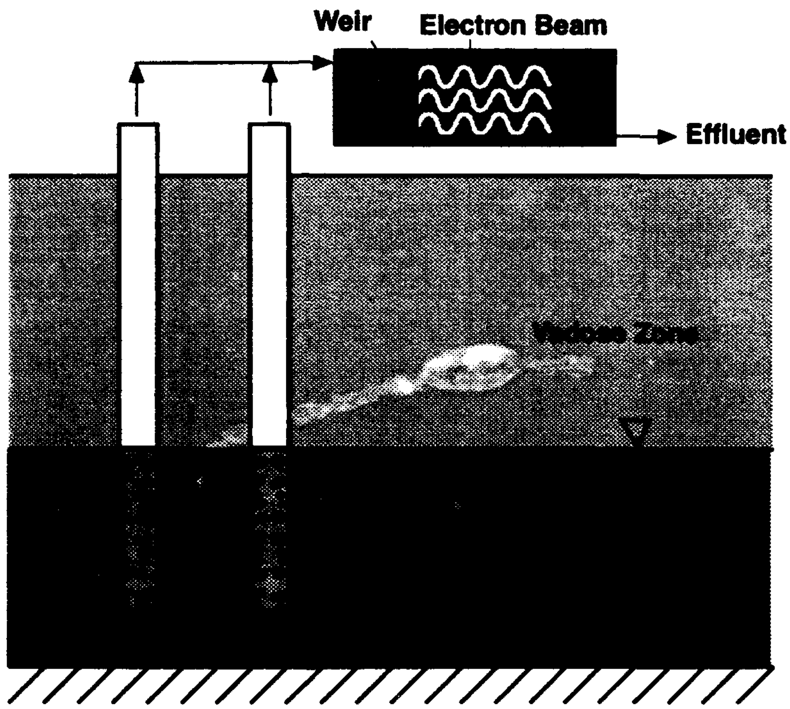

FIGURE L6-1
EX SITU GROUNDWATER TREATMENT
ELECTRON BEAM TREATMENT
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

- An EPA SITE demonstration is planned for early next year at Savannah River by HVEA, although it has not been determined whether the project will involve treatment of chlorinated organics or benzene contaminated groundwater.

- Bench-scale testing of chlorinated VOCs has been performed by vendors.

Potential Benefits

This section describes the performance, advantages and disadvantages, and cost benefits associated with E-Beam treatment of extracted groundwater. This information is intended to provide a basis for evaluating the potential benefits of implementing this technology at the Base as an innovative alternative to standard groundwater treatment processes, such as aqueous phase carbon adsorption, air stripping, and conventional AOPs (e.g., UV/peroxide, UV/ozone, ozone/peroxide oxidation).

General Performance

Effectiveness

- E-Beam technology vendors report that the technology can achieve 95 to 99 percent destruction efficiency of halogenated and nonhalogenated organics in treatment of single contaminant liquid streams.

- Data reviewed on treatment of multiple-contaminant streams indicates that the technology is capable of achieving effective removal of certain chlorinated aliphatic hydrocarbons (CAHs) and chlorinated and nonchlorinated aromatic compounds, but high treatment efficiencies were not always achieved.

- E-Beam treatment is capable of treating amenable contaminants to low μg/l levels.

Robustness

- E-Beam treatment efficiency appears to vary considerably for different compounds. The process is capable of achieving effective treatment of chlorinated ethenes (including TCE and PCE) and trihalomethanes, whereas chlorinated ethanes (such as 1,1,1-TCA and 1,1-DCA) are less effectively treated.

- The E-Beam technology does not treat ketones effectively.

- The E-Beam system can potentially handle a range of flows and concentrations by adjusting dose and via the use of modular units.

- High concentrations of scavengers (alkalinity, dissolved oxygen, or dissolved organic carbon) in the liquid stream increases the dose required to achieve a given level of treatment.

Potential Risk Reduction

It is difficult to quantify risk reduction provided by E-Beam treatment because the potential benefit of the technology is associated with its potential to reduce contaminant mass in extracted groundwater more economically than standard treatment technologies. E-Beam treatment will not provide more extensive treatment than standard technologies, but it would reduce contaminant levels compared to no treatment. Because it is a destruction technology, E-Beam treatment causes a reduction in contaminant mass compared to nondestructive technologies that transfer contaminants to another phase.

Advantages Compared to Other Technologies

- Destructive technology with no residual streams (other than possible reaction by-products in the effluent).

- Nonselective treatment may be effective for at least simple mixtures of compounds.

- Technology expected to be robust with respect to changing flows and concentrations.

Disadvantages Compared to Other Technologies

- Operation may have high energy requirements.

- Not yet demonstrated at the pilot-scale level for chlorinated aliphatic hydrocarbons.

- Treatment effectiveness varies considerably between contaminant types. Chlorinated alkanes and ketones may not be effectively treated.

- Residual by-products include formaldehydes, formic acid, ozone.

- May not achieve treatment requirements without using very high doses resulting in relatively high operating costs.

- Some evidence suggests that the treatment effectiveness may be significantly reduced for complex mixtures of contaminants like those found in McClellan AFB groundwater.

Relative Cost Benefit

The cost benefit of E-Beam treatment would result from its use in place of a more costly ex situ groundwater treatment technology or through its use in combination with other technologies reducing overall treatment costs. Cost benefits should be evaluated on the basis of $/gallon of groundwater treated to a given quality.

Potential Locations

The potential application locations (uses) are the treatment of extracted groundwater at the groundwater treatment systems associated with pump-and-treat operations at the Base.

Approach

Information Needs and Sources

Table L6-1 summarizes information needs and sources for implementation of E-Beam treatment.

Information Gathering and Review

Technology information reviewed to date includes published literature, vendor information and data, and vendor interviews. Also, Westinghouse staff were interviewed about the planned E-Beam demonstration project at the DOE Savannah River site. New information should be reviewed as it becomes available, especially the results of the Savannah River demonstration.

Implementation Issues

- A major implementation constraint at the present is the unavailability of pilot- and full-scale equipment. Pilot units are reportedly being constructed by both equipment vendors, but there is only one full-scale system in existence. For this reason, it is difficult or impossible to anticipate implementation factors, such as scale-up problems, full-scale equipment durability and treatment reliability, long-term treatment performance, and full-scale capital and operating costs.

- The ability of E-Beam systems to treat all of the contaminants requiring reduction through treatment in the complex mixtures of contaminants found in Base groundwater is unproven. Thus the feasibility of implementing E-Beam treatment at McClellan AFB cannot currently be determined.

Table L6-1
Electron Beam Treatment
Information Requirements and Sources

Information Needed for Pilot and Full-Scale Tests	Info Source		
	Bench	Pilot	Full
Feed Stream Characteristics:			
• Flow	--	S	S
• Contaminant types	S	S	S
• Contaminant concentrations	S	S	S,P
• Treatment goals	L	L	L
• Alkalinity, dissolved organic carbon	S	S	S,P
• Flow/Concentration variability	S	S	S,P
System Design: Physical Configuration			
• Unit Size	V	V	P,V
• Residence Time	V	L,V	P,V
• Concrete pad requirement	--	V	P,V
System Design: Equipment Requirements			
• O & M Requirements	--	V	P,V
• Power Requirements	V	V	P,V
• Utility connections	--	V	P,V
Performance Capabilities			
• Destruction Removal Efficiencies	L	B,V,L	P
• Response to Feed Stream Variability	L	B,V,L	P
• Monitoring (Sampling and Analysis Requirements)	L,V	L	L
• Electron Dosage Requirements	L,V	B,V,L	P,V
• Byproduct Formation	L,S	B,L	P

Source Notes:
L = Literature/Experts
B = Bench Scale
P = Pilot Scale
S = Sampling Results
V = Vendor

- Use of the E-Beam technology for treatment and discharge of extracted groundwater at the Base would require compliance with applicable permits (as is the case for any groundwater treatment system).

- Patents are pending for modifications to industrial electron beam systems. Application of this technology would require purchase or lease of proprietary equipment.

Bench Scale Testing

Objectives

Bench-scale testing would be conducted to address the following objectives:

- Determine if the technology can effectively treat the pertinent contaminants in complex mixtures characteristic of Base groundwater.

- Determine achievable contaminant reduction efficiencies and required dosages.

- Evaluate appropriate operating parameters such as electron beam dosage and additive requirements.

- Identify and quantify by-products formation during treatment.

- Assess the effects of scavengers present in Base groundwater.

Approach

Laboratory tests would be required prior to proceeding with a pilot test. Bench scale testing procedures are outlined below.

- At least three 2-gallon groundwater samples would be collected from different locations on the Base and shipped to a vendor for evaluation. The groundwater samples would be selected to contain different contaminant mixtures and different concentrations of potential oxidant scavengers. Aliquots of the samples would be transferred to a series of vials, which would receive electron injection at various doses and then be analyzed to evaluate treatment efficiencies and by-product formation.

- Once the optimal electron beam dose has been established based on the initial tests, new sample aliquots would be retreated at that dose and submitted to an EPA-approved laboratory for confirmation of initial test results.

- Tests would be repeated with additives if appropriate (e.g., if initial treatment efficiencies were unsatisfactory).

- Determine if the treatment performance achieved justifies processing with pilot-scale testing.

Pilot-Scale Testing

Objectives

Pilot-scale testing would be conducted to address the following objectives:

- Determine the achievable reduction efficiencies for individual contaminants and for total VOCs.

- Evaluate full-scale system design and operating parameters such as unit size, configuration, equipment requirements, and dose and power requirements.

- Demonstrate the efficacy and reliability of electron beam technology.

- Evaluate the ability of the technology to handle variations in feed stream characteristics.

- Evaluate residual concentrations of by-products formed during treatment and the need for polishing treatment.

- Evaluate the potential for coating or wear on the treatment window.

- Demonstrate system remote/automatic operation capability.

- Develop a basis for estimating full-scale costs.

Approach

Pilot testing should be conducted onsite at the Base if possible. HVEA's mobile pilot unit is presently under construction. It will contain a 25-kW electron beam and have a flow capacity of up to 40 gpm. Raychem's mobile trailer unit is also under construction, though a prototype currently exists. Consequently, the availability of pilot testing equipment is uncertain. As an alternative, a 5,000- to 6,000-gallon tanker could be shipped to Miami to be treated by the full-scale EBRF, although this option is not recommended.

Pilot-scale testing using Base groundwater would be necessary to rigorously evaluate technology feasibility and to develop design and operating parameters. The specific objectives and approach of the pilot testing program would be refined and detailed following the information gathering and review and bench-scale testing tasks. The general pilot testing approach would include the following components.

- Select an appropriate extracted groundwater stream for testing E-Beam treatment. A slip stream from an existing pump-and-treat operation would likely be used.

- Develop pilot testing workplan.

- Prepare site and bring vendor system online.

- Operate E-Beam treatment system under the selected conditions.

- Analyze data to evaluate performance and evaluate potential benefits of implementing E-Beam treatment at the Base.

- Decide whether to proceed with implementation at full scale.

Full-Scale Conceptual Design

Because full-scale systems have not yet been built, an understanding of the full-scale implementation is very conceptual in nature. Treatment units may either be designed and constructed to meet the needs of a particular application, or may be modular systems connected in series and parallel to meet treatment objectives. Figure L6-2 illustrates how electron beam treatment technology may fit into a full-scale groundwater pump-and-treat system.

Full-scale application of electron beam treatment would involve the following major components:

- A pad of sufficient size to contain modular unit(s) and control equipment

- Power, cooling water, and telephone connections

- Plumbing connections to the groundwater treatment train

- A polishing treatment system to remove formaldehyde and other residual byproducts

Technology Limitations and Uncertainties

As a developing technology, E-Beam performance characteristics and operational difficulties have not been well defined. In addition, there are a number of uncertainties that affect the implementation of this technology.

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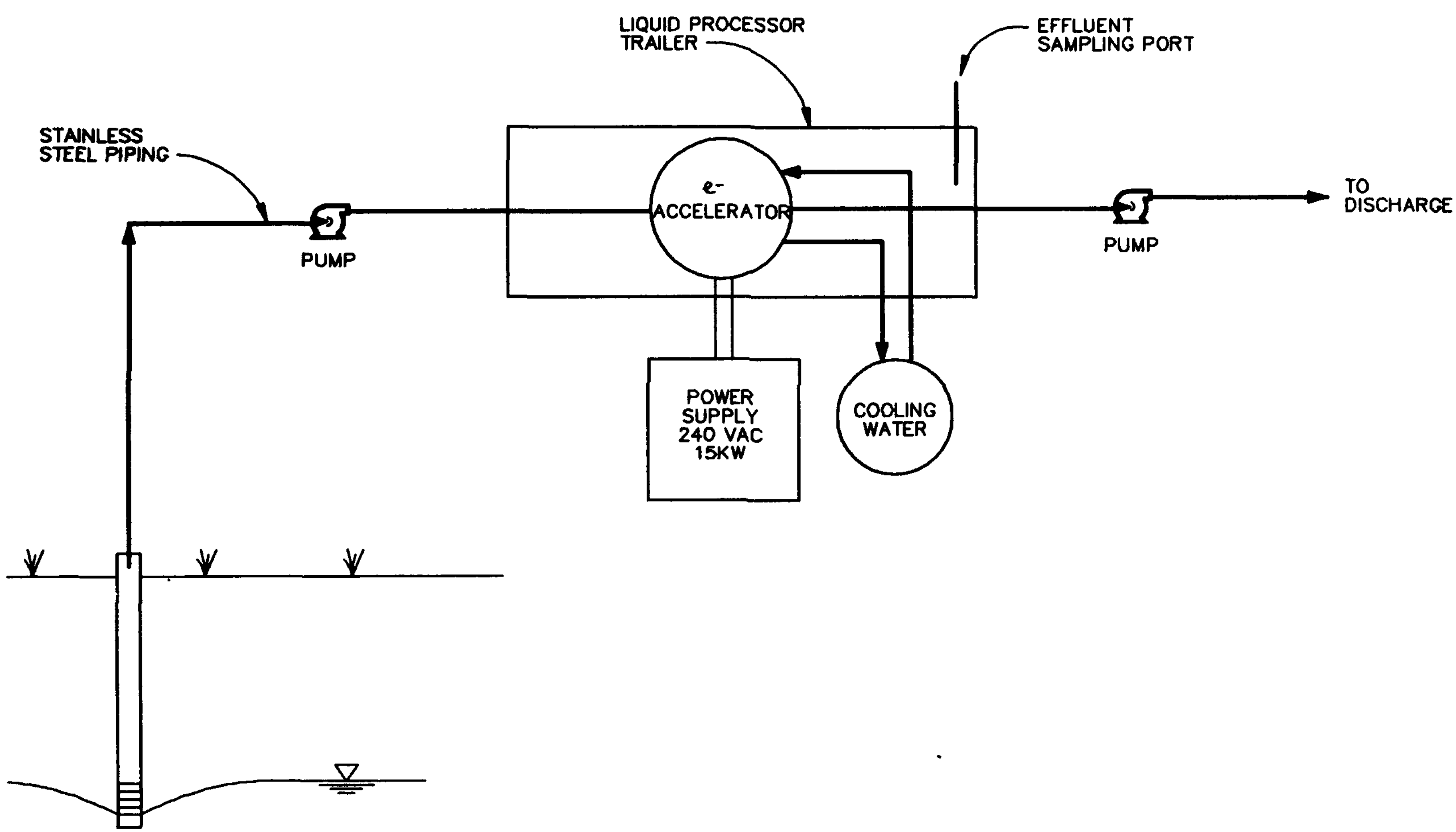

FIGURE L6-2
ELECTRON BEAM
PROCESS SCHEMATIC
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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- Full-scale units for commercial applications have not yet been constructed. The scale-up effects associated with full-scale units from bench-scale systems are unknown.

- The ability of E-Beam to achieve required contaminant reductions for a complex mixture of chlorinated solvents and nonchlorinated organics has not been demonstrated. Antagonistic effects may result in high irradiation dose requirements.

- The dose required to achieve target contaminant reduction efficiencies may not be economically feasible.

- The long-term operational durability of a full-scale system is unknown.

- Chemical additives (e.g., H_2O_2) may be needed to achieve target treatment efficiencies, resulting in higher operating cost.

- The formation of reaction by-products may require polishing treatment.

- The presence of scavengers (e.g., alkalinity, dissolved oxygen, and organic carbon) may require pretreatment to enhance E-Beam effectiveness.

Schedule

An implementation schedule is provided in Figure L6-3. This schedule may change because equipment is unavailable. This technology is not yet sufficiently developed to identify a schedule for full-scale implementation.

Cost

Bench- and pilot-scale testing costs are estimated at roughly $50,000 and $240,000, respectively. Full-scale implementation costs are impossible to estimate at this time because the required equipment is not commercially available.

Works Cited

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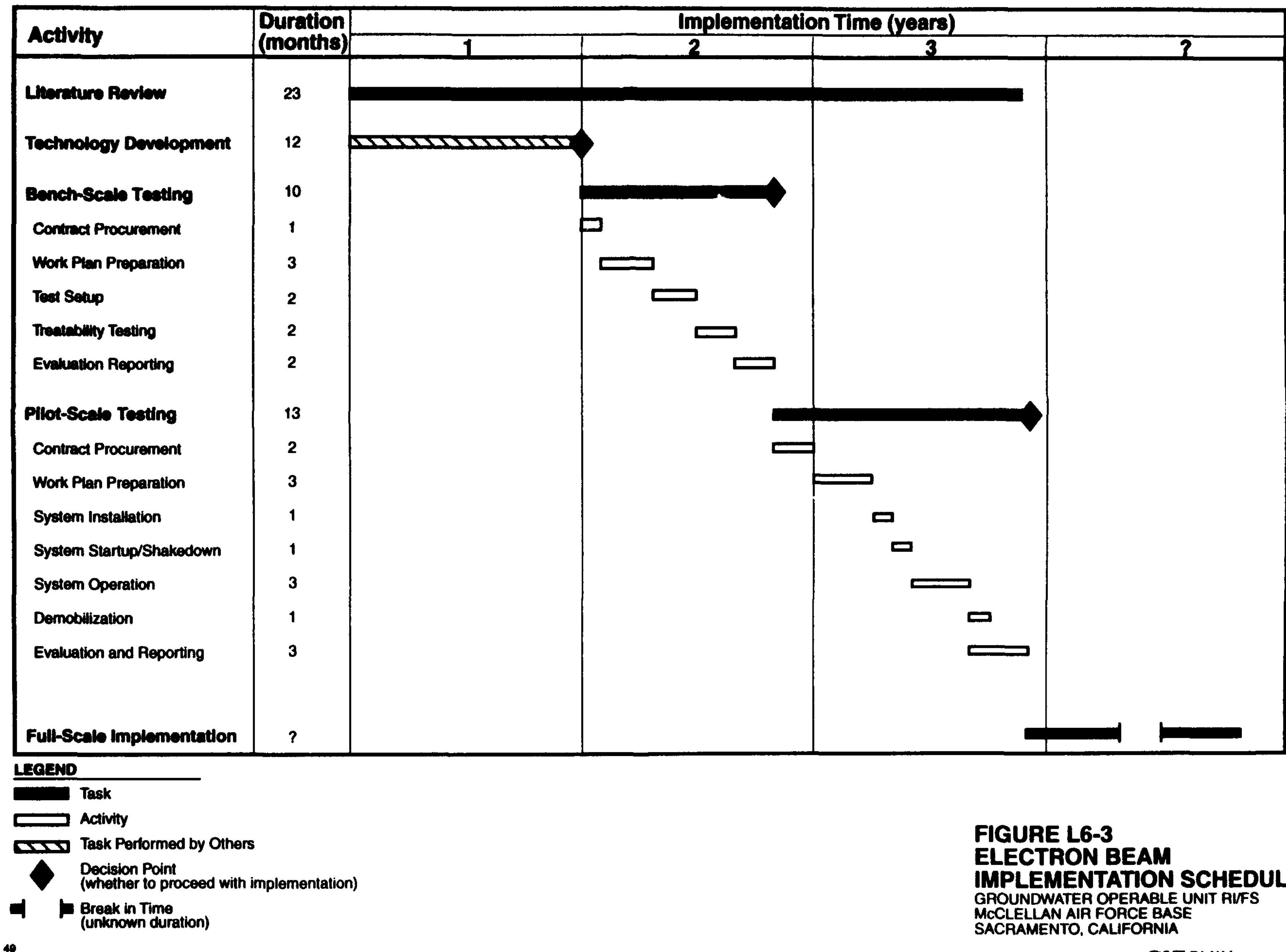

FIGURE L6-3
ELECTRON BEAM IMPLEMENTATION SCHEDULE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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Appendix L7

PREPARED FOR: McClellan Air Force Base

DATE: November 9, 1993

SUBJECT: Cometabolic Biofiltration Implementation Plan
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.NT

Technology Overview

Description

Biofiltration is an established treatment technology for the removal of certain organic and inorganic contaminants from gas streams. Biofiltration has most often been used to remove odor-causing chemicals from offgas streams, such as gases from municipal wastewater treatment plants. Recently, biofiltration has been employed to treat VOCs in industrial offgas streams. These applications have involved compounds that are readily biodegradable by aerobic microorganisms. The use of biofiltration for the treatment of vapor-phase chlorinated aliphatic hydrocarbons (CAHs) is a developing technology.

Many important CAHs, including TCE, are not biodegradable by ordinary aerobic microbial metabolism; however, TCE and certain other CAHs can be biodegraded via cometabolism under aerobic conditions. Cometabolism of CAHs is a process in which a biodegradable organic substrate induces the production of nonspecific enzymes by a certain group of microorganisms, which fortuitously initiate transformation of the CAH molecule. In cometabolic biofiltration, a primary substrate is added to the contaminated gas stream to stimulate cometabolism of CAHs. Substrates that have been most commonly used in studies of TCE cometabolism include methane, toluene, and phenol.

Biofiltration is a general term that encompasses two categories of biological vapor-phase treatment: biofiltration and biotrickling filter (or bioscrubber) processes. Both categories function by the same general principal. The two processes differ primarily in the type of media employed and the mass transfer mechanisms that result. In both processes, a contaminated gas stream is passed through a bed of biologically active media where contaminants are exchanged to the aqueous phase and biodegraded. A schematic of biofiltration is shown in Figure L7-1.

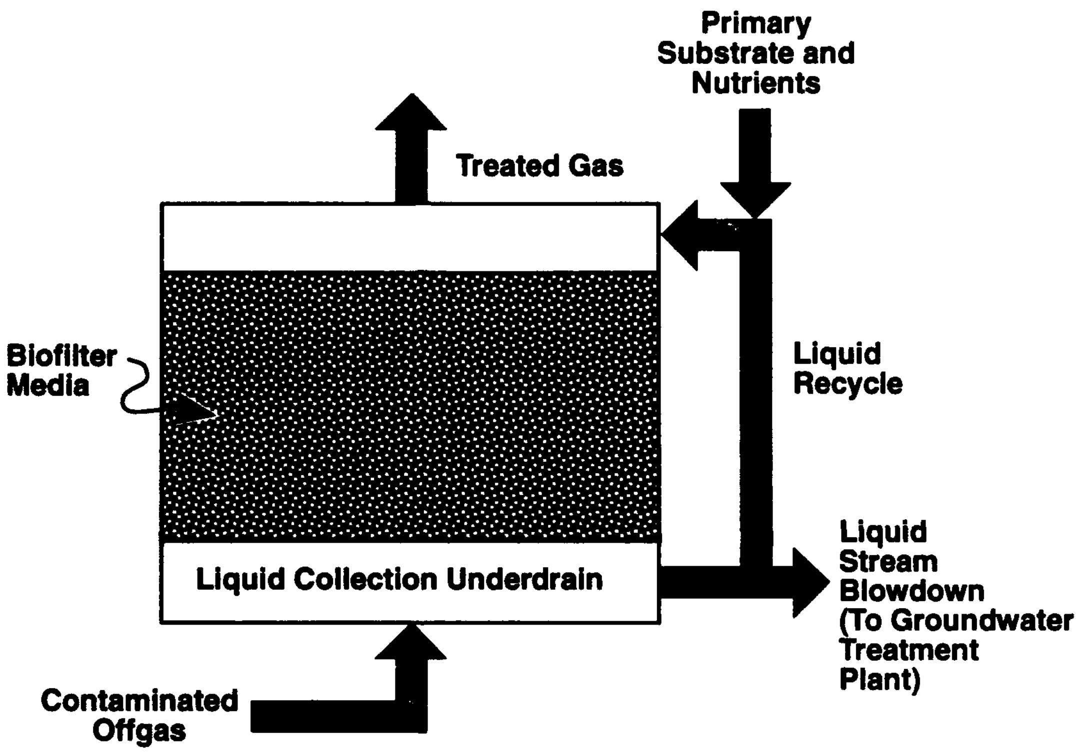

FIGURE L7-1
COMETABOLIC BIOFILTRATION PROCESS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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In the biofiltration process, microorganisms are immobilized within the liquid biofilm layer on a porous media such as soil, compost, peat, granular activated carbon, or polyurethane foam. Contaminants are passed into the bed where they sorb to the media, dissolve into the liquid biofilm layer, and are degraded by the microbial culture. Treatment performance depends on the sorbability and biodegradability of the contaminants.

The biotrickling filter or bioscrubber approach differs primarily in the type of media upon which the microbial mass is attached (i.e., conventional air scrubber/stripper packing material instead of organic media). This type of system is operated with either a co-current or countercurrent flow of an aqueous solution providing nutrients, buffering capacity, and primary substrate. The efficiency of this type of system depends greatly on the extent to which contaminants can be transferred to the aqueous phase and subsequently degraded.

The control of temperature, pH, and nutrients is critical for both types of systems. For organic media biofilters, bed moisture content is also a critical parameter.

Development Status

Both types of biofiltration systems are receiving considerable attention by biofiltration vendors and university researchers for the degradation of chlorinated organics. Research groups that have been leading the investigation of biofiltration for CAHs include Envirogen (Lawrenceville, New Jersey), the EPA Risk Reduction Engineering Laboratory (in cooperation with the University of Cincinnati), and the EPA Environmental Research Laboratory in Gulf Breeze, Florida (in cooperation with the University of West Florida). Also active in biofiltration research for the treatment of chlorinated hydrocarbons are EG&G Biofiltration, Idaho Falls, Idaho; Remediation Technologies, Inc., Seattle, Washington; and Biotrol, Inc., Chaska, Minnesota.

Cometabolic biofiltration for the removal of CAHs is currently being developed at the laboratory scale. Pilot-scale systems are primarily at the conceptual design stage. Most of the present research efforts are focused on the bioscrubbing approach to treatment of chlorinated VOCs. A bench-scale airlift reactor (which operates similarly to a biotrickling filter without any media) has been operated by Envirogen and has achieved some initial success for the removal of TCE. However, cometabolic biofiltration systems have had difficulty treating TCE concentrations greater than about 25 ppmv effectively and in maintaining consistently high treatment efficiencies.

A field demonstration of cometabolic biofiltration at McClellan AFB is reportedly scheduled to occur in July of 1994 (Hoda, 1993).

Potential Benefits

This subsection describes the performance, advantages and disadvantages, and cost benefits associated with biofiltration. This information is intended to provide a basis for evaluating the potential benefits of implementing this technology at the Base as an innovative alternative to standard offgas treatment technologies such as vapor-phase carbon adsorption and catalytic and thermal oxidation.

General Performance

Effectiveness

- The effectiveness of cometabolic biofiltration has not been thoroughly evaluated and reported. No information was found for CAHs other than TCE.

- Greater than 95 percent reduction efficiency has been reported for TCE at concentrations in the low ppmv range. A removal rate of 0.2 $g/m^3/hr$ has been reported for TCE.

- TCE can be completely mineralized to CO_2, water, and chloride.

- Based on aqueous-phase testing of aerobic cometabolism, 1,2-DCE and vinyl chloride are also expected to be treatable by cometabolic biofiltration.

Robustness

- TCE can be effectively treated, but treatment consistency has been difficult to maintain over long periods or at concentrations greater than approximately 25 ppmv.

- Cometabolic biofiltration is not expected to effectively treat PCE, carbon tetrachloride, 1,1,1-TCA, 1,1-DCE, 1,1-DCA, or Freons, based on aqueous phase study results.

- Ketones, alcohols, BTEX, and fuel hydrocarbons can be effectively treated via biofiltration. Cometabolism is unnecessary for these compounds.

- Varying contaminant loads (resulting from variations in flows and/or concentrations) are likely to decrease treatment performance. The effects of periodic variations or shock loads may be temporary, whereas frequent variations may prevent the development of a stable microbial culture and result in inconsistent treatment.

- Polishing treatment probably will be necessary because of fluctuations in treatment performance.

Potential Risk Reduction

It is difficult to quantify risk reduction provided by biofiltration, because the potential benefit of the technology is associated with its potential to remove contaminant mass from an offgas waste stream more economically than standard treatment technologies. Biofiltration will not provide more extensive treatment than standard technologies, but it would reduce VOC emissions compared to no treatment. Because it is a destruction technology, biofiltration causes a real reduction in contaminant mass compared to nondestructive technologies, which transfer contaminants to another phase.

Advantages Compared to Other Technologies

- Overall offgas treatment costs may be reduced by using biofiltration either alone or in conjunction with GAC polishing.
- It is likely that cometabolic biofiltration can effectively treat vinyl chloride, which is difficult and costly to remove by adsorption processes.
- Contaminant mass reduction is achieved by destruction rather than transfer to another phase.
- Cometabolic biofiltration is capable of completely mineralizing TCE. Presumably, 1,2-DCE and vinyl chloride can also be mineralized, based on aqueous phase study results.
- The biofilter media is continuously regenerated, and does not require frequent replacement/disposal.
- Thermal/catalytic oxidation by-products such as HF and HCl would not be generated via biofiltration.
- Public perception of biofiltration is potentially more favorable than for thermal processes.

Disadvantages Compared to Other Technologies

- If treatment of all contaminants is not complete, a contaminated liquid stream will be produced. Untreatable contaminants will accumulate in the scrubbing solution (with biotrickling filters) or leachate (with biofilters), necessitating a liquid blowdown stream.
- Biofiltration is probably more susceptible to upsets and inconsistent treatment than standard offgas treatment technologies.
- Several CAHs are not effectively treatable by cometabolic biofiltration.
- Polishing treatment following biofiltration probably would be required.
- The primary substrate added to induce cometabolism could itself become a contaminant in the effluent gas if not completely utilized during treatment.

- Competitive inhibition between primary substrate and target contaminants can occur, resulting in reduced treatment efficiencies.

- Complex mixtures of contaminants in the offgas may affect treatment performance.

Relative Cost Benefit

The cost benefit of cometabolic biofiltration would result from its use in place of a more expensive offgas treatment technology or through its use in combination with other technologies, reducing the overall treatment cost. Cost benefits should be evaluated on the basis of $1/mass of contaminants treated. When evaluating technology costs, residuals management should be included.

Potential Locations

Potential application locations for cometabolic biofiltration at McClellan AFB include the treatment of offgas from: air stripping groundwater treatment, soil vapor extraction (SVE), SVE/sparging, bioventing, soil composting, or dual-phase extraction.

A suitable offgas stream for treatment via cometabolic biofiltration would be contaminated primarily with TCE, 1,2-DCE, and/or vinyl chloride (and maybe other monochlorinated CAHs). (Biofiltration without induction of cometabolism would also be potentially applicable for treating BTEX or fuel-contaminated gas streams.) Offgas streams containing significant concentrations of PCE, carbon tetrachloride, 1,1,1-TCA, 1,1-DCE, 1,1-DCA, or Freons are probably not suitable for treatment by cometabolic biofiltration.

Because TCE is the predominant CAH contaminant in OU C groundwater, offgas from the treatment of soil and/or groundwater that area of the Base might be suitable for treatment by cometabolic biofiltration.

Approach

Information Needs and Sources

Table L7-1 summarizes information needs and sources for implementation of cometabolic biofiltration.

Table L7-1
Cometabolic Biofiltration
Information Needs and Sources

Information Needs	Project Scale		
	Bench	Pilot	Full
Feed Stream Characteristics			
• Contaminant Types	S	S	S
• Contaminant Concentrations	S	S	S
• Flow Rate	L	L	O
• Flow/Concentration Variability	L,S	O,S	O,S
• Treatment Requirements	L	L	L
System Design			
• Unit Size	L	B,L,O	O,P
• Physical Configuration (e.g. flow regime, support media, microbial consortia, primary substrate)	L	B,L	L,P
• Equipment Requirements	L	B,O	O,P
Performance Capabilities			
• Destruction Removal Efficiencies	L	B	P
• Flow Rate	L	B	P
• Ancillary Treatment Requirements	L	B,O	O,P
• Monitoring (Sampling and Analysis)	L	B	P
• Response to Feed Stream Variability	L	B	P
Operations & Maintenance			
• Biofilter Bed Life	L	B	P
• Substrate Use Requirements	L	B	P
• Nutrient Requirements	L	B	P
• Utility Connections/Installation Requirements	L	B,O	O,P
• Biosolids Management (if any)	L	B	O,P
• Preventative Maintenance Requirements	L	B	P

Notes:
L = Literature/Experts
O = Other Technology Evaluations
P = Pilot Scale
S = Sampling Results

Information Gathering and Review

Information gathering and review to-date has identified a number of vendors and research groups that are actively testing and developing biofiltration processes for treating CAH-laden gas streams. These groups are listed in the Development Status subsection of this Implementation Plan. Because of the relatively undeveloped status of this technology and the intricacies associated with the process, an intensive review of current and future research findings is needed. The progress of these groups in developing this technology should be closely monitored until sufficient information is available to confidently evaluate whether the technology is feasible for implementation in conjunction with remedial activities at McClellan AFB. The results of the field demonstration of biofiltration treatment of CAHs planned for McClellan AFB in July 1994, when available, will be particularly useful for evaluating the feasibility of implementing the technology at Base.

Implementation Issues

- The treatment system will have to meet treatment objectives established to maintain compliance with the Basewide air emissions permit.
- The gas stream(s) selected for treatment by cometabolic biofiltration must have characteristics that are compatible with the capabilities and limitations of the treatment process.
- It may be practical to allow some period of time for the technology to be developed further before proceeding with implementation at the Base. At the present, it is not apparent that any of the research/vendor groups has developed a pilot-scale system that is ready for use in the field. Nevertheless, several groups are actively researching and developing the process, so the technology may be ready for field testing in the near future. Thus, it is important to closely monitor technology development progress and critically evaluate any treatment data generated so that the best system can be selected for testing.

Bench-Scale Testing

Bench-scale testing should be performed by, or in conjunction with, one of the research groups or vendors active in developing the cometabolic biofiltration technology. The overall goals of bench-scale testing would be to make a preliminary evaluation of the feasibility of implementing the technology at the Base and to screen process variables to focus the design and operation of a pilot-scale system.

Objectives

- Determine appropriate gas stream characteristics—including the ranges of contaminant loading rates, gas flow rates, and contaminant concentrations—that can be effectively treated.

- Determine the optimal primary substrate and microorganism group, substrate addition rate, residence time, and any other critical design parameters.

- Evaluate the potentially achievable contaminant reduction efficiencies, mass removal rates, and consistency of treatment performance.

Approach

Bench-scale biofiltration column systems probably would be used to test the technology, although the test system design should be based on the current research developments at the time of testing. Bench-scale testing could either be conducted at the Base using a small slip-stream of actual offgas (if a vapor stream contaminated primarily with treatable CAHs exists), or it could be conducted in a laboratory using a simulated gas stream containing at least a simple mixture of contaminants representative of a gas stream at the Base.

Pilot-Scale Testing

Objectives

- Determine the maximum gas flow rates, influent contaminant concentrations, and contaminant mass loadings that can be treated effectively.

- Evaluate achievable contaminant reduction efficiencies, mass removal rates, and consistency of performance.

- Evaluate system response to influent stream variability, shock loads, and shutdown/startup.

- Evaluate the long-term effectiveness of a biofiltration bed, especially with respect to the management of biosolids.

- Determine appropriate operating parameters, such as liquid recycle rate, liquid blowdown rate, substrate addition rate, and nutrient and buffering requirements.

- Characterize any residual waste streams.

- Develop design and operating criteria and estimate the cost of a full-scale system.

Approach

If bench-scale testing results are promising, the next phase of implementation is pilot-scale testing. Pilot-scale testing would involve the operation of an onsite treatment system designed to simulate the system that would be used at full-scale. The specific objectives and approach of the pilot-testing program would be refined and detailed based on the bench-scale testing results. The general approach to pilot-scale testing is outlined below and as shown in Figure L7-2.

1. Identify an appropriate offgas stream. Ideally, this would be done prior to bench-scale testing. This might be a slip stream from an air stripper treating extracted groundwater or from an in situ soil venting operation.

2. Develop the pilot testing workplan.

3. Select a vendor to supply a biofiltration system that is consistent with preliminary design criteria developed from the bench-scale testing results. If no vendor-supplied pilot-scale system is available, a system could be constructed by contracting the necessary design and construction engineering services.

4. Prepare the test site and mobilize the pilot unit onsite.

5. Operate the pilot test unit at a variety of loading conditions.

6. Operate the system for a sufficient duration to evaluate long-term performance.

7. Analyze data to evaluate performance and the potential benefit of implementing cometabolic biofiltration at the Base.

8. Decide whether to proceed with implementation at full-scale.

Full-Scale Implementation

Cometabolic biofiltration has not been sufficiently developed to prepare a full-scale implementation conceptual design.

Technology Limitations and Uncertainties

- Neither pilot- nor full-scale units have been constructed for treating CAHs. It is not known when these systems will be available.

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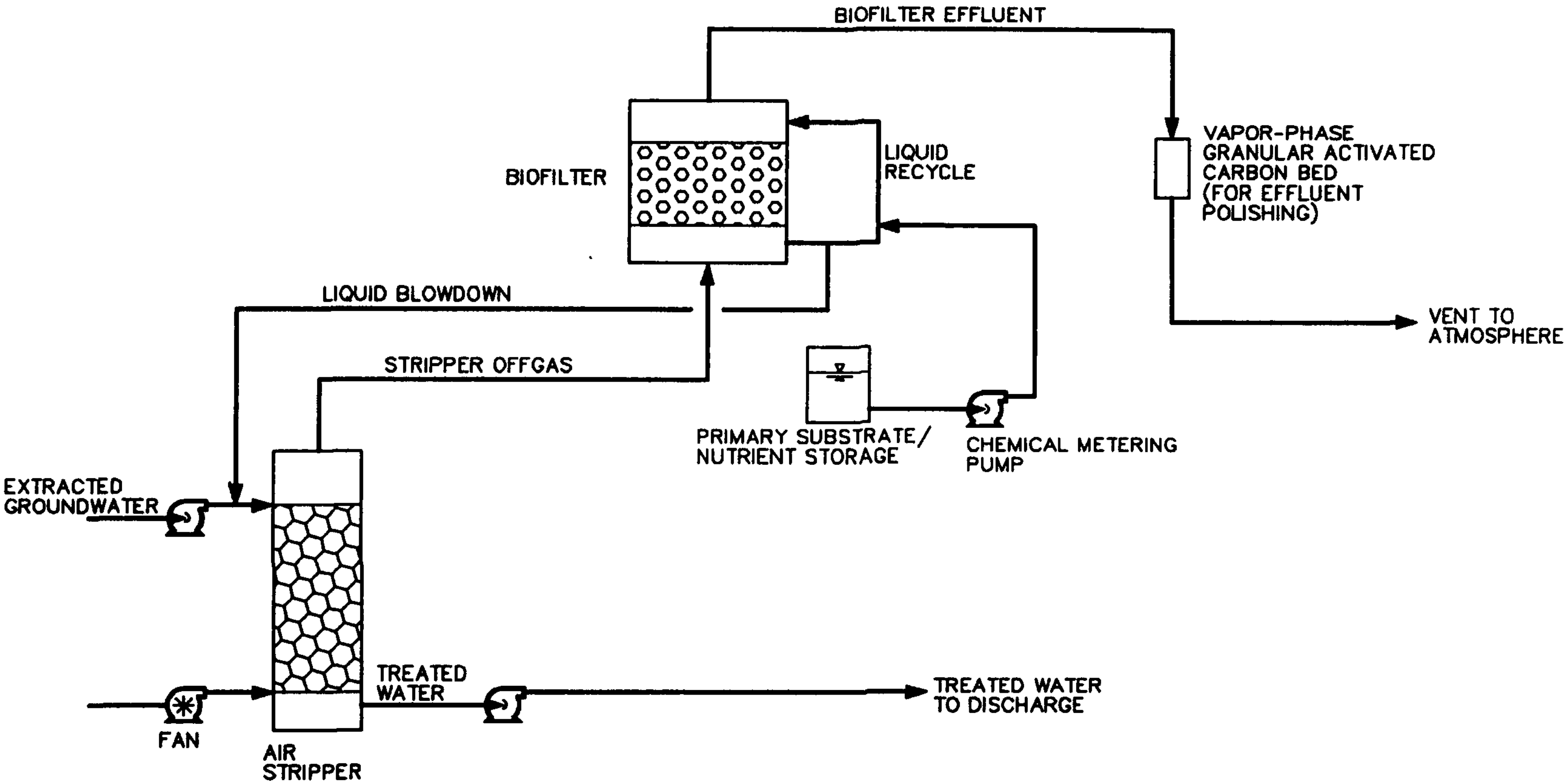

FIGURE L7-2
IMPLEMENTATION OF COMETABOLIC BIOFILTRATION INTO GROUNDWATER TREATMENT PLANT PROCESS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

RDD1454

CH2M HILL

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- The gas stream characteristics for which cometabolic biofiltration would be an effective and economical treatment option have not been established. The maximum influent flows and contaminant concentrations and maximum contaminant mass loading rates are unknown.

- Treatment performance characteristics, such as achievable contaminant reduction efficiencies and mass removal rates, are not well established.

- The currently available information indicates that treatment performance is inconsistent; consequently, polishing treatment may be required.

- The ability of cometabolic biofiltration systems to effectively treat complex contaminant mixtures is unknown.

- Several different research groups are developing this technology. It is not yet clear which group has the best system.

Schedule

A possible implementation schedule is shown in Figure L7-3.

Cost

Bench- and pilot-scale testing costs are estimated at roughly $100,000 and $210,000, respectively. Full-scale implementation costs are impossible to estimate at this time because of the relatively undeveloped status of the technology.

Works Cited

Hoda, B. McClellan AFB, Personal communication with CH2M HILL, November 2, 1993.

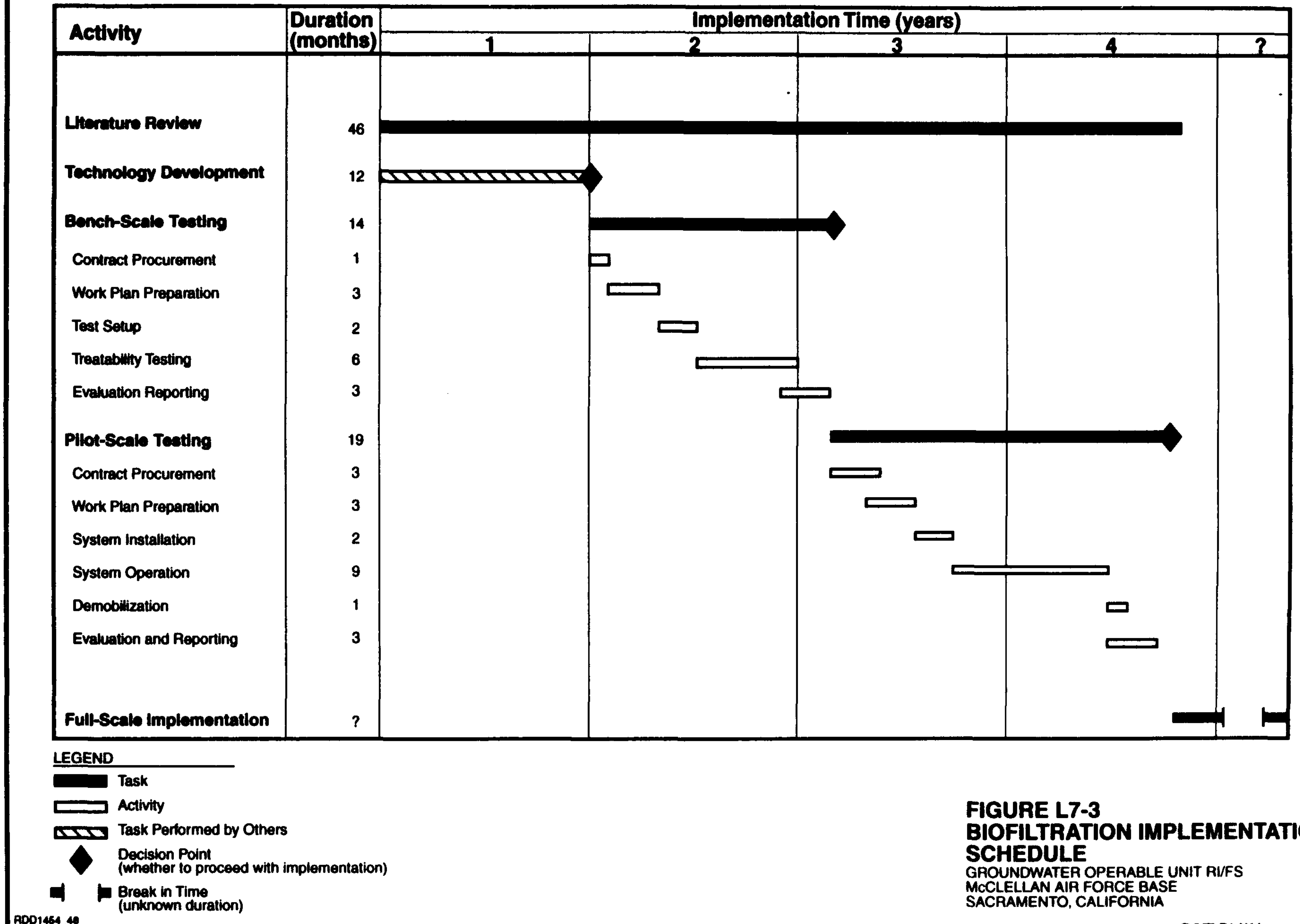


FIGURE L7-3
BIOFILTRATION IMPLEMENTATION SCHEDULE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Appendix L8

TECHNICAL MEMORANDUM L8

CH2M HILL

PREPARED FOR: McClellan Air Force Base

DATE: November 7, 1993

SUBJECT: Resin Adsorption Implementation Plan
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.NT

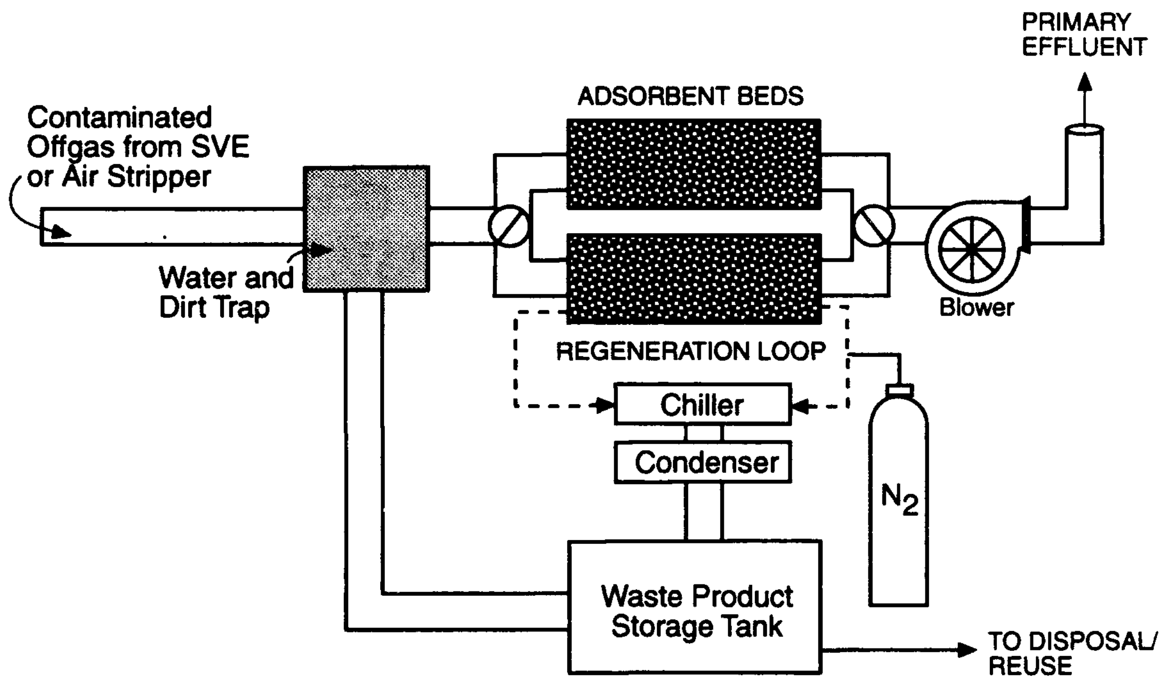
Technology Overview

Description

Resin adsorption is an offgas treatment technology that employs synthetic adsorbents placed in packed or fluidized beds to remove VOCs. It is similar to vapor-phase carbon adsorption, but laboratory testing suggests that the absorbent media (resin) has superior capacity and durability. Consequently, the resin can be regenerated in-place, through a large number of cycles. Possible applications at McClellan AFB are emissions control of offgas from ex situ groundwater treatment (e.g., air stripping) or in situ treatment processes (e.g., soil vapor extraction).

There are two resin adsorption systems on the market. The first system is marketed by Purus, Inc., as the Purus Adsorption Desorption Remediation Equipment (PADRE) system; the other is the Polyad process, marketed in the United States by Weatherly Inc. The processes are similar in principle, with the primary distinction being the mechanisms of contaminant adsorption and adsorbent desorption. Recent technology evaluations conducted by CH2M HILL have indicated that the Purus PADRE system appears to be more economical and therefore, has been chosen for further evaluation. However, subsequent evaluations of resin adsorption at McClellan AFB should consider the Polyad process as cost improvements may accompany further technology development.

The Purus PADRE system consists of one or more modular units, which contain the following major components: knockout tank (air/water separator), parallel adsorption bed modules, blower, chiller/condenser, nitrogen storage tank, product recovery tank, and a process control panel. Figure L8-1 is a conceptual schematic showing the PADRE system components.



Adapted from Purus, Inc.

RDD 1454_70

FIGURE L8-1
PADRE RESIN
ADSORPTION PROCESS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

The unit operates in a cycle of passive adsorption and thermal desorption. During passive adsorption, the contaminated influent air stream passes through two resin-filled filter beds connected in series. Each resin bed contains one or more proprietary synthetic polymeric adsorbents, which have been selected to optimize their affinity for adsorbing the particular suite of VOCs being treated. The treated gas stream that exits the beds is referred to as the primary effluent. It may require further treatment in the form of offgas polishing.

When the beds reach their maximum effective adsorption capacity, the influent gas stream is automatically diverted, on a pre-timed basis, to a parallel unit, and the contaminant-loaded beds begin the thermal desorption cycle. During this cycle, the resin bed is heated to about 150 to 250°C over a period of 60 minutes to volatilize the adsorbed organic contaminants and regenerate the beds. The heat is supplied by noncontact heat tracing cables evenly distributed within the bed supports. Once the desorption temperature is reached, the bed is purged with approximately 10- to 25-bed volumes of an inert carrier gas (typically nitrogen). The use of an inert carrier gas avoids the potential danger of explosion, as the desorbed gas can contain extremely high concentrations of contaminant compounds (several times their respective lower explosive limits). Following the inert gas purge, the bed is cooled to ambient temperatures through circulation of a heat transfer fluid (such as Dowtherm). The thermal desorption cycle is complete when the beds return to ambient temperature, ready to begin the next adsorption cycle.

The frequency of regeneration is limited by the thermal desorption cycle. This process takes approximately 2½ to 6 hours depending on the resin type and sorbed contaminants. Therefore, the number of adsorption/desorption cycles is limited to 4 to 10 cycles per day.

The purge gas (nitrogen) is passed through a chiller/condenser system where most of the gaseous contaminants are condensed to the liquid phase. The contaminant-lean nitrogen gas is then returned to the unit influent stream, or alternately, may be compressed and purified for reuse. The condensed liquid (condensate) may require organic/aqueous phase separation before the organic phase is transferred to a storage drum or tank, then transported for use as a fuel, or disposed as a hazardous waste. The separated aqueous phase would require further treatment.

Development Status

The resin adsorption technology has been demonstrated for industrial applications at the pilot-scale in the U.S. and Europe. There are several full-scale applications in use. Individual components have been tested in the laboratory and the field for hazardous waste remediation applications.

A field test of the PADRE system is being conducted at McClellan AFB in the Fall of 1993 in conjunction with the SVE system at Site S, OU D. The extent of further implementation of the resin adsorption technology in general, and the PADRE system in particular, at McClellan AFB, will depend on the results of this demonstration.

Potential Benefits

This subsection describes the performance, advantages and disadvantages, and cost benefits associated with PADRE resin adsorption. This information is intended to provide a basis for evaluating the potential benefits of implementing this technology at the Base as an innovative alternative to standard offgas treatment technologies such as vapor-phase carbon adsorption and catalytic or thermal oxidation.

General Performance

Effectiveness

- Treatment efficiency is typically greater than 90 percent for removal of total VOCs.
- Treatment efficiency for single contaminant PCE and TCE offgas streams is typically 95 percent; slightly less for DCE.
- 90 to 95 percent removal is typical for aromatics, aliphatics, alcohols, aldehydes, some ketones, and many chlorinated solvents.
- Relatively poor removal efficiencies of vinyl chloride and methylene chloride.
- The treatment efficiency for complex, highly concentrated waste streams is expected to vary, depending on the application, and is difficult to predict.

Robustness

- Halogenated and nonhalogenated VOCs are removed.
- Adsorption capacity for a given contaminant depends on its boiling point, molecular polarity, and competition with other compounds. Low boiling point and highly polar compounds are more difficult to remove.
- Contaminant influent concentrations up to 10,000 ppmv total organics have been treated.
- Resin adsorptive capacity may be maintained through many regenerative cycles, provided the system possesses sufficient desorption capacity. Some suites of compounds may cause very lengthy thermal desorption cycles, reducing overall cost-effectiveness.
- A complete treatment system can be assembled from modular units available for purchase or lease.

- The nature of the passive adsorption process results in some ability to accommodate fluctuations in influent concentrations, as well as a 20:1 turn-down capacity.

- Each modular unit contains a computer controlled/remote communication system for alarm reporting and system monitoring.

Potential Risk Reduction

It is difficult to quantify the risk reduction provided by resin adsorption treatment because the potential benefit of the technology is associated with its potential to reduce contaminants from process offgas streams more economically than standard treatment technologies. Resin adsorption treatment is not likely to provide more extensive treatment than standard technologies, but it would reduce contaminant levels compared to no treatment. Contaminants are recovered in the liquid-phase for disposal/reuse. Although transport and reuse may have an associated risk increase compared to in-place destruction.

Advantages Compared to Other Technologies

- The use of a regenerative resin results in less contaminated media requiring disposal than GAC.

- The media may be able to retain a high adsorptive capacity through numerous regeneration cycles.

- Performance is not as significantly impacted by the relative humidity of the influent stream compared to GAC, though high relative humidity may decrease treatment efficiency.

- The recovery of contaminants offers greater flexibility in determining their ultimate fate.

- Resin adsorption appears to have a niche for high flow, moderate concentration gas streams.

- Little to no HCl, HF, and NOx emissions occur compared to catalytic oxidation.

Disadvantages Compared to Other Technologies

- Removal efficiencies vary by compound and with contaminant stream characteristics. For offgases that contain a wide variety of compounds, the treatment efficiency and cost-effectiveness of resin adsorption is expected to be insuperior to catalytic oxidation.

- Long-term (5 to 10 years) resin performance data is not available for chlorinated VOCs.

- Because it is not a destruction technology, there is further management associated with the condensate (i.e., storage, treatment, disposal or reuse).

- The primary effluent may require polishing treatment in order to achieve emission standards.

- Very few technology vendors are available, possibly limiting cost competitiveness and the rate of technology development.

Relative Cost Benefit

The cost benefit of resin adsorption would result from its use in place of a more costly offgas treatment technology or through its combination with other technologies, reducing overall treatment cost. Cost benefits should be evaluated on the basis of $/mass of contaminants treated. When evaluating technology cost, condensate management should be included.

Potential Locations

Potential application locations for resin adsorption at McClellan AFB related to cleanup of contaminated soil and groundwater include the treatment of: air stripper offgas from groundwater treatment plant(s); SVE, SVE/sparging, or dual phase extraction offgas; and any other VOC-contaminated offgas stream generated at the Base. The operating flexibility of the system allows application to a wide range of locations, though highly complex or highly concentrated streams may be less appropriate, as well as those with vinyl chloride and/or methylene chloride as primary constituents.

Approach

Information Needs and Sources

Table L8-1 provides a summary of the information needs and sources for implementation of resin adsorption.

Information Gathering and Review

Information on resin adsorption collected includes vendor-supplied information on system design, performance, and operation, as well as preliminary results from the Fall 1993 project being performed at the SVE field demonstration site in Site S, OU D at the Base. Further information gathering should include a thorough review

Table L8-1
Resin Adsorption
Information Needs and Sources

Information Needs	Project Scale		
	Bench	Pilot	Full
Feed Stream Characteristics			
• Contaminant Types	S	S	S
• Contaminant Concentrations	S	O,S	O,S
• Contaminant Chemical/Thermodynamic Properties	L	L	L
• Flow Rate	V	O	O
• Flow/Concentration Variability	L,V	O,S	O
System Design			
• Unit Size	V	B	P
• Physical Configuration	V	V	P,V
• Equipment Requirements	V	B,O,V	O,P,V
• Patent Requirements	---	V	V
• Permitting Requirements	---	L,O	L,O
• Treatment Requirements	L,V	L,O	L,O
Performance Capabilities			
• Destruction Removal Efficiencies	V	B	P
• Flow Rate	V	B,V	P,V
• Ancillary Treatment Requirements	V	L,O,V	L,O,P
• Monitoring (Sampling and Analysis)	V	L	L
• Response to Feed Stream Variability	V	B,L,V	L,P
Operations & Maintenance			
• Cycle Times	---	B,V	P,V
• Nitrogen Use Requirements	V	B,V	P,V
• Gas Stream Temperatures	V	B,O	P,O
• Utility Connections/Installation Requirements	---	V	V
• Preventative Maintenance Requirements	---	V	V
• Safety	---	V	V
Residuals Management			
• HCl and HF emission rates	---	L,V	P
• Vinyl Chloride, Methylene Chloride and Acetone emission rates	V	B,V	P
• Condensed Contaminants Storage/Transport/Disposal/Reuse	---	L,V	L,P

Notes:
L = Literature/Experts
O = Other Technology Evaluations
P = Pilot Scale
S = Sampling Results
V = Vendor(s)

of the Site S demonstration final results when they are available, and a review of other demonstration test data from sites treating chlorinated solvent-containing offgas.

Implementation Issues

- The treatment system will have to meet the treatment objectives established to maintain compliance with the Basewide air emissions permit.

- Influent feed stream characteristics (i.e., contaminant distribution, temperature, and relative humidity) need to be compatible with the technology limitations. The use of resin adsorption in conjunction with another technology might be required in the event these limitations prevent sufficient treatment performance.

- A location with sufficient space and utilities connections is required for placement of the modular unit(s).

- A system for the safe management of condensed organics must be installed with the treatment units. Such a system would be composed of a contained storage facility, transfer piping, or a loading area, and a plan for organics disposal/use.

- The nature of the equipment procurement (lease versus buy) should be determined with a cost analysis. A combination lease-purchase agreement could be considered whereby the treatment modules are leased for a short duration at the beginning of operation, then purchased at a discount when successful treatment performance has been established.

Bench-Scale Testing

Bench-scale testing will only be required if technology implementation is being considered for an offgas with contaminant characteristics significantly different than those of the SVE offgas at Site S, since the pilot test at Site S has already targeted these objectives. The vendor should assist in the evaluation of the necessity for bench-scale testing.

Objectives

- Identify the resin or combination of resins most suitable for the specific contaminant stream of interest.

- Evaluate the effect of relative humidity and temperature on adsorption to identify the benefits of controlling humidity and temperature on contaminant sorption.

- Evaluate desorption characteristics of contaminants from the resins selected for testing.

- Establish the working adsorptive capacity of the selected resin(s).

Approach

1. Prepare bench-scale testing workplan.

2. Measure (or review) adsorption isotherms for various contaminants of concern using Purus' standard (vial headspace measurement) methods.

3. Conduct isotherm tests at varying temperatures and humidities to bracket the expected conditions for a specific application.

4. Conduct column studies with actual contaminant mixtures (if possible) simulating the specific application. A breakthrough curve will be measured. Air stream humidity and temperature should be controlled to match application conditions. The bed would be desorbed under standard conditions and the organics recovered in a condenser. At least three adsorption-desorption cycles should be tested.

5. Evaluate data and refine pilot-scale testing objectives.

Pilot-Scale Testing

Objectives

Pilot-scale testing is conducted to meet the following objectives:

- Determine the treatment efficiency achievable for individual contaminants and for total VOCs.

- Develop full-scale system design parameters such as unit size(s), equipment requirements, and process control parameters.

- Determine operations and maintenance criteria such as optimal (adsorption/desorption) cycle times, desorption gas requirements, and temperature or humidity controls.

- Establish the emission rates of HCl, HF, vinyl chloride, methylene chloride, and/or other effluent contaminants. Determine the need for ancillary offgas treatment systems.

- Establish the production rates of condensed liquid water phase and organic contaminants.

- Evaluate the cost benefits of full-scale implementation.
- Evaluate construction materials for treatment equipment, especially those associated with desorption cycle equipment.

Approach

Pilot-scale testing using a Base offgas would be necessary to rigorously evaluate technology feasibility and to develop design and operating parameters for an offgas. The specific objectives and approach of the pilot testing program would be refined and detailed following the information gathering and review and evaluation of the Site S demonstration results. The general pilot testing approach would include the following components.

- Select an appropriate target offgas stream for testing resin adsorption. A slip stream from an existing system would likely be used.
- Develop the pilot-testing workplan, using the existing procedures from the Site S demonstration as a basis.
- Prepare the site and bring a modular unit online.
- Operate the PADRE treatment system under the selected conditions.
- Analyze data to evaluate performance and the potential benefits of implementing resin adsorption treatment of the Base.
- Decide whether to proceed with implementation at full-scale.

Full-Scale Implementation

For the purpose of generating an order-of-magnitude cost estimate for implementation, a conceptual full-scale application of PADRE involves the following components:

- A successful pilot test establishing the potential cost benefit associated with implementation.
- A pad of sufficient size to support the unit(s) and control equipment.
- Utility connections, a nearby water source, a dedicated phone line, and a nitrogen supply system (storage and piping system).
- A condensate drain line and management system (adequately vented storage tanks with secondary containment provisions for disposal or use of the recovered organic phase, and transfer of the aqueous phase to a wastewater treatment system).

- Influent piping connections to the existing groundwater treatment plant offgas stream.

- Modular PADRE units sufficient to meet the contaminant loading rate.

A conceptual schematic of a PADRE system application is shown in Figure L8-2.

Technology Limitations and Uncertainties

- Cost-effective treatment performance for a complex mixture of chlorinated VOCs has not yet been established.

- The desorption capacity of the resin for some contaminants may significantly limit treatment efficiency or reduce cost-effectiveness through excessively long desorption cycles.

- The relative proportion of poorly sorbing contaminants in the influent gas will reduce overall treatment efficiency. High concentrations of vinyl chloride or methylene chloride may significantly reduce cost-effectiveness.

- Resin adsorption treatment efficiency is limited to 90 to 95 percent for many compounds, which may result in an inability to meet discharge requirements or may require effluent polishing.

- The amount of operator attention may vary for each application. The degree of operator attention is a function of the feed stream variability (resulting in the need to adjust cycling times/parameters) and the amount of emissions monitoring.

- Final use, and consequently management costs, of condensed organics (e.g., disposal or recycling) may vary depending on characteristics.

Schedule

Figure L8-3 contains a possible implementation schedule for the incorporation of resin adsorption into the groundwater treatment system at the Base. A significant uncertainty in the schedule is the need for and duration of further pilot testing. The results of the Fall 1993 pilot test at Site S will determine the extent to which further evaluation is required prior to implementation.

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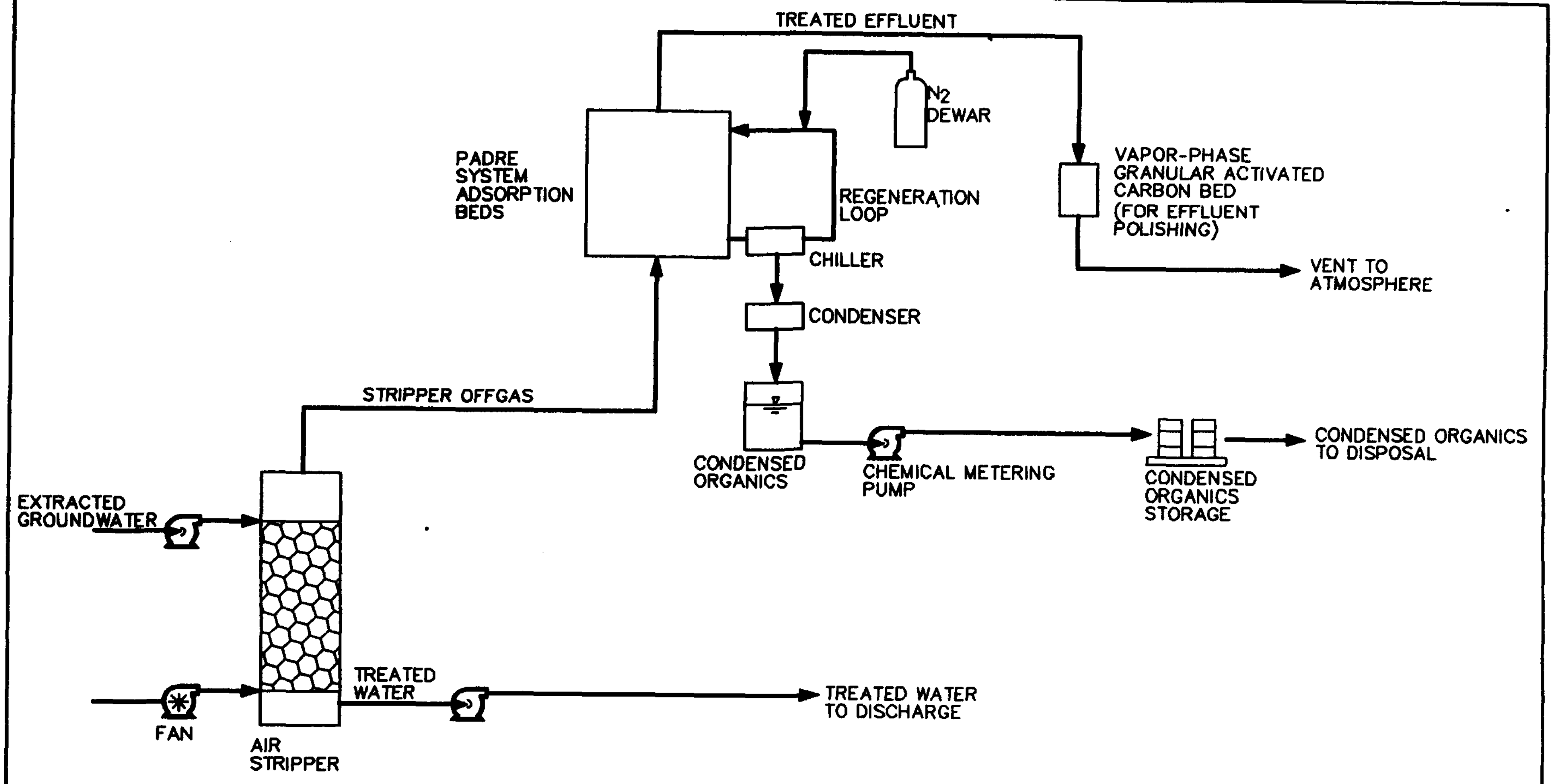

FIGURE L8-2
IMPLEMENTATION OF RESIN ADSORPTION INTO GROUNDWATER TREATMENT PLANT PROCESS
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

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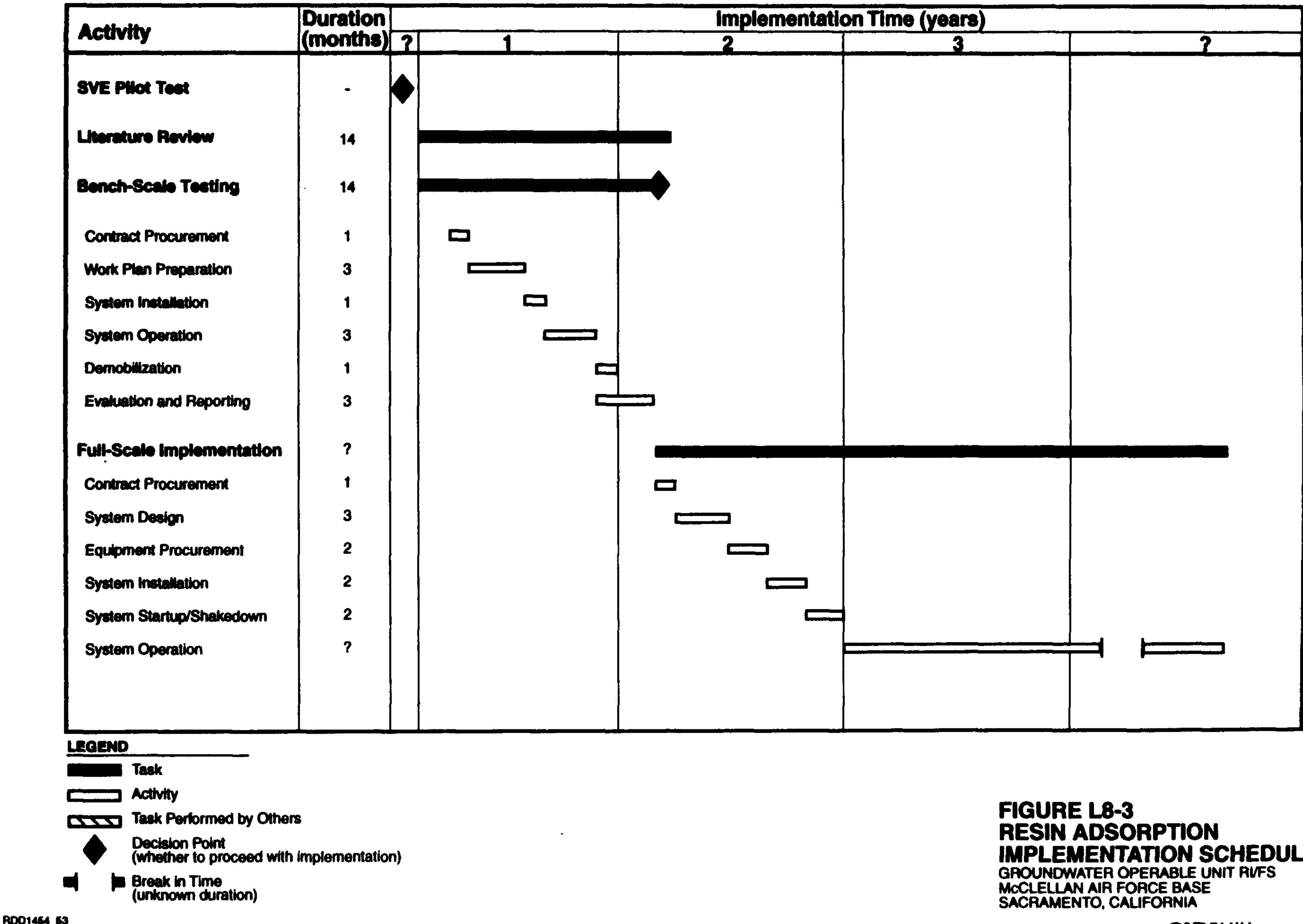

FIGURE L8-3
RESIN ADSORPTION IMPLEMENTATION SCHEDULE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Cost

This section presents an estimated range for order-of magnitude implementation costs based on the conceptual design. Implementation costs may include costs associated with: ongoing literature review, bench-scale testing, pilot-scale testing, and full-scale capital and annual operations and maintenance. The scope of each of these cost-related activities is summarized below:

- **Literature Review.** Vendors such as Purus and Weatherly are likely to further develop the technology such that enhancements (optimization) and limitations will be better understood. The decision to proceed with further implementation of resin adsorption requires ongoing assessment and review of field data. While this activity is not a significant cost factor of implementation, it is an important implementation activity.

- **Bench-Scale Testing.** This activity includes workplan development, contract procurement, and the cost of conducting and overseeing vial and column studies.

- **Pilot-Scale Testing.** This activity includes costs associated with scope and workplan development, contract procurement, equipment procurement, system installation, system operation, demobilization, sampling and analysis (system monitoring), evaluation of system performance, and reporting.

- **Full-Scale Capital.** Capital costs are direct and indirect costs required to initiate and install the technology system components, including (but not limited to) engineering design, mobilization and demobilization of equipment and people, site construction activities (i.e., equipment installation), contractor bonding and insurance, equipment procurement and installation, licensing and permitting, health and safety, and supervision during construction.

- **Full-Scale Operation and Maintenance.** Operation and maintenance (O&M) costs represent those costs which would be incurred during each year of operation from initial startup to final shutdown of the full-scale system. O&M costs include operation and maintenance labor, power, purge gas, condensed organics disposal, and sampling and analysis for system monitoring. Since annual O&M costs occur over a period of years, future costs have been discounted to the present year's equivalent value (i.e., the present value cost) using 5 percent interest, so that annual costs remain comparable. Actual annual costs are likely to be much higher during the first year(s) of operation as the system is commissioned and optimized for operation, and due to higher chemical usage rates and associated labor required for treating higher initial concentrations. Therefore, the annual costs are intended to represent the anticipated average yearly cost of operation over the life of the system.

A contingency of 30 percent has been applied to the full-scale implementation cost to account for possible project cost increases due to scope and bid variations that typically occur with hazardous waste remediation projects. These increases are typically caused by the changes that normally occur as part of final design and implementation, based on observation of actual field conditions/contamination, and factors which affect the cost of subcontracted services, such as labor and material shortages. Not included in the estimates are any agency or Air Force administrative costs, nor any costs associated with modifications of the existing groundwater treatment system(s).

Typically, order-of-magnitude cost estimates for general construction projects are intended to reflect an accuracy of within 50 percent greater to 30 percent less than actual costs. The estimates summarized below are expected to be within these ranges; however, there is greater uncertainty of accuracy as a result of the lesser degree of development associated with this innovative technology compared to general construction technologies. Current pricing data based on quoted equipment costs, construction cost data (e.g., Means, 1993), previous local project experience, and engineering judgment have been used to generate the estimates, using adjustments for local McClellan AFB costs when available. Final project costs will depend on actual labor and material costs, actual site conditions at the time of implementation, productivity, competitive market conditions, final project scope and schedule, contractors selected to perform activities, and many other variables. As a result, the final project costs will differ from the exact value of any estimates presented here.

The following order-of-magnitude implementation costs are estimated for resin adsorption (presuming PADRE system):

- Literature review will require approximately $9,000 over a period of one year.
- Bench-scale testing would cost approximately $20,000, if necessary.
- Pilot-scale testing is estimated to cost approximately $200,000, should the ongoing pilot-testing at Site S prove to be inconclusive.
- Full-scale implementation cost of a two-module system ranges from $1.6M to $3.4M. This corresponds to a treatment cost of $2.70/lb to $5.70/lb.

Key assumptions associated with the full-scale cost estimate, in addition to those previously described, include:

- System operation is for a period of 3 years.
- VOC loading per unit is 100,000 lbs/year.

- Condensed organic disposal is $300/drum.
- Purge nitrogen costs approximately $3.20/operational hour; electrical costs are $2.30/operational hour.
- System monitoring requires the collection and analysis of four canister samples per module per month.

Works Cited

Means, 1993.

PREPARED FOR: McClellan Air Force Base

DATE: March 25, 1994

SUBJECT: Influent VOC Concentration Estimate
Groundwater OU RI/FS
Delivery Order No. 5066

PROJECT: SAC28722.66.FS

Introduction

The objective of this technical memorandum is to calculate the groundwater influent concentrations for order-of-magnitude and budget level treatment cost estimates and plant sizing. Because order-of-magnitude costs were used to compare and rank alternatives, only relative accuracy was needed for the preliminary influent concentrations and flows. Therefore, treatment plant sizing and cost estimations were performed before the completion of the groundwater modeling. Absolute accuracy was needed for the final influent concentrations and flows for the budget level cost estimates. This was achieved by incorporating the results of the groundwater modeling after modeling was completed.

The strategy, procedures, and results of the influent concentration calculations for the order-of-magnitude cost estimates are presented first. Following that will be a discussion concerning the strategy, procedures, and results of the influent concentration estimates for the budget level treatment costs.

Influent Concentrations for Order-of-Magnitude Cost Estimates

Strategy

VOC concentrations vary significantly with distance from the source areas. Concentrations tend to be highest near the source areas (centers of the plume) and tend to decrease logarithmically away from the center of the plume. For this reason, the contaminant plumes were divided into the following target areas, as discussed in Chapter 2, Conceptual Model, of the RI/FS Report:

- Areas with TCE concentrations greater than 500 $\mu g/l$ were considered hot spots. They could require separate hydraulic control and separate treatment trains, possibly innovative technologies. Influent concentrations from these areas would be high, but extraction flow rates would be low.

- Areas with TCE concentrations greater than 5 $\mu g/l$ and less than 500 $\mu g/l$ were considered the MCL containment areas.

- Areas with TCE concentrations greater than 1 $\mu g/l$ and less than 500 $\mu g/l$ were considered the background containment areas.

Influent concentrations would be low and extraction flow rates would be high from the MCL and background containment areas. Innovative technologies would only be part of this remedy if they are an innovation in the treatment process.

Influent VOC concentrations from each of the target volumes described above were estimated. TCE is the most prevalent groundwater VOC contaminant. Thus, the extent of TCE generally defined the target volumes. With few exceptions, other VOCs were detected only in areas where TCE was detected. Most recent sampling results for each well were used to estimate the influent concentrations.

Procedure

The VOC groundwater contamination was divided into three distinct plumes: the OU A, OU B/C, and the OU D plumes. Influent from the OU A plume would be piped to a proposed treatment plant on the east side of the Base. Influent from the OU B/C and the OU D plumes would be piped to the existing treatment plant on the west side of the Base.

Influent concentrations from the hot spots and the containment areas were estimated separately by taking the area weighted mean concentration of the plume for each zone, then compositing the zones to obtain the influent estimates for the plume. The zones would be composited by taking the flow weighted mean concentration for the plume. The following paragraphs will discuss the steps taken and the equations used to perform these estimates.

Area-Weighted Groundwater Concentrations by Plume and by Zone

Concentrations of VOCs in the groundwater were contoured using linear interpolation as discussed in Appendix K, VOC Mass Estimates. The concentrations within each target area (hot spot, MCL, and background) were estimated by taking an area-weighted average of the concentrations within each contour. For example, the areas and concentration intervals within the background target area of the OU D Monitoring Zone A plume are presented in Table M-1.

Table M-1
Area-Weighted TCE Influent Concentration Averages
for OU D Monitoring Zone A Background Containment Area

Concentration Interval (μg/l)	Average Concentration within interval (μg/l)	Area Contour Encloses (ft^2)	Area of Contour Interval Ring (ft^2)	Ring Area * Average Concentration (ft^2 μg/l)
1 to 5	3	19,341,735	8,943,221	26,829,663
5 to 10	7.5	10,398,514	240,291	1,802,183
10 to 100	55	10,158,223	3,747,466	206,110,630
100 to 500	300	6,410,757	5,200,890	1,560,267,000
Total Background Containment Area			18,131,868	
Summation of (Ring Area—Average Concentration)				1,795,009,476
Area-Weighted Background Concentration (Summation/Total Area)				98.998

The calculations in Table M-1 were performed for the target volumes for each zone of each plume.

Area-Weighted Concentrations from Each Zone

The area-weighted concentrations from each zone for a given target volume were combined by performing flow weighted averages. This concept is illustrated in the following equation:

$$C_{ouA} = \frac{C_{ZA} \cdot Q_{ZA} + C_{ZB} \cdot Q_{ZB} + C_{ZC} \cdot Q_{ZC}}{Q_{ZA} + Q_{ZB} + Q_{ZC}}$$

where: C_{ouA} is the flow-weighted concentration in an OU.

C_{ZA} is the concentration in the A Zone.

C_{ZB} is the concentration in the B Zone.

C_{ZC} is the concentration in the C Zone.

Q_{ZA} is the flow from the A Zone.

Q_{ZB} is the flow from the B Zone.

Q_{ZC} is the flow from the C Zone.

Table M-2 list the flow rates used from the groundwater model.

Table M-2
Summary of Extraction Rates by Zone
(gpm)

Background Plume	Zone A	Zone B	Zone C	Total
OU A	90	60	0	150
OU B/C	72	180	462	714
OU D	30	75	0	105
Total	192	315	462	969

Concentrations from the West Treatment Plant

The influent concentrations from the OU B/C and the OU D plumes were combined to be channeled to the west treatment plant by taking flow-weighted averages. This process is illustrated in the following equations:

$$C\ west\ plant = \frac{C_{B/C} \cdot Q_{B/C} + C_D \cdot Q_D}{Q_{BC} + Q_D}$$

Where: C is the flow-weighted concentration to the west treatment plant.

$C_{B/C}$ is the flow-weighted concentration from OU B/C (from Equation 1).

C_D is the flow-weighted concentration from OU D (from Equation 1).

$Q_{B/C}$ is the flow from OU B/C.

Q_D is the flow from OU D.

Summary of Influent Concentrations for Order-of-Magnitude Cost Estimates

Hot spots (VOC concentrations greater than 500 $\mu g/l$) were located only in Monitoring Zone A. The flow weighted concentrations of several VOCs examined during the treatment plant sizing and order-of-magnitude cost estimates are presented in Table M-3.

Table M-3
Order-of-Magnitude Influent Concentration Estimates ($\mu g/l$)

	West Treatment Plant			East Treatment Plant		
Parameter	**Hot Spot**	**MCL**	**Background**	**Hot Spot**	**MCL**	**Background**
TCE	3697	33	17	4559	21	57
1,2-DCA	.2	12.3	12.4	6.5	12.7	12.7
1,1-DCA	7.2	1.0	1.1	1.6	1.6	1.3
1,1,1-TCA	185	12.2	6.7	840	0	1.9
Acetone	148	6.5	5.6	520	2.2	3.3
Methylene Chloride	232	.1	1.9	2.9	0	0

Future conditions were assessed in determining the validity of using area-weighted averages for the hot spot target areas. The following assumptions were made:

- The initial concentration in the extraction well was considered the current estimated value at that location.
- The concentration gradients in the hot spots are steep.

The future concentrations can be predicted from surrounding concentrations. Using flow- and area-weighted averages, a lower concentration area of a hot spot in the future may have higher concentrations. Conversely, the highest concentration area may in the future have lower concentrations. Therefore, the area-weighted mean concentration will provide a reasonable estimate of the influent concentration and is valid even in hot spot areas.

Influent Concentrations for Budget Level Cost Estimates

Strategy

The order-of-magnitude cost estimates and treatment plant sizing concluded that treating the hot spot and containment area influents separately would not be more efficient or economically feasible than treating them together. Therefore, influent concentrations from the hot spots were not calculated separately, but were included in the containment target volume influent concentrations. The target volumes identified for the budget level cost estimates were as follows:

- Areas with TCE concentrations greater than 5 $\mu g/l$ were considered the MCL containment areas.
- Areas with TCE concentrations greater than 0.5 $\mu g/l$ were considered the background containment areas.
- Areas with cancer risk values greater than 10^{-6} were considered the risk target volumes.

Because TCE is the most prevalent VOC contaminant, the MCL and background target volumes were defined by TCE concentrations. Generally, when other VOCs were detected, TCE was also measured at detectable levels.

Procedure

Because hot spots need not be isolated, it was possible to automate and greatly simplify the estimation of influent concentrations. Influent concentrations in the MCL, background, and risk target volumes were estimated by performing statistical analyses on wells with concentrations or risk values exceeding the criteria previously listed. The following paragraphs describe the procedures followed to estimate influent concentrations for the budget level cost analyses.

Monitoring wells were divided into two groups to estimate the east and west treatment plant influent concentrations. The samples from wells with easting coordinates greater than 2,169,853 were considered to delineate the target volumes on the east side. The samples from wells with easting coordinates less than 2,169,853 were considered to define the target areas on the west side.

The most recent VOC sampling results for each well sampled during or after 1988 were used to identify the wells with concentrations greater than MCLs or background. The most recent risk values were used to identify wells with risk values greater than 10^{-6}. Once these wells were identified, summary statistics of all the most recent results of all these selected wells were performed to determine the mean influent concentration from these target volumes. For example, 63 wells on the west side had more recent TCE sampling results greater than 5 μg/l (MCL target volume). Summary statistics were calculated for all sampling results at those 63 wells.

Summary statistics include number of detects, number of samples, frequency of detection, and minimum and maximum detected value and mean concentration. Nondetect values were made equal to zero for these statistics because in many cases of frequently nondetect compounds, the detection levels were high. The summary statistics results for the background MCL and risk target volumes on the east and west sides of the Base are presented in Table M-4 through M-9.

Summary of Influent Concentrations for Budget Level Cost Estimates

The influent concentrations for budget level cost estimates are summarized in Table M-10. These budget level influent concentration estimates for the target volumes are considerably higher than the order-of-magnitude influent concentration - estimates for the target volumes because they include the concentrations from the hot spots, whereas the order-of-magnitude concentrations isolated the hot spots. The order-of-magnitude estimates isolated hot spots from the MCL and risk target volumes. For example, order ofmagnitude influent concentrations from the MCL target volumes came from regions where TCE concentrations were greater than 5 μg/l and less than 500 μg/l. Conversely, budget-level influent concentrations from the MCL target volume came from regions where TCE concentrations were greater than 5 μg/l, including the hot spots.

In addition, since background concentrations have not been established, it is not possible to differentiate between metals concentrations due to natural conditions such as mineral dissolution and metal contamination from Base activities.

The impact of metals concentrations on the effectiveness of the treatment system has been discussed in Chapter 13, Implentation Plans/Detailed Evaluation. The influent concentrations of metals were calculated in the same manner as influent VOC concentrations. Summary statistics were performed on the second and third quarter 1993 metals sampling results of wells that are located within the MCL, risk, and background target volumes. The target volumes were determined by VOC concentrations.

The influent concentrations for the three target volumes to the east and west treatment plants are presnted in Tables M-4 to M-14. As discussed in Section 4, Conceptual Model, it is not possible to determine how these samples were collected, i.e., filterred or unfiltered or with high or low purge rates.

The estimates for vinyl chloride are conservative, because vinyl chloride has not been detected in any wells since 1991. The calculations included all sampling results for wells with most recent values with the target volume criteria.

Table M-4
VOC Influent Concentrations From the Background Target Volume to the East Treatment Plant
Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value		Detected Value		Mean[2]	Standard Deviation
				Minimum	Maximum	Minimum	Maximum		
TRICHLOROETHYLENE (TCE)	34	36	94	0.20	0	0.46	16,000.00	935.98	3,503.26
cis-1,2-DICHLOROETHYLENE	9	31	29	0.04	3	0.58	210.00	8.81	38.32
CHLOROFORM	10	36	28	0.03	100	0.25	22.00	1.43	3.93
CARBON TETRACHLORIDE	9	36	25	0.04	300	0.81	22.40	2.06	5.81
METHYLENE CHLORIDE	7	32	22	0.04	400	0.48	51.40	1.89	9.07
TETRACHLOROETHYLENE(PCE)	7	36	19	0.04	100	0.29	1.59	0.17	0.43
1,2-DICHLOROETHANE	5	36	14	0.03	100	0.50	30.30	1.10	5.13
1,1-DICHLOROETHENE	4	36	11	0.06	700	1.46	6.60	0.43	1.38
1,1-DICHLOROETHANE	2	36	6	0.02	500	1.60	2.30	0.11	0.46
BENZENE	1	24	4	0.01	150	820.00	820.00	34.17	167.38
XYLENES, TOTAL	1	24	4	0.05	200	0.56	0.56	0.02	0.11
1,1,1-TRICHLOROETHANE	1	36	3	0.14	770	0.98	0.98	0.03	0.16
1,2-DICHLOROPROPANE	1	36	3	0.02	100	0.85	0.85	0.02	0.14
trans-1,3-DICHLOROPROPENE	1	36	3	0.03	340	0.62	0.62	0.02	0.10

Notes:

[1] Calculations performed on data set are presented in Chapter 4, Conceptual Model.

[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.

[3] Only parameters that were detected at least once are presented.

Table M-5
VOC Influent Concentrations From the Background Target Volume to the West Treatment Plant
Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value		Detected Value		Mean[2]	Standard Deviation
				Minimum	Maximum	Minimum	Maximum		
TRICHLOROETHYLENE (TCE)	93	102	91	0.07	2	0.32	26,000.00	825.55	3,266.93
cis-1,2-DICHLOROETHYLENE	42	80	53	0.04	120	0.36	38.70	5.27	9.51
METHYLENE CHLORIDE	41	95	43	0.40	800	0.40	351.00	16.35	59.17
TOTAL 1,2-DICHLOROETHENE	1	4	25	0.20	400	2.20	2.20	0.55	1.10
1,1-DICHLOROETHENE	22	102	22	0.06	400	1.06	13,600.00	281.05	1,529.91
TETRACHLOROETHYLENE(PCE)	22	102	22	0.04	200	0.10	2,100.00	34.64	223.69
CHLOROFORM	19	102	19	0.03	200	0.11	4.34	0.22	0.62
1,1-DICHLOROETHANE	18	102	18	0.02	1,000	0.34	230.00	4.81	27.24
1,2-DICHLOROETHANE	18	102	18	0.03	200	0.21	120.00	2.62	15.78
1,1,1-TRICHLOROETHANE	14	102	14	0.14	400	0.65	1,290.00	26.16	177.05
TOLUENE	5	71	7	0.03	400	0.24	51.00	0.74	6.05
1,2-DICHLOROBENZENE	3	102	3	0.03	1,000	0.67	57.30	0.82	6.19
BENZENE	2	71	3	0.01	400	0.94	1.10	0.03	0.17
XYLENES, TOTAL	2	71	3	0.05	400	0.51	2.69	0.05	0.32
CARBON TETRACHLORIDE	2	102	2	0.04	240	0.41	0.57	0.01	0.07
1,3-DICHLOROBENZENE	2	102	2	0.02	640	0.27	1.05	0.01	0.11
1,4-DICHLOROBENZENE	2	102	2	0.01	480	3.80	37.70	0.41	3.75
1,2-DICHLOROPROPANE	2	102	2	0.02	200	0.22	0.25	0.00	0.03
TRICHLOROFLUOROMETHANE	2	102	2	0.06	400	3.70	15.00	0.18	1.53
VINYL CHLORIDE	2	102	2	0.08	400	83.00	360.00	4.34	36.50
BROMODICHLOROMETHANE	1	102	1	0.01	200	0.76	0.76	0.01	0.08
CHLOROBENZENE	1	102	1	0.01	500	1.95	1.95	0.02	0.19

Notes:

[1] Calculations performed on data set are presented in Chapter 4, Conceptual Model.

[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.

[3] Only parameters that were detected at least once are presented.

Table M-6
VOC Influent Concentrations From the Risk Target Volume to the East Treatment Plant
Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value Minimum	Nondetected Value Maximum	Detected Value Minimum	Detected Value Maximum	Mean[2]	Standard Deviation
TRICHLOROETHYLENE (TCE)	27	30	90	0.04	0	0.46	16,000.00	1,122.98	3,820.34
cis-1,2-DICHLOROETHYLENE	9	25	36	0.04	3	0.58	210.00	10.92	42.56
CHLOROFORM	10	30	33	0.03	100	0.25	22.00	1.72	4.26
CARBON TETRACHLORIDE	9	30	30	0.04	300	0.81	22.40	2.47	6.30
TETRACHLOROETHYLENE(PCE)	7	30	23	0.04	100	0.29	1.59	0.20	0.46
METHYLENE CHLORIDE	5	28	18	0.04	400	0.81	51.40	2.12	9.70
1,2-DICHLOROETHANE	5	30	17	0.03	100	0.50	30.30	1.32	5.61
1,1-DICHLOROETHENE	4	30	13	0.06	700	1.46	6.60	0.52	1.51
1,1-DICHLOROETHANE	2	30	7	0.02	500	1.60	2.30	0.13	0.50
BENZENE	1	20	5	0.01	150	820.00	820.00	41.00	183.36
XYLENES, TOTAL	1	20	5	0.05	200	0.56	0.56	0.03	0.13
DIBROMOCHLOROMETHANE	1	30	3	0.01	200	0.49	0.49	0.02	0.09
trans-1,3-DICHLOROPROPENE	1	30	3	0.03	340	0.62	0.62	0.02	0.11
1,2-DICHLOROPROPANE	1	30	3	0.02	100	0.85	0.85	0.03	0.16
1,1,1-TRICHLOROETHANE	1	30	3	0.14	770	0.98	0.98	0.03	0.18

Notes:
[1] Calculations performed on data set are presented in Chapter 4, Conceptual Model.
[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.
[3] Only parameters that were detected at least once are presented.

Table M-7
VOC Influent Concentrations From the Risk Target Volume to the West Treatment Plant
Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value Minimum	Nondetected Value Maximum	Detected Value Minimum	Detected Value Maximum	Mean[2]	Standard Deviation
TRICHLOROETHYLENE (TCE)	76	80	95	0.20	1	1.23	26,000.00	1,052.31	3,661.09
cis-1,2-DICHLOROETHYLENE	40	66	61	0.04	120	0.36	38.70	6.37	10.15
METHYLENE CHLORIDE	35	74	47	0.40	800	0.47	351.00	20.91	66.43
TETRACHLOROETHYLENE(PCE)	21	80	26	0.04	200	0.10	2,100.00	44.17	252.08
1,2-DICHLOROETHANE	18	80	23	0.03	200	0.21	120.00	3.34	17.78
1,1-DICHLOROETHENE	18	80	23	0.06	400	1.06	13,600.00	355.63	1,722.15
CHLOROFORM	18	80	23	0.03	200	0.18	4.34	0.28	0.69
1,1-DICHLOROETHANE	16	80	20	0.02	1,000	1.30	230.00	6.11	30.67
1,1,1-TRICHLOROETHANE	11	80	14	0.14	400	0.65	1,290.00	33.28	199.59
TOLUENE	3	56	5	0.03	400	0.24	51.00	0.92	6.81
BENZENE	2	56	4	0.01	400	0.94	1.10	0.04	0.19
CARBON TETRACHLORIDE	2	80	3	0.04	240	0.41	0.57	0.01	0.08
1,2-DICHLOROBENZENE	2	80	3	0.03	1,000	25.50	57.30	1.03	6.98
1,4-DICHLOROBENZENE	2	80	3	0.01	480	3.80	37.70	0.52	4.23
1,2-DICHLOROPROPANE	2	80	3	0.02	200	0.22	0.25	0.01	0.04
VINYL CHLORIDE	2	80	3	0.08	400	83.00	360.00	5.54	41.19
XYLENES, TOTAL	1	56	2	0.05	400	2.69	2.69	0.05	0.36
BROMODICHLOROMETHANE	1	80	1	0.01	200	0.76	0.76	0.01	0.09
CHLOROBENZENE	1	80	1	0.01	500	1.95	1.95	0.02	0.22
1,3-DICHLOROBENZENE	1	80	1	0.02	640	1.05	1.05	0.01	0.12

Notes:
[1] Calculations performed on data set are presented in Chapter 4, Conceptual Model.
[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.
[3] Only parameters that were detected at least once are presented.

Table M-8

VOC Influent Concentrations From the MCL Target Volume to the East Treatment Plant

Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value Minimum	Nondetected Value Maximum	Detected Value Minimum	Detected Value Maximum	Mean[2]	Standard Deviation
TRICHLOROETHYLENE (TCE)	18	18	100			1.96	16,000.00	1,870.72	4,839.15
CHLOROFORM	8	18	44	0.03	100	2.20	22.00	2.80	5.28
CARBON TETRACHLORIDE	7	18	39	0.06	300	0.82	22.40	3.99	7.84
cis-1,2-DICHLOROETHYLENE	5	13	38	0.04	3	1.90	210.00	20.69	58.37
1,2-DICHLOROETHANE	5	18	28	0.03	100	0.50	30.30	2.19	7.18
1,1-DICHLOROETHENE	3	18	17	0.06	700	1.46	6.60	0.64	1.71
METHYLENE CHLORIDE	3	18	17	0.04	400	1.46	51.40	3.03	12.08
TETRACHLOROETHYLENE(PCE)	3	18	17	0.04	100	0.29	0.64	0.07	0.18
1,1-DICHLOROETHANE	2	18	11	0.02	500	1.60	2.30	0.22	0.64
BENZENE	1	13	8	0.08	150	820.00	820.00	63.08	227.43
XYLENES, TOTAL	1	13	8	0.08	200	0.56	0.56	0.04	0.16
trans-1,3-DICHLOROPROPENE	1	18	6	0.03	340	0.62	0.62	0.03	0.15
1,2-DICHLOROPROPANE	1	18	6	0.02	100	0.85	0.85	0.05	0.20

Notes:

1 Calculations performed on data set are presented in Chapter 4, Conceptual Model.

2 The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.

3 Only parameters that were detected at least once are presented.

Table M-9
VOC Influent Concentrations From the MCL Target Volume to the West Treatment Plant
Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value Minimum	Nondetected Value Maximum	Detected Value Minimum	Detected Value Maximum	Mean[2]	Standard Deviation
TRICHLOROETHYLENE (TCE)	66	69	96	0.20	2	1.70	26,000.00	1,219.63	3,919.85
cis-1,2-DICHLOROETHYLENE	35	56	63	0.04	120	0.60	38.70	7.40	10.69
METHYLENE CHLORIDE	32	64	50	0.40	800	0.40	351.00	23.97	71.01
1,1-DICHLOROETHENE	19	69	28	0.06	400	1.06	13,600.00	415.38	1,849.31
TETRACHLOROETHYLENE(PCE)	18	69	26	0.04	200	0.31	2,100.00	51.20	271.03
1,2-DICHLOROETHANE	16	69	23	0.03	200	0.21	120.00	3.86	19.11
CHLOROFORM	16	69	23	0.03	200	0.18	4.34	0.30	0.73
1,1-DICHLOROETHANE	15	69	22	0.02	1,000	1.30	230.00	7.06	32.96
1,1,1-TRICHLOROETHANE	11	69	16	0.14	400	0.65	1,290.00	38.60	214.65
TOLUENE	3	51	6	0.03	400	0.24	51.00	1.02	7.14
BENZENE	2	51	4	0.01	400	0.94	1.10	0.04	0.20
1,2-DICHLOROBENZENE	2	69	3	0.03	1,000	25.50	57.30	1.20	7.51
1,4-DICHLOROBENZENE	2	69	3	0.01	480	3.80	37.70	0.60	4.55
1,2-DICHLOROPROPANE	2	69	3	0.02	200	0.22	0.25	0.01	0.04
VINYL CHLORIDE	2	69	3	0.08	400	83.00	360.00	6.42	44.33
XYLENES, TOTAL	1	51	2	0.05	400	2.69	2.69	0.05	0.38
BROMODICHLOROMETHANE	1	69	1	0.01	200	0.76	0.76	0.01	0.09
CHLOROBENZENE	1	69	1	0.01	500	1.95	1.95	0.03	0.23
CARBON TETRACHLORIDE	1	69	1	0.04	240	0.57	0.57	0.01	0.07
1,3-DICHLOROBENZENE	1	69	1	0.02	640	1.05	1.05	0.02	0.13

Notes:
[1] Calculations performed on data set are presented in Chapter 4, Conceptual Model.
[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.
[3] Only parameters that were detected at least once are presented.

Table M-10
Metals Influent Concentrations From the Background Target Volume to the East Treatment Plant
Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value		Detected Value		Mean[2]	Standard Deviation
				Minimum	Maximum	Minimum	Maximum		
ALUMINUM	9	14	64	28.00	45	60.00	310.00	111.00	113.16
ARSENIC	1	14	7	0.00	4	8.50	8.50	0.61	2.27
BARIUM	14	14	100			9.90	190.00	55.64	43.07
CALCIUM	14	14	100			10,000.00	68,000.00	20,035.71	14,604.56
CHROMIUM, TOTAL	14	14	100			11.00	17,000.00	1,326.57	4,514.81
COBALT	2	14	14	3.00	7	9.20	18.00	1.94	5.23
COPPER	4	14	29	3.00	6	6.70	250.00	19.59	66.41
IRON	14	14	100			12.20	71,000.00	6,149.80	18,699.75
LEAD	6	14	43	3.00	3	3.00	4.20	1.53	1.86
MAGNESIUM	14	14	100			6,860.00	47,000.00	14,282.86	9,951.38
MANGANESE	14	14	100			6.20	390.00	57.92	100.19
MOLYBDENUM	1	14	7	4.00	8	190.00	190.00	13.57	50.78
NICKEL	12	14	86	16.00	16	16.00	2,700.00	296.33	702.29
POTASSIUM	9	14	64	3,000.00	3,000	3,000.00	8,170.00	2,905.00	2,556.14
SODIUM	14	14	100			13,800.00	33,000.00	17,292.86	4,862.49
VANADIUM	14	14	100			13.00	86.00	30.47	17.00
ZINC	13	14	93	3.00	3	3.60	1,400.00	155.75	366.17

Notes:
[1] Calculations performed on second and third quarter 1993 monitoring results.
[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.
[3] Only parameters that were detected at least once are presented.

Table M-11
Metals Influent Concentrations From the Background Target Volume to the West Treatment Plant
Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value Minimum	Nondetected Value Maximum	Detected Value Minimum	Detected Value Maximum	Mean[2]	Standard Deviation
ALUMINUM	25	51	49	28.00	45	53.30	12,700.00	1,123.16	2,970.27
ARSENIC	9	51	18	0.00	4	4.00	21.90	1.62	4.26
BARIUM	51	51	100			13.00	286.00	78.58	61.39
BERYLLIUM	1	51	2	0.00	1	1.00	1.00	0.02	0.14
CADMIUM	1	51	2	1.00	4	4.00	4.00	0.08	0.56
CALCIUM	51	51	100			11,500.00	59,500.00	22,891.18	10,856.50
CHROMIUM, TOTAL	48	51	94	2.00	7	8.10	8,870.00	425.30	1,325.36
COBALT	8	51	16	3.00	7	8.10	15.90	1.82	4.40
COPPER	21	51	41	3.00	6	6.20	240.00	17.06	45.04
IRON	50	51	98	6.00	6	10.00	46,600.00	4,694.83	8,843.04
LEAD	29	51	57	0.00	42	3.10	24.00	4.08	4.93
MAGNESIUM	51	51	100			3,700.00	43,100.00	15,574.02	8,476.12
MANGANESE	47	51	92	0.00	2	1.40	1,670.00	111.82	254.57
MOLYBDENUM	8	51	16	4.00	8	9.00	94.80	3.99	14.19
NICKEL	32	50	64	9.00	16	16.35	894.00	100.88	169.58
POTASSIUM	11	51	22	3,000.00	3,000	3,050.00	22,000.00	1,778.92	4,243.50
SELENIUM	1	51	2	0.00	41	2.20	2.20	0.04	0.31
SODIUM	51	51	100			13,200.00	36,000.00	19,089.22	4,473.59
VANADIUM	48	51	94	8.00	8	11.00	148.00	34.60	25.60
ZINC	48	51	94	3.00	3	3.00	1,060.00	123.75	223.06

Notes:
[1] Calculations performed on second and third quarter 1993 monitoring results.
[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.
[3] Only parameters that were detected at least once are presented.

Table M-12

Metals Influent Concentrations From the Risk Target Volume to the East Treatment Plant

Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value		Detected Value		Mean[2]	Standard Deviation
				Minimum	Maximum	Minimum	Maximum		
ALUMINUM	8	10	80	28.00	45	60.00	310.00	120.90	103.62
ARSENIC	1	10	10	0.00	4	8.50	8.50	0.85	2.69
BARIUM	10	10	100			9.90	190.00	59.67	50.75
CALCIUM	10	10	100			11,000.00	68,000.00	22,690.00	16,695.94
CHROMIUM, TOTAL	10	10	100			18.00	17,000.00	1,831.92	5,333.75
COBALT	2	10	20	3.00	7	9.20	18.00	2.72	6.10
COPPER	3	10	30	3.00	6	6.70	250.00	26.70	78.54
IRON	10	10	100			200.00	71,000.00	8,064.20	22,135.46
LEAD	4	10	40	1.00	3	3.20	4.10	1.42	1.85
MAGNESIUM	10	10	100			7,800.00	47,000.00	15,847.00	11,470.85
MANGANESE	10	10	100			6.20	390.00	71.12	116.94
MOLYBDENUM	1	10	10	4.00	8	190.00	190.00	19.00	60.08
NICKEL	8	10	80	16.00	16	16.00	2,700.00	335.73	834.90
POTASSIUM	5	10	50	3,000.00	3,000	3,000.00	4,800.00	2,036.00	2,208.28
SODIUM	10	10	100			14,000.00	33,000.00	18,000.00	5,600.00
VANADIUM	10	10	100			13.00	86.00	31.08	20.02
ZINC	9	10	90	3.00	3	9.00	1,400.00	192.43	432.84

Notes:

[1] Calculations performed on second and third quarter 1993 monitoring results.

[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.

[3] Only parameters that were detected at least once are presented.

Table M-13

Metals Influent Concentrations From the Risk Target Volume to the West Treatment Plant

Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value		Detected Value		Mean[2]	Standard Deviation
				Minimum	Maximum	Minimum	Maximum		
ALUMINUM	21	44	48	28.00	45	53.30	12,700.00	1,288.00	3,170.80
ARSENIC	7	44	16	0.00	4	4.00	12.20	1.09	2.85
BARIUM	44	44	100			17.80	286.00	85.07	63.11
BERYLLIUM	1	44	2	0.00	1	1.00	1.00	0.02	0.15
CADMIUM	1	44	2	1.00	4	4.00	4.00	0.09	0.60
CALCIUM	44	44	100			11,500.00	59,500.00	24,132.95	11,135.58
CHROMIUM, TOTAL	42	44	95	7.00	7	9.30	2,500.00	282.70	585.96
COBALT	7	44	16	3.00	7	8.10	15.50	1.75	4.17
COPPER	19	44	43	3.00	6	6.20	203.00	13.58	33.93
IRON	43	44	98	6.00	6	10.00	36,900.00	3,860.00	6,875.85
LEAD	25	44	57	0.00	42	3.10	24.00	4.23	5.18
MAGNESIUM	44	44	100			3,700.00	43,100.00	16,370.34	8,819.82
MANGANESE	40	44	91	0.00	2	1.40	1,670.00	113.76	272.67
MOLYBDENUM	7	44	16	4.00	8	9.00	27.00	2.47	6.14
NICKEL	29	43	67	9.00	16	16.35	534.00	86.26	128.34
POTASSIUM	10	44	23	3,000.00	3,000	3,050.00	22,000.00	1,789.20	4,250.59
SELENIUM	1	44	2	0.00	41	2.20	2.20	0.05	0.33
SODIUM	44	44	100			13,200.00	36,000.00	19,478.41	4,667.25
VANADIUM	43	44	98	8.00	8	11.00	96.80	34.34	19.99
ZINC	41	44	93	3.00	3	3.00	1,060.00	109.69	211.28

Notes:

[1] Calculations performed on second and third quarter 1993 monitoring results.

[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.

[3] Only parameters that were detected at least once are presented.

Table M-14
Metals Influent Concentrations From the MCL Target Volume to the East Treatment Plant
Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value Minimum	Nondetected Value Maximum	Detected Value Minimum	Detected Value Maximum	Mean[2]	Standard Deviation
ALUMINUM	3	4	75	28.00	28	67.00	310.00	161.75	151.48
BARIUM	4	4	100			48.00	190.00	95.35	65.29
CALCIUM	4	4	100			14,400.00	68,000.00	30,925.00	25,272.04
CHROMIUM, TOTAL	4	4	100			77.00	720.00	281.15	302.06
COBALT	1	4	25	3.00	7	9.20	9.20	2.30	4.60
COPPER	1	4	25	3.00	6	10.30	10.30	2.58	5.15
IRON	4	4	100			410.00	3,300.00	1,750.00	1,219.04
LEAD	2	4	50	3.00	3	3.60	4.10	1.92	2.23
MAGNESIUM	4	4	100			10,300.00	47,000.00	21,675.00	17,222.35
MANGANESE	4	4	100			6.20	118.00	48.40	48.36
NICKEL	4	4	100			16.00	222.00	116.00	114.46
POTASSIUM	3	4	75	3,000.00	3,000	4,460.00	4,800.00	3,465.00	2,314.21
SODIUM	4	4	100			14,400.00	33,000.00	20,300.00	8,595.35
VANADIUM	4	4	100			23.80	31.90	26.93	3.84
ZINC	4	4	100			12.00	289.00	95.48	130.18

Notes:

[1] Calculations performed on second and third quarter 1993 monitoring results.

[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.

[3] Only parameters that were detected at least once are presented.

Table M-15

Metals Influent Concentrations From the MCL Target Volume to the West Treatment Plant

Units µg/l

Parameter	Number of Detects	Number of Samples	Frequency of Detection[3] (%)	Nondetected Value Minimum	Nondetected Value Maximum	Detected Value Minimum	Detected Value Maximum	Mean[2]	Standard Deviation
ALUMINUM	19	39	49	28.00	45	53.30	12,700.00	1,446.91	3,338.91
ARSENIC	5	39	13	0.00	4	4.10	12.20	1.02	2.93
BARIUM	39	39	100			17.80	286.00	90.48	64.87
BERYLLIUM	1	39	3	0.00	1	1.00	1.00	0.03	0.16
CADMIUM	1	39	3	1.00	4	4.00	4.00	0.10	0.64
CALCIUM	39	39	100			11,500.00	59,500.00	25,010.26	11,462.55
CHROMIUM, TOTAL	38	39	97	7.00	7	8.10	2,500.00	285.63	601.90
COBALT	7	39	18	3.00	7	8.10	15.50	1.98	4.39
COPPER	17	39	44	3.00	6	6.20	203.00	13.80	35.33
IRON	38	39	97	6.00	6	10.00	36,900.00	4,072.38	7,254.30
LEAD	23	39	59	0.00	42	3.10	24.00	4.54	5.36
MAGNESIUM	39	39	100			3,700.00	43,100.00	17,076.28	9,043.11
MANGANESE	35	39	90	0.00	2	1.40	1,670.00	122.61	288.70
MOLYBDENUM	6	39	15	4.00	8	12.00	27.00	2.56	6.39
NICKEL	25	38	66	9.00	16	16.35	534.00	87.64	134.73
POTASSIUM	8	39	21	3,000.00	3,000	3,050.00	22,000.00	1,730.90	4,406.34
SELENIUM	1	39	3	0.00	41	2.20	2.20	0.06	0.35
SODIUM	39	39	100			14,600.00	36,000.00	19,982.05	4,655.48
VANADIUM	39	39	100			11.00	96.80	35.88	19.93
ZINC	36	39	92	3.00	3	3.00	1,060.00	111.09	218.78

Notes:

[1] Calculations performed on second and third quarter 1993 monitoring results.

[2] The mean was calculated with nondetects as zero. Thus, in some cases the mean may be less than the detection limit.

[3] Only parameters that were detected at least once are presented.

PREPARED FOR: McClellan Air Force Base

DATE: November 6, 1993

SUBJECT: Production Well Pumping Information
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.DA

Introduction

The purpose of this technical memorandum is to describe the procedures used in collecting information on production wells within a 5-mile radius of McClellan AFB. This technical memorandum also summarizes availability of data for these wells. Compilation of data, discrepancies found in some of the data, pumping distribution and impacts, and potential future pumping condition are also discussed.

Compilation of Data

Construction data and cumulative pumpage information have been summarized for all wells within a 5-mile radius of McClellan AFB. These wells are shown in Figure N-1 (located in a pocket at the end of this appendix). The production well owners within the specified radius include McClellan AFB, Arcade Water District, Caltrans, Northridge Water District, Rio Linda Water District, City of Sacramento, Del Paso Water Agency, Carmichael Water Agency, and Sacramento County.

A summary of contacts made and the type of data obtained are included in Table N-1. No information was obtained from Del Paso or Carmichael Water Agencies since their wells are located near the perimeter of the 5-mile radius and they do not pump large quantities of water. Sacramento County also has two wells near the perimeter of the 5-mile radius for which no information was obtained.

Many sources were reviewed to obtain construction and pumpage information. Initially, existing documents were reviewed to determine the extent of available data. Radian Corporation was also contacted for information on these wells. The main references consulted in compiling data include the following:

- Dewante and Stowell, Consulting Engineers. 1981. *Arcade Water District Operations Planning Project, Water Master Plan*. August.

Table N-1
Summary of Types of Purveyor Data Obtained

Information	Citizens Utilities[a]	Northridge[b]	Arcade[c]	City of Sacramento[d]	County of Sacramento[e]	Rio Linda[f]	McClellan AFB[g]	Caltrans[h]	Carmichael[i]	Del Paso[j]
Acronym	CU	NR	ARC	CW	SAWWA	RIO	BW	CT	CM	DP
Construction Data	Well Drillers Reports	Summary List from District	Arcade Master Plan and Radian	Well Drillers Reports and Radian	None	Radian	Radian	Radian	None	None
Well Pumpage Data	Annual Cumulative and Radian[k]	Annual Cumulative and Radian[k]	Radian[k]	Monthly Volume and Radian[k]	None	Radian[k]	Form 1461 Radian	Gross volume not cumulative	None	None
Pumpage Data Year End	1992	1992	[k]	1992		[k]	1992	1989		
Pumpage Data Year Begin	1970	1972	[k]	1988		[k]	1987	1979		
Contact Name	Jim Mulligan	Warren Jung	Roy Hafar	Walt Short	Mike Crooks	Ben Sanchez		Dan Pollock, Area Superintendent		
Contact Phone No.	916/481-7350	916/332-4111	916/972-7171	916/264-7830	916/440-6851	916/991-3044		916/662-9694		
FAX	916/481-0230	916/332-6215	916/972-7639	916/264-7955		916/991-6616				
Contacts Made: Workshop Followup Rude Memo Followup Lanier Memo	 X X X	 No X X	 X X X	 X X X	 X X No	 X X X	 X No No	 X X No	 No No No	 No No No
Water District Maps: District Boundary Well Locations Main Distribution System	 X X X	 X X X	 X X (N. Highlands) X (N. Highlands)	 City map X No	 X X No	 X X X	 X X (Radian) X	 No No Map No	 None None None	 None None None
Other Information	Static water level and pumping rates on seven McClellan AFB area wells	Online date was given. Water level soundings 3/92 to 2/93	Efficiency and specific capacity for some wells.	Well address, capacity, and depth also given for standby municipal wells and park irrigation wells.				Location by description.		

[a]Citizens Utilities pumpage data were used instead of Radian Corporation's data.
[b]Incomplete production data that were available to 1969, was not included.
[c]Waiting for pumpage information.
[d]City of Sacramento monthly volume report had missing data so Radian Corporation pumpage data were used.
[e]Wells are actually out of radius of influence.
[f]Waiting for pumpage information.
[g]Form 1461 is McClellan AFB's monthly operating report. Data unavailable prior to 1987.
[h]Pumpage data not available. No construction data available. One number was given that represents pump capacity from 1979 to 1989.
[i]No contact was made because of the limited number of wells in the radius of influence.
[j]No contact was made because of the limited number of wells in the radius of influence.
[k]Radian has some data for some wells from approximately October 1989 to December 1992.

- CH2M HILL. 1992. *Well Closure Methods and Procedures Phase II Delivery Order 5031 McClellan AFB.* August.

- CH2M HILL. 1990. Draft Well Closure Methods and Procedures. December.

- Radian Corporation. Production Well Data for McClellan AFB and Municipal Wells (Quarterly Reports for 1990, 1991, and 1992; second quarter report not available for 1992).

- Luhdorff & Scalmanini, Consulting Engineers. 1984. *Final Report Sealing of Base Wells, McClellan AFB, California.* February.

Well owners were contacted first through the initial screening workshop held August 10, 1993, (McClellan Air Force Base Contaminated Groundwater Cleanup Workshop). Water purveyor attendees included the following:

- Ernie Rinde – Caltrans
- Mike Crooks – Sacramento County
- Ben Sanchez – Rio Linda Water Agency
- Ed Schnabel – Sacramento Metropolitan Water Agency
- Walt Libal/C. J. DiPietro – Arcade Water District
- Jim Mulligan – Citizens Utilities

A followup memorandum was then sent to those attendees. Followup calls were made to the major water purveyors and an information request memorandum was faxed to them. These major water purveyors include Citizens Utilities, Northridge Water District, Rio Linda Water Agency, and City of Sacramento. Caltrans was not contacted beyond the followup call because they had sent in all available information. Arcade Water District was not requested to provide construction data since that information was obtained from the Arcade Water District Master Plan.

Specific data requested of most of the purveyors included the following:

- Well ID number
- Well name
- Location information (street address and coordinates)
- Depth to screen
- Length of screen interval
- Casing diameter
- Average annual well pumping rate
- Annual cumulative pumpage from 1954 to 1993
- Specific capacity
- Estimated future pumping rates
- Anticipated future changes in groundwater management

Almost all the water districts sent the requested information. Most of the information on the well locations was received from the County of Sacramento. The County sent a well site location map for the Sacramento Area Water Works Association (SAWWA) Well Testing Program and a diskette containing the computer file for the map in AutoCAD format as well as the database inventory of the wells in dBASE IV format. The database file contains state well numbers and California coordinates (northing and easting) for the wells that are tested in the well testing program. The City of Sacramento is not included in this program.

Construction data are summarized in Table N-2. Construction data were obtained in different formats. Well drillers' reports were sent by Citizens Utilities and the City of Sacramento. Northridge Water District sent a summary list of the data requested. Rio Linda, Caltrans, and McClellan AFB well construction data were obtained from Radian.

Pumpage data are summarized in Table N-3. Pumpage data also came in different formats. Citizens Utilities and Northridge sent annual volumes and the City of Sacramento sent monthly volume reports. Monthly volumes for McClellan AFB were obtained from Form 1461, which was copied from microfiche records at the Base. Rio Linda and Arcade information came from Radian. These two purveyors are being contacted for more information.

Caltrans sent a gross weekly pumping volume that is actually based on the pump capacity and pumping rate from 1989, back to about 1979, for the irrigation season. These numbers are not actual pumping volumes since no volume is measured. Caltrans information on construction and cumulative pumpage was not pursued since the gross pumping volume indicated that Caltrans did not pump large quantities of water.

Data Discrepanices

Figure N-1 was created from information from Radian and SAWWA. The AutoCAD file was plotted and checked against District-supplied well location maps. The wells were off graphically in a southwestern direction because of the map base in the AutoCAD file. These well locations were adjusted to match the water district map locations. McClellan AFB wells located by coordinates were moved to align with the map base using Radian information as a guide.

Some discrepancies were found when compiling the data. The conflict was typically resolved by adhering to the information supplied by the water district. When district-supplied information was not available, the most reasonable information was used. Decisions are documented on the tables where necessary. Well names need to be verified in Table N-3.

Table N-2

Production Well Construc

Purveyor (a)	Well I.D. (b)	Well Name	Northing	Easting	Ground Elevation above msl (ft)	TOC above msl (ft)	Borehole Length (ft)	Completed Well Depth (ft)	Screen Begin Below TOC (ft)	S Belo
ARC	2A	Park Estates	342770	2172000	56			600		
ARC	3A	?	339540	2172220	48			440		
ARC	5	?	344440	2168670	40			425		
ARC	7	Country Club Estates	349320	2172330	65			210		
ARC	8	Hazelwood East			83			305		
ARC	9	Hazelwood West	344440	2182100	75			270		
ARC	10	Country Club Estates	352000	2175000	75			265		
ARC	11	Government Building	346550	2171200	59			310		
ARC	12	?	343540	2169000	40			294		
ARC	13	Bohemian Gardens	347780	2172550	62			374		
ARC	14	?	367362	2166810	60			470		
ARC	16	North Haven	365560	2176760	85	85	363	374		
ARC	18	Arden Oaks	340270	2180920	68			420		
ARC	19	New Broadmoor			68			365		
ARC	22	?	352330	2178000	80			350		
ARC	23	Department of the Interior	347650	2170210	59			360		
ARC	24	?	348880	2178880	70			360		
ARC	25	Arden Oaks Vista	339780	2182980	75			318		
ARC	26	?	347210	2183200	87			360		
ARC	27	McClellan Meadows	370550	2178000	90			320		
ARC	28	Red Robin			45			370		
ARC	30	?	341760	2165200	35			460		
ARC	32	?	345760	2185870	93			360		
ARC	33	Evergreen Estates	355320	2180170	72			320		
ARC	34	Larchmont	371320	2178880	93			400		
ARC	35	Arden Oaks Vista	340880	2183200	79			297		
ARC	36	Arcade Square	350220	2175660	71			335		
ARC	37	Parkhills	342330	2174120	47			405		
ARC	38	Larchmont	353540	2176760	80	80	370	375		
ARC	39	?	374260	2178230	98			385		
ARC	40	District Yard	351650	2171780	65	65	420	425		
ARC	41	?	347010	2164870	52	50	420	425		
ARC	42	Becerra	348000	2179540	75			410		
ARC	43	Edison	348990	2167650	49	45	385	390		
ARC	44	Highlands Terrace	368440	2181660	110		577	575		
ARC	45	Swanston Estates Gas	340550	2164760	37			395		
ARC	52	Larchmont Submersible	374220	2182100	110			600		
ARC	54	Woodcrest	349540	2185760	80			550		
ARC	56	Fruitvale	367320	2177310	91	85	640	645		
ARC	57	Larchmont Commercial	377320	2176760	103	98	650	655		
ARC	58	N.H. Assessment District No. 2	371890	2173560	78	77	747	690		
ARC	59	Larchmont No. 21	377320	2179540	129			600		
ARC	60	Whitney Avenue			89			450		
ARC	64	Galbrath and Hutchins	376000	2178990	117			630		
ARC	65	Merrily Way	354110	2178330	80	75	460	347		
ARC	66	Eastern Avenue	350000	2182100	80			398		
ARC	20A	Arden Village	339320	2177200	65			475		
ARC	31A	?	366770	2178880						
ARC	69R	?	338330	2172220	43			427		
BW	1	Building 231	361830	2174380		76	400	396	162	
BW	2	Building 232	362330	2174380		76	298	296	100	
BW	3	Unknown	357810	2168550		62	604	No Data		

G:\users\da\lunder\5066\TableN-2.xls

(1)

Table N-2

Well Construction Information

Screen Begin w TOC (ft)	Screen End Below TOC (ft)	Depth to Screen (ft)	Screen Interval (ft) (c)	Screen Begin bgs (ft)	Screen End bgs (ft)	Casing Diameter (in)	Location
		170	245			14	2250 Park Estates
		200	225			14	1191 Kubel Circle
		230	82			10	2550 Bell Street
		n/a	n/a			10	2798 Rubicon
		n/a	n/a			10	2625 Wrendale Way
		n/a	n/a			12	4308 Ravenwood Avenue
		210	50			10	3351 Potter Lane
		n/a	n/a			12	2500 Marconi Avenue
		168	63			16	Santa Anita Park
		350	18			14	2951 Calderwood Lane
		465	10			14	2520 Marconi Avenue
		345	14	345	363	12	5633 Georgia Drive
		n/a	n/a			14	4012 Riding Club Lane
		n/a	n/a			14	3330 Balmoral Drive
		n/a	n/a			12	3812 West Way
		n/a	n/a			14	2445 Marconi Avenue
		n/a	n/a			14	3858 Woodcrest Road
		n/a	n/a			14	4420 Thor Way
		194	35			14	4501 Marconi Avenue
		OB	OB			14	6503 Melrose Drive
		222	32			14	Red Robin Lane (end)
		370	40			14	2116 Rockbridge Road
		254	61			12	Root Avenue and Eden Court
		198	120			14	Auburn Avenue and Norris
		225	61			14	6503 La Cienga Drive
		252	19			14	4421 Ulysses Drive
		OB	OB			12	3405 Watt Avenue
		180	220			14	End of Morse Ave and Cottage Pa
		180	190	198	333	14	3830 Watt Avenue
		195	185			14	6900 Thomas Drive
		190	185	190	420	14	2736 Auburn Boulevard
		180	240	180	420	12	1812 Iris Avenue
		195	210			14	3927 Marconi Avenue
		200	185	200	385	14	3101 Truax Court
		195	330	195	570	14	6048 Gillman Way
		180	210			14	1848 Jamestown Drive
		220	380			14	6820 Weddigan Avenue
		160	176			14	4833 North Avenue
		220	420	220	640	14	Fairbairn, North end
		250	400	250	650	14	7416 Watt Avenue
		220	465	220	685	14	6609 32nd Street
		258	342			14	3948 Bainbridge Drive
		165	360			14	Between 4528 and 4534 Whitney
		232	384			14	Galbraith and Hutchins
		187	155	187	342	14	Merrily Way, East end
		170	323			14	3312 Eastern Avenue
		194	206			14	Arden and Watt Avenues
		195	230			14	2800 Hilldale Road
162	396	162	*234*	162	396	12	Building 231
100	296	100	*196*	100	296	12	Building 232
						6	SW in field near Bell Avenue and Kilzer Avenue - near BW-19

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									Table N-2	
									Production Well Construction	

Purveyor (a)	Well I.D. (b)	Well Name	Northing	Easting	Ground Elevation above msl (ft)	TOC above msl (ft)	Borehole Length (ft)	Completed Well Depth (ft)	Screen Begin Below TOC (ft)	Screen End Below TO
BW	4	Unknown	361563	2177186			382	382	169	382
BW	6	Unknown	361878	2168440				No Data		
BW	7	Unknown	359599	2173892			398	No Data	170	398
BW	8	Building 91	362034	2176735			625	625 ?		
BW	9	Unknown	362923	2175990			660	No Data		
BW	10	Unknown	364180	2176350		85	400	392	170	392
BW	11	Unknown	359670	2176370		80	400	400	154	378
BW	12	Building 395	361330	2174940		76	390	390	164	390
BW	13	Building 614	357350	2170750		62	391	391	178	391
BW	16	Site 22	363500	2168830		57		No Data		78
BW	17	Building 699	358450	2168780		62	390	353	216	312
BW	18	Unknown	357430	2168650		60	408	408	169	387
BW	19	Unknown	357960	2168550		62	399	399	214	314
BW	20	Unknown	362730	2175140		77	600	598	178	598
BW	21	Unknown	359840	2169000		62		No Data	78	98
BW	22	Unknown	368100	2175050		85		No Data	78	98
BW	23	Unknown	367130	2173980		77		No Data	78	98
BW	24	Unknown	366990	2175010		80		No Data	78	98
BW	27	Unknown	367470	2166780		55	261	No Data	17[illegible]	260
BW	28	Unknown	366830	2170100		67	263	263	14[illegible]	236
BW	31	Unknown						No Data		
BW	33a	Unknown	358990	2165120		53		No Data		
CM	1	Cottage Way	341950	2185760						
CM	2	Engle	352330	2187660						
CM	3	Garfield	348880	2190000						
CM	4	Hidden River Vista	338770	2190220						
CM	5	Jan Dr	357780	2194760						
CM	6	La Vista	347780	2190880						
CM	8	Paddock	357780	2193220						
CM	11	Barrett Road	357440	2196590						
CM	15	Barrett School	355870	2195700						
CT	1	Watt Avenue Pump	352700	2173020		65				
CT	2	Longview Pump	355560	2171570		50				
CT	3	Orangegrove Pump	354280	2170010		52				
CT	4	Fulton Avenue Pump	357320	2175830		77	535		4	535
CT	5	Starlight Pump				50				
CT	6	Arden Way Pump								
CU	3	Andrea No. 1	372770	2188320			516	506		
CU	4	Andrea No. 2	374330	2190880			495	475		
CU	5	Antelope Oaks (Twin Trails)	384330	2182320			450	436		
CU	11	Cherbourgh	377210	2186890			510	490		
CU	15	Colonnade Way	381210	2166000			495	495		
CU	19	Covered Wagon	382660	2167100			495	395		
CU	21	Davidson	378550	2173650			506	506		
CU	22	Diablo Drive	372880	2189780			410	410		
CU	28	Fort Sutter	366660	2188980			390	390		
CU	34	Auburn-Halifax	371390	2196090			364	364		
CU	35	Hemlock	366000	2188430			354	354		
CU	36	Howe	338440	2167100			403	350		
CU	53	Prior Way	383210	2176100			495	495		
CU	54	Rhine Way	383540	2168560			547	542		
CU	58	Roseville Road	376330	2191320			459	450		

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Table N-2
Well Construction Information

Screen Begin w TOC (ft)	Screen End Below TOC (ft)	Depth to Screen (ft)	Screen Interval (ft) (c)	Screen Begin bgs (ft)	Screen End bgs (ft)	Casing Diameter (in)	Location
169	382	169	*213*	169	382	12	Near Watt Avenue and Roseville Road, off the base
							Near Patrol road and Buildings 714 and 715
170	398	170	*228*	170	398	12	Near Building 429
		625		625	No Data	12	Building 91
						14	Nearby Building 200 - on old maps near BW-20
170	392	170	*222*	170	392	12	East near Building 93 on O'Malley Avenue
154	378	154	*192*	154	346	12	E of the Base, near Watt Avenue and Winona Street - located on old maps
164	390	164	*226*	164	390	12	Building 395
178	391	178	*213*	178	391	12	Building 614
	78	78		78	No Data	No Data	Site 22 on Patrol Road - located on old maps
216	312	216	*96*	216	312	16	Building 699
169	387	169	*218*	169	387	14	SW near Building 664 on Winters Street
214	314	174	*186*	174	360	14	SW in field near Bell Avenue and Kilzer Avenue - near BW-3
178	598	178	*420*	178	598	14	In parking lot south of Building 220
78	98	78	*20*	78	98		Near Building 689
78	98	78	*20*	78	98		Near Building 1445
78	98	78	*20*	78	98		Near Building 1445
78	98	78	*20*	78	98		Near Building 1445
17	260	175	*185*	175	360	12	Near Building 1099
14	236	144	*92*	144	236	8	Near Building 1082
							Unknown
		67		67	No Data		Unknown
				4	38		West of Watt Avenue, above W/B 80 on ramp on Orangegrove Avenue
				4	38		End of the W/B off ramp W/B 80 at Longview
				4	38		End of the Orangegrove Avenue off Auburn Boulevard
4	535			4	535		W/B Business 80 East of Fulton Avenue next to Haggin Oaks Golf Course
				4	35		W/B Business 80 East of Arden Way Off Ramp, next to Neon Sign Co.
							Arden Way West of Business 80 Interchange by Wonder Bread
		218	*278*	218	496	16	120' N of Andrea Blvd. and Leatherwood Drive (Larchmont Foothills)
		252	*113*	252	365		Lot A, Andrera Boulevard
		212	*214*	212	426	16	PFE Road (North Highlands)
		290	*190*	290	480		Cherbourgh Well
		330	*150*	330	480	14	Lot A, approx 1/4 mi. South of Elverta Rd., 1 mi. West of Watt Avenue
			35	295	330	14	2 mi. West of Watt Avenue, 400' East Elverta Road
		No Screen Information				14	32nd and U Streets (Rio Linda)
		206	*194*	206	400	14	Diablo Drive (Foothill Oaks Sub.)
		220	*158*	220	378	12	350' E of Antelope Road, 1500' N of Auburn Blvd. (Foothills Farm Trust)
		274	*8*	274	282	14	Arlington Heights
		169	*162*	169	331	12	1800' North of Auburn Boulevard., 2000' West of Antelope Road
		180	*165*	180	345	16	Howe Avenue
		280	*195*	280	475	16	Corner Lot Prior Way and Elverta Road
		300	*224*	300	524	14	NE of Intersection of Hague Way and Rhine Way, North of Elverta Road
		260	*178*	260	438	14	1 mi. NE of North Highlands, 1/2 mi N of Greenback and Roseville Road

Table N-2

Production Well Constructi

Purveyor (a)	Well I.D. (b)	Well Name	Northing	Easting	Ground Elevation above msl (ft)	TOC above msl (ft)	Borehole Length (ft)	Completed Well Depth (ft)	Screen Begin Below TOC (ft)	Sc E Below
CU	59	Rushmore	369100	2188870			316	316		
CU	62	Scotland	379870	2172550			602	602		
CU	63	Shenandoah	368000	2188320			312	312		
CU	73	Van Maren (Mercedes)	369540	2196650			No Well Report			
CU	79	Watt Avenue	379650	2175660			540	470		
CU	86	Wittkop	337540	2169660			322	322		
CU	88	Wyda Way	340550	2168780			295	295		
CW	48	Haggin Oaks Golf Course	352000	2169340		50	250	250		
CW	50	Haggin Oaks Golf Course	352720	2171010		55	191	191		
CW	52	Haggin Oaks Golf Course	353160	2171720		45	387	387		
CW	61	Haggin Oaks Golf Course	354140	2173300		45	390	390		
CW	91	2507 Northview Drive, Northgate	345879	2149546			384	370		
CW	92	Northview and Bridgeford	348175	2149723			435	422		
CW	93	636 Tenaya Avenue	349264	2150164			328	316		
CW	94	S. end K Mart, behind block wall	351530	2150135			351	351		
CW	109	?	344267	2154217			No Well Report			
CW	110	Southgate Road	342203	2155530			390	390		
CW	111	?	343750	2156509			360	300		
CW	112	1018 Calvados Avenue	343949	2160171			No Well Report			
CW	114	Swanston Plant	342495	2160744			366	366		
CW	116	702 Plaza Avenue	345880	2157622			519	340		
CW	117	?	345505	2160796			No Well Report			
CW	119	?	345447	2163495			No Well Report			
CW	120	2938 Branch Street	349555	2160301			440	440		
CW	122	1495 Juliesse Avenue	348638	2163601			422	422		
CW	123	Near R.R. and Canal	350668	2152961			305	305		
CW	124	202 Danville Way	350307	2154245			Illegible Data			
CW	125	Fairbanks and Norwood Avenues	351180	2155968			300	300		
CW	126	14th and Riviera	351875	2161728			432	432		
CW	127	1659 Arcade Avenue	350285	2163480		40	410	401		
CW	129	806 Harris Avenue	354340	2158400		35	300	300		
CW	131	1660 North Avenue	354920	2163930		51	No Well Report			
CW	132	3935 Astoria Avenue	354910	2167070		50	300	300		
CW	133	4600 Pell Drive	359973	2152258			514	514		
CW	134	350 Bell Avenue	358361	2155901			515	513		
CW	135	Hagginwood Park	*351085*	*2162455*		40	No Well Report			
CW	136	Hagginwood Park	350485	2162255		40	385	385		
CW	137	Del Paso and Los Robles Blvds.	352360	2165900		35	410	410		
CW	138	4106 Bell Street	355340	2161500		40	408	375		
CW	139	?	339881	2155588			No Well Report			
CW	142	2586 Norwood Avenue	346382	2155771			390	384		
CW	143	3001 Rio Linda Blvd.	349668	2158938			330	330		
CW	144	1709 Eldridge Avenue	349010	2164030			400	396		
CW	150	4200 Astoria	356940	2167340		56	380	372		
CW	151	301 Jefferson Avenue	343346	2152041			395	346		
CW	153	Main Avenue and Rio Linda Blvd.	360881	2158156			643	626		
CW	154	5510 Dry Creek Road	365270	2160755		50	430	412		
CW	155	2320 Roanoke Avenue	353040	2168340		53	430	427		
CW	156	Tribute Road and S.R. 160	340719	2159828			390	380		
CW	158	Challenge Way and Response Road	339718	2164850			328	328		
CW	159	E. Bowman Avenue and Sump 102	347419	2152412			375	375		
DP	1	Avalon	345540	2180560						

Table N-2

n Well Construction Information

Screen Begin low TOC (ft)	Screen End Below TOC (ft)	Depth to Screen (ft)	Screen Interval (ft) (c)	Screen Begin bgs (ft)	Screen End bgs (ft)	Casing Diameter (in)	Location
		165	*119*	165	284	14	100' North of Highway 40 Freeway, 300 yds West of Spruce Overpass
		No Screen Information				20	Citrus Heights near Drive-in Theatre, corner Sandalwood and Cordelia
		290	*15*	290	305	12	1800' W/Antelope Road, 150' S/Roseville Frwy (Hitchcock Homes Tract)
			0				Van Maren (Mercedes)
		245	*215*	245	460	16	Approx.100 yds NW of Watt Avenue and Blackfoot Way intersection
		280	*34*	280	314	12	3 blocks South of Arden and 1 block West of SE corner of Tract
		120	*135*	120	255	14	150' East of Bell Street, 45' North of Wyda Way
		165	*70*	165	235	14	Auburn Road and Fulton
		65	*126*	65	191	12	1100' North of Auburn, 100' West of Fulton
		222	*153*	222	375	14	Auburn Road and Fulton
		176	*181*	176	357	No Data	Auburn Road and Fulton
		170	*174*	170	344	12	Northgate and West El Camino Avenues - North West Corner
		118	*190*	118	308	12	997' W of intersection of Lower Marysville Road and Bowman Avenue
		146	*56*	146	202	12	South side of Tenaya Avenue, approx. 100' east of Northgate Drive
		288	*10*	288	298	12	NW of Lower Marysville/ San Juan Roads (200' W, 75' N of this junction)
		No Well Report				No Data	
		152	*213*	152	365	12	Southgate Road
		165	*181*	165	346	No Data	No Data on report
		No Well Report				No Data	1018 Calvados Avenue
		166	*200*	166	366	14	Swanston Plant
		200	*140*	200	340	14	702 Plaza Avenue
		No Well Report				No Data	
		No Well Report				No Data	
		265	*155*	265	420	12	2938 Branch Street
		230	*170*	230	400	12	1495 Juliesse Avenue
		Illegible Data				12	Near R.R. and Canal
		Illegible Data				No Data	
		202	*89*	202	291	12	Fairbanks and Norwood Avenues
		188	*222*	188	410	No Data	14th and Riviera
		161	*79*	161	240	14	1650 Arcade Avenue
		136	*50*	136	186	14	806 Harris Avenue
		36	*59*	36	95	No Data	1660 North Avenue
		191	*41*	191	232	14	300' West of Astoria Avenue, 210' South of North Avenue
		260	*250*	260	510	16	600' East of Pell Street, ½ mi. South of Main Street
		250	*250*	250	500	16	Between Sally and Austin
		No Well Report				No Data	Hagginwood Park
		36	*349*	36	385	14	120' West of Marysville Boulevard, 300' South of Los Robles Boulevard
		80	*175*	80	255	14	Del Paso and Los Robles Blvds.
		113	*257*	113	370	14	350' North of North Avenue, 50' East of Fell Street
		No Well Report				No Data	
		144	*96*	144	240	14	75' West of Grove Avenue, 600 ' North of El Camino
		140	*190*	140	330	14	300' West of Rio Linda Blvd., 50 ' North of Acacia Street
		144	*252*	144	396	14	Eldridge and Arcade
		144	*228*	144	372	14	630' South of Bell Avenue, 60' East of Astoria
		118	*227*	118	345	14	Jefferson and Levie
		260	*256*	260	516	16	Main Avenue and Rio Linda Boulevard
		148	*264*	148	412	14	5510 Dry Creek Road
		175	*252*	175	427	14	240' W of Winters Avenue, 60' S of Roanoke Street N
		190	*85*	190	275	14	SW Corner of Tribute Road (Cal EXPO Area)
		113	*200*	113	313	14	50' SW of Challenge Way, 100' NE of Response Road
		112	*240*	112	352	14	End of Bowman Street and East Northgate Blvd

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Production Well Const

Purveyor (a)	Well I.D. (b)	Well Name	Northing	Easting	Ground Elevation above msl (ft)	TOC above msl (ft)	Borehole Length (ft)	Completed Well Depth (ft)	Screen Begin Below TOC (ft)	B
DP	2	Maryal	342770	2179980						
DP	3	4110 Lusk	343210	2178880						
DP	6	4268 Lusk	343210	2181440						
DP	7	Butano	345210	2178440						
DP	8	Watt	345210	2176970						
NR	1	Evergreen	356660	2182320	71				180	
NR	3	Engle	351720	2184880	100				150	
NR	5	Hillsdale	370320	2183860	142				210	
NR	6	Palm	365210	2190440	99				n/a	
NR	7	Rosebud	366770	2190770	98				235	
NR	8	Field	368550	2192640	109				330	
NR	9	Cameron	358440	2189090	103				220	
NR	10	Walnut	363650	2185870	123				225	
NR	11	Diablo	366880	2185430	133				250	
NR	12	St. Johns	356880	2191980	119				200	
NR	14	Orange Grove	357760	2173540	73				206	
NR	15	Cabana	365540	2182760	105				205	
NR	17	Oakdale	359890	2177200	87				220	
NR	18	McCloud	369320	2185430	134				293	
NR	19	Larchmont	351100	2181440	88				243	
NR	20	Cypress	354880	2188100	111				350	
NR	21	Yucca	359890	2179870	95				214	
NR	22	River College	359890	2184880	99				240	
NR	23	Freeway	361650	2183780	104				270	
NR	24	Don Julio	372880	2182320	138				260	
NR	25	Sutter	374330	2181880	124				260	
NR	26	Monument	376660	2184880	172				316	
NR	27	Jamestown	361100	2196550	128				180	
NR	28	Oakbrook	366286	2197248	124				172	
NR	29	Merrihill	364000	2192780	118				258	
NR	30	Park Oaks	367540	2195640	121				168	
NR	31	Barret Meadows	359540	2193660	139				180	
NR	32A	Poker Lane No. 1	379660	2191220	149				240	
NR	32B	Poker Lane No. 2	381000	2191200	149				240	
RIO	1	Number 1 - Office	372660	2157330			412	412		
RIO	2	Number 2 - 6th and E Streets	374880	2156420			136	136		
RIO	3	Number 3 - I Street	371340	2153520			No Data	No Data		
RIO	4	Number 4	368770	2160000		45	492	492		
RIO	5	Number 5 (New Liner Installed)	384770	2152100			508	508		
RIO	6	Milldale	379210	2160660			520	520		
RIO	7	Number 7	376880	2157330			356	335		
RIO	8	2349 Elkhorn Boulevard	373860	2167760		66	393	393		
RIO	9	Elkhorn Boulevard and W 4th Street	371430	2151000			526	522		
RIO	10	Marysville Boulevard	367450	2154440			585	575		
RIO	11	Number 12	370990	2165890			435	417		
RIO	12	Number 11	372550	2157330			605	585		

Table N-2
Well Construction Information

Screen Begin ow TOC (ft)	Screen End Below TOC (ft)	Depth to Screen (ft)	Screen Interval (ft) (c)	Screen Begin bgs (ft)	Screen End bgs (ft)	Casing Diameter (in)	Location
180			129			14	
150			135			14	
210			162			14	
n/a			n/a			14	
235			n/a			14	
330			165			14	
220			300			14	
225			300			14	
250			310			14	
200			324			14	
206			264			16	Jet Court and Orange Grove
205			276			14	
220			300			14	
293			276			14	
243			372			14	
350			240			14	
214			192			14	
240			300			14	
270			270			14	
260			240			14	
260			270			14	
316			122			16	
180			350			14	
172			n/a			14	
258			243			14	
168			234			14	
180			n/a			14	
240			80			16	
240			195			14	
		No Data	No Data	No Data	No Data	15	Residential L Street, near R.R.
		No Data	No Data	No Data	No Data	15	"O" and 6th Streets
		375		375	No Data	12	No location information
		No Data		No Data	No Data	No Data	No location information
		188	*287*	188	475	10¾	50' West side of Rio Linda. Blvd. , ¾ mi. North of Elverta Boulevard
		445		445	No Data	14	No location information
		180	*121*	180	301	12	½ mi. North of Rio Linda Fire Station, .4 mi. East of Rio Linda Boulevard
		243	*142*	243	385	14	330' West of 24th St - Rio Linda, 30' North of Elkhorn Boulevard
		435	*24*	435	459	12	SW Corner Lot 99, ½ mi. E of RR track, 1 mi. W of Rio Linda Boulevard
		340	*9*	340	349	14	1½ mi. South of Rio Linda, 100' East of Marysville Boulevard
		202	*210*	202	412	16	Elkhorn to 20th South ¼ mi. East Side
		210	*370*	210	580	16	No location information

Table N-2

Production Well Constructi

Purveyor (a)	Well I.D. (b)	Well Name	Northing	Easting	Ground Elevation above msl (ft)	TOC above msl (ft)	Borehole Length (ft)	Completed Well Depth (ft)	Screen Begin Below TOC (ft)	Sc I Below

(a) Purveyor Acronyms and Data:

ARC - Arcade Water District
BW - McClellan Air Force Base
CM - Carmichael Water Agency
CT - Caltrans
CU - Citizens Utilities
CW - City of Sacramento
DP - Del Paso Water District
NR - Northridge Water District
RIO - Rio Linda Water District

Well depth information for BW wells is from LUHDORFF & SCALMANINI Final Report Sealing of Base Wells, February 1984.

Data for ARC wells taken from Arcade Water District Operations Planning Project, Water Master Plan 1981, Table 7-5, Radian data.

Information on Caltrans (CT) wells was provided by Caltrans.

Northridge Water District (NR) construction data and pump rate information was obtained from Northridge Water District, with the exception of ground elevation dat

(b) Well I.D. = number used by SAWWA if purveyor is member of that organization, otherwise provided by purveyor. TOC above msl for RIO Wells No.4 and No.8 is

(c) Screen Interval italicized indicates a calculated value from information provided.

Key to abbreviations:

OB = open bottom
NG = not given
n/a = not available
SAWWA = Sacramento Area Water Works Association
? = Unknown well names or well names that have not been verified.
Toc = Top of Casing
bgs = Below Ground Surface

Note: Discrepancies in data are the result of combining information from many different sources. These discrepancies will be resolved in the final report.

Table N-2

Well Construction Information

Screen Begin Below TOC (ft)	Screen End Below TOC (ft)	Depth to Screen (ft)	Screen Interval (ft) (c)	Screen Begin bgs (ft)	Screen End bgs (ft)	Casing Diameter (in)	Location

of ground elevation data, which was taken from the Northridge Water District Map or SAWWA.

Wells N .4 and No.8 is from Radian (Radian calls it elevation).

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Table N-3
Production Well Cumulative Pumpa
(Thousand Gallons Per Year

Purveyor (a)	Well I.D. (b)	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
ARC	5														
ARC	7														
ARC	9														
ARC	10														
ARC	11														
ARC	12														
ARC	13														
ARC	14														
ARC	15														
ARC	16		42	34	77										
ARC	18														
ARC	22														
ARC	23														
ARC	24														
ARC	25														
ARC	26														
ARC	27														
ARC	30														
ARC	32														
ARC	33														
ARC	34														
ARC	35														
ARC	36														
ARC	37														
ARC	38														
ARC	39														
ARC	40														
ARC	41														
ARC	42														
ARC	43														
ARC	44														
ARC	45														
ARC	52														
ARC	54														
ARC	56														
ARC	57														
ARC	58		50,368	9,039	4,557										
ARC	59														
ARC	64														
ARC	65														
ARC	66														
ARC	20A														
ARC	31A														
ARC	69R														
BW	1														
BW	2														
BW	2-C														
BW	3														
BW	4														
BW	6														
BW	7														
BW	8												336,178	142,942	
BW	9														
BW	10	211,171	126,011	145,445	214,356	172,658	198,494	285,115					248,441	99,921	
BW	11												385	17,565	
BW	12														
BW	13						139,085	174,575	139,085				307,412	158,634	
BW	16														

Table N-3
Vell Cumulative Pumpage Data
isand Gallons Per Year)

1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Reference (c)
													Radian
													Radian
336,178	142,942												AFB Data 1461
248,441	99,921												AFB Data 1461
385	17,565												AFB Data 1461
307,412	158,634												AFB Data 1461

Table N-3
Production Well Cumulative Pump
(Thousand Gallons Per Yea

Purveyor (a)	Well I.D. (b)	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
BW	17												101,785	180,024	
BW	18	128,317	490,706	475,276	355,940	500,301	236,450	29,743						36,113	
BW	19														
BW	20														
BW	21														
BW	22														
BW	23														
BW	24														
BW	27														
BW	29	42,045	156,173	157,297	279,946	213,443	242,296	312,317					65,325		
BW	31														
BW	33a														
CM	1														
CM	2														
CM	3														
CM	4														
CM	5														
CM	6														
CM	8														
CM	11														
CM	15														
CT	1	3,744													
CT	2	94													
CT	3	6,552													
CT	4	25,272													
CT	5	1,872													
CT	6	14,976													
CU	3		250,850	266,160	361,670	244,300	474,250	326,800	209,970	221,410	305,400	151,170	221,130	273,250	166,960
CU	4		84,288	76,773	121,120	203,100	40,172	107,030	106,530	496,690	467,170	479,690	388,430	76,288	154,490
CU	5		369,240	220,440	250,490	14,649	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS
CU	11		439,920	636,590	487,100	467,370	501,010	391,440	481,600	327,520	309,980	343,260	290,170	609,720	584,130
CU	15		134,190	64,005	91,189	20,561	80,359	49,018	45,174	27,083	3,585	15,404	2,303	598	1,005
CU	19		104,810	149,980	227,490	225,730	263,960	258,600	216,830	147,130	127,310	147,750	145,510	152,510	103,330
CU	21		55,899	63,075	96,833	16,640	54,789	106,610	140,200	138,970	74,516	104,750	208,910	137,450	175,200
CU	22		494	105	734	2,236	241	728	1,608	44,693	10,740	1,349	1,105	2,487	996
CU	28		134	147	532	160	17,968	298	8,260	2,097	9,102	7,711	9,374	3,850	9,378
CU	34		113	60	33	99	1,194	70	665	699	2,218	245	39,084	6,414	1,827
CU	35		2,344	158	1,182	426	6,161	12,969	59,162	55,172	54,891	93,496	121,460	939	3,922
CU	36		531,790	444,630	475,380	541,470	609,380	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS
CU	48		224,270	147,660	145,650	63,519	168,740	94,021	94,234	181,520	1,406	30,438	70,610	152,630	160,960
CU	50														
CU	53		326,870	571,600	625,780	528,050	0	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS
CU	54		29,102	3,323	4,933	79,372	37,102	4,213	3,967	13,738	31,545	597	1,544	2,795	521
CU	58		291,590	176,720	366,140	326,320	398,950	320,600	165,870	16,624	53,137	11,765	10,936	21,196	39,362
CU	59		181,910	206,210	205,950	146,840	138,430	249,560	317,290	117,840	147,270	95,351	92,449	97,606	102,920
CU	61		46,432	30,752	41,283	122,540	92,862	94,785	164,220	65,725	144,830	134,570	2,257	7,246	18,527
CU	62		278	6,143	60,470	26,409	167,020	71,014	8,301	1,894	1,668	223	7	32	27
CU	63		7,917	7,013	328	55,459	702	34	142,120	10,988	10,986	116	4,578	72,003	34,623
CU	73		314,090	290,400	236,130	142,070	192,190	78,489	167,910	110,400	131,680	90,373	201,150	203,900	185,190
CU	79		164,220	189,680	187,090	249,430	274,600	381,410	255,580	210,780	234,760	153,020	105,690	154,760	28,660
CU	86		1,442	55,886	41,181	10,985	41,087	181,980	120,900	141,260	145,500	101,290	56,372	111,200	21,950
CU	88		127,400	124,120	217,160	165,110	307,380	395,550	335,250	360,290	357,250	292,490	328,480	345,450	295,240
CW	83	4,320	15,410	3,450	17,280	101,300	5,690								
CW	91	340	1,660	200	80	4,120	70								
CW	92	178,280	142,320	144,660	152,790	144,750	47,030								
CW	93	2,130	46,420	5,500	22,780	43,370	12,730								
CW	94	178,890	89,820	127,060	176,370	152,650	87,950								
CW	107	13,930	81,250	18,070	21,250	180,500	64,830								

Table N-3
on Well Cumulative Pumpage Data
Thousand Gallons Per Year)

983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Reference (c)
	101,785	180,024												AFB Data 1461
		36,113												AFB Data 1461
	65,325													AFB Data 1461
														Caltrans
														Caltrans
														Caltrans
														Caltrans
														Caltrans
														Caltrans
,170	221,130	273,250	166,960	488,330	257,840	310,420	387,120	283,790	144,030	NIS (d)	NIS	NIS	NIS	Citizens
,690	388,430	76,288	154,490	29,830	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	Citizens
IS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	Citizens
,260	290,170	609,720	584,130	172,880	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	Citizens
404	2,303	598	1,005	32,569	31,639	0	16,787	NIS	NIS	NIS	NIS	NIS	NIS	Citizens
,750	145,510	152,510	103,330	71,973	8,824	24,853	129,300	167,850	14,253	46,729	27,075	16,580	7,553	Citizens
,750	208,310	137,450	175,200	119,220	42,511	47,108	86,070	76,164	30,984	2,639	45,637	43,627	48,713	Citizens
349	1,135	2,487	996	941	1,620	244	14,403	4,788	6,702	54,658	57,195	47,649	104,880	Citizens
711	9,374	3,850	9,378	6,002	13,429	10,117	24,113	24,856	10,967	28,232	39,169	11,187	32,570	Citizens
45	39,084	6,414	1,827	19,708	133,640	320,630	74,237	19,804	8,267	34,927	55,148	40,304	16,441	Citizens
496	121,460	939	3,922	0	13,986	139,290	75,945	39,939	114,350	62,446	62,188	49,281	50,247	Citizens
IS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	Citizens
438	70,610	152,630	160,960	80,737	249,540	131,830	135,150	103,980	26,542	181,210	232,710	94,002	132,720	Citizens
														Citizens
IS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	Citizens
97	1,544	2,795	521	8,683	22,283	11,609	16,638	38,043	17,729	NIS	NIS	NIS	NIS	Citizens
765	10,936	21,196	39,362	72,620	79,706	10,919	34,299	52,812	115,340	NIS	NIS	NIS	NIS	Citizens
351	92,449	97,606	102,920	103,700	287,130	155,560	216,380	56,149	113,150	149,970	146,780	113,050	106,880	Citizens
9,570	2,257	7,246	18,527	7,902	4,232	0	35	32,685	96,160	39,055	12,812	103,060	54,585	Citizens
23	7	32	27	71	97	174	39	65,225	29,157	57,670	429	251	0	Citizens
6	4,578	72,003	34,623	35,030	13,986	139,300	75,945	243,890	154,130	229,180	217,980	254,640	239,250	Citizens
373	201,150	203,900	185,190	83,426	106,710	223,150	131,630	110,120	110,990	5,830	NIS	NIS	NIS	Citizens
,020	105,690	154,760	28,660	30,190	39,126	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	Citizens
290	56,372	111,200	21,950	32,485	125,630	150,900	141,210	24,045	91,803	NIS	NIS	NIS	NIS	Citizens
,490	328,480	345,450	295,240	341,050	272,700	309,130	94,463	250,820	201,520	298,250	303,100	251,320	248,180	Citizens
														City of Sacramento
														City of Sacramento
														City of Sacramento
														City of Sacramento
														City of Sacramento
														City of Sacramento

Table N-3
Production Well Cumulative Pump
(Thousand Gallons Per Yea

Purveyor (a)	Well I.D. (b)	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
CW	109	0	2,900	0	0	0	0								
CW	110	0	39,260	0	40	40	0								
CW	111	0	0	60	1,880	120	60								
CW	112	0	8,220	4,430	10,040	470	7,800								
CW	114	0	0	50	50	100	70								
CW	116	170,430	330,940	274,140	174,040	80	146,890								
CW	117	260	50	190	320	50	100								
CW	119	0	60	210	720	130	200								
CW	120	114,760	194,600	194,650	129,770	167,700	81,960								
CW	122	234,260	499,240	397,150	287,590	242,540	158,160								
CW	123	0	3,190	830	2,470	720	360								
CW	124	43,380	209,480	207,870	172,900	173,890	142,110								
CW	125	0	0	0	0	90,220	182,060								
CW	126	0	0	30	0	0	140								
CW	127	500	2,090	28,220	5,270	590	18,730								
CW	129	178,390	365,860	359,210	361,890	330,400	175,550								
CW	131	166,820	338,380	256,960	298,760	254,430	168,560								
CW	132	0	0	19,050	0	119,480	155,060								
CW	133	263,790	514,970	425,030	379,310	381,620	85,240								
CW	134	223,010	459,870	434,860	373,410	380,700	248,360								
CW	136	129,370	274,310	296,550	294,010	271,520	177,680								
CW	137	129,740	275,190	459,330	346,410	405,400	249,480								
CW	138	162,630	328,030	303,770	331,020	304,640	200,650								
CW	139	0	50	0	1,000	100	0								
CW	142	129,230	296,200	331,210	314,210	248,930	13,610								
CW	143	180,780	360,420	318,810	299,900	296,100	192,560								
CW	144	161,960	318,240	280,640	261,150	262,560	159,980								
CW	150	0	0	0	0	19,730	24,700								
CW	151	39,410	115,540	63,950	256,980	311,930	174,610								
CW	153	0	0	5,080	452,080	725,140	420,570								
CW	154	169,720	365,330	280,010	242,860	226,260	138,750								
CW	155	131,440	291,600	212,780	189,630	76,670	142,620								
CW	156	235,670	409,330	316,070	151,930	92,690	198,550								
CW	157	161,530	315,190	292,270	279,910	271,700	165,990								
CW	158	11,830	75,500	41,680	305,110	314,950	46,530								
CW	159	274,280	554,060	516,590	512,320	469,800	308,170								
CW	161	0	0	0	0	90	0								
DP	1														
DP	2														
DP	3														
DP	6														
DP	7														
DP	8														
NR	1		286,447	234,634	140,488	209,784	286,169	263,913	316,290	358,539	285,183	236,858	272,051	342,179	368,71
NR	3		318,833	149,051	271,584	270,558	402,820	359,313	453,216	297,105	428,872	362,197	329,841	350,740	283,52
NR	5		487,188	498,284	437,506	435,558	428,586	382,397	412,251	389,494	521,093	503,053	425,812	22,348	123,56
NR	6		0	158	62,749	51,707	131,713	44,239	50,054	57,881	57,615	41,262	41,072	66,342	88,04
NR	7		228,020	34,398	128,674	216,330	152,040	178,806	176,675	235,170	154,618	102,694	133,084	198,576	180,23
NR	8		3,825	0	255	38,723	23,774	20,690	34,556	33,967	39,361	19,024	22,873	92,856	0
NR	9		27,881	63,873	139,174	188,924	33,230	38,132	103,856	141,395	122,358	141,095	109,671	79,234	81,01
NR	10		593,331	585,817	423,528	377,213	469,978	518,225	376,409	392,568	422,716	386,814	392,339	442,700	356,29
NR	11		0	0	5,191	9,325	2,907	2,126	4,988	17,073	36,370	49,424	30,114	54,517	27,51
NR	12		164,045	88,367	225,582	192,055	265,429	214,903	268,434	325,564	251,235	211,783	129,337	173,112	132,35
NR	13		0	0	0	0	7,667	0	800	5,597	8,591	653	420	17,811	21,07
NR	14		113,595	225,637	56,176	128,780	174,190	96,438	71,399	32,435	32,530	25,656	6,456	77,916	14,68
NR	15		318,572	164,257	271,712	207,844	488,941	487,683	364,507	344,554	434,297	222,600	120,010	218,017	219,09
NR	17		88,910	415	17,404	1,836	266,029	256,341	256,914	271,117	276,510	240,292	208,936	399,701	231,62
NR	18		54,768	197,434	186,642	108,006	69,610	70,316	61,902	104,567	182,244	156,786	228,526	285,220	251,37

Table N-3
Well Cumulative Pumpage Data
usand Gallons Per Year)

1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Reference (c)
													City of Sacramento
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													City of Sacramento
272,051	342,179	368,716	335,843	16,090	160,090				196,686	147,380			NR Water District
329,841	350,740	283,525	256,164	399,570	399,570				374,631	311,310			NR Water District
425,812	22,348	123,563	276,886	319,084	319,084				495,590	490,340			NR Water District
41,072	66,342	88,047	53,611	4,895	4,895				52,033	54,830			NR Water District
133,084	198,576	180,232	173,346	229,166	229,166				147,987	177,140			NR Water District
22,873	92,856	0	0	0	0				29,510	37,650			NR Water District
109,671	79,234	81,018	72,429	32,787	32,787				149,386	163,110			NR Water District
392,339	442,700	356,294	209,694	336,374	336,374				311,515	342,150			NR Water District
30,114	54,517	27,511	16,483	2,088	2,088				72,063	161,920			NR Water District
129,337	173,112	132,354	122,758	58,794	58,794				80,486	85,420			NR Water District
420	17,811	21,071	86,788	139	139				506	8,220			NR Water District
6,456	77,916	14,681	27,799	2,163	2,163				90,298	115,690			NR Water District
120,010	218,017	219,092	104,624	282,850	282,850				232,790	385,030			NR Water District
208,936	399,701	231,625	144,687	83,077	83,077				187,127	16,760	NIS	NIS	NR Water District
228,526	285,220	251,379	158,955	6,592	6,592				311,416	NIS	NIS	NIS	NR Water District

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Table N

Production Well Cumula

(Thousand Gallo

Purveyor (a)	Well I.D. (b)	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	19
NR	19		0	0	0	13	26	31	1,587	1,792	229	64	49	90
NR	20		155,163	158,596	19,290	46,216	81,512	155,673	1,634	12,408	8,093	16,188	36,349	15,4
NR	21		1,696	164	111,032	41,072	24,184	42,841	50,783	43,736	66,074	8,521	8,217	17,9
NR	22		133,637	40,193	140,345	164,557	267,711	312,606	296,680	443,619	314,314	368,985	282,099	174,
NR	23		22,799	22,299	105,643	49,325	67,194	17,585	101,554	115,389	126,877	78,411	126,342	128,
NR	24		170,604	250,820	67,944	264,806	291,647	192,161	241,049	164,893	533,925	585,607	628,919	657,
NR	25		610,231	117,665	381,105	814,734	729,933	754,403	809,140	811,143	139,534	NIS	NIS	NI
NR	26		263,452	299,332	332,464	366,084	397,668	420,454	317,077	103,538	NIS	NIS	NIS	NI
NR	27		84,564	167,804	129,796	146,248	114,593	160,868	15,973					
NR	28		108,699	203,783	387,516	324,918	0	173,399	59,370					
NR	29		93,606	374,268	316,002	86,962	242,662	414,698	569		See Note C Below			
NR	30		98,877	405,244	480,415	516,589	206,655	177,788	0					
NR	31		186,257	426,733	418,849	352,621	419,258	366,765	46,664					
NR	32A		62,541	92,748	318,984	185,349	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NI
NR	32B		485,611	402,735	231,970	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NI
NR	34													
RIO	1													
RIO	2													
RIO	3													
RIO	4		80,896	124,661	127,878									
RIO	5													
RIO	6													
RIO	7													
RIO	8		80,699	36,266	47,043									
RIO	9													
RIO	10													
RIO	11		233,262	99,655	185,675									
RIO	12													

a). Notes on Purveyor Acronyms:

- ARC - Arcade Water District
- BW - McClellan Air Force Base
- CM - Carmichael Water Agency
- CT - Caltrans
- CU - Citizens Utilities
- CW - City of Sacramento
- DP - Del Paso Water District
- NR - Northridge Water District
- RIO - Rio Linda Water District

b). Well I.D. = Number used by SAWWA if purveyor is member of that organization, otherwise provided by purveyor.

c). Radian = Information on production wells for Arcade and Rio Linda is still being obtained. For now, Radian data is used (1992 goes just through Noveml

AFB Data 1461 = Form 1461 is the monthly operating report of McClellan Air Force Base wells.

Caltrans = Caltrans sent a memo with gross pumping volume for a week, which was based on the pumping rate from 1979 to 1989. This number is based

Citizens = Citizens Utilities sent a summary of annual cumulative pumpage volumes.

City of Sacramento = Data came from two different sources. Radian data was used for 1992 and 1993 since the information supplied by the City was inco
1993 data is incomplete, missing July, August, September, October, November and December. These numbers should probably be higher than shown

NR Water District = Northridge Water District sent a summary of annual cumulative pumpage volumes. Complete monthly data was unavailable for 197(
Water District on 10/31/86. Data for 1986 for these wells are probably not representative of total volume pumped.

d). NIS = Not in Service

un Table N-3

Y'ell Cumulative Pumpage Data

ıand Gallons Per Year)

198	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	Reference (c)
50-	49	902	504	3,773	185	185				7,738	NIS	NIS	NIS	NR Water District
3,37	36,349	15,450	3,370	9,221	79,971	79,971				0	NIS	NIS	NIS	NR Water District
15,3	8,217	17,938	15,307	34,050	34,482	34,482				4,510	NIS	NIS	NIS	NR Water District
29,0	282,099	174,178	229,081	459,850	211,028	133,815								NR Water District
71,8	126,342	128,593	171,877	155,800	133,815	211,028				541,173	117,650			NR Water District
65,2	628,919	657,530	665,225	599,456	227,449	227,449								NR Water District
NI	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NR Water District
NI	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NR Water District
														NR Water District
														NR Water District
w														NR Water District
														NR Water District
														NR Water District
NI	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NR Water District
NI	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NIS	NR Water District
														NR Water District
														Radian
														Radian
														Radian

Rio l

hrough November for Rio Linda).

atio

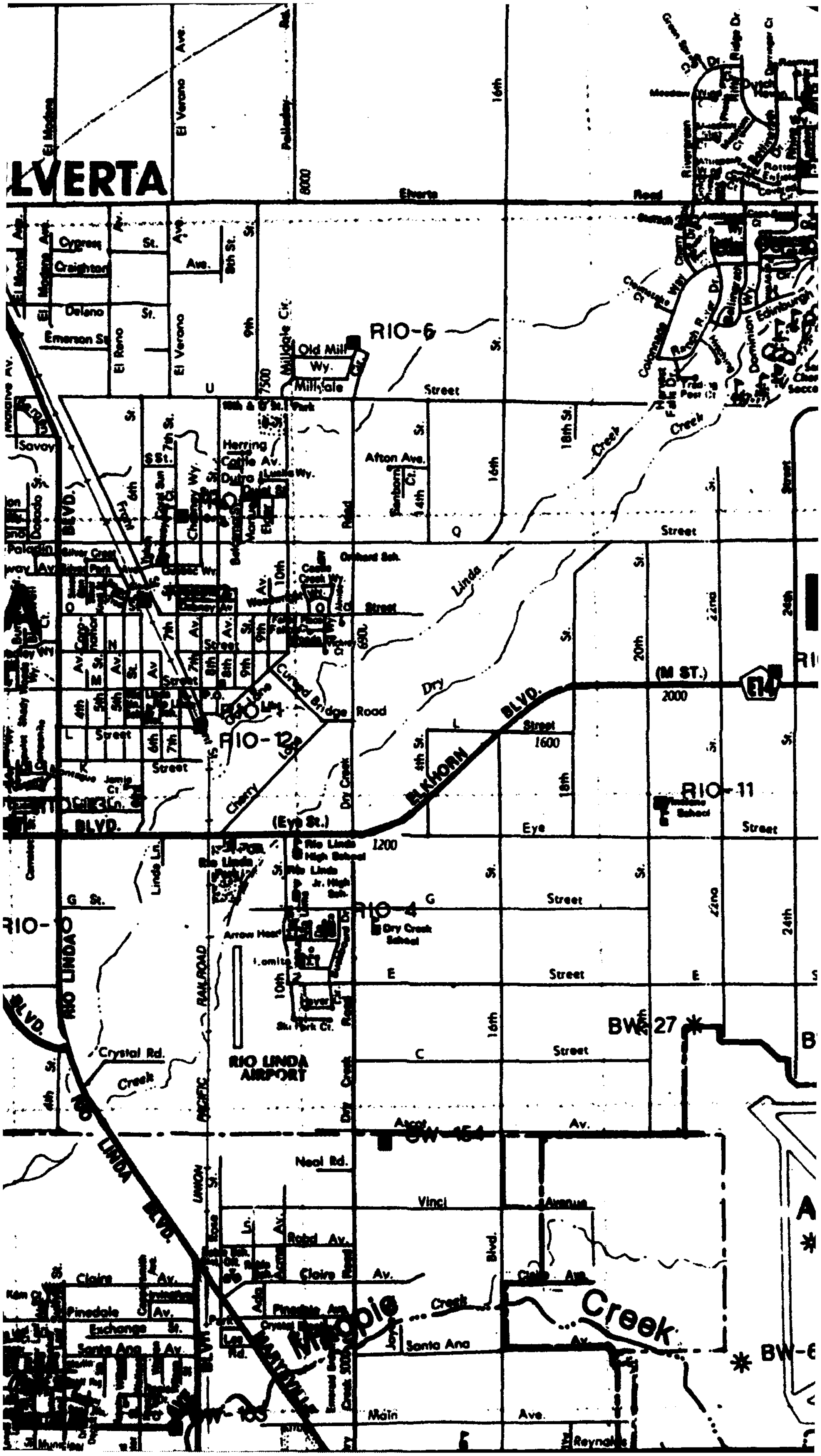
umber is based on irrigation season pumping rates.

for 1 e City was incomplete.

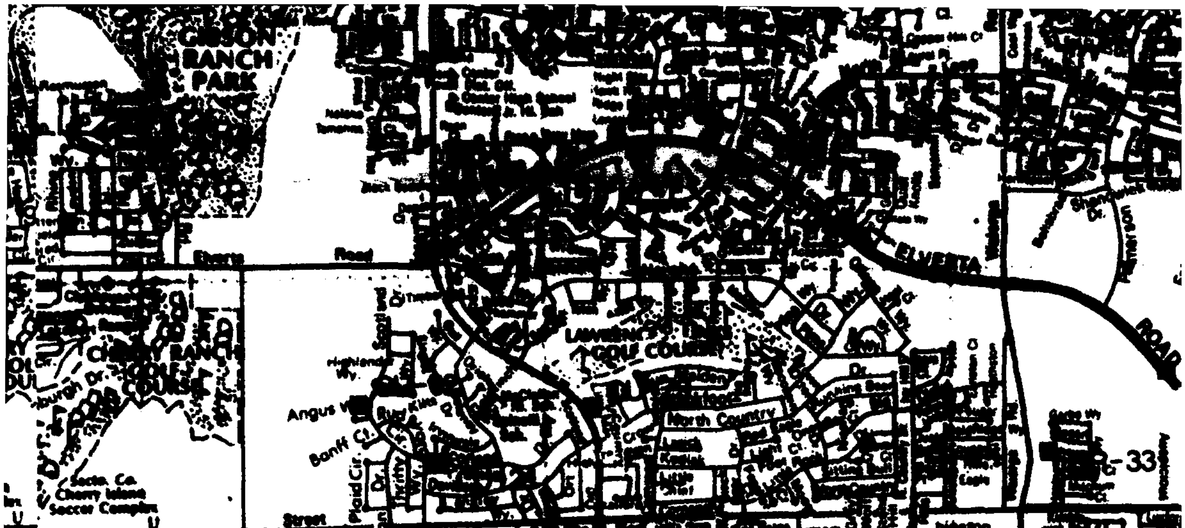
197 her than shown. Data for 1988 is also incomplete, missing January, February, March, April, and May.

ailable for 1970, 1971, 1974, 1975, and 1976. Wells 27 through 31 were purchased from Arvin

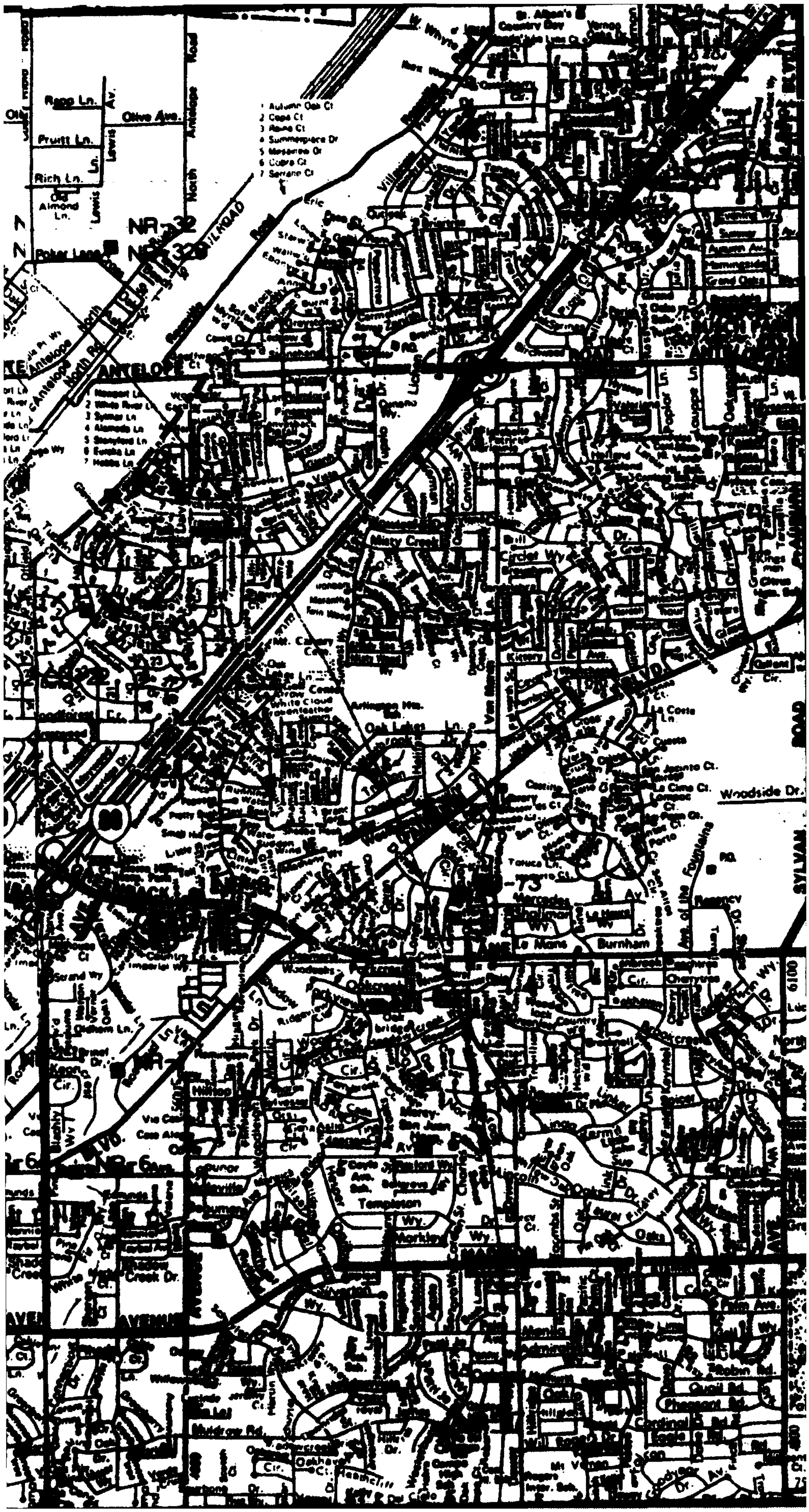
2



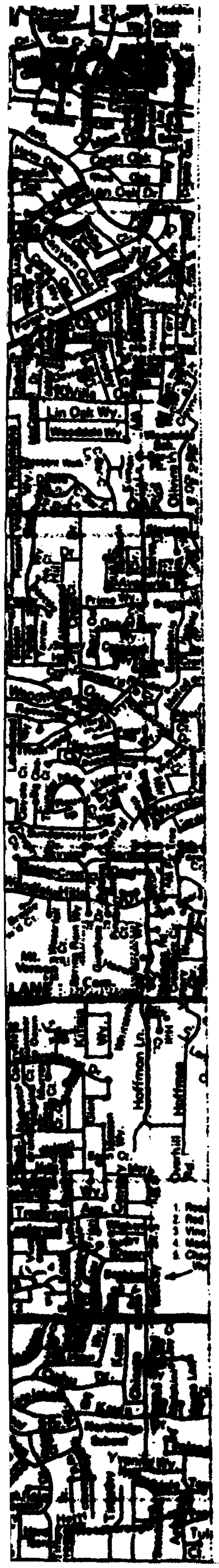
ELVERTA
Elverta
Road
RIO-6
Old Mill Wy.
Millsdale
Street
Afton Ave.
Q
Street
Linda
Creek
Dry
(M ST.)
2000
ELKHORN BLVD.
L Street
1600
RIO-12
RIO-11
Curved Bridge Road
Cherry Lane
Dry Creek
(Eye St.)
1200
Eye
Street
G Street
RIO-4
RIO-10
Dry Creek School
E Street
C Street
BW 27
RIO LINDA AIRPORT
RAILROAD
PACIFIC
UNION
Crystal Rd.
Creek
RIO LINDA BLVD.
Ascot Av.
Neal Rd.
Vinci Avenue
Claire Av.
Robd Av.
Pinedale Av.
Exchange St.
Santa Ana Av.
Magpie Creek
Main Ave.
BW-6
16th
20th
24th
El Verano Ave.
El Modena
Cypress St.
Creighton
Delano St.
Emerson St.
El Reno
Rio Linda High School
Rio Linda Jr. High Sch.



NORTH
HIGHLANDS
ELKHORN BLVD.
ELKHORN
RIO-8
ARC-58
GIBSON
RANCH
PARK
ELVERTA
ROAD
North Country
Winthrop
Quinn
Bainbridge
Milton
Street
2500
3500
26th
30th
32nd
34th



Rapp Ln.
Olive Ave.
Pruitt Ln.
Rich Ln.
Old Almond Ln.
Poplar Lane
1 Autumn Oak Ct
2 Copa Ct
3 Roma Ct
4 Summerplace Dr
5 Mesamee Dr
6 Cobra Ct
7 Serrano Ct
ANTELOPE
Antelope North Rd.
Woodside Dr.
SYLVAN
ROAD
Burnham
Le Mans
Mercedes
Templeton
Markley
Oak Lakes Ln.
Misty Creek
Creek Dr.
Quail Rd.
Pheasant Rd.
Robin Rd.



2500 0 2500 5000 FEET

LEGEND

■ WELLS FROM DISTRICT/SAWWA MAPS

McCLELLAN AFB WELLS (ACTIVE)

McCLELLAN AFB WELLS
(To be abandoned during Phase III)

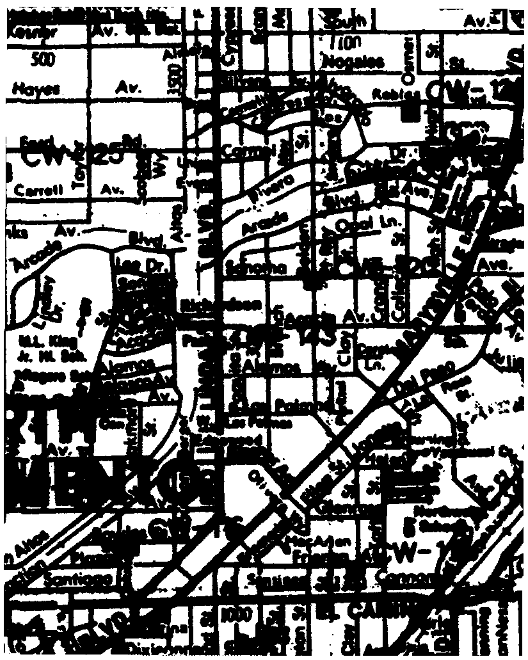
McCLELLAN AFB WELLS (ABANDONED)

o SEISMIC SURVEY WELLS

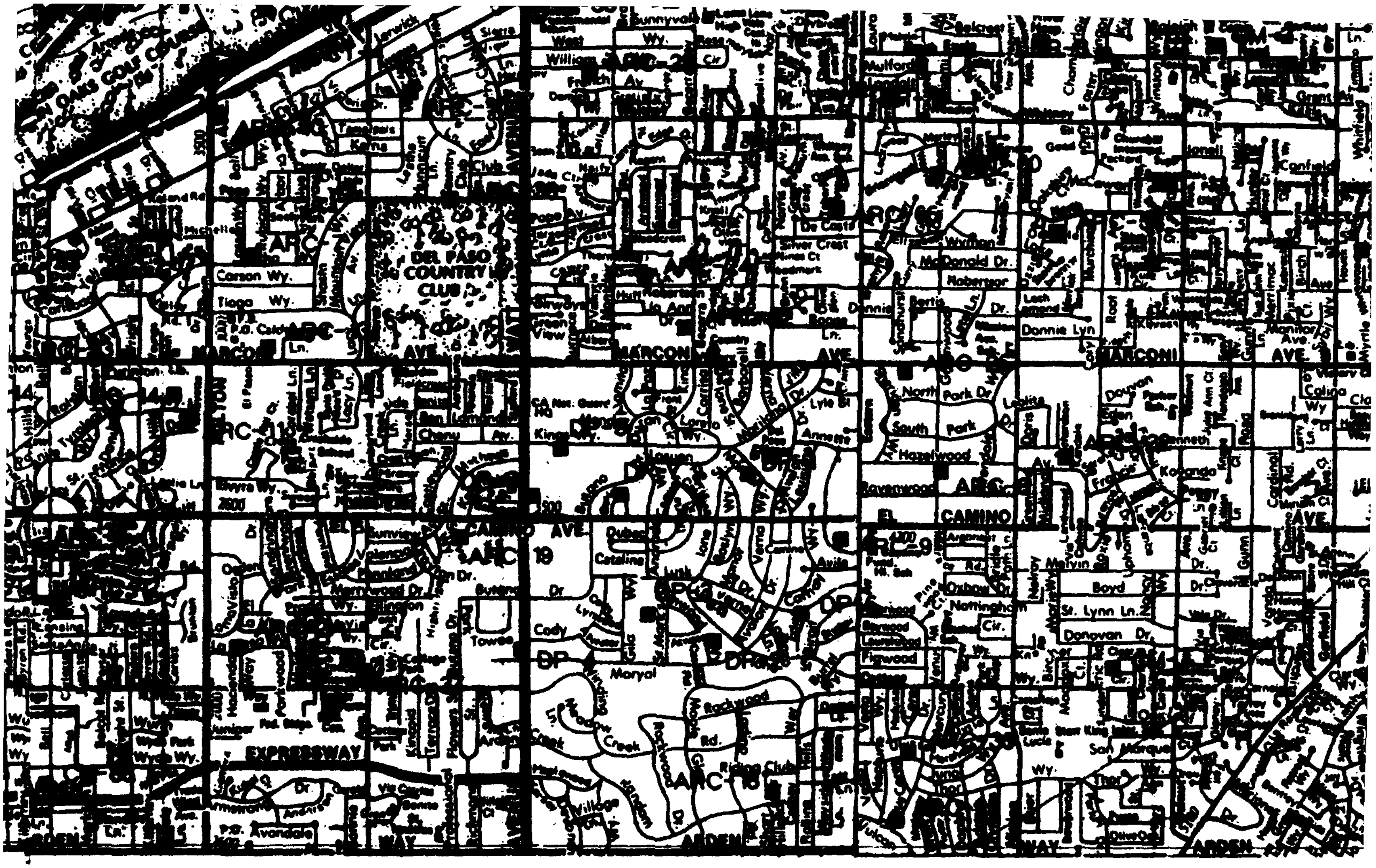
ARC-24 ← WELL NUMBER

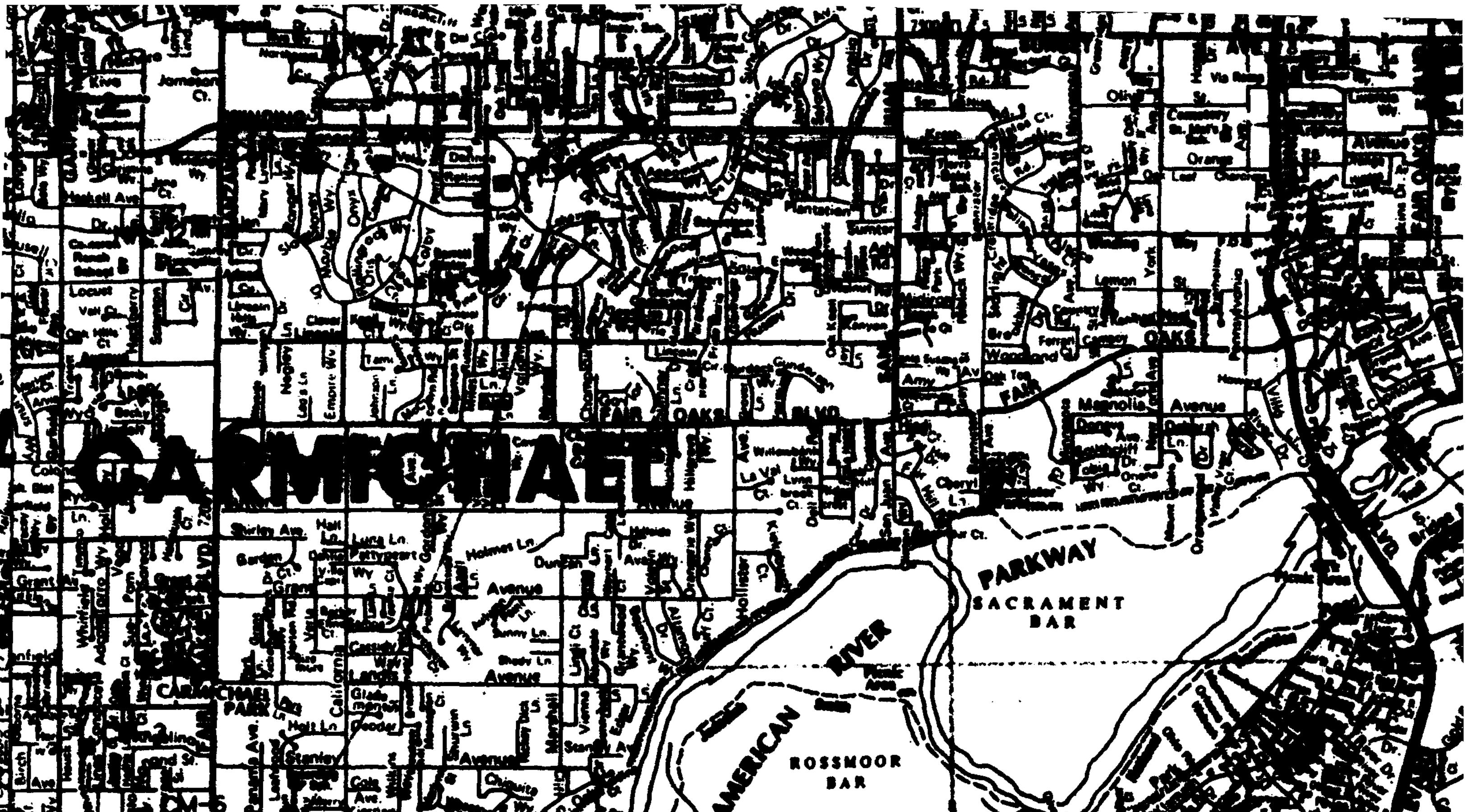
WATER PURVEYOR

NOTES:



500
Hayes
Av.
Nogales
Robles
Carroll
Av.
Arcade
Blvd.
Opal Ln.
Santiago


DEL PASO COUNTRY CLUB
MARCONI
AVE
EL CAMINO
AVE
EXPRESSWAY
ARDEN
WAY
Carson Wy.
Tioga Wy.
Donnie Lyn
Hazelwood
South Park
North Park Dr.
Rockwood
Riding Club
Moryal
Donovan Dr.
St. Lynn Ln.
Boyd
Avondale
Catalina
McDonald Dr.
Robertson


CARMICHAEL
FAIR OAKS BLVD.
PARKWAY
SACRAMENT
BAR
AMERICAN RIVER
ROSSMOOR
BAR
ANCIL HOFFMAN PARK
CORDOVA COMMUNITY PARK
GOETHE
Group Campground
FOLSOM
BOULEVARD
SOUTHERN
Magnolia
Avenue
Kenneth Ave.
Palm Drive

WATER PURVEYOR

NOTES:

1. ACRONYMS USED FOR WELLS ARE:

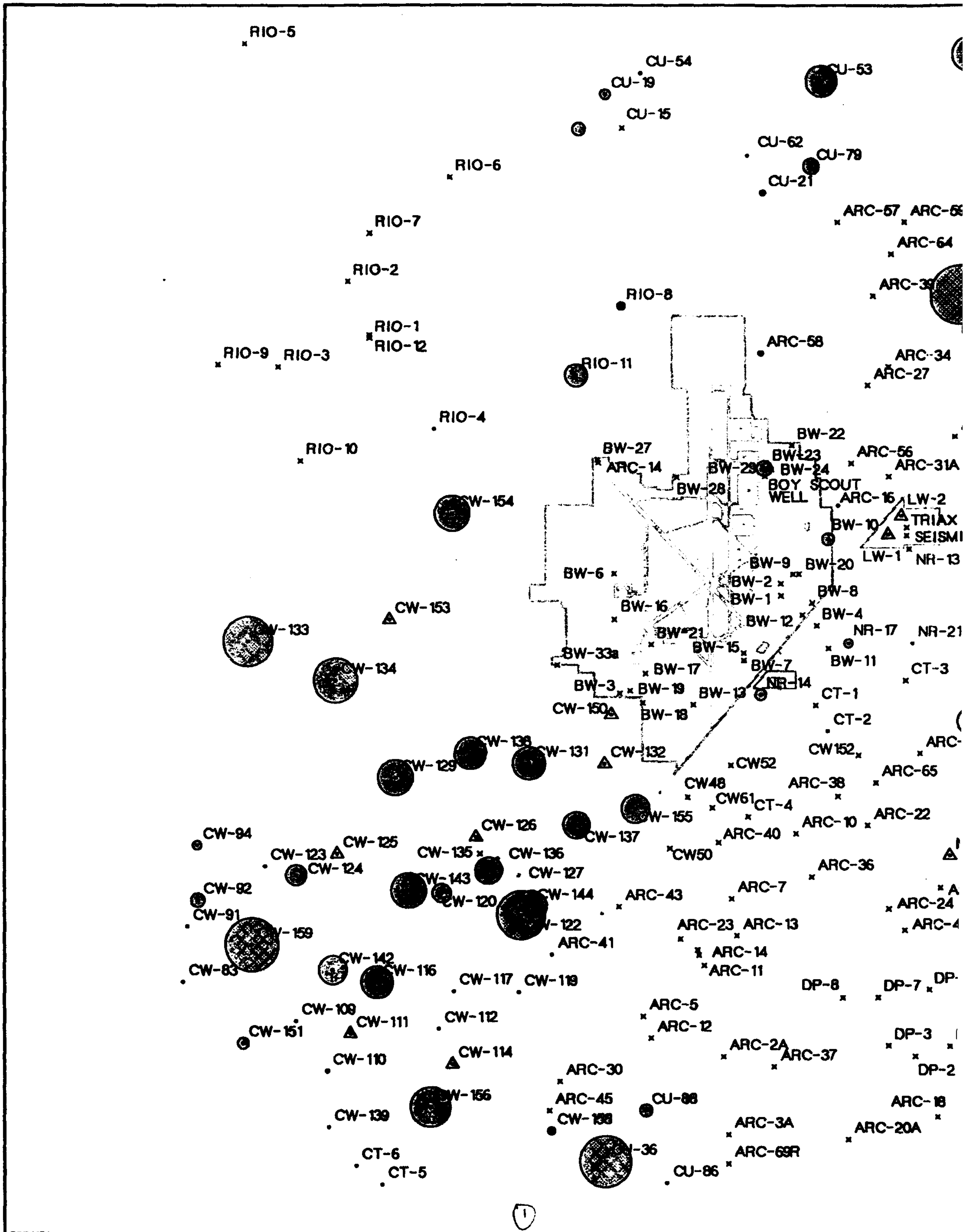
ARC	ARCADE WATER DISTRICT
NR	NORTHRIDGE WATER DISTRICT
CM	CARMICHAEL WATER AGENCY
CU	CITIZENS UTILITIES
RIO	RIO LINDA WATER DISTRICT
CW	CITY OF SACRAMENTO
SA-NW	COUNTY OF SACRAMENTO
DP	DEL PASO WATER AGENCY
BW	McCLELLAN AFB
CT	CALTRANS

2. ALL PRODUCTION WELLS WITHIN A 5-MILE RADIUS OF THE BASE ARE SHOWN

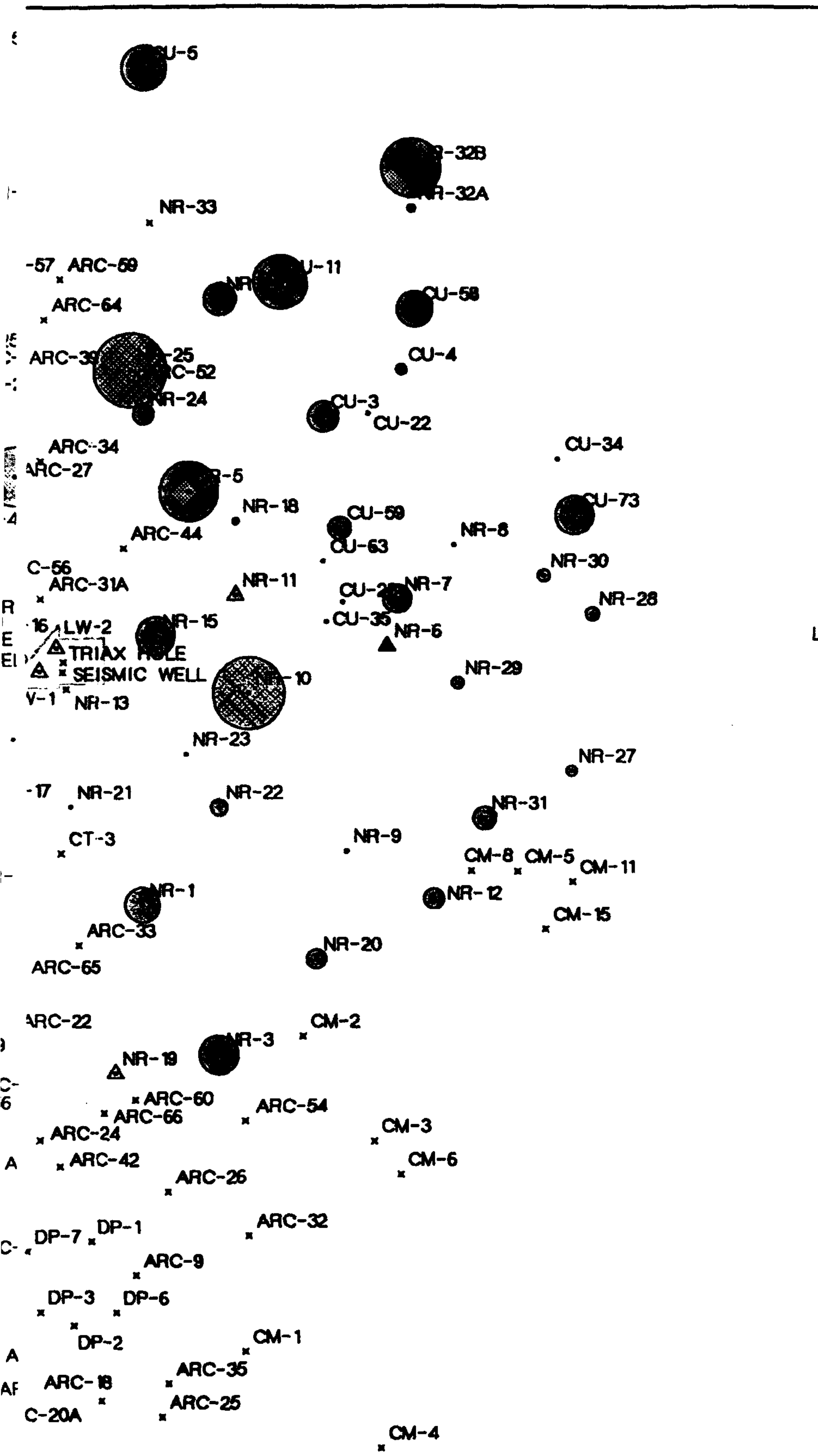
FIGURE N-1
PRODUCTION WELLS WITHIN A 5-MILE RADIUS OF McCLELLAN AIR FORCE BASE
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

(8)



RDD1454
GWOU/n-2.dgn



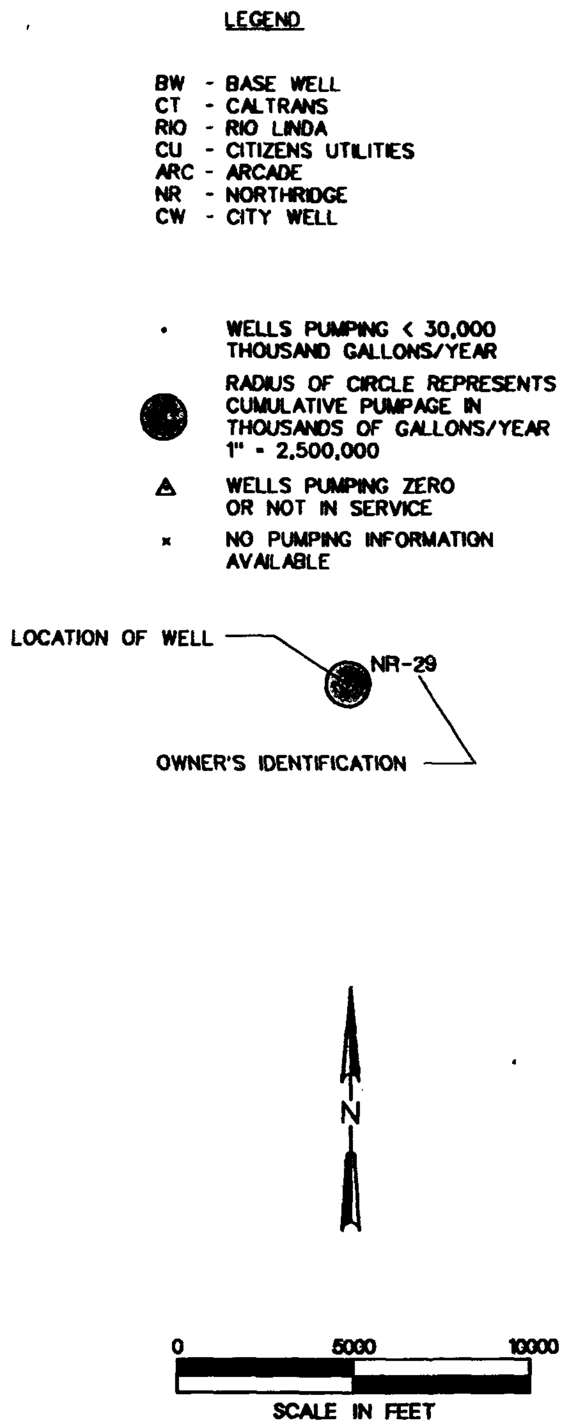
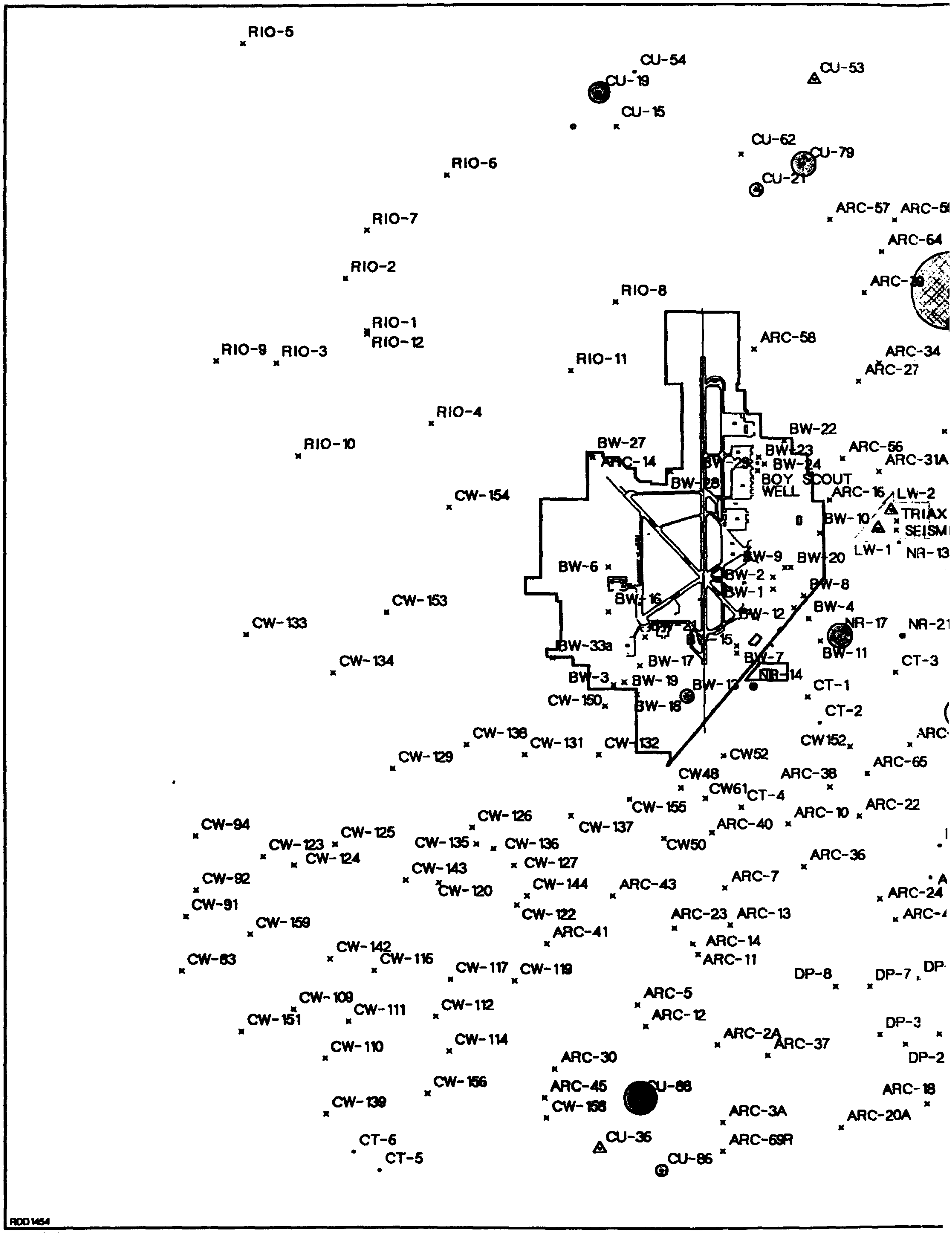


FIGURE N-2
PUMPING DISTRIBUTION OF PRODUCTION WELLS AROUND MCCLELLAN AIR FORCE BASE (1992)

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

CH2M HILL


RIO-5
CU-54
CU-19
CU-53
CU-15
CU-62
CU-79
CU-21
RIO-6
RIO-7
ARC-57
ARC-64
RIO-2
RIO-8
RIO-1
RIO-12
RIO-9
RIO-3
ARC-58
ARC-34
ARC-27
RIO-11
RIO-4
RIO-10
BW-22
BW-27
ARC-14
BW-23
BW-24
ARC-56
ARC-31A
BW-28
BOY SCOUT
WELL
ARC-16
LW-2
CW-154
BW-10
TRIAX
LW-1
NR-13
BW-9
BW-20
BW-6
BW-2
BW-1
BW-8
BW-16
BW-4
CW-153
BW-12
NR-17
NR-21
CW-133
BW-33a
BW-11
CW-134
BW-17
BW-7
CT-3
BW-3
BW-19
NR-14
CT-1
CW-150
BW-18
CT-2
CW-138
CW-131
CW-132
CW52
CW152
CW-129
CW48
ARC-38
ARC-65
CW61
CT-4
CW-155
CW-126
CW-137
ARC-40
ARC-10
ARC-22
CW-94
CW-123
CW-125
CW-135
CW-136
CW50
CW-124
CW-127
ARC-36
CW-92
CW-143
CW-120
CW-144
ARC-43
ARC-7
ARC-24
CW-91
CW-122
ARC-23
ARC-13
CW-159
ARC-41
ARC-14
CW-142
CW-116
ARC-11
CW-83
CW-117
CW-119
DP-8
DP-7
CW-109
CW-111
CW-112
ARC-5
CW-151
ARC-12
DP-3
ARC-2A
ARC-37
CW-110
CW-114
ARC-30
DP-2
CW-156
ARC-45
CU-88
ARC-18
CW-139
CW-158
ARC-3A
ARC-20A
CU-36
ARC-69R
CT-6
CT-5
CU-86
RDD 1454

GWOU/n-3.dgn

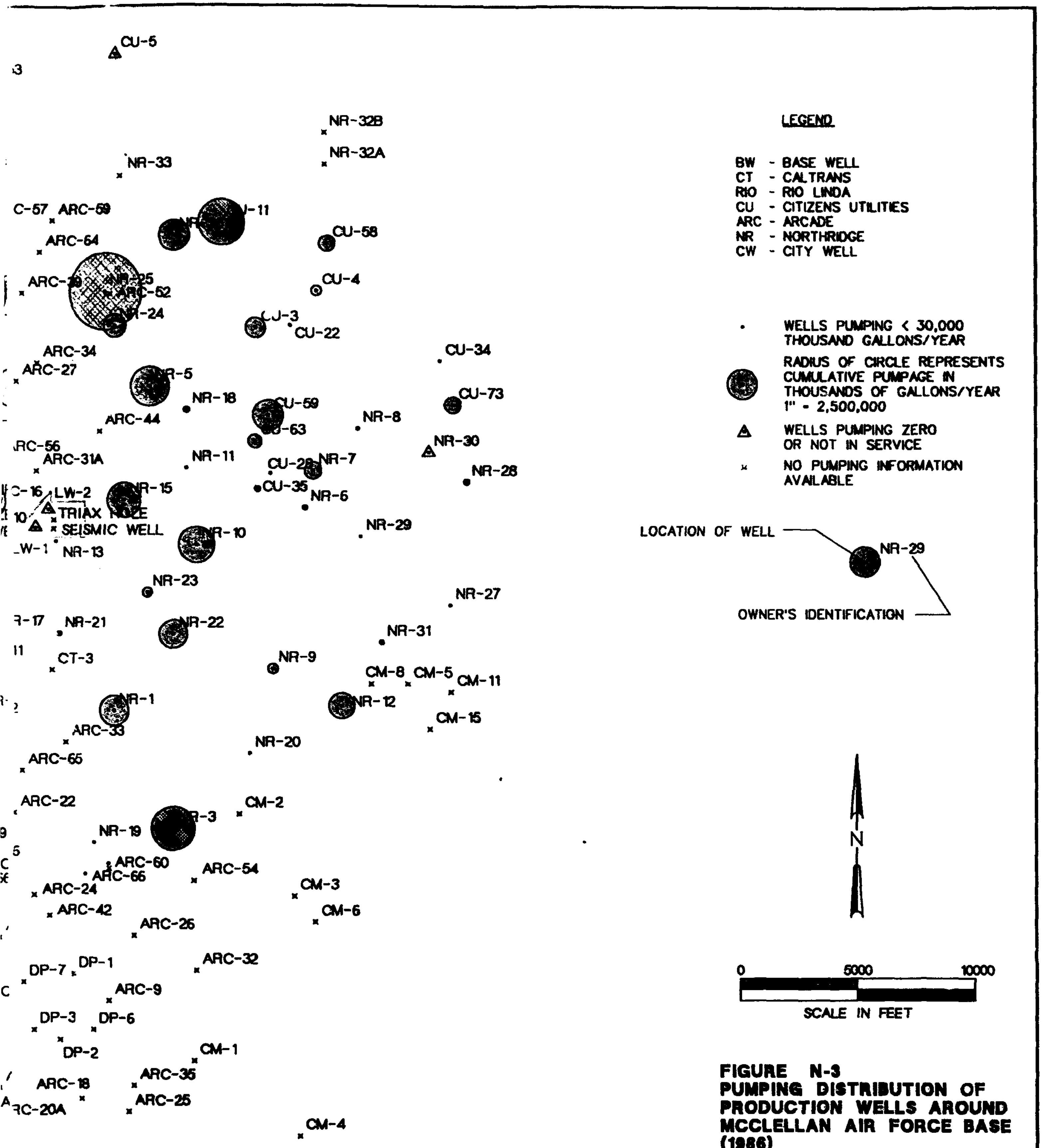
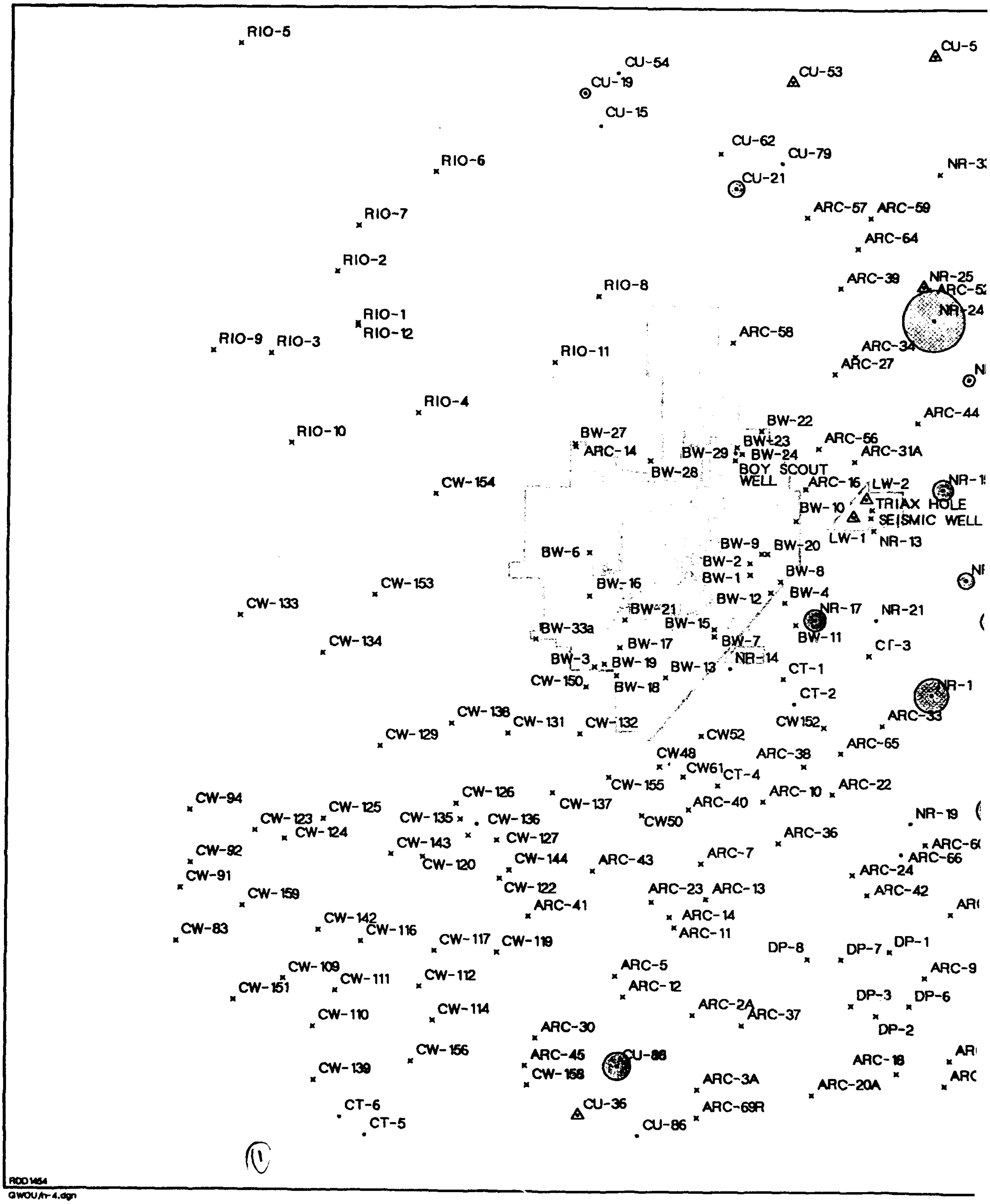


FIGURE N-3
PUMPING DISTRIBUTION OF PRODUCTION WELLS AROUND MCCLELLAN AIR FORCE BASE (1986)

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

CH2M HILL


RIO-5
CU-54
CU-19
CU-15
CU-53
CU-5
CU-62
CU-79
CU-21
RIO-6
RIO-7
RIO-2
RIO-8
RIO-1
RIO-12
RIO-9
RIO-3
RIO-11
RIO-4
RIO-10
ARC-57
ARC-59
ARC-64
ARC-39
NR-25
NR-24
ARC-58
ARC-34
ARC-27
ARC-44
BW-22
BW-23
BW-24
BW-27
ARC-14
BW-28
BW-29
BOY SCOUT WELL
ARC-56
ARC-31A
ARC-16
LW-2
TRIAX HOLE
SEISMIC WELL
BW-10
LW-1
NR-13
CW-154
BW-6
BW-9
BW-20
BW-2
BW-1
BW-8
BW-4
BW-12
CW-153
BW-16
CW-133
BW-21
NR-17
NR-21
BW-15
BW-11
BW-33a
CW-134
BW-17
BW-7
CT-3
BW-3
BW-19
BW-13
NR-14
CT-1
CW-150
BW-18
CT-2
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CW-131
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CW50
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CW-124
CW-127
ARC-36
CW-143
CW-92
CW-120
CW-144
ARC-43
ARC-7
ARC-66
ARC-24
CW-91
CW-122
ARC-23
ARC-13
ARC-42
CW-159
ARC-41
ARC-14
CW-142
CW-116
ARC-11
CW-83
CW-117
CW-119
DP-8
DP-7
DP-1
CW-109
ARC-5
ARC-9
CW-111
CW-112
CW-151
ARC-12
DP-3
DP-6
CW-110
CW-114
ARC-2A
ARC-37
DP-2
ARC-30
CW-156
ARC-45
CU-88
ARC-18
CW-139
CW-158
ARC-3A
ARC-20A
CT-6
CU-36
ARC-69R
CT-5
CU-86
ROD 1454
GWOU/n-4.dgn

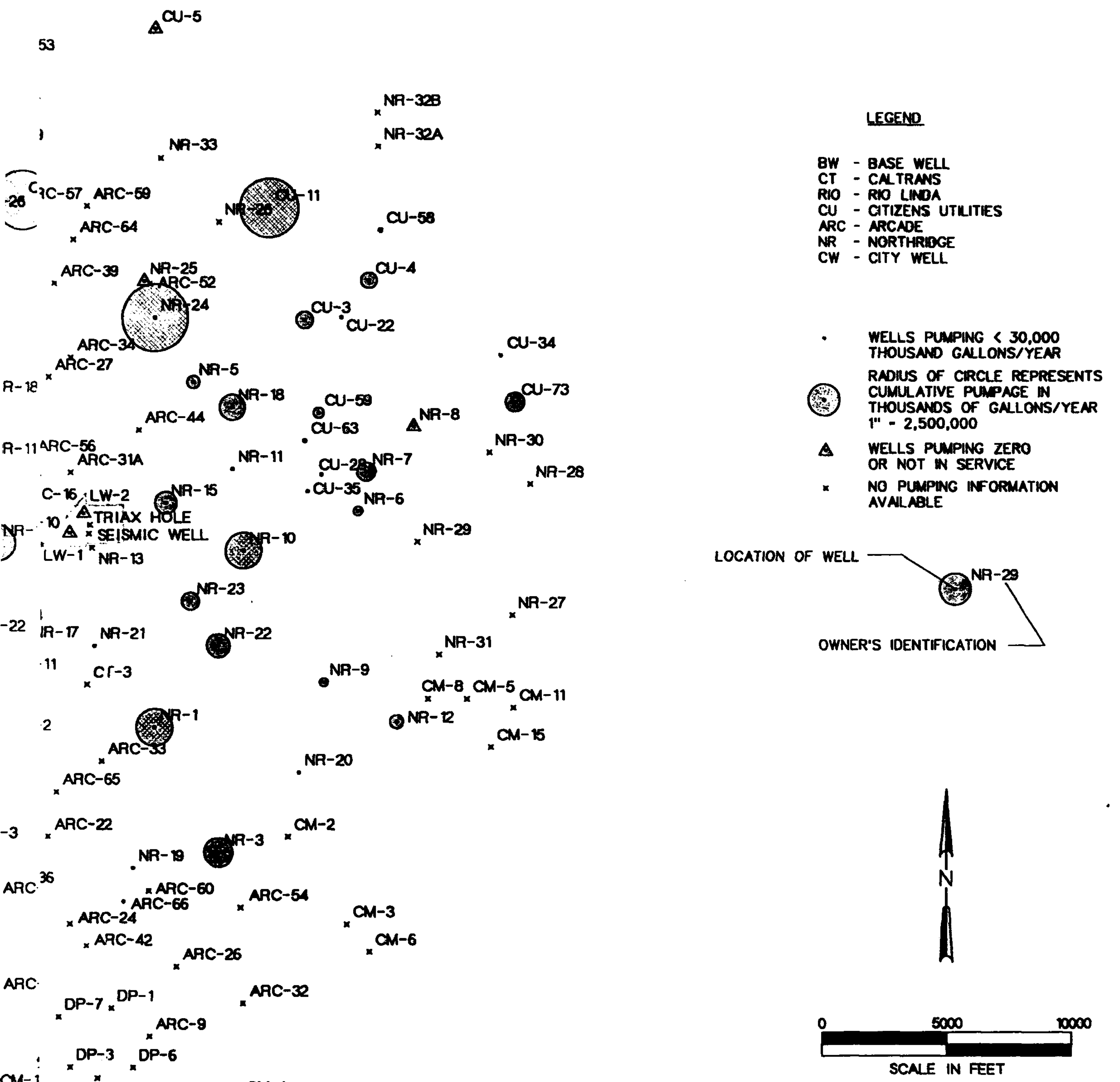
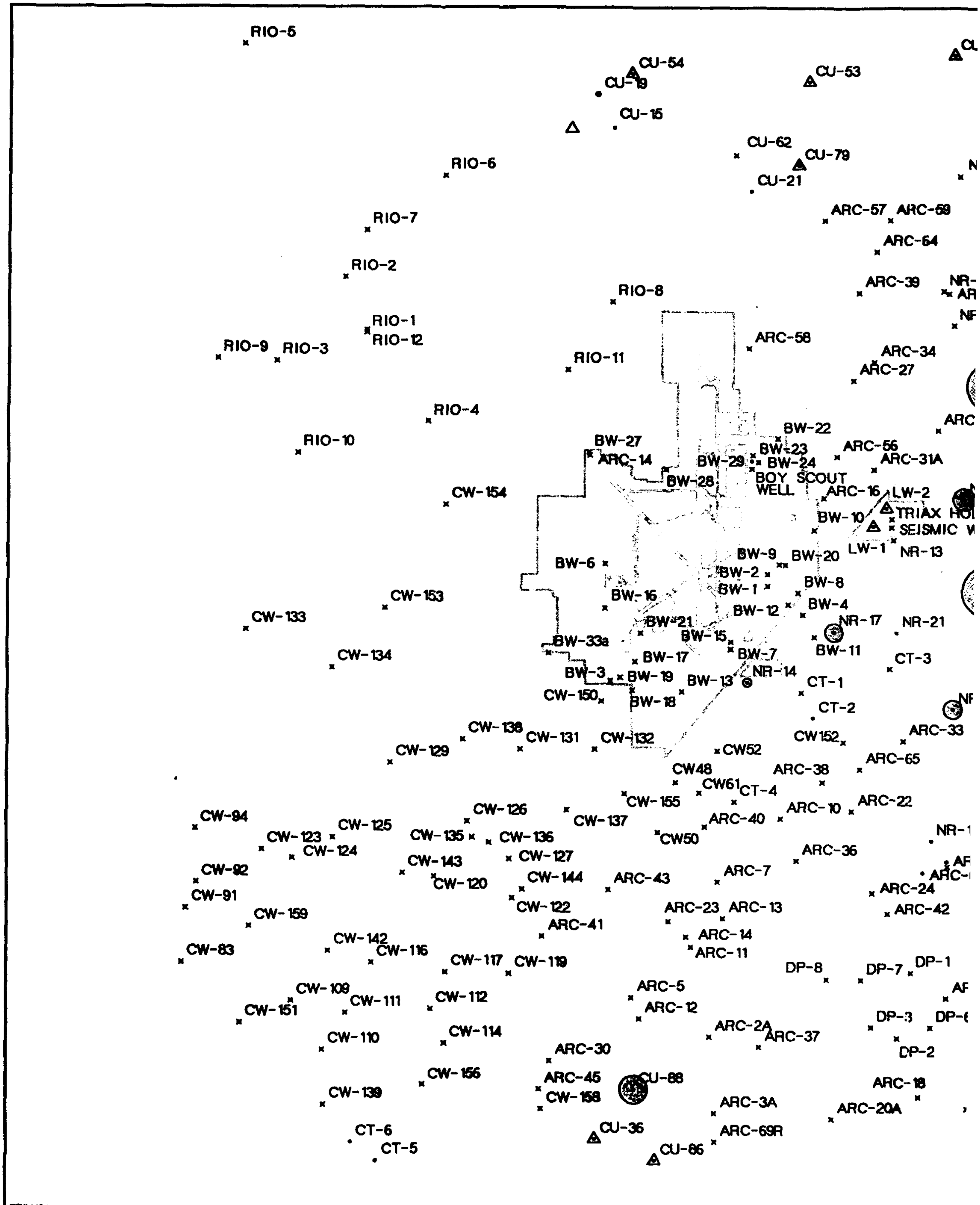


FIGURE N-4
PUMPING DISTRIBUTION OF PRODUCTION WELLS AROUND MCCLELLAN AIR FORCE BASE (1980)

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

CH2M HILL



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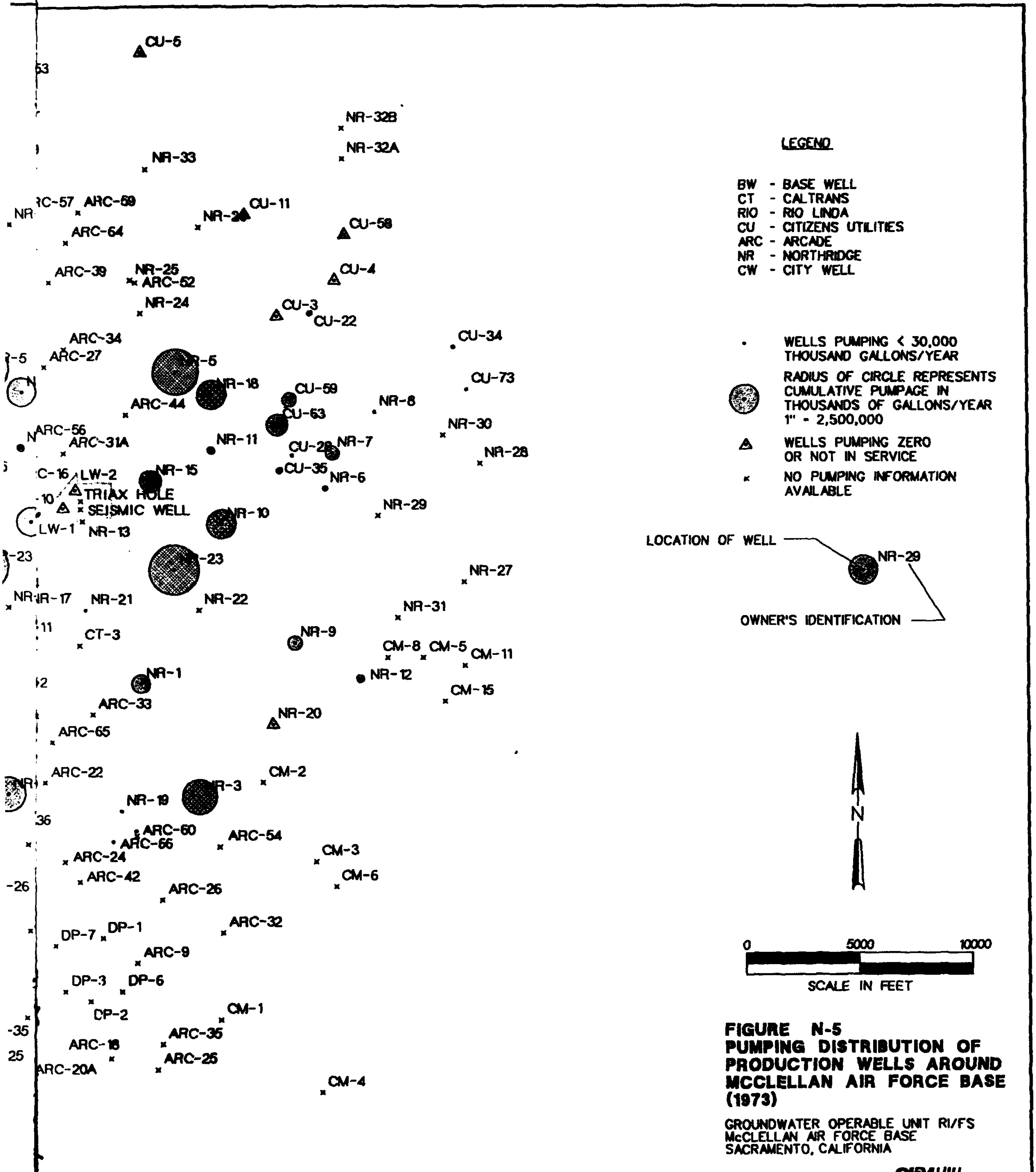

FIGURE N-5
PUMPING DISTRIBUTION OF PRODUCTION WELLS AROUND MCCLELLAN AIR FORCE BASE (1973)

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

Pumping Distribution and Impacts

The available pumping volumes during 1973, 1980, 1986, and 1992 for wells within a 5-mile radius of the Base are presented in Figures N-2, N-3, N-4, and N-5, respectively. The information provided indicates that most water withdrawal occurred in the southwest and northeast region of McClellan AFB.

Pumping information was not made available for all production wells within a 5-mile radius of the Base. However, production wells that are not marked with a pumpage magnitude may actually have ben pumped and may contribute to flow directions. Wells marked as having zero pumpage were not pumped.

Potential Future Pumping Conditions

No changes in pumping conditions are anticipated in the future by the City of Sacramento, Caltrans, or Citizens Utilities. The status of pumping conditions for the other water purveyors is unknown at this time.

Revised Final Well Closure Methods and Procedures Report and Revised Final Field Summary Technical Memorandum for BW-8

Delivery Order 5031
Line Item 0014

Prepared for
McClellan Air Force Base
Contract No. F04699-90-D-0035
Sacramento, California

Prepared by

CH2M HILL
3840 Rosin Court, Suite 110
Sacramento, California 95834

SAC28722.31.A4

October 1993

SAC/T207/030.51-1

Revised Final
Well Closure Metl
and Procedures Re
and Revised Final Field
Technical Memorandum

Delivery Order 50
Line Item 0014

Prepared for
McClellan Air Force B
Contract No. F04699-90-D
Sacramento, Califor

Prepared by

CH2M HILL

3840 Rosin Court, Suit
Sacramento, California

SAC28722.31.A4

SAC/T207/030.51-1

Revised Final
Well Closure Methods and Procedures
Phase II

Prepared for

McClellan Air Force Base

Sacramento, California

REGISTERED GEOLOGIST
CHARLES S. ELLIOTT JR.
No. 4751
STATE OF CALIFORNIA

This document has been prepared under the direction of a registered geologist.

Prepared by

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3840 Rosin Court, Suite 110
Sacramento, California 95834

SAC28722.31.A4

October 1993

SAC/T207/030.51-2

Revised Final
Well Closure Methods
and Procedures
Phase II

Prepared for

McClellan Air Force Base

Sacramento, California

REGISTERED GEOLOGIST
CHARLES S. ELLIOTT JR.
No. 4751
STATE OF CALIFORNIA

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Prepared by

CH2M HILL
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Sacramento, California 95834

SAC28722.31.A4

October 1993

SAC/T207/030.51-2

DISCLAIMER

This report has been prepared for the United States Air Force for the purpose of aiding in the implementation of a final remedial action plan under the Interagency Agreement (IAG). As the report relates to actual or possible releases of potentially hazardous substances, its release prior to Air Force final decision on remedial action is in the public interest. The limited objectives of this report, the ongoing nature of remediation, and the evolving knowledge of site conditions and chemical effects on the environment and health all must be considered when evaluating this report, since subsequent facts may become known which may make this report premature or inaccurate. Acceptance of this report in performance of the contact under which it was prepared does not mean that the U.S. Air Force or the Department of Defense 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 either department.

DISCLAIMER

This report has been prepared for the United States Air Force for the purpose of aiding in the implementation of a final remedial action plan under the Interagency Agreement (IAG). As the report relates to actual or possible releases of potentially hazardous substances, its release prior to Air Force final decision on remedial action is in the public interest. The limited objectives of this report, the ongoing nature of remediation, and the evolving knowledge of site conditions and chemical effects on the environment and health all must be considered when evaluating this report, since subsequent facts may become known which may make this report premature or inaccurate. Acceptance of this report in performance of the contact under which it was prepared does not mean that the U.S. Air Force or the Department of Defense 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 either department.

Contents

Tables

Figures

Introduction

McClellan Air Force Base (AFB) is located about 7 miles northeast of downtown Sacramento, California (see Figure 1). The base was originally established in 1936 as an air repair depot and supply base for the War Department. During World War II, McClellan AFB became a major industrial facility; in the early 1950s, it became a jet fighter maintenance depot. Today, McClellan AFB is an Air Force Logistics Command Center, occupying about 2,600 acres and employing more than 20,000 people.

Historically, McClellan AFB has used a variety of hazardous materials as part of routine operations and maintenance activities. These hazardous materials have included industrial solvents, caustic cleaners, electroplating wastes containing heavy metals, jet fuels, and a variety of oils and lubricants (Radian Corporation, 1990). In August 1979, the McClellan AFB Environmental Protection Committee created a special groundwater contamination task force to determine whether groundwater quality problems existed in the area. This voluntary action was prompted by concern that previous use of toxic chemicals, particularly trichloroethylene (TCE), could have affected groundwater quality. Samples collected from several wells on and near the base during 1979 and 1980 confirmed the presence of TCE in certain wells. As a result, those wells were taken out of service.

Since the discovery of groundwater contamination, investigations have been conducted at McClellan AFB under the Air Force Installation Restoration Program. Results of these investigations show that contamination is mainly confined to the uppermost groundwater zones beneath the base. Drinking water wells in the vicinity of the base draw primarily from deeper groundwater zones (Radian Corporation, 1990). Heavy pumping from many of these wells has created a downward gradient of flow in the groundwater system beneath the base.

However, concern mounted that existing inactive water supply wells at McClellan AFB may serve as conduits, allowing contaminated groundwater near the water table to migrate to deeper zones through the casing and gravel pack and potentially threaten downgradient drinking water supplies. Therefore, McClellan AFB issued a Statement of Work in June 1990 that authorized a Water Well Abandonment Project to decommission several inactive water supply wells on the base.

Originally, eight inactive water supply wells were targeted for decommissioning. However, four of these wells (Base Wells [BW-] 3, 6, 16, and 19) were eliminated from consideration because they could not be located. Later, City Well 150 (CW-150), on Astoria Street near the southwestern base boundary, was added to the list for decommissioning. The general locations of the five wells abandoned during this project are shown in Figure 2.

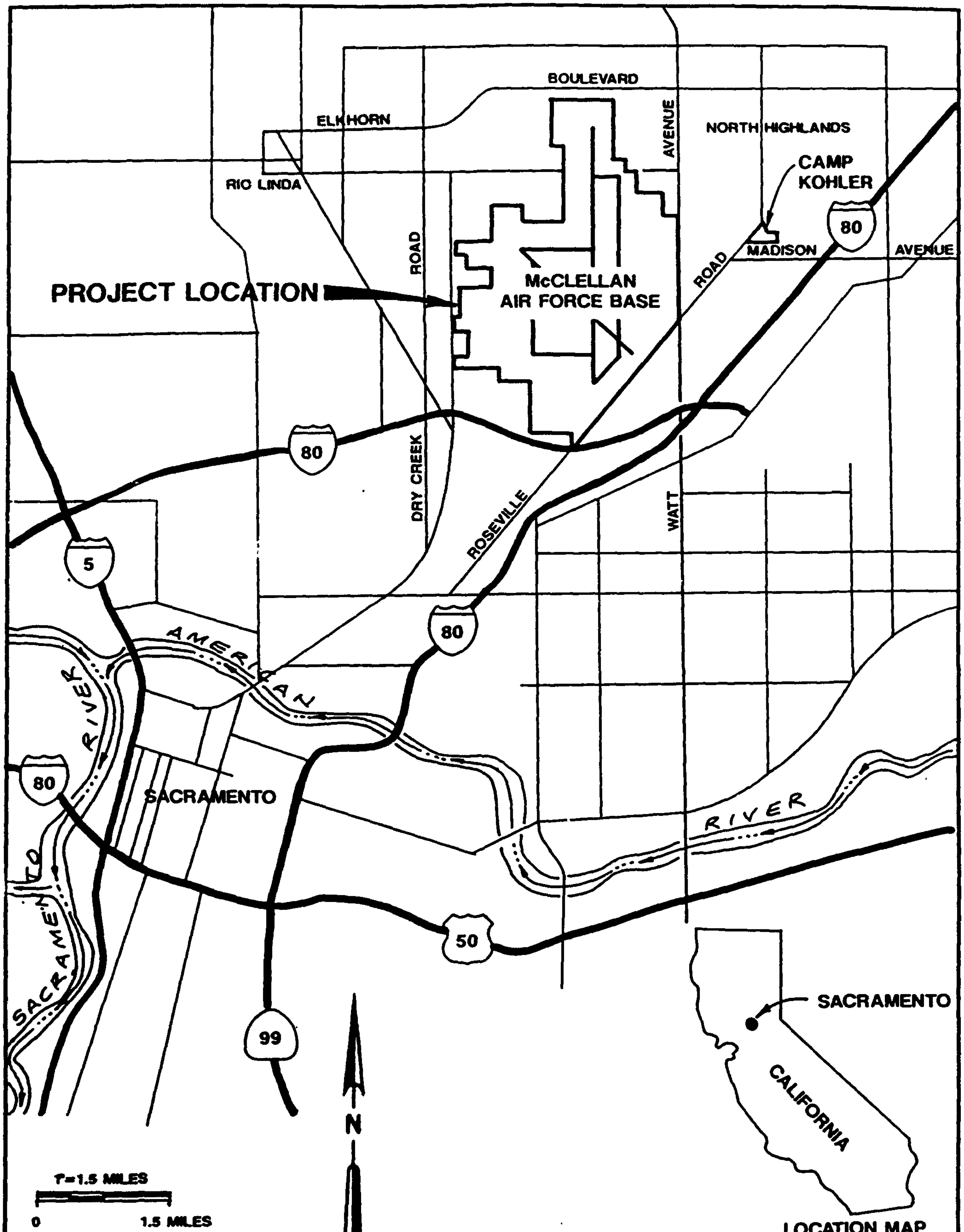

FIGURE 1
LOCATION OF McCLELLAN AIR FORCE BASE

CH2M HILL

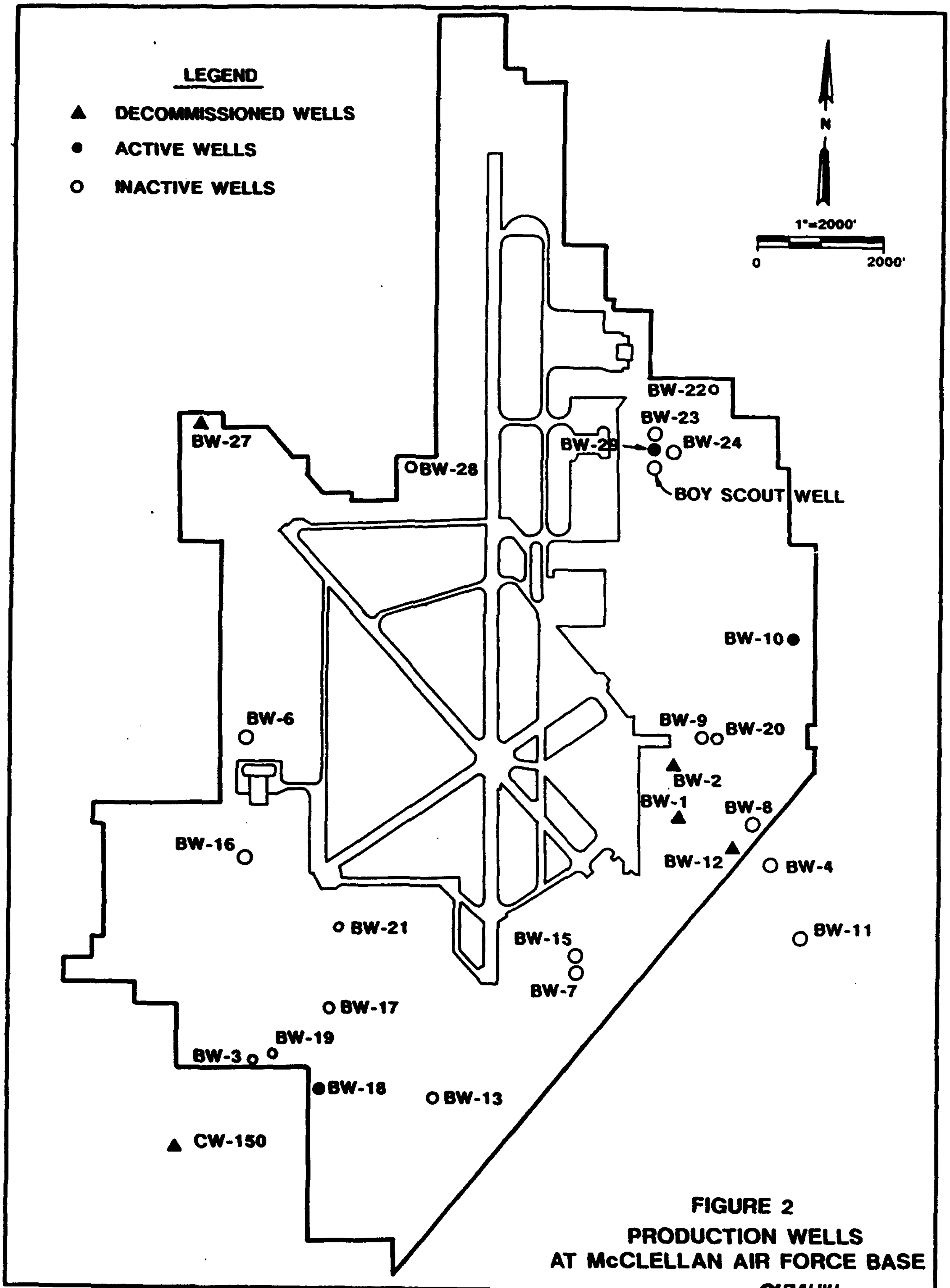

FIGURE 2
PRODUCTION WELLS
AT McCLELLAN AIR FORCE BASE

CH2M HILL

On September 30, 1991, McClellan AFB issued a contract that initiated a second phase of water well decommissioning on and near the base. Phase II includes the decommissioning of BW-7, -13, -17, -20, and -28: five inactive water supply wells at McClellan AFB. One other inactive well, BW-8, will be sealed in its upper zone and then returned to service for standby use in fire emergencies. The general location of these wells is shown in Figure 2.

In addition, Phase II includes the decommissioning of two wells formerly constructed as part of a seismic survey at nearby Camp Kohler (see Figure 3). Two other wells at Camp Kohler, Laundry Wells (LW-) 1 and 2, have been previously abandoned by filling the casing with concrete. Neither of the wells are presently visible at the ground surface, and LW-2 has not been precisely located. LW-2 will be located, and LW-1 and LW-2 will be redrilled and decommissioned. The general location of these wells is shown in Figure 3. Thus, Phase II of the Water Well Abandonment Project at McClellan AFB provides for the modification or decommissioning of up to 10 additional wells.

This Well Closure Methods and Procedures Report addresses the decommissioning and modification of wells during Phase II. Based on a review of existing files and documents and field work conducted at Camp Kohler, the report will provide a brief history of the wells, describing their construction details and discussing their hydrogeological setting. An inventory of all McClellan AFB wells is also provided. This inventory lists McClellan AFB water supply wells and summarizes what is currently known about their status. The report also proposes an approach to decommissioning the Phase II wells and modifying BW-8. The approach to decommissioning is based on the successful approach followed during Phase I. A Site Safety Plan that will govern safety procedures during the field work is provided in Appendix A. Well logs obtained for McClellan AFB production wells from the California Department of Water Resources (DWR) are provided in Appendix B. Cement bond logs run on the two seismic wells at Camp Kohler are provided in Appendix C. Finally, Appendix D contains a response to comments received from the regulatory agencies on the Draft Well Closure Methods and Procedures Report for Phase II.

Hydrogeology

The following discussion of geology and groundwater is taken primarily from investigations performed on behalf of McClellan AFB by Radian Corporation, whose staff has worked at the base since 1984. Hydrogeologic conditions in the immediate vicinity of base wells subject to decommissioning are described in the sections below.

Regional Geology

McClellan AFB is located in the Great Valley Geologic Province, a large depositional basin bounded by the Sierra Nevada on the east and Coast Range on the west (see Figure 4). The basin is filled with a thick sequence of sedimentary deposits, mainly derived from the Sierra Nevada in the vicinity of the base.

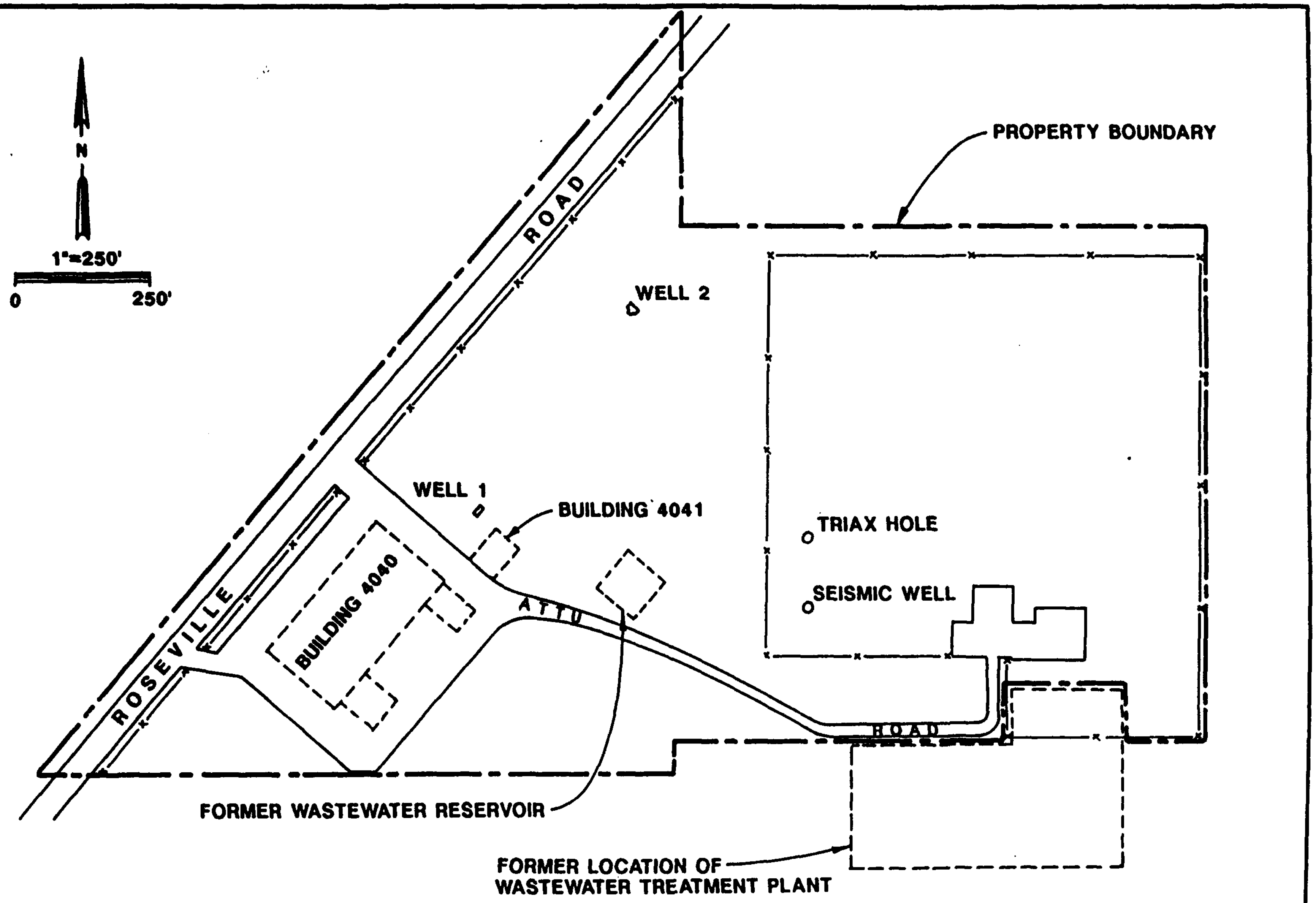

FIGURE 3
WELLS AT CAMP KOHLER
McCLELLAN AIR FORCE BASE

CH2M HILL

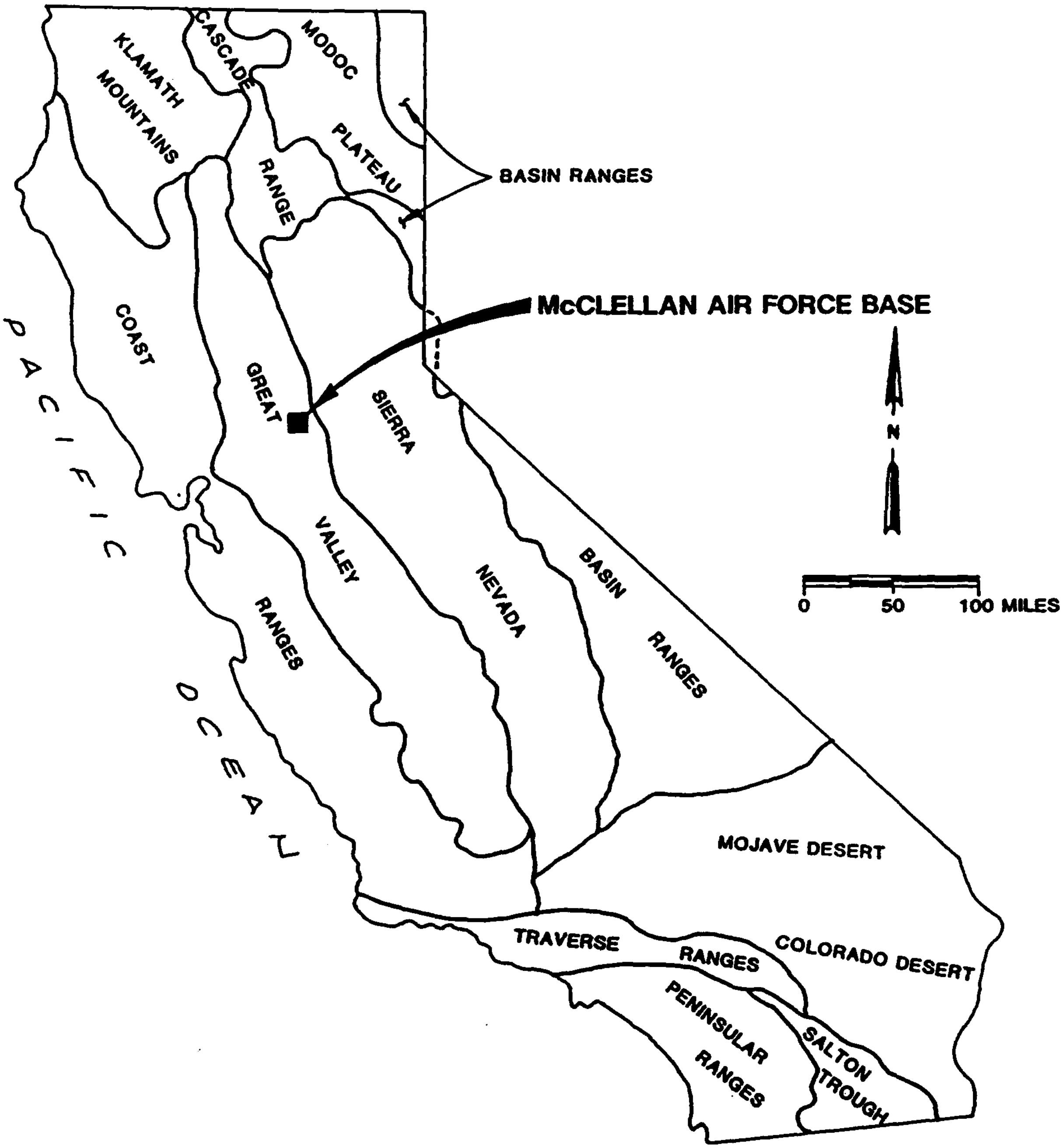

FIGURE 4
GEOLOGIC SETTING OF McCLELLAN AIR FORCE BASE

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Near-surface deposits near McClellan AFB are unconsolidated Quaternary sediments of the Riverbank, Turlock Lake, and Laguna Formations that extend from the surface to a depth of about 400 feet. These units consist of alluvium deposited by meandering streams, mainly as coarse-grained streambed sands and gravels, and fine-grained overbank silts and clays. As streams meandered across the valley, they alternately deposited, eroded, and redeposited sediment in a complex pattern. Thus, deposits exist as discontinuous interfingered lenses that are difficult to correlate from one location to another (Radian Corporation, 1991). Because of their similarity of origin and deposition, sediments of the Riverbank, Turlock Lake, and Laguna Formations are also difficult to distinguish from each other.

Underlying these formations in the vicinity of McClellan AFB is the Mehrten Formation, a Pliocene-age unit that lies at depths beneath about 400 feet. Although this formation also consists mainly of unconsolidated alluvium, it is distinguishable by its lithology and color. The Mehrten Formation is derived from volcanic material that was deposited as black to blue sands, silts, gravels, and clays (California DWR, 1978).

Although correlations have been difficult, geologic and geophysical logs collected from monitoring wells constructed between 1980 and 1991 have allowed investigators to distinguish several zones that appear to have roughly similar characteristics and be widely distributed at the base. These zones, designated as Zones A through F, are considered to act as preferential pathways for horizontal groundwater flow. However, evidence suggests that the subsurface system acts as one groundwater flow system, with hydraulic communication among the zones (Radian Corporation, 1991).

Groundwater

Historically, groundwater in the McClellan AFB area moved from the northeast to the southwest. However, withdrawals from pumping wells in the region have gradually caused gradients to change and water levels to decline. Today, a regional pumping depression approximately centered under the base and south of the base has caused regional groundwater to flow generally to the south (Radian Corporation, 1990).

Monitoring wells installed at McClellan AFB as a part of ongoing environmental investigations have allowed groundwater levels to be monitored and local groundwater flow patterns to be determined. These efforts have revealed local deviations from the regional flow pattern, caused mainly by the operation of extraction wells on base and by on-base and off-base water supply wells (Radian Corporation, 1991). The locations of active and inactive base supply wells is shown in Figure 2.

In the southeast area of the base, groundwater in the upper zones, which roughly correspond to the A, B, and C zones described above, appears to flow mainly toward the west-southwest, probably toward active well BW-18 (Radian Corporation, 1991). Previous investigations had noted a local flow to the northeast toward BW-8 prior to 1985, when the well was taken off-line (McClaren, 1986). Active well BW-10 may still influence flow patterns in this area. Pumping wells southeast of McClellan AFB may also influence local flow patterns (Radian Corporation, 1991).

Groundwater flow in the southwest and central portions of the base appears to be toward the south-southwest. Locally, flow appears to be converging toward active production well BW-18. However, groundwater flow may also be influenced by the pumping of off-base supply wells located south of the base (Radian Corporation, 1991).

In the northwest area of the base, groundwater in the uppermost zones appears to be flowing toward extraction wells on the northwest base boundary. Flow directions in the north and northeast areas of the base are mainly toward the southwest in the uppermost zones. Lack of data prevent an understanding of flow directions in the deeper zones (Radian Corporation, 1991).

Vertical gradients of groundwater flow have been generally downward around McClellan AFB, as groundwater moves to points of discharge in pumping wells. The strongest downward gradients have been observed in the uppermost zones. However, gradients vary seasonally and locally in response to patterns of pumping (Radian Corporation, 1991).

Aquifer tests have been performed in many parts of the base by various contractors as part of ongoing environmental investigations. Results have been varied, both because of the different lengths of the tests and methods used to interpret the data, and because of the natural heterogeneity of the subsurface geology. Values of transmissivity have ranged from about 1,200 to 28,600 gpd/ft, while values of hydraulic conductivity have ranged from about 97 to 500 gpd/ft^2 (Radian Corporation, 1990).

Groundwater levels beneath McClellan AFB have declined more than 60 feet during the 20th century because of withdrawals for agriculture and urban water uses (McLaren, 1986). Today, the water table occurs at a depth of about 95 to 105 feet beneath the surface, with seasonal fluctuations of up to 5 feet. In the deeper zones, groundwater occurs under generally semiconfined conditions (Radian Corporation, 1991).

Wells to be Decommissioned or Modified

Information on McClellan AFB production wells was obtained by a search of files at the base Civil Engineering Section and the California DWR, and by a review of environmental reports previously issued by the base.

McClellan AFB has established a consecutive numbering sequence for its supply wells. As it has acquired or constructed wells, it has assigned them the next available number in sequence. Today, 29 wells have been assigned numbers (Luhdorff and Scalmanini Consulting Engineers [LSCE], 1984).

This section provides information on the six base supply wells scheduled for decommissioning or modification under the present Phase II task order (BW-7, -8, -13, -17, -20, and -28) and the four wells at Camp Kohler (LW-1 and -2, and the two seismic wells). Available Well Drillers' Reports for base supply wells are presented in Appendix B. The known locations of the wells are shown in Figures 2 and 3.

Base Well 7

History and Well Data

BW-7 is located in the southeastern part of McClellan AFB in a parking lot about 100 feet east of Building 429 (see Figure 5). All that is visible today is a 12-inch-diameter steel casing extending about 3 feet above the pavement and fitted with a removable steel cap. Previously, there was some confusion about whether this well was BW-7 or BW-16, thought to be located in the vicinity of Building 440 immediately across Dudley Boulevard. However, research has indicated that the well is most likely BW-7.

BW-7 was first located in 1982 by Engineering-Science as part of the Phase II Installation Restoration Program (IRP) at McClellan AFB. Establishing the location of BW-7 was included as an IRP activity because of the potential for cross-contamination of aquifers by contaminants. Interviews with base personnel had led Engineering-Science to believe that the well had been grouted in the late 1960s or early 1970s, but utility records provided only an approximate location for the well and contained no record of previous abandonment. Engineering-Science located the buried well building with a magnetic flux indicator, and the site was excavated. This excavation revealed that the well was sealed with a non-waterproof fabricated cap and confirmed previous records that described a 24-inch conductor casing enclosing the 12-inch casing, with a gravel pack annulus. After sounding the well, it was found that an obstruction was present at a depth of 80 feet. An extension was welded onto the casing to bring it above grade, and the excavation was filled in. Engineering-Science then attempted to drill out the obstruction, presumed to be grout, through "rotary-wash" drilling, but was unsuccessful (Engineering-Science, 1983).

Well construction details for BW-7, obtained from McClellan AFB Civil Engineering records, are summarized in Table 1. It is uncertain when the well was constructed. A well log obtained from DWR (Appendix B) indicates that the well was drilled in 1941 by "Aulman," but the lithology on this log conflicts with base records and casts doubt on its accuracy. According to Luhdorff and Scalmanini (1984), the gravel pack was not destroyed during the previous abandonment of BW-7. A recent sounding of BW-7 conducted for this project confirmed an obstruction at a depth of about 80 feet below grade.

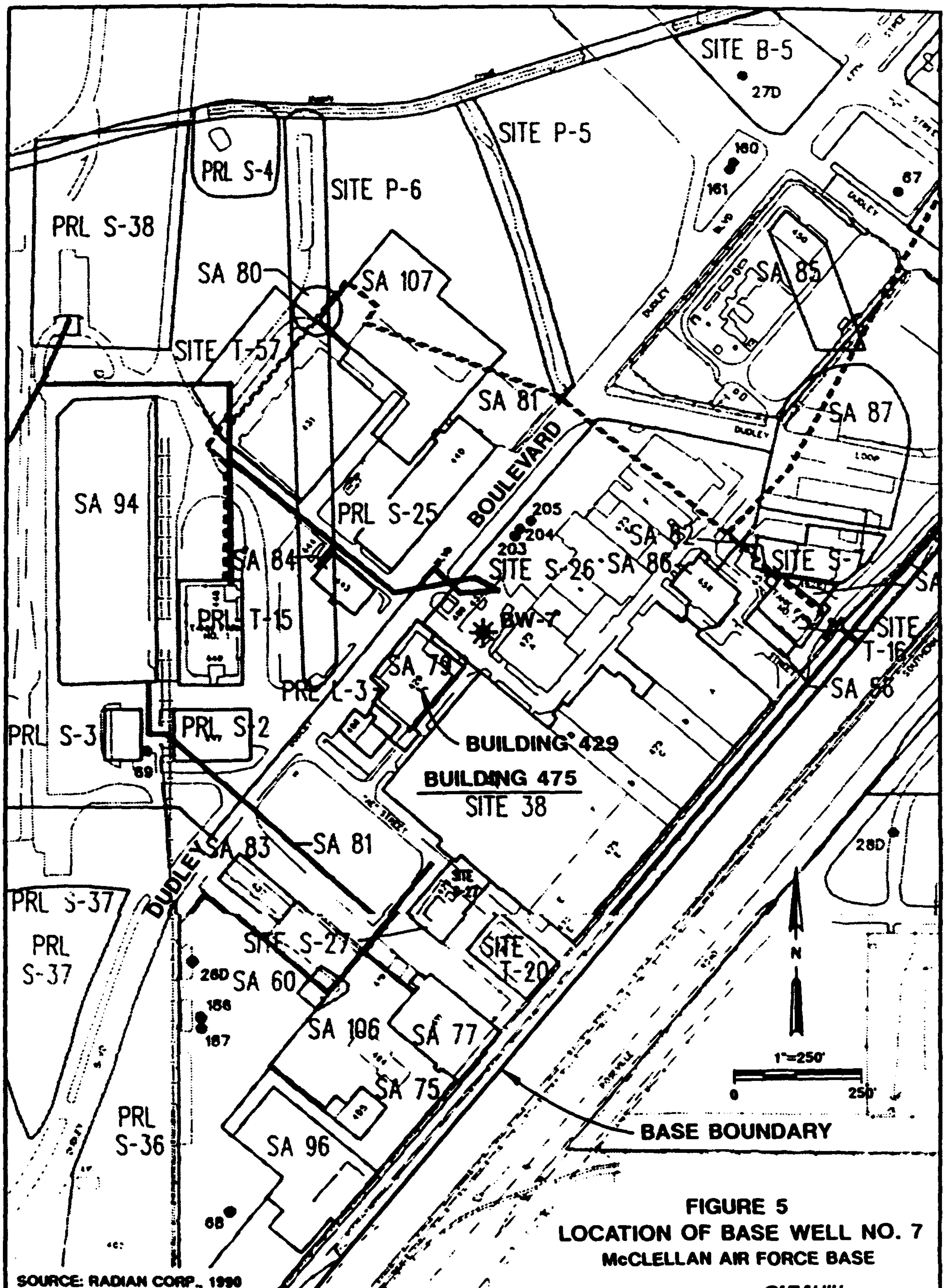

FIGURE 5
LOCATION OF BASE WELL NO. 7
McCLELLAN AIR FORCE BASE

SOURCE: RADIAN CORP., 1990

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Table 1 Well Data: Base Well 7			
Location:		East of Building 429 on Dudley Boulevard	
Status:		Inactive since 1955 due to contamination	
Driller:		Aulman	
Method:	Rotary	Date:	July 1941
Surface Conductor Casing Diameter:	24 inches	Depth:	50 feet
Seal:	Concrete	Depth:	25 to 50 feet
Blank Casing:	12-inch-diameter #10 steel double casing	Depth:	0 to 398 feet
Borehole Diameter:	22 inches	Depth:	50 to 398 feet
Perforations:	Type of perforation uncertain	Depth:	170 to 398 feet
Gravel Pack:	Pea gravel	Depth:	0 to 398 feet

Groundwater Quality

According to base records, BW-7 went inactive in 1955 due to the presence of a contaminant variously described as "oil" and "solvent." Engineering-Science referred to the contaminant as cresylic acid (Engineering-Science, 1983), and Luhdorff and Scalmanini referred to it as phenols (Luhdorff and Scalmanini, 1984). Base records indicate that the contaminant was first detected in a water main in November 1954, and discovered in BW-7 in June 1955. The well was placed on inactive status in July 1955 after a long period of pumping failed to eliminate the oily contamination. The pump was pulled in September 1955 and various attempts to rehabilitate the well through pumping out the contaminant were made through 1959. Records indicate that from 1.5 to 8 feet of floating product were measured in the well at various times during that period, with the source of the contamination uncertain. A video survey run in the well in 1959 found the casing to contain "heavy slime and algae," as well as oil.

Samples collected from monitoring wells in the vicinity of BW-7 have contained contaminants. Well 67, located about 1,200 feet northeast of BW-7, contained 1.1 ppb of 1,1,1-trichloroethane (1,1,1-TCA) in 1985, and 4.7 ppb of 1,2-dichloroethane (1,2-DCA) in 1986 (Radian Corporation, 1990). Recent investigations of shallow groundwater contamination found 64 ppb of TCE in the second quarter of 1991 in Well 203, about 250 feet northeast of BW-7, and 2,400 ppb in Well 209, about 750 feet north of BW-7. Each of these wells is potentially upgradient of BW-7. Lower concentrations of TCE were found at deeper zones in monitoring wells near BW-7 (Radian Corporation, 1991).

Local Geology

A driller's log of subsurface geology encountered during the drilling of BW-7 was located in base records. This log describes varying intervals of clay, hardpan, sand, and gravel along the borehole. Of greatest concern in abandonment are the depths of sand and gravel zones, where formation losses of cement may potentially take place. Because the entire well is cemented during the decommissioning approach taken at McClellan AFB, the location of zones of lower permeability, such as clay and hardpan, are of lesser importance. The driller's log describes the following depths of sand and gravel zones: sand and fine gravel from 115 to 130 feet; sand and gravel from 181 to 192 feet; fine gravel and sand from 196 to 224 feet; fine gravel from 255 to 261 feet; fine sand and gravel from 269 to 277 feet; cobbles and gravel from 281 to 295 feet; and intermingled sand and gravel with hard layers from 325 to 398 feet. The most permeable of the intervals appear to be from 196 to 224 feet, 255 to 261 feet, and 281 to 295 feet. The water table was about 103 feet below the ground surface near BW-7 in the second quarter of 1991 (Radian Corporation, 1991).

Base Well 8

History and Well Data

There are conflicting data both on well construction details and subsurface lithology at BW-8. This well is located in Pumphouse Building 91, which is adjacent to and north of Building 338 on Howard Street in the eastern part of McClellan AFB (see Figure 6). A well log for BW-8 obtained from DWR is included in Appendix B. McClellan AFB files and drawings, and a 1980 video survey were also reviewed for BW-8. Well construction details taken from the video survey and the LSCE (1984) report are summarized in Table 2.

Table 2
Well Data: Base Well 8

Location:		Inside Building 91 on Howard Street (north of Building 338)
Status:		Inactive since 1985 due to high iron and magnesium levels
Driller:		Unknown
Method:	Rotary	Date: July 1942
Surface Conductor Casing Diameter:	24 inches	Depth: 43 feet
Seal:	Concrete	Depth: 18 to 43 feet
Blank Casing:	12-inch-diameter 10-gage double steel	Depth: 625 feet
Borehole Diameter:	22 inches	Depth: 732 feet
Perforations:	Unknown	Depth: Unknown
Gravel Pack:	Unknown	Depth: Unknown

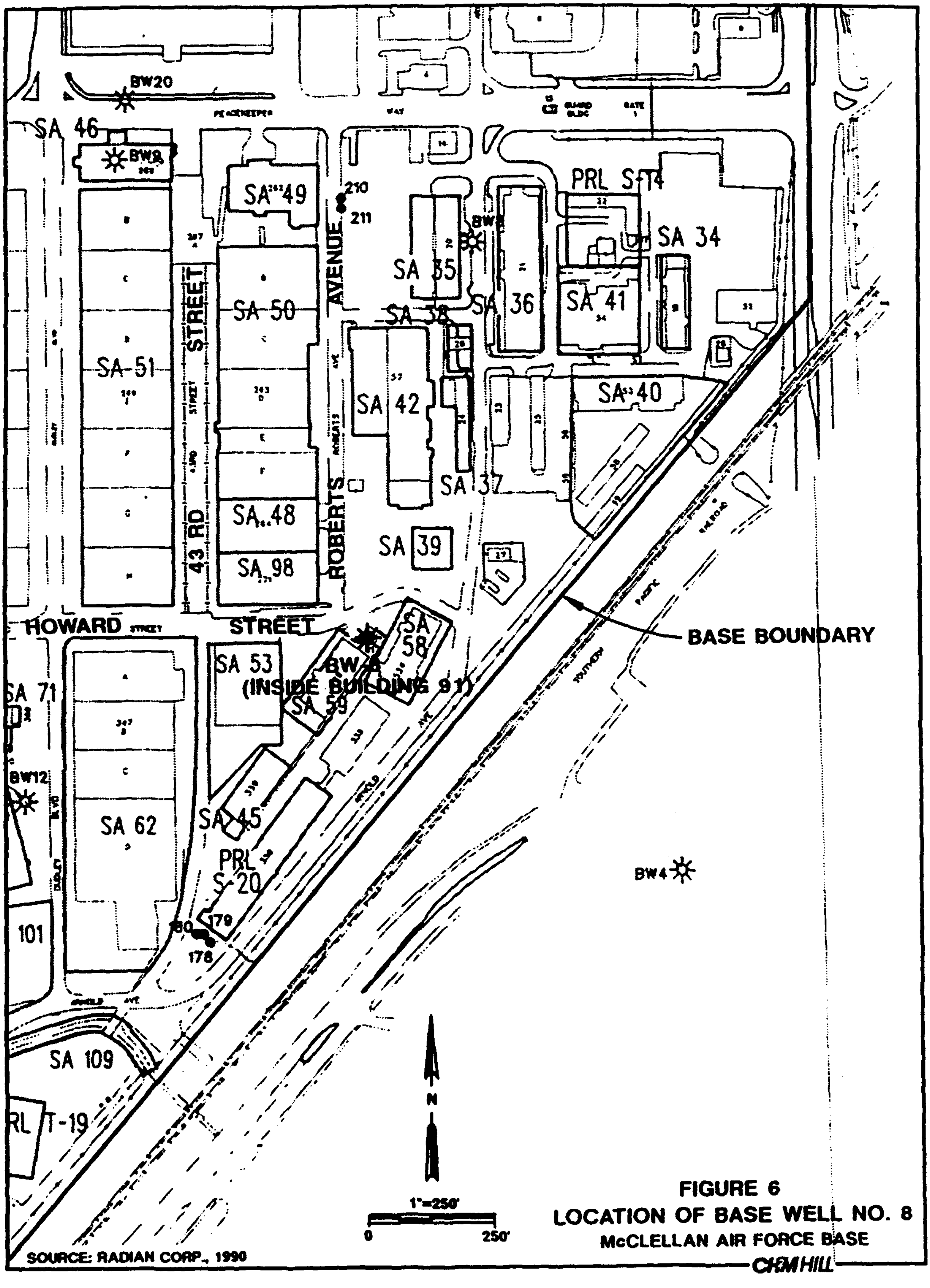

FIGURE 6
LOCATION OF BASE WELL NO. 8
McCLELLAN AIR FORCE BASE

SOURCE: RADIAN CORP., 1990

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According to the well log obtained from DWR, BW-8 was drilled in July 1942. No other information is available on the age of the well. However, a notation on the log indicates the data were obtained from the Army, and other data on the log conflict with data on file at McClellan AFB. Well construction details are available on Drawing No. U-44 on file at the base, on the well log obtained from DWR, on a handwritten note on file at the base, from correspondence from a pump contractor (Odell, 1980), and from the L&S report (L&S, 1985). The L&S report references Air Force Drawing P.U. 662, not found during this investigation. Information was also obtained from a downhole video survey performed in 1980, and reviewed for this investigation.

All of the data sources agree that BW-8 contains a 43-foot, 24-inch-diameter, 10-gage double steel conductor casing. The outside of this conductor casing is sealed with concrete from 18 to 43 feet. Most of the sources agree that the production casing is 12-inch-diameter, 10-gage double steel. However, the pump contractor's letter states that the casing is 10 inches in diameter. According to the drawings and the handwritten note, the casing was contained within a 22-inch-diameter borehole that extended from the conductor casing to the bottom of the well.

The depth of the casing is uncertain. LSCE (1984) state that the casing extends to approximately 625 feet. This depth was confirmed in the 1980 video survey. However, the drawings show the casing extending to 389 feet, while the well log and handwritten note state that it extends to 398 feet. A note on one of the drawings declares that there is a "large cavity" from 666 feet to the bottom at 785 feet. The pump contractor also states that the depth of the well is 800 feet. The 1980 video survey revealed that an open hole extended beyond the bottom of the casing to a depth of 732 feet. This hole appeared to be larger than the casing.

Similarly, the perforated interval of the casing is uncertain. The drawings show the well as perforated from 170 to 389 feet. The well log and handwritten note state the perforations as extending from 170 to 398 feet. Luhdorff and Scalmanini state that information on the perforated interval was unavailable, while the handwritten note on the drawing states that there are no perforations. Perforations were not visible on the video survey, but this may have been due to the scale present on the casing. However, it is also uncertain whether the well casing is enclosed within a gravel pack.

BW-8 contains a Peerless oil-lubricated turbine pump with a 100-hp electric motor. Records conflict on the depth at which the pump is set, being either 170 feet (LSCE, 1985) or 200 feet (Odell, 1980). During a 1980 pump service, the pump column had to be jacked out of the well, since the pump column and well casing were apparently not in plumb (Odell, 1980). Base records indicate that in a pump test in 1980 the well discharged 1,046 gpm with a drawdown of 21 feet, for a specific capacity of 49.8 gpm/ft. BW-8 is completed below grade in Building 91, a concrete pumphouse. Access is through a 10-foot-square trapdoor in the roof.

During Phase II, the pump will be removed from BW-8 and a downhole video survey performed in the casing. If the casing is obscured by iron bacteria, it will be cleaned and a second video survey will be performed. The video survey will then reveal the actual construction details and confirm which data set, if any, actually describes the well construction details of BW-8.

Groundwater Quality

According to base records, BW-8 was placed on standby status in 1985 due to high iron and magnesium levels. Other contaminants have also been detected in BW-8, the most notable being TCE. The highest level of TCE found in this well was 61 ppb in 1981 (Radian Corporation, 1991). There are few wells located in the immediate vicinity of BW-8. However, Monitoring Well (MW-) 178, located about 700 feet southwest of BW-8, contained 90 ppb of TCE and 16 ppb of carbon tetrachloride in April 1991 (Radian Corporation, 1991). BW-12, located about 700 feet west-southwest of BW-8, contained trace amounts of pesticides and herbicides and levels of TCE ranging up to 54 ppb in 1982 (Engineering Science, 1983). Monitoring Well 210, located about 900 feet north of BW-8, contained 3.7 ppb of TCE and 4.5 ppb of carbon tetrachloride in May 1991. Monitoring Well 212, located about 1,100 feet northeast of BW-8, contained 5.5 ppb of TCE, and trace amounts of 1,1,1-TCA and chloroform in April 1991. Each of the monitoring wells described here is completed in the shallow groundwater zone. Groundwater in this area flows mainly toward the southwest, although production wells located south of the base may influence flow directions in the vicinity of BW-8 (Radian Corporation, 1991).

Local Geology

As with the well construction details, conflicting data represent the borehole lithology at BW-8. Three versions purport to represent the lithology recorded by the driller. One version is found on the well log obtained from DWR and a handwritten note on file at the base; another version is found on two separate drawings on file at the base; and a third version is found in LSCE (1984) and yet another drawing on file at the base.

Borehole lithology is important at BW-8 because this well is not intended to be decommissioned. Rather, the objective is to seal the uppermost groundwater zone where contaminants are potentially found (within about 200 feet of the ground surface), and then return the well to service on a standby basis for use in fire emergencies.

It would be desirable to seal the well in a unit of low permeability at a depth of between about 160 to 200 feet. Above this depth, it is useful to know the zones that may contain materials of high permeability, where losses of cement to the formation may potentially occur. The depth to groundwater in spring 1991 was about 107 feet (Radian Corporation, 1991).

Following the video survey of BW-8, it may be possible to determine which geologic log accurately depicts the lithology at BW-8. If the survey reveals one data set to accurately describe the well construction details, the associated geologic log will most likely will describe the subsurface lithology.

Base Well 13

History and Well Data

BW-13 is located in Building 614, a concrete pumphouse located about 150 feet south of Dudley Boulevard in the southern part of McClellan AFB. Figure 7 shows the location of BW-13 and Table 3 summarizes the available information on this well. Original construction drawings and well logs were not located for BW-13. Data are derived mainly from a photolog taken in 1961 and pump service records on file at Civil Engineering, and LSCE (1984).

Table 3
Well Data: Base Well 13

Location:		Inside Building 614 on Dudley Boulevard (south edge of base)
Status:		Inactive since 1988 due to TCE and carbon tetrachloride contamination
Driller:		Unknown
Method:	Rotary	Date: 1945
Surface Conductor Casing Diameter:	Unknown	Depth: Unknown
Seal:	Unknown	Depth: Unknown
Blank Casing:	14-inch-diameter steel reducing to 12-inch-diameter steel at 147 feet	Depth: 0 to 391 feet
Borehole Diameter:	Unknown	Depth: 0 to 391 feet
Perforations:	Unknown type	Depth: 178 feet--total depth
Gravel Pack:	Gravel	Depth: 0 to 391 feet

The 1961 photolog noted the following problems in the casing: possible hole from 120 to 122 feet; vertical seam open from 156 to 166 feet, 170 to 177 feet, and 192 to 196 feet; and light to moderate scale from 274 to 391 feet. During a servicing of the pump in 1982, it was noted that the well was very crooked. The pump is a Peerless turbine pump set at a depth of 160 feet, with an electric motor. A 1988 pump test found that the well discharged 424 gpm, with a specific capacity of 31.4 gpm/ft of drawdown. BW-13 is completed below grade. Access is through a 4-foot by 4-foot trapdoor in the roof of Building 614.

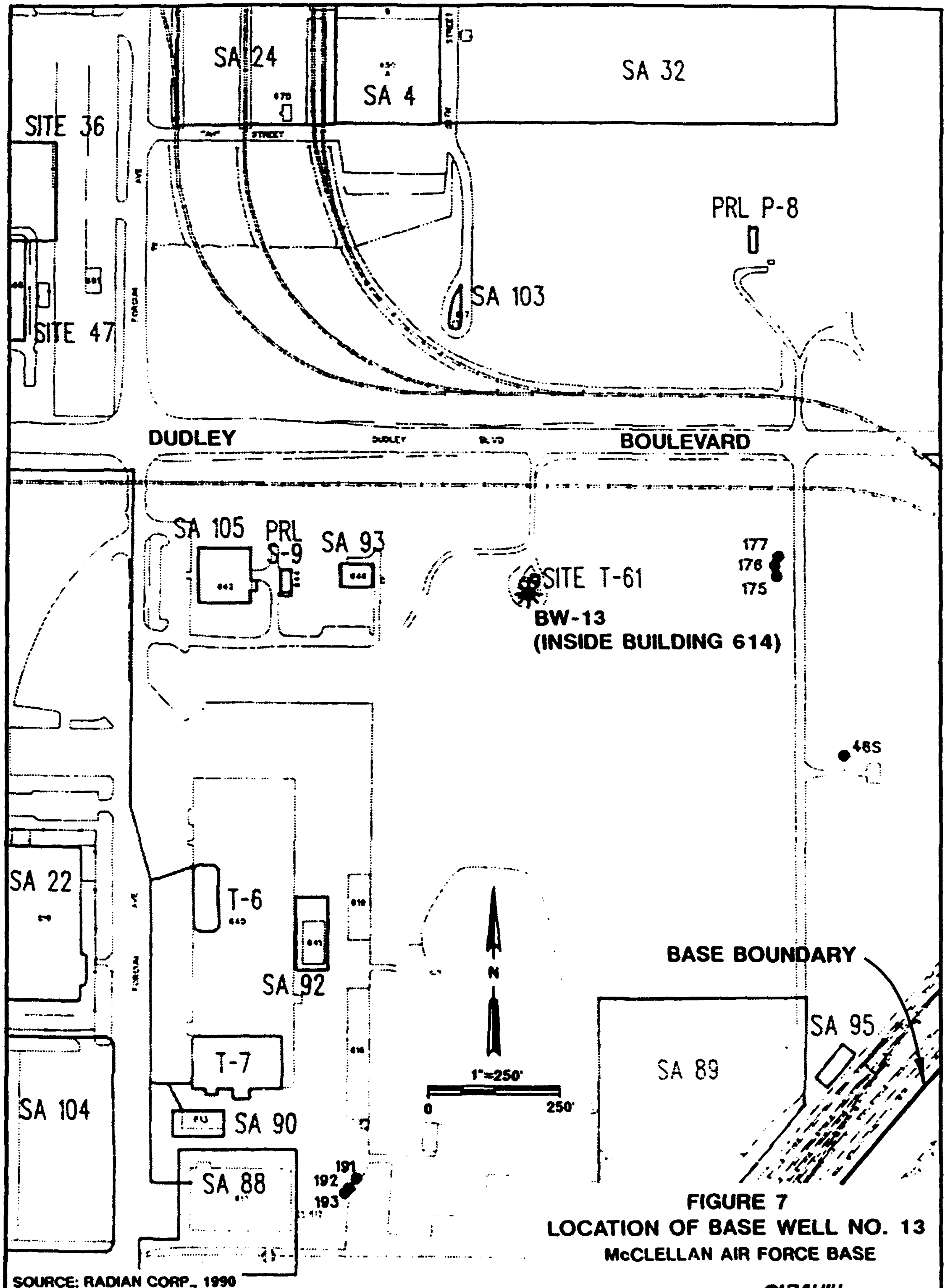

FIGURE 7
LOCATION OF BASE WELL NO. 13
McCLELLAN AIR FORCE BASE

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Groundwater Quality

BW-13 was removed from service in September 1988 after a series of sampling episodes found carbon tetrachloride above the Maximum Contaminant Level (MCL) of 5 ppb. It had previously been taken out of service for a time in 1987 because tetrachloroethylene (PCE) concentrations exceeded the drinking water standard. Weekly samples collected between May and September 1988 found carbon tetrachloride concentrations ranging from 0.6-9.2 ppb. TCE was found at levels ranging from not-detected to 4.3 ppb. Other contaminants detected included chloroform, Freon-113, and toluene.

Few monitoring wells in the vicinity of BW-13 lie either upgradient or downgradient from BW-13. Groundwater in the area flows nearly due west, toward BW-18, which is located about 2,200 feet west of BW-13. MW-175, -176, and -177, located about 500 feet east of BW-13, contained no detectable levels of organic contaminants in April 1991 (Radian Corporation, 1991).

Local Geology

No borehole lithologic logs are available for BW-13. However, during the construction of MW-175, -176, and -177, a *pilot hole (8-P)* was drilled. Both a geologic and geophysical log are available for 8-P. Although alluvial deposits such as those in which BW-8 is constructed tend to be quite variable, the logs of 8-P identify permeable zones that could affect the decommissioning of BW-13. These logs show a very permeable sand unit from a depth of about 92 to 105 feet; a gravelly sand from about 220 to 230 feet; and a sand and gravel unit that extends from about 360 to 390 feet. The latter unit in particular may extend to BW-13. Groundwater was found about 100 feet below the ground surface in January 1991 (Radian Corporation, 1991).

Base Well 17

History and Well Data

BW-17 is located inside Building 699, a pumphouse on the east side of Kilzer Avenue about 750 feet north of Dudley Boulevard in the southwest part of the base. Information on BW-17 was taken from the well log on file at DWR and from McClellan AFB records. Table 4 summarizes the known data and Figure 8 shows the location of BW-17.

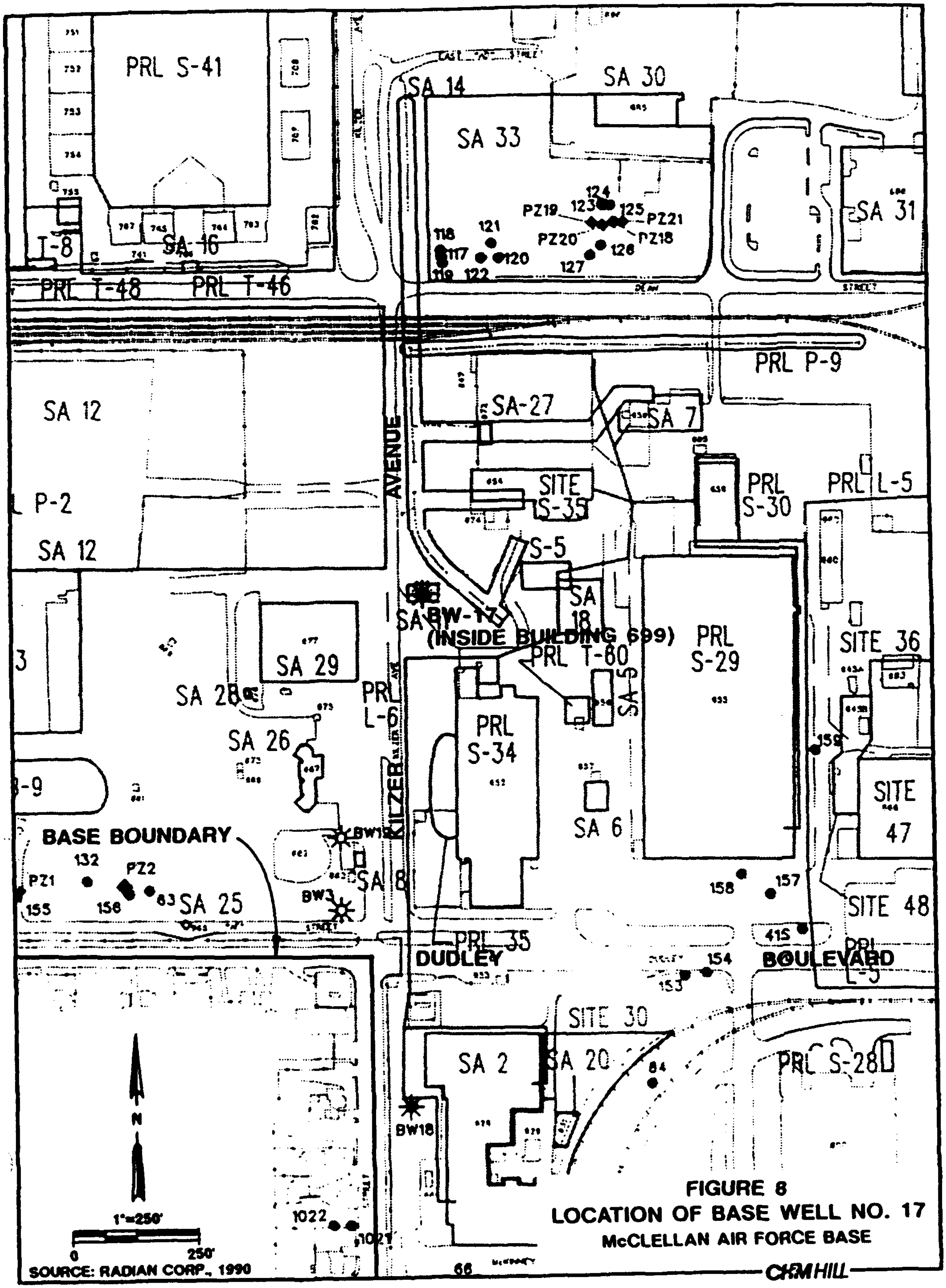

FIGURE 8
LOCATION OF BASE WELL NO. 17
McCLELLAN AIR FORCE BASE

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Table 4 Well Data: Base Well 17		
Location:		Inside Building 699 on Kilzer Avenue
Status:		Inactive since 1985 due to TCE contamination
Driller:		Unknown
Method:	Cable Tool	Date: Prior to 1947
Surface Conductor Casing Diameter:	Unknown	Depth: Unknown
Seal:	Unknown	Depth: Unknown
Blank Casing:	*16-inch-diameter steel*	Depth: 0 to 344 feet
Borehole Diameter:	16 inches	Depth: 0 to 390 feet
Perforations:	Unknown	Depth: 216 to 224 feet; 286 to 294 feet; 302 to 312 feet
Gravel Pack:	Not applicable	Depth: Not applicable

BW-17 was apparently drilled by the cable tool method, in which the casing is driven into the ground. Therefore, there is no gravel pack surrounding the casing. The well was originally drilled to 930 feet in depth. However, files indicate that the well was sealed off below 390 feet because of the high iron content of the water below that depth. This sealing took place in 1947 and consisted of filling the casing with mud from 760 to 930 feet, and sand from 420 to 760 feet. The casing was then ripped from 400 to 420 feet, and a concrete plug was set from 390 feet to 420 feet.

The original construction drawing for BW-17 described the perforations as extending from 216 to 225 feet, 262 to 270 feet, 284 to 290 feet, and 300 to 308 feet in depth. The perforated interval listed in Table 4 was based on a 1971 photographic survey performed in the well. This survey also described the bottom of the well as lying at 344 feet, rather than 390 feet. This discrepancy may be due to sediment filling the lowermost section of the casing.

BW-17 currently has installed a Floway oil-lubricated turbine pump with bowls set at 150 feet. In 1972 it discharged 1,100 gpm with a specific capacity of 61.1 gpm/ft of drawdown. BW-17 is a surface completion in a concrete pumphouse. Access is through a 4-foot by 4-foot trapdoor in the roof.

Groundwater Quality

Base records indicate that BW-17 was placed on inactive status in 1985 due to TCE contamination. However, the only sample results that have been located to date show no contamination in this well in 1982 (Engineering Science, 1983). Several monitoring wells are located about 700 feet north of BW-17 and are screened at various depths beneath the ground surface. Contamination appears to be confined mainly to the uppermost groundwater zone, and groundwater flows to the south in this part of the base toward BW-18. Monitoring Well 120, screened in this zone, yielded samples with TCE concentrations ranging from 9.3 to 26 ppb, chloroform ranging from 0.35 to 1.9 ppb, and 1,2-DCE ranging from not-detected to 18 ppb between 1986 and 1988. The historical maximum TCE value in this well was 87 ppb (Radian Corporation, 1990).

Local Geology

The original drillers lithology log for BW-17 was located as part of this investigation. This log shows the following intervals of materials of potentially high permeability that may affect the decommissioning of BW-17: lava sand from 153 to 171 feet; sand and fine rock from 216 to 230 feet; lava sand from 262 to 275 feet; fine gravel from 284 to 290 feet and 300 to 311 feet; and soft lava sand from 376 to 390 feet. Groundwater was found about 100 feet below the ground surface in January 1991 (Radian Corporation, 1991).

Base Well 20

History and Well Data

BW-20 is located in a vault in a parking lot adjacent to Peacekeeper Way and just south of Building 200 in the eastern part of the base. It was drilled in 1953 to replace nearby BW-9, which supposedly collapsed, and has recently served as a standby emergency source for Building 200. Well construction details are taken mainly from construction drawings on file at McClellan AFB and are summarized in Table 5. Figure 9 shows the location of BW-20.

BW-20 is equipped with a Johnson oil-lubricated turbine pump with a 75-hp electric motor. Capacity of the well is uncertain. Access to the well is through a removable concrete lid supported by metal gridwork.

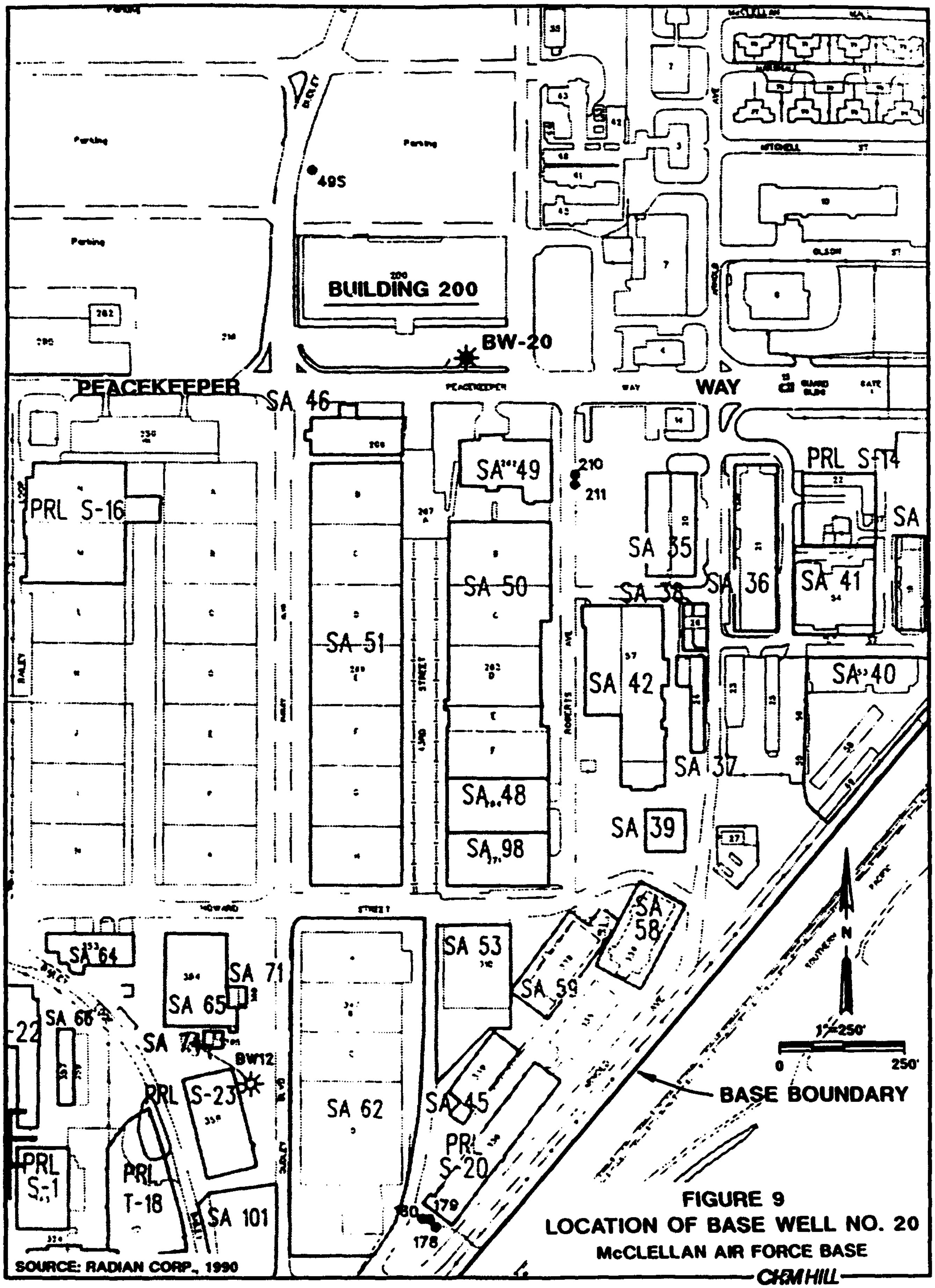

FIGURE 9
LOCATION OF BASE WELL NO. 20
McCLELLAN AIR FORCE BASE
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Table 5 Well Data: Base Well 20		
Location:		South of Building 200 in parking lot next to Peacekeeper Way
Status:		Standby source for Building 200
Driller:		Western Well Drilling Company
Method:	Rotary	Date: October 1953
Surface Conductor Casing Diameter:	32-inch steel	Depth: 67 feet
Seal:	Cement Grout	Depth: 0 to 67 feet
Blank Casing:	14-inch-diameter steel	Depth: 0 to 600 feet
Borehole Diameter:	32 inches	Depth: 67 to 600 feet
Perforations:	1/8-inch x 3-inch slots	Depth: 178 to 190 feet, 234 to 274 feet, 338 to 374 feet, 494 to 506 feet, 564 to 598 feet
Gravel Pack:	3/16- to 3/8-inch pea gravel	Depth: 0 to 600 feet

Groundwater Quality

No data were located on groundwater quality in BW-20. However, sample data exist for MW-210 and -211, located about 500 feet east of BW-20. Groundwater in this area of the base flows from east to west, so these wells are approximately upgradient from BW-20. MW-210, screened in the uppermost groundwater zone, contained TCE at 4.1 ppb, carbon tetrachloride at 6.1 ppb, and 1,1-DCE at 0.76 ppb in May 1991. MW-211, constructed adjacent to 210 and screened in a deeper zone, contained TCE at 1.0 ppb and benzene at 0.40 ppb in May 1991 (Radian Corporation, 1991).

Local Geology

The original driller's log is available at McClellan AFB. This log shows units of potentially high permeability that may affect the decommissioning of BW-20 at the following depths: fine sand from 200 to 204 feet; loose fine to medium sand from 354 to 381 feet; fine to medium sand from 491 to 505 feet; and fine to coarse sand and sandy silt from 550 to 600 feet. A pilot hole drilled in conjunction with MW-210 and 211 in May 1990 lies about 500 feet from BW-20. Geologic and geophysical logs indicate that a zone of permeable sands and gravels lies at a depth of 145 to 160 feet.

Base Well 28

History and Well Data

BW-28 is located on Patrol Road next to Building 1082 along the northwest boundary of McClellan AFB. According to base personnel this private domestic well was obtained by the Air Force during a land purchase. Construction details are derived from a diagram on file at McClellan AFB and are summarized in Table 6. Figure 10 shows the location of the well. BW-28 is located outdoors and contains a 2-hp Town and Country submersible pump capable of discharging about 30 gpm (LSCE, 1984). Water Department personnel stated that the water table dropped below the pump setting during the summer of 1991.

Table 6
Well Data: Base Well 28

Location:		Next to Building 1082 on Patrol Road on the northwest base boundary
Status:		Inactive since about 1990
Driller:		Unknown
Method:	Cable Tool	Date: 1966
Surface Conductor Casing Diameter:	14 inches	Depth: 76 feet
Seal:	Cement Grout	Depth: 0 to 60
Blank Casing:	8-inch-diameter steel	Depth: 0 to 248 feet
Borehole Diameter:	Not applicable	Depth: 76 to 248 feet
Perforations:	Milled slots	Depth: 144 to 147 feet; 205 to 212 feet; 233 to 236 feet
Gravel Pack:	Not applicable	Depth: Not applicable

Groundwater Quality

Limited data are available for samples collected from BW-28. According to McClellan AFB records, samples collected in 1979 indicated levels of cadmium and chromium above drinking water standards, but these samples were later determined to be in error. Samples collected by Engineering-Science in 1982 found no detectable levels of volatile organics, but did find the herbicides 2,4-D and 2,4,5-T at levels of 0.008 ppb, and 0.002 ppb, respectively (Engineering-Science, 1983).

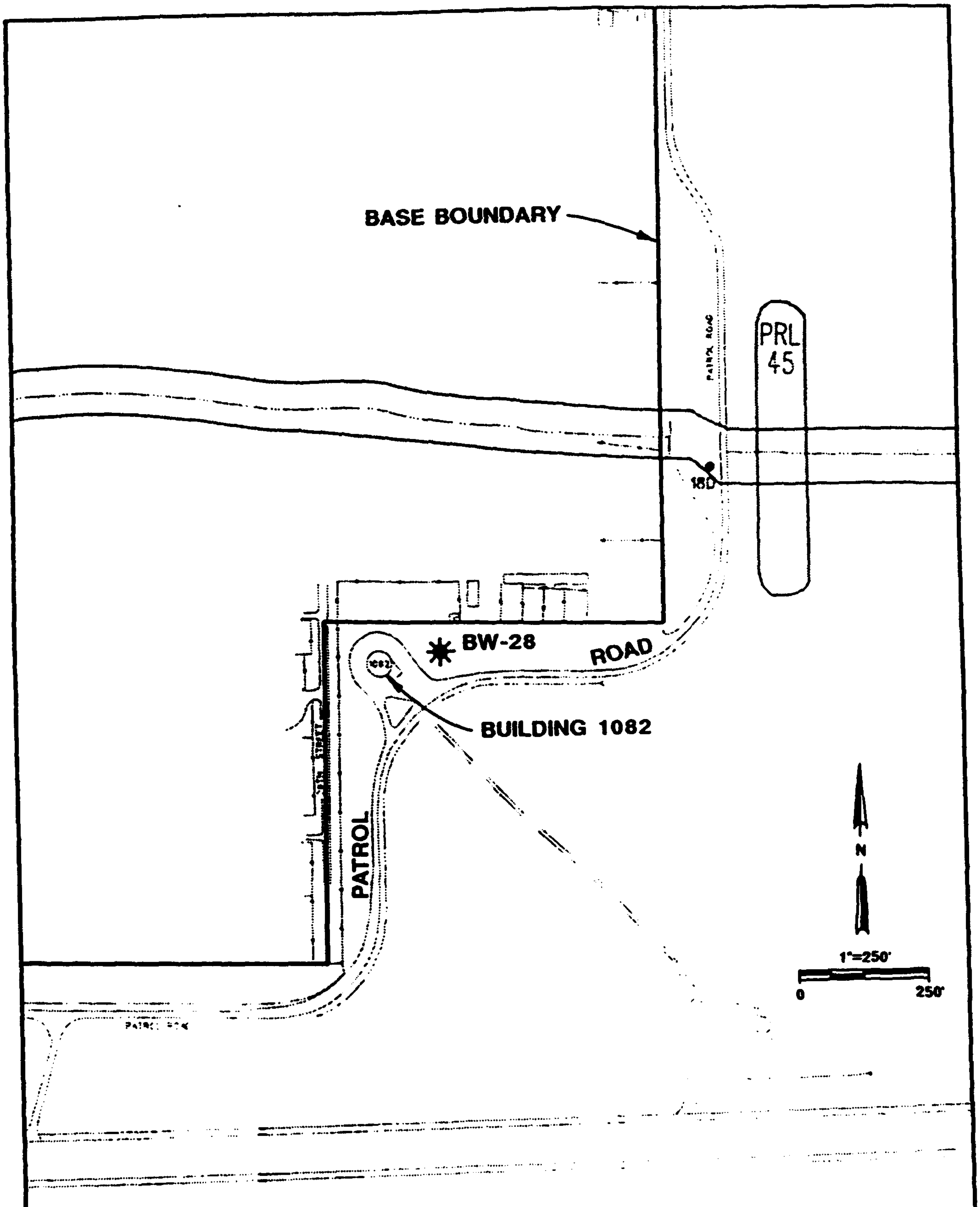


FIGURE 10
LOCATION OF BASE WELL NO. 28
McCLELLAN AIR FORCE BASE

SOURCE: RADIAN CORP., 1990

CH2M HILL

A double completion monitoring well was constructed in 1982 about 500 feet northeast of BW-28. Groundwater in this area appears to move south to southwesterly (Radian Corporation, 1991). The shallow well, MW-18s, was screened across the water table at a depth of 90 to 100 feet. The deeper well, MW-18d, was screened from 130 to 140 feet below the ground surface. Samples collected from MW-18s in 1982 contained the following concentrations of pesticides and herbicides: aldrin-0.052 ppb; alpha-BHC-0.032 ppb; lindane-0.036 ppb; heptachlor epoxide-0.027 ppb; and 2,4-D-0.138 ppb. A 1982 sample collected from MW-18d had the following concentrations of pesticides and herbicides: aldrin-0.01 ppb; beta-BHC-0.005 ppb; heptachlor epoxide-0.017 ppb; 2,4-D-0.122 ppb; and 2,4,5-T-0.022 ppb (Engineering-Science, 1983). More recent data have not been located for these wells.

Local Geology

The driller's log showing lithology at BW-28 was not located for this investigation. A geologic log for nearby MW-18 was obtained, however. This log describes silts and clays for nearly the entire interval of the borehole, with only minor zones of sandy materials.

Camp Kohler Wells

History and Well Data

Laundry Wells. Camp Kohler is a 35-acre annex of McClellan AFB located about 1 mile east of the main McClellan AFB facility on Roseville Road (see Figure 1). A large military laundry was operated here from about 1942 to 1973. This laundry has since been demolished and the site is currently vacant except for a Federal Aviation Administration radar facility and office building. Four wells are located at Camp Kohler, as shown on Figure 2.

The laundry used two water supply wells, identified as LW-1 and -2. Although the laundry operations discontinued in 1973, a previous investigation determined that the wells were used as a drinking water source until 1981. An attempt was made to sample the wells in 1985, but it was found that the wells were abandoned with their pumps still in place (Radian Corporation, 1985). These wells are not visible today. No records are available at McClellan AFB regarding the fate of these wells, nor do either of the two area water districts, Northridge Water District and Arcade Water District, have any information on the wells.

Investigation of McClellan AFB records uncovered slides taken during a photographic survey of LW-1 and -2 in 1971. In addition, an Eaton Drilling Company well log was located. According to Marshall Eaton, the log most likely refers to LW-2 (Eaton, 1991, pers. comm.). Other Camp Kohler well records were located at McClellan AFB and DWR, but appear to refer to one or more wells in other parts of Camp Kohler beyond the present boundaries. Formerly, Camp Kohler occupied a much larger tract of land than at present.

According to this research, LW-1 was about 420 feet deep. Although iron bacteria obscured much of the casing, perforations were visible at depths of 138 feet, 356 to 358 feet, 396 to 400 feet, and 404 to 420 feet. LW-2 was constructed in 1955 to a depth of 514 feet. This well contained a 50-foot, 24-inch-diameter conductor casing, and 496 feet of 14-inch-diameter, 3/16-inch steel production casing. Perforations consisted of 3/16-inch by 2-inch vertical slots at depths of 190 to 202 feet, 238 to 248 feet, 264 to 284 feet, 320 to 330 feet, 347 to 355 feet, 380 to 411 feet, 437 to 440 feet, 463 to 468 feet, and 476 to 496 feet. The casing was contained within a filter pack consisting of 3/8- to 3/4-inch pea gravel.

As a part of the present investigation, the locations of the former wells were tentatively identified by a team of surveyors using old maps of the laundry complex. These locations were then excavated with a backhoe. LW-1 was successfully located by this method. The excavation found that LW-1 was abandoned with concrete about 3 feet below the ground surface. No evidence of the pump was visible. However, LW-2 was not located, even though several pits were excavated. Based on the 1985 Radian report and the verification that LW-1 was abandoned, it is probably safe to conclude that LW-2 has also been abandoned.

Seismic Wells. The other two wells at Camp Kohler were constructed as part of a seismic survey. These wells, known as the Seismic Well and the Triax Hole, are still present. According to construction diagrams on file at McClellan AFB, the wells were constructed in 1969. It is uncertain why the survey was performed or who constructed the wells. The Seismic Well is 500 feet deep and contains 7-inch-diameter 17.0# API Grade steel casing that extends about 1.5 feet above grade. The borehole diameter is unknown. The Triax Hole is 200 feet deep and contains 11 3/4-inch-diameter 42# API Grade steel casing that extends about 2 feet above grade. The borehole diameter in this well is 13¾ inches. Both wells are sealed along their entire length with cement and are not open to groundwater at any point. Both contain 10-foot cement plugs at their base.

Cement bond surveys were conducted in the seismic wells in December 1991 to evaluate the integrity of the cement seals in which they are encased. As a preparation for these surveys, the caps on the wells were removed and the wells filled with water. The quality of a cement bond survey is greatly enhanced if the sonic transmitter is immersed in water at a minimum pressure of about 200 pound per square inch (psi). Had the wells not been watertight, it would have been necessary to pump water into the wells during the survey. However, the wells held the water with no apparent leakage. The survey found that the seal on both wells was adequately bonded to the casing and the borehole wall to prevent groundwater from migrating among subsurface zones. In both wells, minor disruptions in the seals were noted at or above the water table. Copies of the cement bond logs are provided in Appendix C.

Groundwater Quality

Camp Kohler was investigated in 1984 as part of the overall IRP investigation taking place at McClellan AFB. The Camp Kohler investigation was prompted by concern about deteriorating water quality in Arcade Water District Well No. 31, located about 2,000 feet west of Camp Kohler. From about 1960 until the well was taken out of service in 1979, samples from the well indicated a gradual increase in levels of hardness, chlorides and total dissolved solids (TDS). Hardness ($CaCO_3$) increased from about 150 to 600 mg/l during this time, while chlorides increased from about 75 to 450 mg/l and TDS increased from about 250 to about 850 mg/l (CH2M HILL, 1981). The old laundry at Camp Kohler had contained a concrete-lined wastewater holding basin that stored wastewater for pumping to a wastewater treatment plant. The concern was whether water may have leaked from the basin, infiltrated to the groundwater, and migrated to Arcade Well No. 31.

Soil and water samples were collected from the basin in March 1984. Results found levels of cadmium, chromium, copper, lead, nickel, and lead high enough to cause the sediments within the basin to be classified as hazardous (Radian Corporation, 1985). This finding initiated additional sampling, including 16 soil samples to a depth of 30 feet in 5 borings around the outside of the basin; seven exploratory borings drilled to an average depth of 310 feet, with collection of soil samples and groundwater samples at various depths; and additional sediment sampling within the basin.

Results of groundwater samples found chloride and TDS levels in excess of drinking water standards in deep samples from one boring located southwest of the basin, and the deepest sample from one other boring. Iron and manganese exceeded drinking water standards in all groundwater samples. Constituents in soil samples were generally at background levels, except for samples taken from within the former wastewater holding basin. These samples again exceeded hazardous levels (Radian Corporation, 1985).

The investigators concluded that the basin was not the source of the degraded water in Arcade Well No. 31, for the following reasons: the basin was lined with concrete; the groundwater samples containing high levels of chlorides and TDS were collected from deep zones, and were not found in the uppermost groundwater samples; and a 1979 sample from LW-1, taken when the well was being used as a drinking water source, had shown background levels of these constituents. The investigators speculated that contaminants may have originated at a wastewater treatment plant located east of Camp Kohler (Radian Corporation, 1985).

Local Geology

A drillers' log was located for LW-2 as part of this investigation. This log showed an alternating sequence of gravel, sand, and clay. Subsurface permeable zones consisted of gravel units at 163 to 170 feet, 191 to 197 feet, 240 to 246 feet, 270 to 281 feet, 320 to 327 feet, 381 to 406 feet, and 435 to 439 feet; and a sand unit from 480 to 497 feet. Geologic logs were kept for the seven deep exploration borings completed during the 1984 IRP investigation at Camp Kohler.

Geologic cross sections were prepared from these logs that reveal a heterogeneity typical of alluvial sediments in the McClellan AFB area. However, zones of sands and gravels were correlated at various depths among the boreholes. Major zones of materials of relatively high permeability were found at depths of about 140 to 160 feet; 230 to 260 feet; and 270 to 310 feet. Groundwater was found at a depth below 115 feet. Although the groundwater gradient was not well-defined in the area, it was believed to flowing toward the southwest (Radian Corporation, 1985).

Status of Water Supply Wells at McClellan AFB

A total of 35 wells have been identified during data collection activities associated with the well decommissioning program at McClellan AFB. These include 29 water supply wells designated in McClellan AFB files as BW-1 through BW-29. Over McClellan AFB's years of operation, McClellan AFB has constructed these wells or acquired land with existing wells. Two additional wells have been located at McClellan AFB as part of this investigation. Four wells are located at Camp Kohler—two former laundry wells, and two wells constructed as part of a seismic survey, as described earlier in this report. The locations of the McClellan AFB wells are shown in Figure 2 and the locations of the Camp Kohler wells are shown in Figure 3. Table 7 summarizes the status of production wells at McClellan AFB.

Four McClellan AFB wells and one City of Sacramento well were decommissioned during the first phase of well abandonment at the base. These include BW-1, BW-2, BW-12, BW-27, and City Well 150. Five wells at McClellan AFB, BW-7, BW-13, BW-17, BW-20, and BW-28, are scheduled for decommissioning during Phase II. BW-8 is scheduled for modification during Phase II. The four wells at Camp Kohler, LW-1, LW-2, the Seismic Well and the Triax Hole, are also scheduled for decommissioning during Phase II. Known data on these wells has been summarized in previous sections of this report. Three production wells—BW-10, BW-18, and BW-29—are currently actively pumping at McClellan AFB. This section will summarize the currently known information on the remaining McClellan AFB water supply wells.

Base Wells 3, 6, 16, and 19

BW-3, BW-6, BW-16, and BW-19 were originally scheduled for decommissioning during the first phase, but could not be located in 1990. BW-3, BW-16, and BW-19 have now been tentatively located. BW-3 and BW-19 are thought to be in the southwest part of the base near Buildings 662 and 667 at the intersection of Bell Avenue and Kilzer Avenue. A recent field inspection discovered what appears to be two former wells in a field about 200 yards west of the Bell/Kilzer intersection. The location of these wells is shown on Figure 11. One of the wells, presumed to be BW-3, has a 6-inch-diameter casing. BW-3 is thought to be an old agricultural well, acquired during an earlier expansion of the base. It was reportedly abandoned by McClellan AFB Water Department personnel (LSCE, 1984). The other well, presumed to be BW-19, contains a 14-inch-diameter casing. This well was reportedly constructed in 1952 to a depth of 360 feet, at about the same time that nearby wells BW-17 and BW-18 were constructed.

Table 7
Status of Existing McClellan AFB Production Wells

Page 1 of 2

Well No.	Location	Comments
1	Building 231	Decommissioned in 1991.
2	Building 232	Decommissioned in 1991.
3	Southwest in field near Bell Avenue and Kilzer Avenue	Tentatively located with BW-19. Casing filled with concrete.
4	Near Watt Avenue and Roseville Road, off the base	Inactive. Not visible. Located on old maps.
5	Off the base on Old Garden Highway	Known as "Old River Dock Well." Constructed in 1941.
6	Near Patrol Road and Buildings 714 and 715	Inactive. Has not been located. Thought to be old agricultural well.
7	Near Building 429	Will be decommissioned during Phase II.
8	Building 91	Uppermost portion to be sealed during Phase II, then returned to standby status.
9	Near Building 200	Reported to have collapsed. Not visible. Located on old maps in parking lot near BW-20.
10	East near Building 93 on O'Malley Avenue	Active well.
11	Southeast of the Base, near Watt Avenue and Winona Street	Inactive. Not visible. Located on old maps.
12	Building 395	Decommissioned in 1991.
13	Building 614	Will be decommissioned during Phase II.
14	Unknown	Uncertain status. No known location. May be located at Whitney and Eastern Avenue.
15	North of Building 440 on Dudley Boulevard	Inactive, status uncertain.
16	Site 22 on Patrol Road	Inactive. Not visible. Located on old maps.
17	Building 699	Will be decommissioned during Phase II.
18	Southwest near Building 664 on Winters Street	Active well.
19	Southwest in field near Bell Avenue and Kilzer Avenue	Tentatively located with BW-3. Casing filled with concrete. Reported to have collapsed.

Table 7
Status of Existing McClellan AFB Production Wells

Page 2 of 2

Well No.	Location	Comments
20	In parking lot south of Building 200	Will be decommissioned during Phase II.
21	Near Building 689	Status uncertain. Has not been located. Thought to be an old agricultural well. May have served the old Aero Club.
22	Near Building 1445	Status uncertain. Has not been located. Thought to lie near northeast corner of building.
23	Near Building 1455	May have been found during parking lot construction. Thought to be an old agricultural well.
24	Near Building 1455	May have been found during parking lot construction. Thought to be an old agricultural well.
25	Off the base at the Lincoln Communication site	Active well.
26	Off the base at the Davis Communication site	Active well. Water may be contaminated.
27	Near Building 1099	Decommissioned in 1991.
28	Near Building 1082	Will be decommissioned during Phase II.
29	North area, in Building 1455 on Perrin Avenue	Active well.
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.
LW-1	Camp Kohler	Uncovered by backhoe. Has been filled with concrete.
LW-2	Camp Kohler	Located on old maps, but not uncovered. Thought to be abandoned.
Seismic Well	Camp Kohler	Casing exterior sealed wtih cement. Not a water well.
Triax Hole	Camp Kohler	Casing exterior sealed wtih cement. Not a water well.

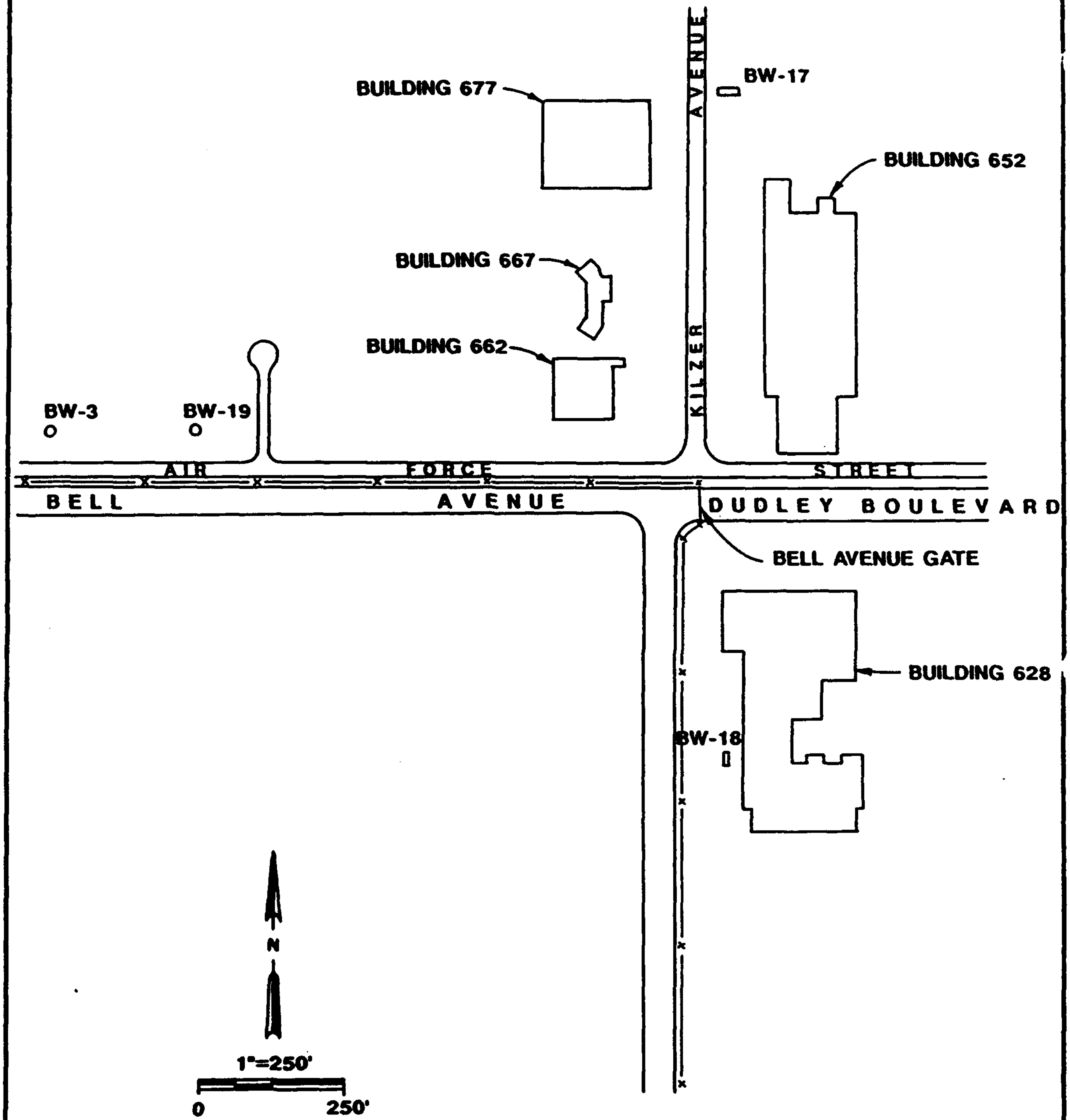


FIGURE 11
LOCATION OF
BASE WELLS NO. 3 AND 19
McCLELLAN AIR FORCE BASE

SOURCE: FIELD INSPECTION, 1992

CH2M HILL

These three wells served a nearby water treatment facility. Perforations in BW-19 extended from 174 to 193 feet, 214 to 239 feet, and 305 to 360 feet. BW-19 is said to have collapsed (LSCE, 1984). The casing in both BW-3 and BW-19 extends a few inches above the ground surface and is filled with concrete with gravel aggregate.

BW-16 was thought to be located in the southeast area of the base, based on the recollections of Water Department personnel and a previous investigation (LSCE, 1984). However, during this investigation an old map was located in McClellan AFB files that depicts the location of BW-16 in the western part of the base near Patrol Road. The location of the former well is shown in Figure 12. Although the exact location of the well is shown on the old map, it is not visible today and its status is unknown.

BW-6 is also thought to be located in the western part of the base, in the vicinity of the present industrial wastewater treatment plant (see Figure 2). According to LSCE (1984), this well is probably another former agricultural well acquired during an early expansion of the base. No records have been obtained for the well, nor has any visible structure been observed in the field.

Base Well 9

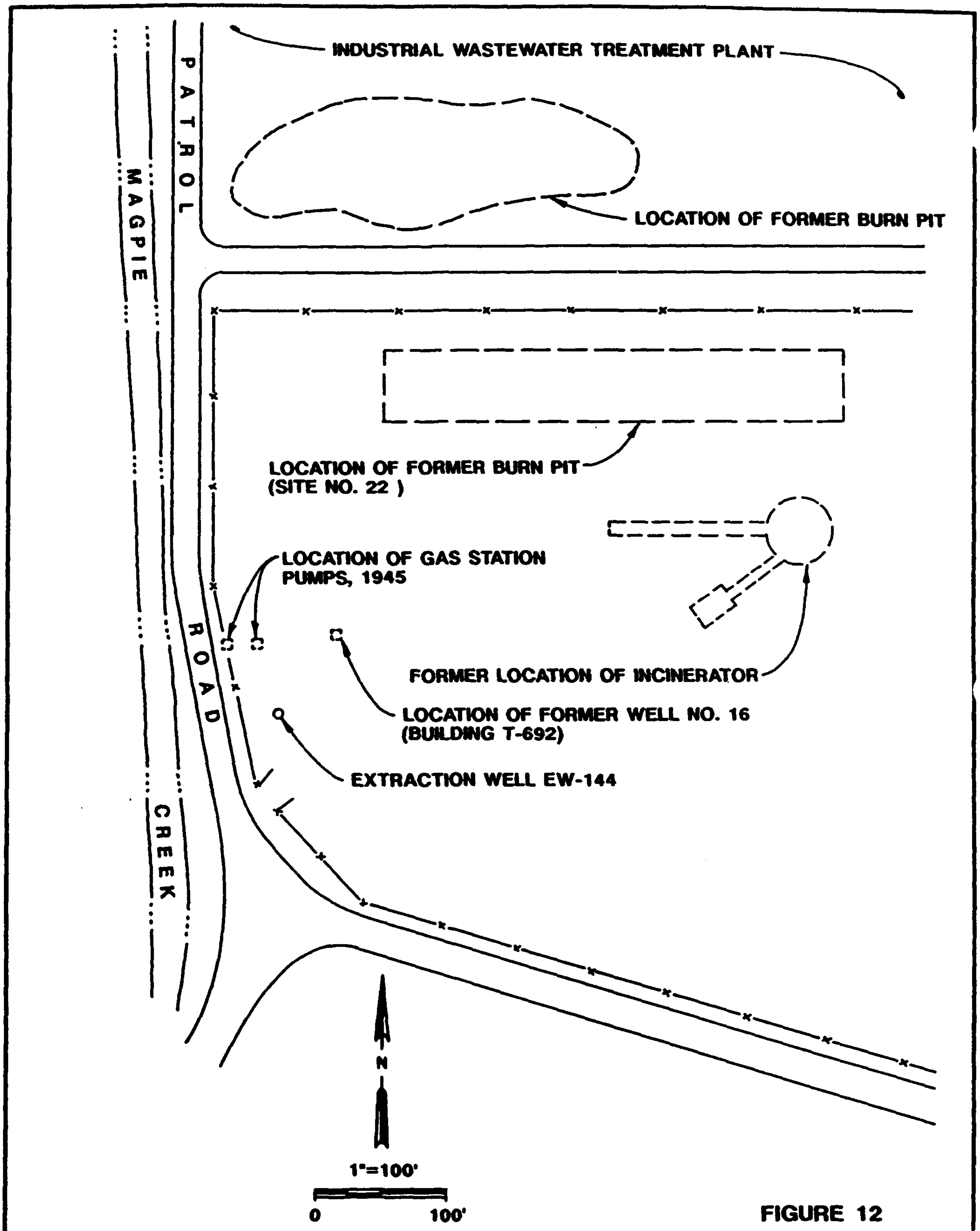
BW-9 is located in a parking lot south of Building 200 on Peacekeeper Way in the eastern portion of McClellan AFB. Previously the precise location of this well was unknown. However, during this investigation an old map was found that shows the location of this well relative to known features, including BW-20 and an existing water line. This location is shown on Figure 13, which indicates that BW-9 lies about 200 feet west of BW-20. There is currently no visible evidence of BW-9 at the site.

Very little is known about BW-9. Information presented in a previous investigation (LSCE, 1984) has been found to have been mistaken. According to Water Department personnel, BW-20 was constructed in 1953 to replace BW-9, which apparently had collapsed. Drawings indicate that BW-9 was located in subsurface vault, typical of wells constructed during WWII. Based on the well number, BW-9 was probably constructed after 1942, when BW-8 was constructed. No information has been found regarding BW-9 well construction details.

Base Well 15

BW-15 was previously thought to be located several miles away from McClellan AFB, on the corner of Whitney and Eastern Avenues (LSCE, 1985). As part of this investigation, however, old maps dating from 1945 and 1955 were found that located BW-15 immediately north of Building 440, on Dudley Boulevard across the street from BW-7 in the southeast portion of the base. The location of well BW-15 is shown in Figure 14.

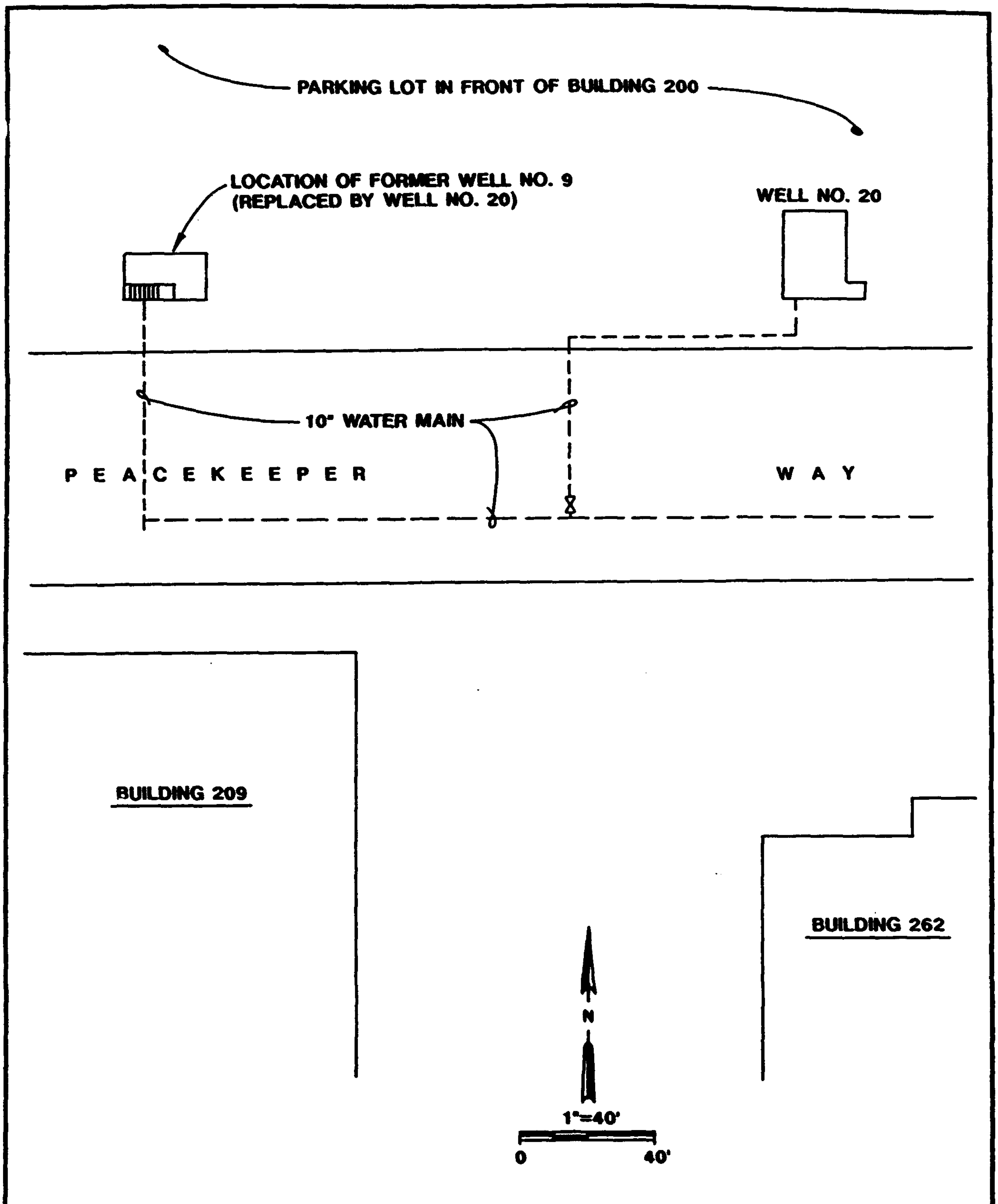
BW-16 had previously been thought to be located in this area (LSCE, 1985) but, as described above, was found to be located in the western part of the base. Robert Zenda of the Water Department recalled that a below-grade well was constructed on the corner of Whitney and Eastern Avenues at a site presently occupied by a church (conservation with Robert Zenda, December 18, 1991). However, field inspection failed to find any sign of a well.



SOURCE: McCLELLAN FIELD UTILITY MAP, SHEETS NO. 18 & 19, 1945
AIRPHOTO OF McCLELLAN AFB, 1987

FIGURE 12
LOCATION OF
BASE WELL NO. 16
McCLELLAN AIR FORCE BASE

CH2M HILL



SOURCE: McCLELLAN AFB UTILITY MAP "UTILITIES ON "J" STREET FROM 40th TO 44th STREETS, SHEET NO. 205, 1955

FIGURE 13
LOCATION OF
BASE WELLS NO. 9 AND 20
McCLELLAN AIR FORCE BASE

CH2M HILL

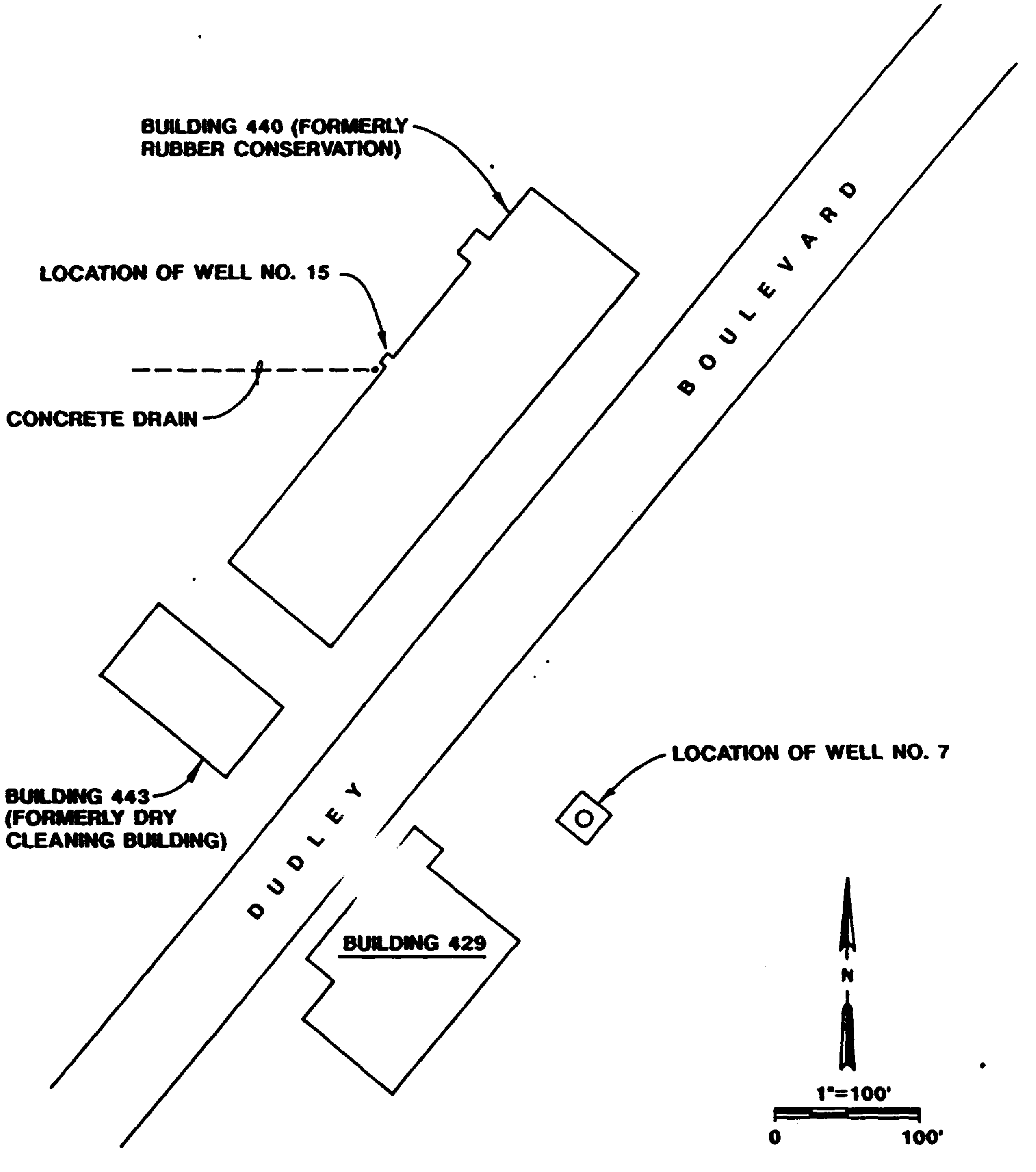


FIGURE 14
LOCATION OF
BASE WELLS NO. 7 AND 15
McCLELLAN AIR FORCE BASE

SOURCE: McCLELLAN FIELD UTILITY MAP, SHEET NO. 9, 1945

CH2M HILL

A well log was found at DWR that identified a well located at the Rubber Conservation Building at McClellan Field (see Appendix B). 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. All that is visible today is a concrete pad with a circular hole covered with asphalt. Concrete footings that were probably used to support a pump motor are also visible, as is a drain leading away from the former well location.

Wells in the Vicinity of Base Well 29

Four wells are known to be present in the immediate vicinity of BW-29, an active production well located on Perrin Avenue in the northeastern part of the base. These wells are thought to be BW-23, BW-24, "old" BW-29, and the "Boy Scout Well." The locations of the wells is shown in Figure 15. Another well, BW-22, is located at Building 1440 about 1,300 feet northeast of BW-29. The location of this well is shown in Figure 2.

According to a previous investigation, interviews with base personnel had indicated that BW-22, BW-23, and BW-24 were old agricultural wells acquired during early expansion of McClellan AFB. BW-23 and BW-24 were thought to be located in general vicinity of the present location of BW-29 (CSCE, 1984). Recent parking lot construction at BW-27 uncovered two old wells that may be BW-23 and BW-24. The well north of BW-29, assumed here to be BW-23, had a 6-inch-diameter casing. Workers determined that this well had not been abandoned, and welded a plate on the casing (conversation with Robert Zenda, December 18, 1991). The present investigation located a 1984 map that identified an "old agricultural well" at that location. Both BW-23 and BW-24 will be protected by the paving contractors for potential future access to the wells.

Mr. Zenda of the Water Department also described a well in this area called the "Boy Scout Well." Field inspection located a well with 6-inch-diameter casing sticking up out of the ground in front of Building 1457 on Perrin Avenue. Building 1457 has historically been used for Boy Scout activities at McClellan AFB. A cap has been welded onto the casing, so that field personnel were unable to determine whether the well has been grouted.

BW-29 has been constructed twice at this location. The original well was built in 1981 by Water Development Corporation. Drawings found during this investigation located the well at the position shown in Figure 15. Old BW-29 was drilled to a total depth of 604 feet, and then cemented to a depth of 400 feet. It contained 16-inch-diameter casing in a 26-inch-diameter borehole, with 50 feet of conductor casing. No information is available on the screened interval. Unfortunately, the gravel feed tube was inadvertently covered by the cement sanitary seal, so that gravel could not be added to the well. As a result, the well began pumping sand. Eventually, so much sand was pumped that a depression was visible at the ground surface. According to base Civil Engineering personnel, the casing was cut below grade and a metal plate was welded over it.

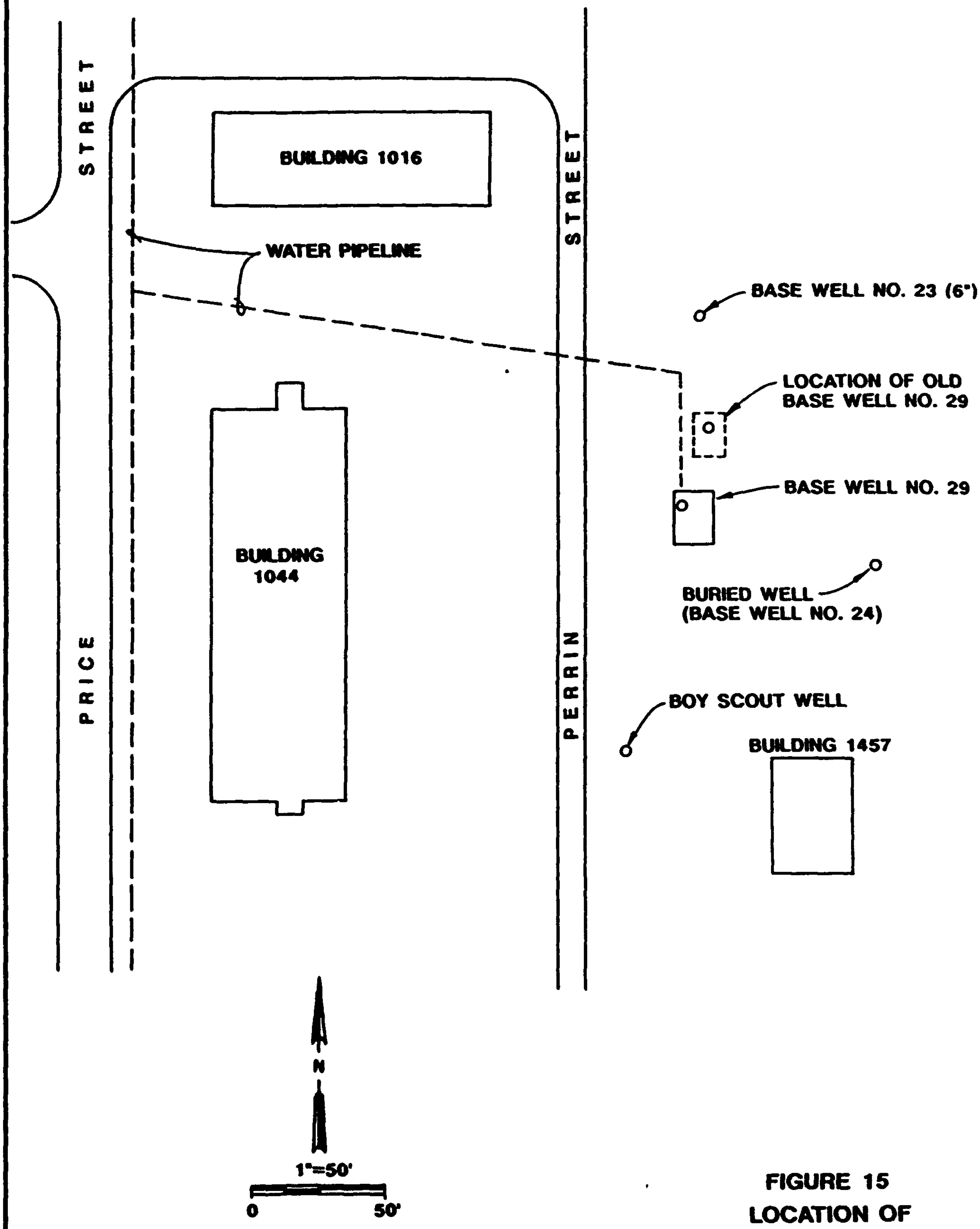


FIGURE 15
LOCATION OF BASE WELL NO. 29 AND NEARBY WELLS
McCLELLAN AIR FORCE BASE

SOURCE: WELL 29 PLANS, McCLELLAN CIVIL ENGINEERING DEPARTMENT, 1980, 1984
FIELD INSPECTION, 1992

CH2M HILL

This plate was then buried. The present BW-29 was constructed in 1984 by the Maggiora Brothers. BW-29 is 580 feet deep and contains 190 feet of screen, according to McClellan AFB files.

BW-22 was located near one of the corners of Building 1440, which houses recreational equipment checkout for base personnel. This well is thought to have been an agricultural well originally, and later served Building 1440. Eventually Building 1440 was placed on the McClellan AFB water supply system. The fate of the well is uncertain (Robert Zenda, 1992, pers. comm.). A field inspection revealed no sign of the well. However, a circuit box labeled "Well Pump" was found on the northeast corner of the building.

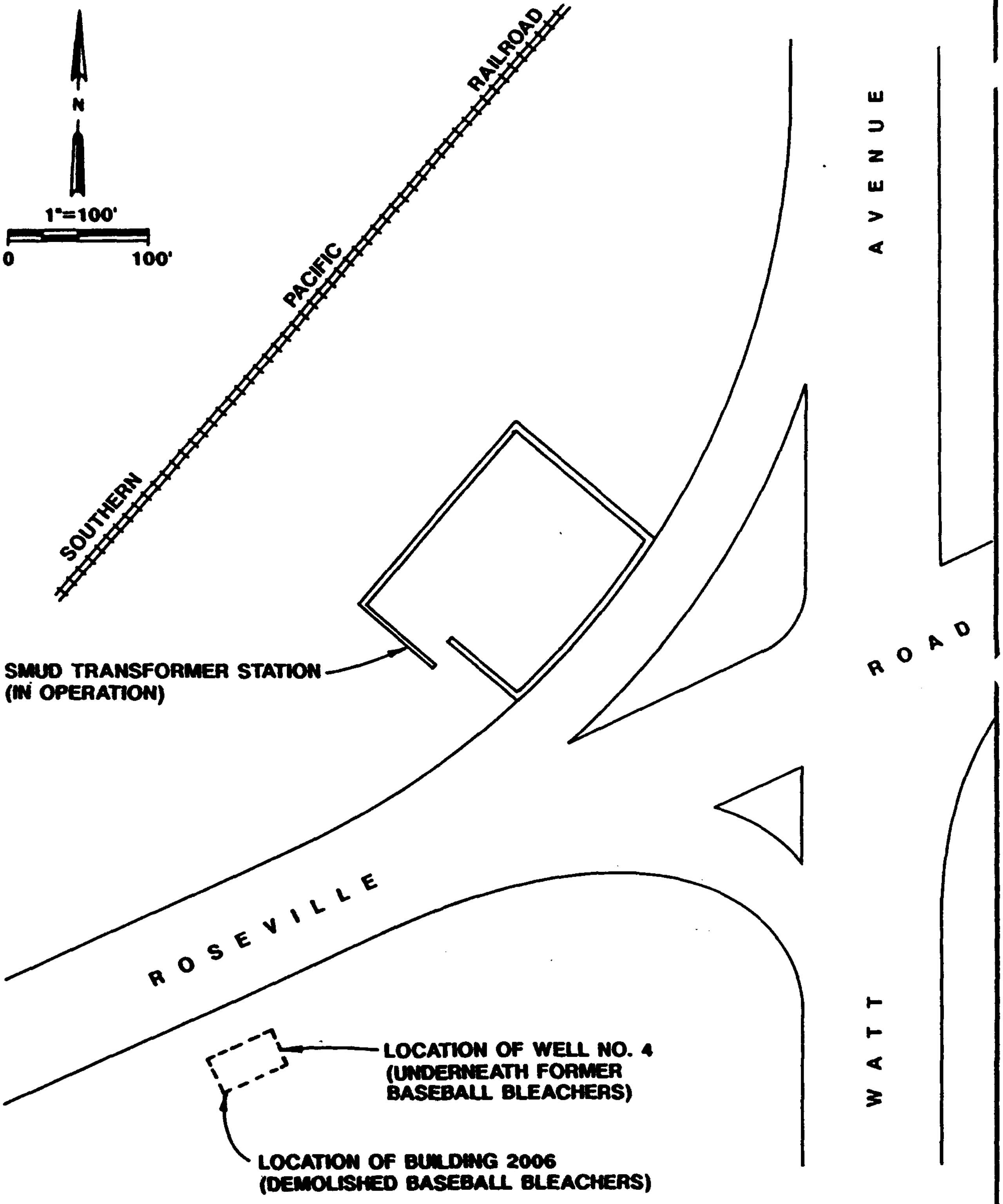
Wells Located Outside McClellan AFB Boundaries

Five wells are located outside the present boundaries of McClellan AFB: BW-4, BW-5, BW-11, BW-25, and BW-26. Two of these wells, BW-4 and BW-11, are presently inactive and no longer visible. The other wells are currently operating and serving off-base facilities. A sixth well is thought to have been located near the present corner of Whitney and Eastern Avenues, but the status and number of this well is uncertain as described previously.

Well BW-4 is located south of Roseville Road about 400 feet west of the intersection with Watt Avenue (see Figure 16). This area was formerly the Winstead Athletic Field, located in a region of McClellan AFB known informally as "Splinter City." BW-4 was located directly beneath the bleachers next to a baseball diamond, and served as an irrigation well for the field. As part of this investigation, maps were located that show the location of the former well. Field inspection revealed no sign of the well, but piles of concrete rubble are visible that are likely the remains of the old bleachers. BW-4 was a rotary well drilled in July 1941 to a depth of 382 feet. It contained 12-inch-diameter casing that was perforated from 169 to 382 feet, and a 24-inch-diameter conductor casing that extended to a depth of 81 feet. BW-4 is known to be gravel-packed, but the details of the pack and the borehole diameter are unknown (LSCE, 1984). It is uncertain when the well was taken out of service, but Winstead Athletic Field is thought to have been present until the mid 1980s.

Well BW-5 is known as the "Old River Dock well." This well is located on Old Garden Highway, several miles southwest of McClellan AFB. Constructed in 1941 to a depth of 368 feet, BW-5 is still in service. Construction drawings and geologic information on the well are on file at the base.

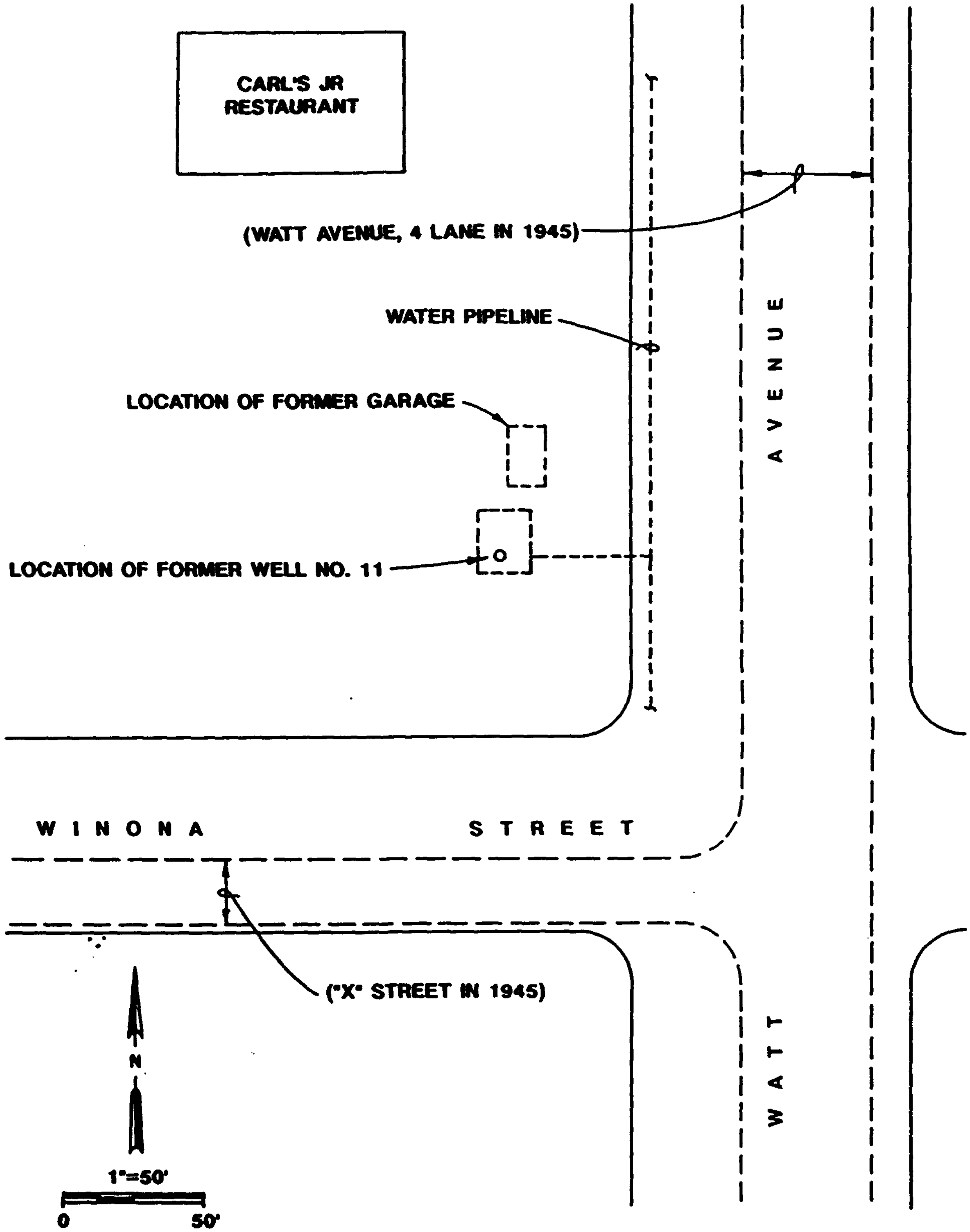
Well BW-11 is located about 75 feet north of the current intersection of Winona Street and Watt Avenue about one-half mile south of McClellan AFB, in the area formerly known as "Splinter City" (see Figure 17). It is not presently visible at the surface, but maps were located during this investigation that show the former location of the well. BW-11 was constructed in 1945 in a subsurface vault, as was typical of McClellan AFB wells from that time. The well was 378 feet deep, according to a photolog on file at the Base. Casing was 14-inch-diameter steel, reducing to 12 inches in diameter at a depth of 140 feet. Perforations extend from 154 feet to the total depth of the well.



SOURCE: McCLELLAN FIELD UTILITY MAP, SHEET NO. 2, 1945

FIGURE 16
LOCATION OF BASE WELL NO. 4
McCLELLAN AIR FORCE BASE

CH2M HILL



SOURCE: McCLELLAN FIELD UTILITY MAP, SHEET NO. 2, 1945
AIRPHOTO OF McCLELLAN AFB, 1987

FIGURE 17
LOCATION OF BASE WELL NO. 11
McCLELLAN AIR FORCE BASE

CH2M HILL

The well is thought to have been gravel packed. However, details of the borehole diameter and surface seal are unknown. It is also uncertain when or how the well was taken out of service. However, BW-11 was still online in 1984 (LSCE, 1984). At some point in the past, BW-11 was reported to have been contaminated with gasoline (conversation with Robert Zenda, January 3, 1992).

Well BW-25 is located at the Lincoln Communication site. It is reported to be an active well, drilled to a total depth of 408 feet. Other data has not been obtained for this well.

Well BW-26 is located at the Davis Communication site. This well is also an active well, being used for fire protection, irrigation, and cooling tower water. Construction data on file at the base reveal that the well was constructed in 1951 to a depth of 358 feet, with 10-inch-diameter casing installed to a depth of 320 feet. However, the casing apparently collapsed at a depth of about 225 feet. Subsequently in 1986 8⅝-inch-diameter casing was inserted into the well. This casing is screened from depths of 102 to 122 feet, and 140 to 201 feet. A cement plug was placed in the casing below 201 feet. BW-26 has experienced contamination by TCE, PCE, and 1,1-DCE, according to records on file at the Water Department. Data from 1988 indicate that TCE concentrations ranged from trace amounts to 6.0 ppb between 1986 and 1988, while PCE concentrations ranged from trace amounts to 3.2 ppb, and 1,1-DCE ranged from trace amounts to 3.0 ppb. However, Mr. Zenda stated that TCE levels had ranged as high as 3,000 ppb in previous years (Robert Zenda, 1992, pers. comm.). Records indicate that underground storage tanks were removed from the site. Current remedial efforts include the implementation of a Remedial Investigation for groundwater contamination.

Other Wells

Two wells have not been located at McClellan AFB. These include BW-14 and BW-21. No information has been found regarding the location or disposition of BW-14. It is possible that this well was located on the corner of Whitney and Eastern Avenues, several miles southeast of McClellan AFB. BW-21 is reported to be an old agricultural well. Apparently, this well served as the "Aero Club Well." At some point in the past the club was lodged in an original old farmhouse, that lay in the vicinity of the present Building 696 (Conversation with Robert Zenda, January 3, 1992). The general location of this well is in the south-central portion of the base (see Figure 2). Further search of old base maps may precisely locate this well.

Decommissioning Base Wells

Two subcontractors will be employed in the abandonment of base wells: a drilling subcontractor who will provide a drill rig or crane with a mast to hang equipment over the hole and other specialized equipment such as perforating equipment, and who can perform downhole television surveys; and a subcontractor who specializes in the mixing and pumping of grouts under pressure for well abandonments. All cementing operations will be performed under the supervision of a California Registered Geologist or Professional Engineer from CH2M HILL who will maintain a chronological record of field activities.

Field work will be arranged so that only personnel from the drilling crew will be allowed to work over the open well and handle oil or water removed from it. These personnel will be trained in safety aspects of work involving potential contact with hazardous materials and participate in an ongoing medical evaluation program, as required by the Occupational Safety and Health Administration. CH2M HILL will provide screening of ambient air with a photo-ionization instrument. It is not anticipated that base wells will pose a safety risk from hazardous materials if proper safety procedures are followed. Safety requirements are detailed in Appendix A in the Site Safety Plan.

During Phase I it was found that state or county permits were not necessary for well decommissioning at McClellan AFB, because the work is governed by the terms of the InterAgency Agreement, which provides for supervision by representatives of the various agencies of the county and state. The Well Closure Methods and Procedures Report prepared for Phase I (CH2M HILL, 1991) contains a complete description of ordinary permit requirements and well abandonment regulations.

All equipment used in well abandonment that may come into contact with groundwater will be decontaminated prior to arrival at each well. This decontamination will consist of steam-cleaning. Equipment will be steam-cleaned at the contractor's yard prior to arrival at the first well. Equipment that is used in wells and contacts groundwater will be steam-cleaned when it is pulled from the well. Steam-cleaning water will be allowed to run back down the well to avoid disposal problems. Disposal of wastewater, if necessary, is discussed at the end of this document.

Preliminary Activities

As preparation for abandonment or modification of base wells, a pump contractor will be supervised in the removal of existing turbine pumps from five inactive wells (BW-8, BW-13, BW-17, BW-20, and BW-28). Wells BW-8, BW-13,and BW-17 are each located inside buildings (BW-8 and BW-13 are contained in vaults) and will need to be removed through trapdoors in the roof. BW-20 is located in a vault in a parking lot. Concrete pads will have to be removed to gain access to this well. The contractor will mobilize a pump rig to each well head, dismantle the pump, and pull it from the well. All pump equipment-wellhead motors, pump column piping, pump shafts and bowls, strainers, etc., will be transported to the Defense Reutilization and Marketing Office (DRMO) at Building 700. Pump equipment will be steam-cleaned as it is pulled from the well, and prior to delivery to DRMO.

Plumbing at BW-8 will be temporarily capped pending reinstallation of the pump. At BW-13, the water line from the pump will be disconnected from the main line near the power pole and a blind flange installed on the "T." At BW-17, the 12-inch valve on the supply line from the well located about 85 feet south of Building 663 will be removed, and blind flanges installed on both ends of the pipe. At BW-20, the 2-way valve in the vault will be removed and replaced with pipe spool.

A field log will be maintained during this and all other field activities. This log will provide a chronological record of all field activities. Field notes will be organized so that each page is numbered and dated. The well number or location will be written on each page. A fresh page will be used at each new well. The field notes will also include a daily sketch, if applicable, that depicts the well with grout intervals, perforated intervals, or other pertinent information. In addition, pictures will be taken to record the highlights of field work, and provide a basis for agency presentations. A record of pictures taken will be recorded in the notes.

Following removal of the pumps, a contractor specializing in downhole television surveys will lower a television camera down each well to be abandoned or modified. This survey will provide information on the condition of the casing, such as the presence of encrustations or obstructions in the casing or fill material in the bottom of the well, and the ability of the casing to withstand cementing pressures, as indicated by the presence of cracks and holes, and corrosion along the perforations. The television survey will also indicate whether pump lubricating oil is floating on the top of the water in the well, and provide a preliminary indication of well construction details (casing diameter, intervals of perforations, depth of the casing, etc.).

Any pump lubricating oil found in the wells will then be bailed from the wells and stored in 55-gallon drums. Arrangements will be made for the oil to be disposed to a petroleum recycler. Air Force personnel will sign any manifests or forms required by the petroleum recycler.

After the pump lubricating oil has been removed, it will be necessary to perform some rehabilitation on the wells. Based on experience gained during the first phase of well abandonment at McClellan AFB, it is expected that all wells except the seismic wells and redrilled wells will be contaminated with iron bacteria. However, wells revealed during the initial television survey to be free of obstructions that block a view of the casing will not require rehabilitation. Wells that are considered to require some rehabilitation will be cleaned with a steel brush fabricated for each well diameter to remove gelatinous masses of iron bacteria and encrustations of iron oxide. The purpose of the cleaning will be to allow improved evaluation of the condition of the well casing. For this reason, it is assumed that only the upper portion of BW-8, which will be sealed off, will require cleaning with a steel brush.

Following the cleaning of the casing, excessive debris lying in the bottom of the wells will be bailed out and stored in 55-gallon drums at the wellhead. Ten feet or less of soft sediment should not affect the cementing operations. If greater than 10 feet of sediment is found, then it will be necessary to remove it. It is assumed that no more than 25 55-gallon drums will be required for all the wells. Any salvageable materials found in the wells, such as piping, will be transported to DRMO.

Cores will then be drilled into the concrete pads at the wellhead of each well that will be abandoned or modified, with the exception of the seismic wells. The coring will be accomplished with a small hand-held drill, and cores will be extended to the top of the gravel pack annulus in each well, a distance of only about 1 to 2 feet. The purpose of the coring is to determine the composition of the gravel pack and the diameter of the annular space. This information will reduce uncertainty during cement volume calculations when the wells are being sealed.

A second television survey will be performed in each well that has been cleaned by brushing. As before, this survey will provide information on the condition of the casing, such as the presence of encrustations or obstructions in the casing and the ability of the casing to withstand cementing pressures, as indicated by the presence of cracks and holes, and corrosion along the perforations. The television survey will also provide an indication of well construction details.

When video tapes of the television survey of wells on base are received, a technical memorandum will be prepared for submission to the Air Force Project Officer. This memorandum will summarize field activities to that point and discuss the findings of the television survey and coring into the wellhead pads. If any additional work is found to be necessary prior to abandonment based on the results of the survey, that work will be described and recommendations made in the technical memorandum. Similarly, the technical memorandum will propose any modifications to the "Well Closure Methods and Procedures" report that appear to be necessary based on the results of the survey and coring. Agency approval will be obtained before performing any of the modifications recommended in the technical memorandum.

Grout Materials

Cement grout mixtures used to seal the annular space around a well casing must display certain properties. Grout should be of low permeability to resist the flow of fluids through them, be capable of bonding to both the well casing and borehole wall to provide a tight seal, develop sufficient strength within a short period to permit completion of the abandonment without excessive delay, be chemically inert or nonreactive with formation materials or groundwater, be easily mixed, be of a consistency that will allow the grout to remain in a pumpable state for an adequate period of time, have minimal penetration into permeable zones, and be safe to handle (Gaber and Fisher, 1988).

Various types of cement mixtures are available that display these properties and accommodate varying geological and chemical conditions found in the subsurface. Experience in the oil industry led the American Petroleum Industry (API) to establish specifications for classes of cement. API Class G and H cements, which are specially formulated to be used with additives and suitable under a wide range of pressure and temperature conditions, will be used in the decommissioning of base wells.

Common Portland cement is made from limestone (or other materials high in calcium carbonate), clay, or shale, with some iron and aluminum oxides added if they are not present in sufficient quantity in the clay or shale. The principal compounds formed during the burning process that produces cement are tricalcium aluminate, tetracalcium aluminoferrite, tri-calcium silicate, and dicalcium silicate. API Class G or H cement is chemically similar to common Portland cement but is manufactured to more rigorous chemical and physical specifications which result in a more uniform, fine-grained product (Halliburton Services, 1981). The typical hydraulic conductivity of a neat cement, composed of Portland cement and water (6 gallons per 94-pound sack), is about 10^{-7} centimeters per second (Gaber and Fisher, 1988).

Class H cement is commonly mixed by Halliburton Services in a 50/50 ratio with pozzolans, siliceous materials that develop cementing properties by reacting chemically in the presence of lime and water. When mixed with cement in dry bulk form, pozzolans decrease the weight of the slurry, provide low permeability and low water/solids ratio, and make pumping easier. The 50/50 mixture, marketed by Halliburton as Pozmix, has a hydraulic conductivity of less than 10^{-10} cm/sec after curing (Halliburton Services, 1981). Pozmix will be the basic cement used in decommissioning wells at McClellan AFB.

A special cement known as standard fine cement will also be used during cementing operations. Marketed by Halliburton Services as Micro Matrix Cement, this cement will be used in wells with fragile casings or where long intervals of existing perforations are found in wells. Micro Matrix Cement is chemically similar to Portland cement. However, Matrix Cement particle sizes are approximately 10 times smaller than standard cement particles. This property reduces the viscosity of the cement and enables it to penetrate openings as fine as 0.05 mm (Halliburton Services, 1991).

The amount of water mixed with the cement has an important effect on the properties of the cement. Tests have indicated that 5.2 gallons of water are required to hydrolyze one 94-pound sack of Portland cement, producing a slurry weight of 15.6 lb/gal (Driscoll, 1986). Less water than this will not hydrate the cement and will cause a high-viscosity product that is difficult to pump. Too much water causes shrinkage, as water is squeezed out of the mixture into permeable formations, or as cement settles to the bottom of the mixture. The proper mixture produces effective bridging of cement particles in the pores of permeable formations, which prevents penetration of the grout into these formations (Driscoll, 1986). DWR regulations specify that 4.5 to 6.5 gallons of water per sack of cement be used, depending on the cement type and additives used (DWR, 1981). The appropriate water-to-cement ratio will be continually monitored during the decommissioning of base wells through use of density measurements with an electronic cement balance.

Various additives may be added to the cement to improve the characteristics of the grout material. During the decommissioning of base wells, these may include bentonite powder, CFR-3, calcium chloride, Flocele, and quick-setting gypsum cement. Bentonite is a colloidal clay (chiefly montmorillonite). Addition of bentonite increases the slurry and set volume and reduces shrinkage because of the water adsorption properties of colloidal clay. Bentonite also reduces the weight of the cement column, which is beneficial where permeable formations will not sustain a high hydrostatic pressure. Finally, addition of bentonite improves the fluidity of the mixture by increasing the suspension qualities, thus reducing the settling out or separation of cement particles from the slurry (Halliburton Services, 1985). If the percentage of bentonite exceeds about 6 percent, excessive shrinkage of the cement will occur (Driscoll, 1986). During the decommissioning of base wells, about 2 percent bentonite powder will be mixed with water prior to the addition of the cement.

CFR-3 is a dispersant, or friction reducer, that is composed of sulfonic acid salt. CFR-3 improves the mixing of other components of the grout by increasing the turbulent flow of the slurry. This is a property that aids when using small-diameter tremmie pipes and attempting to infiltrate gravel packs and formation walls. It also densifies the cement, aids in fluid-loss control, and increases salt tolerance of the grout if calcium chloride is added (Halliburton Services, 1985).

Calcium chloride is added to the mix in quantities of about 2 percent to accelerate the early strength of the cement, thus reducing the time required for the mix to set up. Available in either powdered or flake form, it can be added either to the dry mix or to the mixing water. For example, Class H cement with 2 percent calcium chloride achieves a compressive strength of 1,100 psi after 6 hours at 95°F (Halliburton Services, 1981).

Two other additives may be used to reduce losses to permeable formations. Flocele consists of cellulose film flakes, about 3/8-inch in diameter, that are chemically inert and do not affect the compressive strength of the cement (Halliburton Services, 1985). Flocele will be added to the mixing water at a ratio of about 0.75 percent by weight. Cal-Seal, or gypsum (calcium sulfate), sets up in 20 minutes when blended with Portland cement. In addition, it expands 0.3 percent in setting, forming a tight seal. These properties make Cal-Seal a good choice to seal lost circulation zones (Halliburton Services, 1985). Cal-Seal will be mixed with Class G cement at a ratio of about 8 percent to help seal off permeable zones.

Grout will be mixed in the field with a recirculating mixer. The mixer and a diesel-powered positive-displacement pump will be delivered to the site on a truck and trailer.

Grout Placement

Several methods are commonly employed to decommission water wells. The most common technique involves first perforating the well casing adjacent to units of low permeability, such as clay or silt, and adjacent to aquifers containing deleterious water. A tremmie pipe is then suspended in the casing and grout pumped next to these zones, while sand is placed next to aquifers containing good quality water. A variation involves perforating and cementing the entire length of the casing in one lift. In all cases, the tremmie pipe is suspended near the bottom of the zone to be sealed, and grout is pumped from the bottom to the top of the zone. In addition, the uppermost 20 feet is always sealed.

Improved grout control and gravel pack penetration is achieved by maintaining a desired level of pressure on the grout in excess of hydrostatic pressure as it sets up in the hole. The amount of pressure applied depends on the characteristics of the cement slurry, size of the perforations, characteristics of the gravel pack and formation, temperature, and depth of the interval being sealed. A maximum pressure, or fracture pressure, represents an upper limit that should not be exceeded in grout placement. Above this level, grout penetration of the gravel pack and formation may not be uniform, due to the development of fractures, or routes of less resistance, through which the grout would preferentially flow.

A step-rate injectivity test is commonly used in oil well abandonment to estimate the fracture pressure of a formation. However, an accepted practice in water-well abandonment is to limit pressures to less than 1 psi per foot of depth below the surface. In this way, each lift in the hole is grouted until the volume of grout is sufficient to fill the voids in a hypothetical cylinder of casing and surrounding soil, or until resistance builds up to the pressure limit (Albritton, 1982). In the bottom of a 400-foot-deep well, for example, pressures should not exceed 400 psi.

Pressure at the surface (downstream from the pump) will be monitored with a gauge. During Phase I, this pressure never exceeded about 50 psi. Since this pressure is propagated evenly throughout the fluid, the pressure downhole should be equal to the pressure at the pump plus the pressure exerted by the column of fluid (0.458 psi/ft for water above the water table). The water table at McClellan AFB lies about 100 feet below the ground surface. Therefore, the pressure in the well should not rise much above 100 psi.

Grout placement by applying external pressure in excess of hydrostatic pressure is known as squeeze grouting. Pressure is maintained by sealing off the casing while pumping fluid into the casing with a positive displacement pump and monitoring pressures at the surface with a gauge. When the seal is placed at the surface, the technique is referred to as a Bradenhead squeeze. This technique would be less effective in base wells because of pressure losses through perforations above the interval being sealed. Pressures may also be maintained downhole through the use of drillable grout plugs, or retrievable balloon packers, retrievable tension-set packers (set by applying a tension, or pull, on the packer with the pipe attached to the packer), or retrievable cup-packers (set by the fluid pressure below the packer, which creates a seal by forcing the cup against the well casing). Grout is squeezed through the perforations and into the gravel pack by the high forces developed through the hydraulic effect of transmitting pressure through a small-diameter pipe and into a large-diameter pipe (the casing).

Two main approaches were most successful in properly abandoning wells at McClellan AFB during the first phase of well decommissioning. One approach, application of a downhole squeeze utilizing a cup packer, is a low-cost method applicable for wells screened intermittently along the length of the casing with casing that is capable of withstanding the hydraulic pressures generated by the packer. The other approach, special low-viscosity cements and application of a head of water, is a more expensive method that is applicable for wells screened continuously along the length of the casing or those that contain weak or damaged casing. Both approaches call for the well to be cemented in stages, with external pressure applied to the cement to force it into the gravel pack. These approaches will be followed during Phase II. In either case, wells that are believed to pose fewer technical challenges will be decommissioned before more difficult wells.

Abandonment With a Packer

Wells that are perforated at intervals along the casing and judged to be capable of withstanding high pressures, based on television survey evaluation, are suitable for cementing using a cup packer. Grout may consist of Portland cement with additives to improve performance. At McClellan AFB, the grout mix that worked well in the first phase consisted of API Class H cement, pozzolans, 2 percent bentonite gel, and 3 percent calcium chloride. This grout should be pre-mixed dry at the plant, and mixed with water at the job site. The steps in abandoning with a packer are as follows:

- Perforate the casing immediately prior to cementing if necessary.
- Set the cup packer in a blank section of casing above the interval to be cemented. Chain the tremmie pipe down evenly at the wellhead.
- Calculate a volume of cement necessary to fill the casing and 40 percent of the gravel pack to a point about 2 feet above the perforated interval.
- Calculate a volume of water necessary to fill the casing above the cement and below the cup packer, plus the entire tremmie pipe, and all surface piping downstream from the volume gauge.
- Pump a sufficient amount of water into the well to establish circulation and estimate the permeability of the formation.
- Mix the required volume of grout with a recirculating mixer to the desired density. Collect a sample and set it aside in the shade.
- Pump the required volume of grout with a positive displacement pump. Monitor the injection rate (less than 20 gpm) and the pressure (less than 100 psi).
- Pump the required volume of water slowly (less than 20 gpm) and monitor the pressure (less than 100 psi). Watch the tremmie pipe and chains for possible buckling. This is especially important in wells with large-diameter casing.
- Withdraw the cup packer from the well immediately to prevent it from being cemented in place.

- Inject cement wash water into the well.

- Tag the cement in the well with a weighted line after the cement sample sets up (minimum of 3 hours).

- Perforate the next interval, if necessary.

- Cement the well in a series of lifts. The length of the lift is determined by the length of existing perforations, the expected lithology, and the outcome of the previous lift.

On the next-to-last lift, the casing should be perforated about 15 feet above the water table.

The cement volume should then be calculated to bring the top of the cement to about 1 or 2 feet above the water table. As the cement sets up, water should drain out of the casing into the formation above the water table. This avoids the need to dispose of potentially contaminated water. On the final lift, cement should be brought to within 5 to 10 feet of the ground surface. It will be necessary to pump cement wash water into a tank trunk for disposal on the final lift. The earth will be excavated and the casing cut about 3 feet below grade. Finally, the cement should be topped off to the ground surface on outdoor wells. Wells located within buildings will be cemented so that the top of the cement is flush with the floor surface. All equipment should be steam-cleaned before use at the next well.

Perforation of the casing will take place immediately prior to cementing. The length of casing to be perforated will not exceed the length of the interval to be cemented on the next lift. Typically, perforation will be accomplished with a mills knife perforator, in which hydraulics cause the blade to cut into the casing. Four perforations will be cut per row, with one row per foot. Each perforation will be about one-third inch in thickness, and about 3 inches in length. Based on the conclusions drawn during the Preliminary Work, it may be necessary to employ an alternative method of perforation in certain wells. This method may be explosive shot perforation, hydro-jetting, or some other method, and will be described in the Technical Memorandum.

The length of the interval to be cemented will depend on the length of existing perforations and the experience of previous lifts in that well. Expected lithology may also affect the length. For example, shorter lengths may be necessary in zones of high permeability because of the need to employ special techniques (see the discussion below). In general, decommissioning at a given well will begin with a short lift of about 15 feet, and increase with experience to a maximum of no more than about 50 feet.

Abandonment with a Low-Viscosity Cement

A different approach is necessary in wells that are perforated continuously for great lengths or that contain casing that is judged too weak to sustain the pressure generated by use of the cup packer. Setting a cup packer within a perforated zone is pointless because the closed piston necessary to generate hydraulic pressure may not be obtained. Setting a cup packer within a zone of weak casing risks casing collapse or may cause holes to open, thereby allowing sediment to flow into the well.

Studies performed by Halliburton have shown that neat cement, cement containing pozzolans, and cement containing CFR-3 will be forced through well perforations and into a surrounding gravelpack mixed with formation material under a driving pressure of less than 30 psi. The hydrostatic pressure of a column of water is about 0.433 psi per foot. Thus, a driving pressure of 30 psi is obtained by a column of water about 70 feet high. A feasible abandonment technique below a depth of 70 feet would therefore involve pumping grout into the interval to be sealed, raising the tremmie pipe above the grout, and then adding water sufficient to maintain a column of water at least 70 feet high above the grout. In other words, the hydrostatic pressure of a column of water greater than 70 feet should provide sufficient pressure to force the grout mixture into the gravel pack.

In wells with weak casing or that are perforated continuously for long lengths, the approach will be to cement the well in a series of lifts using a low-viscosity cement. At McClellan AFB standard fine cement with the addition of CFR-3 was found to work well during the first phase. The tremmie pipe should be set about 10 feet off the bottom, and water circulated down the hole prior to cementing. After the cement is pumped, an attempt should be made to apply a head of water to the well. At McClellan AFB, the static water level is about 90 to 110 feet below the ground surface. A head of water provides about 45 to 55 psi of pressure, which is transmitted directly to the top of the cement. It may not be possible to maintain a full head during the early stages of abandonment because the water will be lost to the formation. As the well is cemented off, however, it becomes easier to apply the head. Success with this method is observed by comparing the calculated top of cement for the volume pumped with the actual top as measured by the tag.

Zones of High Permeability

Potential problems may result when grouting next to very permeable formations. Inability to maintain pressure at the wellhead may be countered by any or a combination of several techniques (Halliburton Services, 1985):

- Blocking circulation loss channels with flaky, fibrous, granular, or gelling additives. These may include walnut shells, bentonite, quick-setting gypsum cement, or Portland cement with an accelerator.
- Plugging with quick-setting cements which set up while flowing into channels.
- Lightening the column of slurry and/or decreasing the pressure.
- Using the hesitation method-placing cement in alternate pumping/waiting periods, encouraging the controlled deposition of cement solids against the formation.

Modificc⁺ion of Base Well 7

Available records indicate that BW-7 is probably grouted from a depth of about 80 feet to a total depth of about 398 feet. In order to ensure that the gravel park is properly sealed, it will be necessary to drill the well out and perforate the entire length of casing. However, a potential problem may result from the fact that previous efforts to drill out the inside of the casing were unsuccessful. For example, the former pump or pump column may be in the casing. The television survey may provide insight that will assist in developing an appropriate approach. Alternative methods of abandonment may involve rotary overwash of the casing, or drilling out the gravel pack with a small diameter drill bit, followed by cementing the annulus with a tremmie pipe. Any abandonment approach that differs from the approach described in previous sections of this report will be approved by the regulatory agencies in advance. If this approach can be developed based on the results of the television survey, it will be outlined in the technical memorandum prepared after preliminary work on the McClellan AFB wells is complete.

Modification of Base Well 8

Based on additional information collected during Phase II in 1992, BW-8 was found to have two well casings; a 12-inch well casing (assumed to be the original well which extended down to 389 feet) and a solid 10-inch casing or liner that extended to 662 feet. The total depth of the well was 779 feet. Three voids were noted during a 1992 television survey between 662 and 779 feet.

The lower portion of BW-8 extending from approximately 779 feet to 662 feet will be filled with a sand slurry cement to seal the three large voids. The 10-inch inner casing will then be perforated from 662 feet to 410 feet and sealed with another lift of sand slurry cement. From 380 to 410 feet the inner casing will be perforated to induce sand which might be in the annular space between the 10 and 12-inch casing to flow into the well.

The inner casing will then be cut at the bottom of the original well (around 389 feet) with a Mills knife. An attempt will be made to pull the 10 inch casing from the well. If the 10-inch casing is successfully removed, then the well will be bailed out and another downhole television survey will be performed. Depending on the conditions of the 12-inch casing, it may be necessary to clean the casing and perform a second television survey. The well would then be pressure grouted from 170 to 389 feet and then perforated and pressure grouted from 170 to 85 feet.

If the attempt to pull the liner is unsuccessful, it may be possible to cut shorter lengths of the casing and to pull these segments out using borehole "fishing" tools. If this method is unsuccessful, it may be necessary to shot-perforate through the liner and casing. BW-8 will then be decommissioned by pressure-grouting according to the procedures described in this report.

Base Wells 17 and 28

BW-17 and BW-28 were both drilled by the cable tool method. The main difference between a well drilled by the cable tool method and one drilled by the rotary method from a well abandonment perspective is that there is no gravel pack associated with a cable tool well. Since there is no gravel pack, the calculations for cement volumes must be adjusted. Cement volumes will therefore be calculated based on the inside volume of the casing, plus an additional 10 percent to fill the micro-annulus outside the casing. This additional 10 percent is felt to be conservative since subsurface clays may be expected to have swelled up tightly against the well casing. Otherwise the decommissioning approach will be the same as other wells, with grout applied under pressure in a series of lifts.

Camp Kohler Wells

LW-1 and LW-2 have been found to be abandoned at Camp Kohler, although it is uncertain whether the pumps were cemented in the casing. An initial step for these wells may be to drill a core into the concrete to determine whether the pump is present, and whether a gravel pack is present between the production casing and conductor casing. If no pump column is found, then the core will be extended into the concrete for a few feet.

Afterward, the concrete may be drilled out using mud rotary techniques and a tricone drill bit. The casing would then be perforated and cemented as at other wells. The actual approach followed to decommission LW-1 and LW-2 will depend on field conditions. If an alternative approach to decommissioning the wells is developed, it will be submitted to the regulatory agencies for approval prior to beginning the work. It is expected that LW-1 and LW-2 will be decommissioned before BW-7, which is located in an area of potential contamination at McClellan AFB. Experience gained at LW-1 and LW-2 should be helpful at BW-7.

The Seismic Well and the Triax Hole were given a cement bond survey to evaluate the integrity of the cement seal that completely contains the casing throughout the length of the well. Copies of the cement survey logs are included in Appendix C. The surveys indicated that the seal appeared to be in relatively good condition in the Seismic Well, which is 500 feet deep. The cement seal in this well probably provides adequate isolation of aquifer zones.

The log for the Triax Hole appeared to be ambiguous, with conflicting signals of the quality of the cement seal. According to base records, the Triax Hole is 200 feet deep with a surface elevation of 110 feet. The water table elevation in the vicinity of Camp Kohler in 1989 was about -35 feet Mean Sea Level with long-term trends indicating gradual decline (Radian Corporation, 1991). Therefore, the depth to water at present is approximately 135-140 feet below the ground surface. The Seismic Well will be cemented in one continuous operation by pumping a sand cement mix through a tremmie pipe that has been lowered to within a few feet of the bottom of the wells.

The Triax Hole will be decommissioned by pressure-grouting. A detailed approach will be provided in the Technical Memorandum that will follow a television survey performed during the Preliminary Work.

Disposal of Waste Materials

Two main categories of waste may be generated during the decommissioning of base wells: pump lubricating oil removed from the casing prior to cementing; and water generated during the decontamination of equipment between wells. Pump lubricating oil will be stored in 55-gallon drums at the well site. Although the California Health and Safety Code requires that used oil be managed as a hazardous waste, provisions allow for the oil to be recycled. By recycling the used oil, the RCRA Land Ban is bypassed (California Department of Toxic Substances Control, 1990, pers. comm.).

Manifesting requirements for used oil are thus greatly simplified. The recycler must fill out a uniform hazardous waste manifest for each vehicle operated during a particular day, completing both the generator and hauler sections using the hauler's name. The hauler will attach receipts for each quantity of used oil received from a generator and give copies of receipts to each generator of used oil, identifying the generator and the hauler, the amount and the date, and stating the manifest number. The generator must keep receipts for at least 3 years.

Two tests must be performed on the oil by the recycler: a chloro-detect test and a flash point test. These tests may be performed in the field prior to hauling the oil. The chloro-detect test will detect chlorides and halides, including contaminants potentially present in water, at a level of 1,000 ppm. The flash point test will determine whether the oil has a flash point less than 140°F. If contaminants are present above 1,000 ppm, or if the flash point of the oil is less than 140°F, the oil can still be recycled, but the Air Force will be immediately notified. However, it is not expected that these levels will be exceeded.

CH2M HILL will make arrangements for shipping, handling, and disposal of the drummed oil as approved by the Air Force. However, the Air Force will sign any manifests as generator. The Air Force will be given 48-hour notice before collection of the oil by the recycler.

The decommissioning process has been designed so that no wastewater will be generated and will therefore require no disposal. If it should become necessary to generate wastewater for disposal from decontamination or some unanticipated event during the field work, this water will be pumped into a portable Baker tank and transported to the groundwater treatment plant on base for treatment and disposal. If the water is unacceptable for treatment at the groundwater treatment plant, such as because of high turbidity, it will be delivered to the industrial wastewater treatment plant. The Air Force will be given 48-hour notice before delivery of the well water to either treatment plant.

Conclusion

After base wells have been decommissioned or modified, CH2M HILL will prepare an Informational Field Report, summarizing all field activities associated with the field work, as recorded in the field log. This report will be prepared and signed by a licensed professional, and will include any conclusions and recommendations that may be necessary. All field notes will be included as appendixes.

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Pexton, Rob. Conversation with Robert Zenda, McClellan AFB Water Department, January 3, 1992.

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_________. Conversation with Marshall Eaton, Eaton Drilling Company, December 9, 1991.

Correspondence from George Odell to McClellan Air Force Contracting Officer, July 30, 1980.54

Appendix A

Site Safety Plan

SAC/T207/030.51-6

MASTER SITE SAFETY PLAN

McCLELLAN AIR FORCE BASE
Sacramento County, California

Prepared for

McCLELLAN AIR FORCE BASE
Sacramento County, California

Prepared by

CH2M HILL

3840 Rosin Court, Suite 110
Sacramento, California 95834

October 1991

SAC/T192/043.51

This document is the CH2M HILL Site Safety Plan (SSP) covering potential activities that may be required under CH2M HILL's master contract with McClellan AFB. Therefore, activities described in the SSP and Attachments A and B may not specifically apply to Well Abandonment work. The Addendum contains information specific to Well Abandonment activities.

CH2M HILL
SITE SAFETY PLAN

I. GENERAL INFORMATION

CLIENT: McClellan Air Force Base JOB NO: SAC28722
PROJECT MANAGER: Starr Dehn
SITE NAME: McClellan Air Force Base (MAFB)
SITE LOCATION: McClellan Air Force Base, California
PURPOSE OF FIELD VISIT(S): Source testing, site survey, waste minimization and treatability studies, site inspections (see Attachment A).
DATE OF VISIT(S): April 30, 1990 through 1992
BACKGROUND INFORMATION: Complete ____ Preliminary X
INFORMATION AVAILABLE FROM: SAC (office)
OVERALL HAZARD SUMMARY: Serious ___ Moderate ___ Low ___ Unknown X

II. SITE CHARACTERISTICS

A. Site Description and Overview of Planned Activities (attach site map):

- McClellan Air Force Base is located north of Sacramento, California. According to Dave Faulkner (Navy), the base is approximately 3 miles north-south and approximately 2 miles east-west in length

- The description of planned activities are listed in Attachment A

- The base is on the Central California Valley with excellent city street and interstate highway access. Access by air is excellent

- Toxic or hazardous substances known or expected onsite, discussion of physical and chemical properties, and probable pathways of migration or dispersion will be addressed on a task-specific basis in the CH2M HILL Site Safety Plan Addendum (see attached addendum form)

- Emergency response support is available from MAFB. First response is obtained from the fire department and calls can be made to the department directly or through the duty officer (see telephone numbers Section VI, J). The base has a Disaster Response Force, as second response, which consists of military personnel, the bioenvironmental group, and the on-base clinic.

B. Status (active, inactive, unknown; and nature of any site activity):

Active Air Force base

C. History (worker or nonworker injury; complaints from public; previous investigations or remedial action):

The MAFB is a RCRA facility and a CERCLA site. The site is on the National Priority List.

D. Principal Materials Handling Activities (type, amount, and location of wastes or hazardous materials disposed of, stored, treated, or handled at the site):

Not applicable.

E. Features and Unusual Features (water supply, telephone, radio, power lines, gas lines, watermains, suspect terrain, etc.):

Utility lines, both above ground and below ground, may pose a safety hazard for team members during excavation or boring. If a driller is used, the driller must maintain a safe clearance (at least 20 feet) between overhead utility lines and the drill-rig mast at all times during site operations. The location of utility lines must be determined prior to startup and the utility must be contacted 48 hours prior to excavation or drilling by contacting Underground Services Alert at 800/422-4133 and Tom Egan, MAFB Engineering at 916/643-4875.

III. WASTE CHARACTERISTICS

A. Waste Type(s):

Liquid _X_ Solid _X_ Sludge _X_ Gas _X_

B. Characteristic(s):

Corrosive _X_ Ignitable _X_ Radioactive __ Mixed Waste __

Volatile _X_ Toxic _X_ Reactive __ Unknown __ Other (name) __

IV. HAZARD EVALUATION

A. Overall Hazard Level:

The hazard level of each activity will be assessed and reported on the addendum form.

B. Chemical Hazards:

The major types of processes in operation on the base are paint removal, painting, plating, and foundry. Each process has overall types of chemicals that are associated with the process. For example, in the removal of paint, paint removers containing compounds such as methylene chloride, are used. In the painting operations, toluene- and xylene-based paints are applied to parts. Plating processes contain several types of chemicals including degreasers, acids, rust removers, and cyanide. Finally, foundries may contain metallic fumes. The above processes are not inclusive of all the base operations as are the examples of the process associated chemicals. Therefore, for each task and/or site visit, a SSP addendum will be attached to the overall SSP which addresses each site's hazard. The addendum will contain more detailed information on chemical hazards and will address task and/or site-specific chemical hazards.

C. Physical Hazards:

The major potential physical hazards possible at the site are: flammability of vapors, explosive conditions; utilities; moving and mobile equipment; trips, slips, and falls; and heat stress. These physical hazards may not represent every site at MAFB, therefore, for each task and/or site, a SSP addendum will contain more detailed information on physical hazards and will address task and/or site-specific physical hazards.

Explosions of vapor in confined spaces can be fatal, and workers must be attentive to this danger and guard against carelessness at all times. The lower explosive limit (LEL) is compound specific. When the vapors are heavier than air, their explosivity and flammability hazard are increased. Vapors will tend to concentrate near the ground and in low lying areas, and will not be readily mixed or diluted with ambient air. When monitoring LEL, it is important to take measurements at ground level. In order to prevent explosivity and flammability hazards, each team member must make sure that no spark sources, such as lighters, matches, unapproved flashlights, etc., are brought into the exclusion zone. The Site Safety Coordinator (SSC) must inspect the exclusion zone for spark sources including wiring, motors, etc., and enforce the requirements for fire prevention, including intrinsically safe electrical equipment, spark arrestors on vehicles, and exclusion of unauthorized personnel.

D. Hazards Posed by Site Activities:

Hazards may exist from moving process equipment (such as pumps and conveyors and mobile equipment (such as forklifts). Personnel must be alert for these hazards, and protect clothing and hair from entrapment in equipment, and use common sense in these situation. To protect from slips, trips, and falls,proper precautions and good judgement must be exercised. Personnel should be especially alert when working near pits and excavations. Exercising caution, using safe ladder practices, and using the buddy system around stacks is important.

E. Heat and Cold Stress Hazards:

Heat stress is a hazard of concern during summer months. Heat stress at hazardous waste sites usually occurs because impermeable protective clothing decreases natural body ventilation. Attachment B addresses heat stress hazards specifically.

F. Biological Hazards:

G. Unusual Hazards:

(Note: List unique hazards of site, if any.) (Insects, snakes, microbes, etc.)

H. Hazards Posed by Chemical Substances Provided by CH2M HILL:

In accordance with 20 CFR 1910.1200, Hazard Communication, Material Safety Data Sheets are provided for the following chemicals: (list) (Examples, sample preservatives, calibration gases, etc.)

V. PROCEDURES

A. SITE ORGANIZATION:

Map/Sketch Attached _Yes_ Site Secured _Yes_

Perimeter Identified _Yes_

Zone(s) of Contamination Identified _No_

B. SITE PERSONNEL:

Team Organization

Team Member/Office	Responsibility
Starr Dehn/SAC	Project Administrator/Observer
John Castleberry/SAC	Project Scientist/Level C
Susanne Davis/SAC	Project Scientist/Level C
Bill Morgan/MGM	Project Scientist/Level C
John Spitsley/RDD[a]	Project Scientist/Observer
Allison Gammel/SFO[a]	Project Scientist/Observer
Pamela Beekley/SAC[a]	Project Scientist/Observer
Sue Keydel/SFO	Project Scientist/Level C SSC
Robert Koster/SAC	Project Scientist/Level C
Karla Ebert/SAC	Project Scientist/Level C SSC
Chuck Ouellette/SAC	Project Scientist/Level C

[a]Observers must remain in clean areas and upwind of the exclusion zone. Observers will not conduct sampling activities.

Each of the team members named above has been certified as fit for the anticipated work by the CH2M HILL medical surveillance program, and has completed the training requirements of 29 CFR 1910.120. In addition, each is currently certified by the American Red Cross, or equivalent, in both first aid and CPR.

C. ONSITE ENGINEERING CONTROLS:

Onsite engineering controls include covers for waste piles and cuttings and barricades to keep unauthorized people from entering contaminated areas.

D. WORK PRACTICES:

Site personnel will avoid any visibly contaminated areas onsite. In general, work practices shall be designed to decrease time of exposure, increase distance to the source, or shield the exposed individual.

E. PERSONAL PROTECTIVE EQUIPMENT:

Basic Site Level of Protection:

A ____ B ____ C _X_ D _X_

Polycoated Tyvek coveralls with nitrile outer gloves and latex inner gloves will be worn when splash protection is needed. Nitrile outer gloves and latex inner gloves will be worn during sampling and when handling samples. Safety glasses, hard hat, and neoprene steel toe/shank boots will be worn while onsite. A TLD or equivalent badge must be worn by all team members.

Level C will include the equipment listed above plus a full-face air purifying respirator (APR) with organic vapor cartridges (GMC-H).

Task	Initial Level of Protection
Site inspection and walkthrough	Level D
Source testing	Level C (may be downgraded to Level D by SSC if HNu readings are less than 1 ppm.)
Treatability studies	Must prepare an amendment with further descriptions of each activity to be conducted.
Other tasks	Must prepare an amendment with further descriptions of task

F. GENERAL HAZARDOUS WASTE SITE MONITORING EQUIPMENT AND PROCEDURES:

Periodic monitoring of the site is required to determine the effectiveness of engineering controls, to re-evaluate levels of protection, and determine if site conditions have changed. At a minimum, monitor at the beginning of each shift, periodically (e.g., every 15 minutes) throughout the work, whenever work begins at a new area onsite or when different contaminants are encountered or a different work activity begins. Specific monitoring locations and frequencies are given below.

Carefully inspect each piece of monitoring equipment prior to work startup. Failure of any of the equipment listed below to work properly must be reported to the Project Manager immediately.

1. Explosimeter/0_2 meter: Calibrate prior to each day's activities according to manufacturer's instructions. Recharge at the end of each day. Monitor (Note to Preparer: Specify frequency, location) and record measured levels in the log book (Note to Preparer: Specify frequency).
   Action levels:

   Explosive Atmosphere (measured at source, i.e., borehole, test pit, etc.)

   Action Levels (measured at the borehole):

   - Less than 5 percent LEL--Continue drilling.
   - Greater than 5 to 20 percent LEL--Continue drilling with caution.
   - Greater than 20 percent LEL-Shutdown drilling operations and allow area to ventilate until LEL falls below 10 percent before resuming work. Mechanical ventilation (i.e., blower) may be required to reduce flammable vapors to below 20 percent. Do not place blower in atmospheres greater than 20 percent of the LEL.

   Oxygen (measured in breathing zone)

≤19.5%	Shut down drilling operations and ventilate until O_2 increases to above 19.5%
19.5% to 25%	Monitor
≥25%	Evacuate

2. Rad-mini (used at sites where exposure to ionizing radiation is not expected): Check background and check response using a Coleman lantern mantle. Monitor continuously and record location and time of alerts in the log book.

   Action levels: The Rad-Mini is used on initial entry to sites or where exposure to radiation is not expected but may occur (trenching operations, opening containers, etc.). The Rad-mini sounds an alarm at 10 mRem/hr. Site personnel will mark the spot where the alarm occurred, leave the site following as nearly as possible the path taken into the site, and call the Project Manager to arrange for health physics support. The following action levels apply during routine use of radiation survey meters at sites where exposure to radiation is not expected but may be possible.

   - Background to 1 mR/hr above background--continue operations; identify zone of radiation contamination and minimize work time in this area.

   - 1 mR/hr to 2 mR/hr above background--notify SSP approver of measurements and any unusual conditions or specific control measures.

   - Greater than 2 mR/hr above background--stop operations; evacuate work area; and notify SSP approver. Field work will require health physics evaluation and protection measures to be implemented before proceeding with field activities.

3. HNU (with 10.2 eV Lamp): Calibrate prior to each day's activities, according to manufacturer's instructions. Record calibration in the SSC log book. Recalibrate after cleaning the lamp or when background levels drift. This instrument is sensitive to humidity and may require periodic lamp cleaning if it is humid. Monitor for background concentrations (specify frequency, location) and then upon initial entry record measured levels in the log books (specify frequency). Monitor continuously while drilling or performing intrusive activities. Readings should be recorded every 1/2 hours.

   Action levels: Note to preparer: Action levels for the 10.2 eV HNU are specified based on knowledge of the contaminants present, the response of the instrument to those contaminants or mixtures of contaminants, weather conditions, engineering controls. and level of personal protection being worn. In situations wher information does not exist for a more informed decision, monitor continuously, record readings at a minimum of 15-minute intervals and use the following action levels:

Reading	Action/PPE
0-1 ppm above background[a,b]	Level D; continue monitoring
>1-5 ppm above background[b]	Level C; full facepiece respirator with GMC-H cartridges. Continue monitoring.
>5 ppm	Call safety plan approver

[a]Background is established offsite and upwind before the start of daily activities.
[b]Readings are taken in the breathing zone over a 5-minute period.

G. SITE ENTRY PROCEDURES:

- Conduct Site Safety briefing before starting field activities
- Determine wind direction, install wind flags, and establish work zones onsite (e.g., exclusion zone; contamination reduction zone; and support zone)
- Set up decontamination facilities.
- If toilet facilities are not located within a 3-minute walk from the decontamination facilities, either provide a chemical toilet and hand washing facilities or have a vehicle available (not the emergency vehicle) for transport to nearby facilities.
- Conduct site entry monitoring using the HNu, explosimeter/ O_2 detector and Rad mini.

H. WORK LIMITATIONS: (Time of day, etc.)

- No eating, drinking, or smoking onsite.
- No contact lenses onsite.
- No facial hair that would interfere with respirator fit.

- Buddy system at all times in exclusion zone.

- CH2M HILL employees to wear TLD badges or equivalent at all times when on or near the site.

- Site work will be performed during daylight hours whenever possible. Any work conducted during hours of darkness will require the following minimum illumination intensity:

General Site Areas	5 foot-candles
First Aid Station/Office/Lab	30 foot-candles
Storerooms, Changehouse, Toilets, Rest Areas	10 foot-candles

- Motors used in the exclusion zone will be non-sparking electrical motors or equipped with spark arrestors.

- Fuel supplies will be properly stored and grounded.

I. DECONTAMINATION PROCEDURES:

Set up decontamination area upwind of the exclusion zone. Water and TSP detergent should be placed in buckets prior to beginning work. The decontamination area should be a sufficient distance from the work in the exclusion zone so that the decon area will not become contaminated by splashing water or flying dirt.

Personnel Decontamination Procedures:

Wash boots and outer gloves in detergent and water, rinse, and remove outer gloves; remove and bag coveralls; if cotton coveralls are used, bag in plastic bags and wash prior to rewearing; remove respirator, if worn; remove surgical gloves and dispose in a plastic trash bag; wash hands and face; sanitize respirator nightly, if used; take a shower and wash hair as soon as possible after leaving the site.

Equipment Needed:

Buckets, detergent, cleaner-sanitizer, brushed, garbage bags, hand soap, and paper towels.

For Sampling Equipment:

Follow procedures outlined in sampling plan.

For Heavy Equipment:

Wash off the bucket of the backhoe or the drilling equipment with detergent and water; rinse in water. Use the hNu to monitor the backhoe or drilling equipment. If hNu readings are detected from the equipment, steam clean it prior to removing it from the site.

Documentation:

It is the responsibility of the SSC to make sure that all equipment coming offsite is properly decontaminated according to the procedures outlined above. At a minimum, visual indication of contamination will be removed, and no organic vapors detectable above background should remain. The equipment and samples will be clean, dry, and free from stains, deposits, encrustations, or discoloration. Documentation of decontamination must be made in the field log notebook, which will bec ome part of the permanent project file. A suitable tag is to be placed on each piece of decontaminated CH2M HILL equipment (or group of equipment, such as a bag of hand tools) stating the date of decontamination and initialed by the SSC.

J. MATERIAL HANDLING PROCEDURES:

The following general material handling procedures apply:

- Drums and containers meeting the appropriate DOT, OSHA, and EPA regulations for the waste contents (e.g., decon water) will be used.
- Site operations will be organized to minimize the amount of drum or container movement.
- DOT salvage drums and suitable quantities of absorbent will be available and used on sites where hazardous waste spills could occur.
- Electrically powered material handling equipment used to transfer decon solutions will meet the requirements of 29 CFR 1910.307 for the classification of materials being handled.

Disposal of Materials Generated During Field Work:

- Material generated during field work (decontamination fluids, disposable protective gear or sampling devices, drilling cuttings, well development fluids, etc.) will be considered as contaminated and handled accordingly unless adequate monitoring or analytical data exists to properly classify the materials as non-hazardous.

- Material generated offsite (well drilling fluids, etc.) will be returned to the site unless otherwise specified by the site owner or responsible party.

- Ultimate responsibility for disposal of the material rests with the site owner or responsible party. CH2M HILL may coordinate analysis, packaging, storage, transport and disposal of waste material, but will not assume responsibility for the waste (i.e., sign manifests as generator, etc.). Prior to beginning field work, the waste handling procedures will be agreed to with the client, site owner, and / or responsible party.

- Laboratory samples will be returned to the site, client, site owner, or responsible party for disposal following analysis unless otherwise specified.

VI. EMERGENCY RESPONSE PLAN

A. Pre-Emergency Planning:

The SSC is to perform the following pre-emergency planning tasks before starting field activities and will coordinate emergency response with the operating facility when appropriate:

- Locate nearest telephone to the site and inspect onsite communications (air horns, two-way radios).

- Confirm and post emergency telephone numbers (Form 311) and route to hospital.

- Post site map marked with locations of emergency equipment and supplies.

- Review emergency response plan for applicability to any changed site conditions, alterations in onsite operations, or personnel availability.

- Drive route to hospital.

- Evaluate capabilities of local response teams.

- Where appropriate and acceptable to the client, inform emergen cy room / ambulance service and emergency response teams of anticipated types of site emergencies.

- Designate one vehicle as the emergency vehicle; place hospital directions and map inside; keep keys in ignition during field activities.

- Inventory and check-out site emergency equipment and supplies.

- Setup emergency personnel decontamination station(s).

B. Personnel Roles and Lines of Authority:

The SSC takes the lead in emergencies. The SSC has the authority to stop any site activities posing an immediate health and safety hazard to site personnel and must notify the Project Manager or designee as soon as practical of this action. The Project Manager is ultimately responsibl e for health and safety of the CH2M HILL workers.

C. Training:

At least two personnel currently certified in both first-aid and CPR will be present during field activities within the exclusion zone. The site's Emergency Response plan will be reviewed in the initial site safety briefing and will include:

- Emergency procedures for personnel injury, or suspected overexp osures, fires, explosions, chemical, and vapor releases.

- Location of onsite emergency equipment and supplies of clean water.

- Local emergency contacts, hospital routes, evacuation routes, and assembly points.

- Site communication and location of nearest phone to the site.

- Names of onsite personnel trained in first aid and CPR.

- Notification procedures for contacting CH2M HILL's medical consultant and team member's occupational physician.

- The emergency response plan will be rehearsed at least once before site activities begin, and periodically afterwards.

- New workers on the site will be briefed on the emergency response plan before entering the exclusion zone.

D. Communications:

The "buddy system" will be enforced for field activities involving potential exposure to hazardous, toxic or radioactive materials, and during any work within the exclusion zone. Each person will observe his/her partner for symptoms of chemical overexposures or heat stress and provide emergency assistance when warranted. Personnel working in the exclusion zone will maintain line of sight contact or maintain communications (e.g., two-way radios) with the site support facilities. Offsite communications will consist of either onsite telephone service or using the nearest telephone to the site.

E. Emergency Signals:

The following emergency signals shall be used:

Grasping throat with hand	Emergency--help me
Thumbs up	OK; understood
Grasping buddy's wrist	Leave site now
2 short blasts or sounds, repeated	All clear
Continual sounding of horn	Emergency--leave site

F. PPE and Emergency Equipment and Supplies:

The following emergency equipment and supplies will be available onsite with the locations marked on the site map and posted in the support zone:

- 20-lb ABC fire extinguisher(s)
- First-aid kit
- Stretcher or blanket
- Supplies of clean water
- Eye wash
- Deluge shower (when required for emergency decon)
- PPE (protective clothing, boots, and gloves)
- Air monitoring equipment

G. Emergency Recognition and Prevention:

Prevention of emergencies will be aided by the effective implementation of the health and safety procedures specified in this SSP. The initial site safety briefing will emphasize recognition of the types of emergencies anticipated onsite. Periodic safety briefings will be conducted by the SSC as field activities proceed. Hazards that warrant specific emergency recognition and prevention techniques will be discussed.

H. Site Security and Control:

(Note to preparer: Identify, locate, and describe road and approaches to site, security measures such as fencing and guards, flagging or other means of marking zones, and access control procedures, such as sign-in logs, access control points, etc.)

I. Emergency Medical Treatment and First-Aid:

- Prevent further injury, perform appropriate decontamination, and notify the SSC and the Project Manager.
- Initiate first aid and get medical attention for the injured *immediately*.
- Depending upon the type and severity of the injury, call the medical consultant and/or occupational physician.
- Notify the Health and Safety Manager.
- Notify the injured person's personnel office.
- Notify the client representative.
- Prepare an incident report. The SSC is responsible for preparing and submitting the report to the Director of Health and Safety and to the CH2M HILL corporate personnel office within 48 hours.
- The SSC will assume charge during a medical emergency.

J. Emergency Routes and Telephone Numbers (Map to be Posted)

	Building 123
Duty Officer	32751 (on base) 916/643-2751 (of base)
Police	112 (on base) 916/643-6168 (off base)
Fire	117 (on base) 916/643-5622 (off base)
Emergency Assistance	116 (on base)
Ambulance	116 (on base)
Site Contact	916/643-3675--Charles Miles
Utilities	34875 (on base) 916/643-4875 (off base)
McClellan Clinic	35420 (on base) 916/646-8420 Urgent Care Hours: 0730 to 1900
General Hospital	American River Hospital 4747 Engle Road. Carmichael, CA 95608 916/848-2100
Directions to Hospital	Exist McClellan Air Force Base through the main gate to Watt Avenue. Turn right onto Watt Avenue and travel south to Whitney Avenue. Turn left onto Whitney Avenue and travel east t Mission Avenue. Turn left onto Mission Avenue and travel north to Engle Road. Turn right (east)onto Engle Road. Hospital is at 4747 Engle Road. (See attached map.)
CHEMTREC	800/424-9300
TOSCA Hotline	202/554-1404
CDC	404/452-4100
National Response Center	800/424-8802
EPA ERT Emergency	201/321-6660
RCRA Hotline	800/424-9346

K. Emergency Decontamination: Personnel will be decontaminated to the extent feasible (usually a "gross decon" or deluge) but life saving and first-aid procedures take priority over personnel decontamination efforts. The personnel decontamination procedures specified in Section V.J of this SSP will apply for injuries deemed non-life threatening by the SSC.

L. Evacuation Routes and Procedures: Onsite evacuation routes will be designated. Personnel will exit the site exclusion zone / contamination reduction zone and assemble at the onsite assembly point in the support zone. The SSC wi account for personnel at the onsite assembly point and notify local emergency responders. The SSC will assess the need for site evacuation based on the degree of hazard posed to site personnel remaining in the support zone. Offsite evacuation routes and assembly points will also be designated. A person designated by the SSC will account for personnel at the offsite assembly point. The SSC and an assistant will remain onsite in the event of site evacuation (if feasible) to assist local responders and advise them on the nature and location of the incident.

Onsite and offsite evacuation routes / assembly points will be designated on the site map and posted. They will be based on site topography and layout; anticipated safe distances for places of refuge; prevailing weather conditions; and anticipated location magnitude of site emergencies. Wind flags will be installed in the exclusion and support zones to assist personnel in determining upwind evacuation routes.

Evacuation Routes (Onsite and Offsite): Evacuation routes will be dependent on the type of accident and wind direction. MAFB has first and second responders to handle evacuations (see Section II, A).

Assembly Points (Onsite and Offsite): Assembly points vary by building and areas. Therefore, it will be the responsibility of the SSC to determine the assembly point for each location from the appropriate base representative.

M. Critique of Response and Follow-up: The SSC will evaluate the effectiveness of the emergency response and recommend procedures for improving emergency response to the SSP approver. Follow-up activities include notification of the injured person's personnel office within 24 hours of the injury. Incidents of suspected overexposures will require the notification of CH2M HILL's medical consultant and the injured's occupational physician so that they may provide assistance and relevant information to the local hospital's emergency room physician.

VI. EMERGENCY CONTACTS

- CH2M HILL Medical Consultant

Name: Dr. Kenneth Chase, Washington Occupational Health Associates, Inc.
Phone: 202/463-6698 (8-5 EST)
202/463-6440 (after hours answering service; physician will return call within 30 minutes)

- CH2M HILL Health and Safety Manager

  Name: David Lincoln/SEA
  Phone: 206/453-5005

- District Health and Safety Officer (HSO)

  Name: Lynn Laszewski/SEA
  Phone: 206/453-5005

- Occupational Physician

  Name: Dr. Allen Krohn
  Phone: 916/246-7464
  Address: Redding Industrial Occupational health Center
  1920 California Street
  Redding, California 96001

- Occupational Physician

  Name: Health Check
  Ralph K. Davis Medical Center
  Phone: 415/565-6000
  Address: Castro and Duboce Street
  San Francisco, California 94114

- Occupational Physician

  Name: Drs. Robinson, Webb, Strong, Yates
  Phone: 205/262-0342; 205/262-0390
  Address: 1722 Pine Street, Suite 309
  Montgomery, Alabama 36194-2701

- CH2M HILL Project Manager

  Name: Starr Dehn/SAC
  Phone: 916/920-0300

- Client Contact

  Name: Larry Button/Charlie Thorpe
  Phone: 916/643-1250

- CH2M HILL Regional Manager

  Name: Steve DeCou
  Phone: 916/920-0300

- Personnel Office

  Name: Scott Olsen
  Phone: 916/920-0300

If an injury occurs, notify the injured person's personnel office as soon as possible after obtaining medical attention for the injured. Notification MUST be made within 24 hours of the injury.

- CH2M HILL Director of Health and Safety for Waste Management and Industrial Processes

  Name: David Lincoln
  Phone: 206/453-5005
  Address:

- CH2M HILL Corporate Personnel Office

  Name: Marie Haezenbrouck/DEN
  Phone: 303/771-0900 (O)
  Address: CH2M HILL
  6060 South Willow
  Englewood, CO 80111

VIII. PLAN APPROVAL

This site safety plan has been written for the use of CH2M HILL's employees and subcontractors. CH2M HILL claims no responsibility for its use by others. The plan is written for the specific site conditions, purposes, dates, and personnel specified and must be amended if these conditions change.

PLAN PREPARED BY: Robert Evangelista (name/office/home phone) Date: 4/24/90

APPROVED BY: Jane Stansfield (name/office/home phone) Date: 4/27/90

APPROVED BY: ____________ (name/office/home phone) Date: ____________

(Note to Preparer: SSPs for sites where the potential exists for exposure to ionizing radiation require the approval of the Radiation Health Officer.)

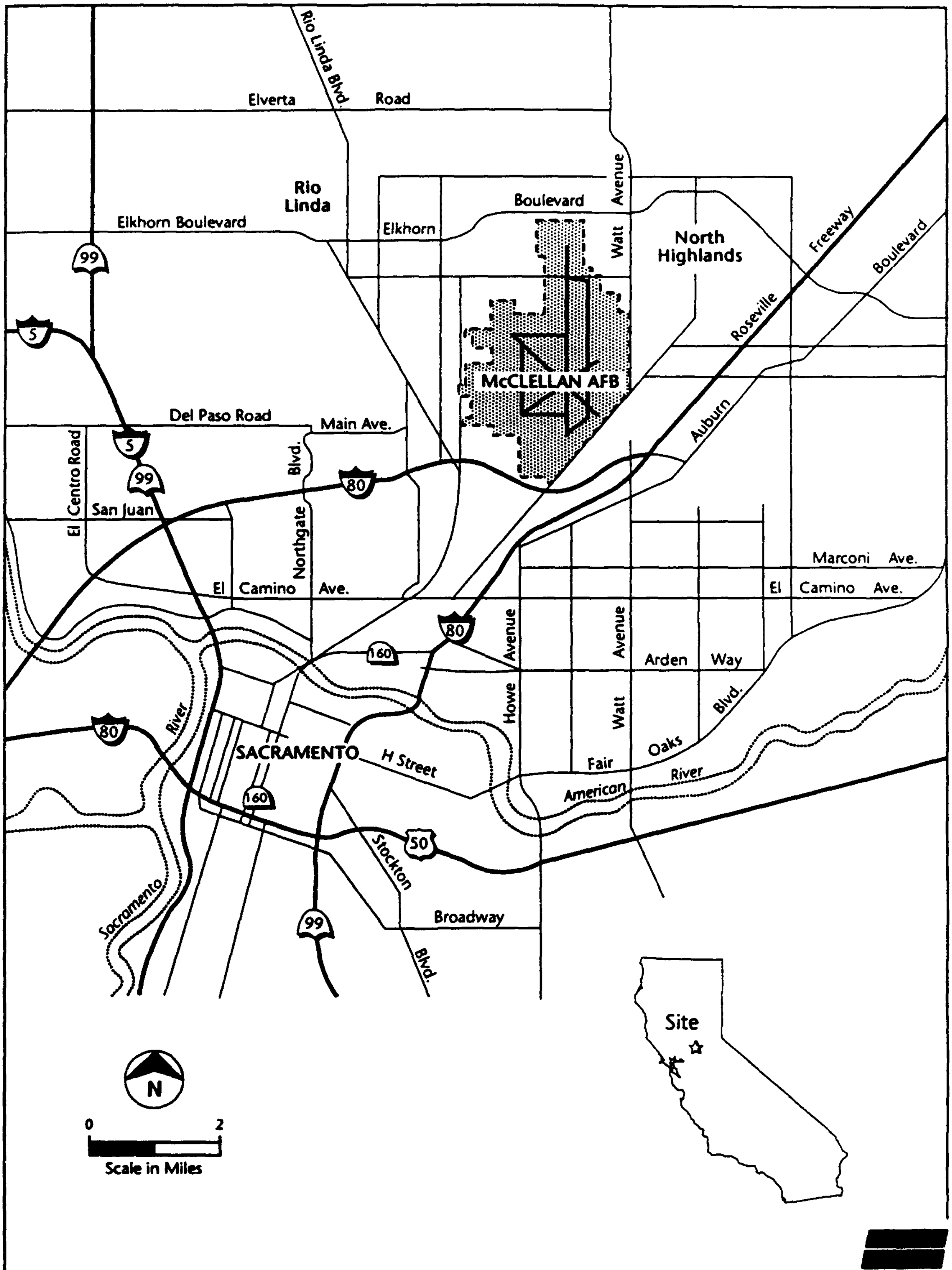
MODIFIED BY:	Karla Ebert/SAC	Date:	10/24/91
MODIFICATIONS APPROVED BY:	Jayne Stansfield/DEN	Date:	10/24/91

Attachments:

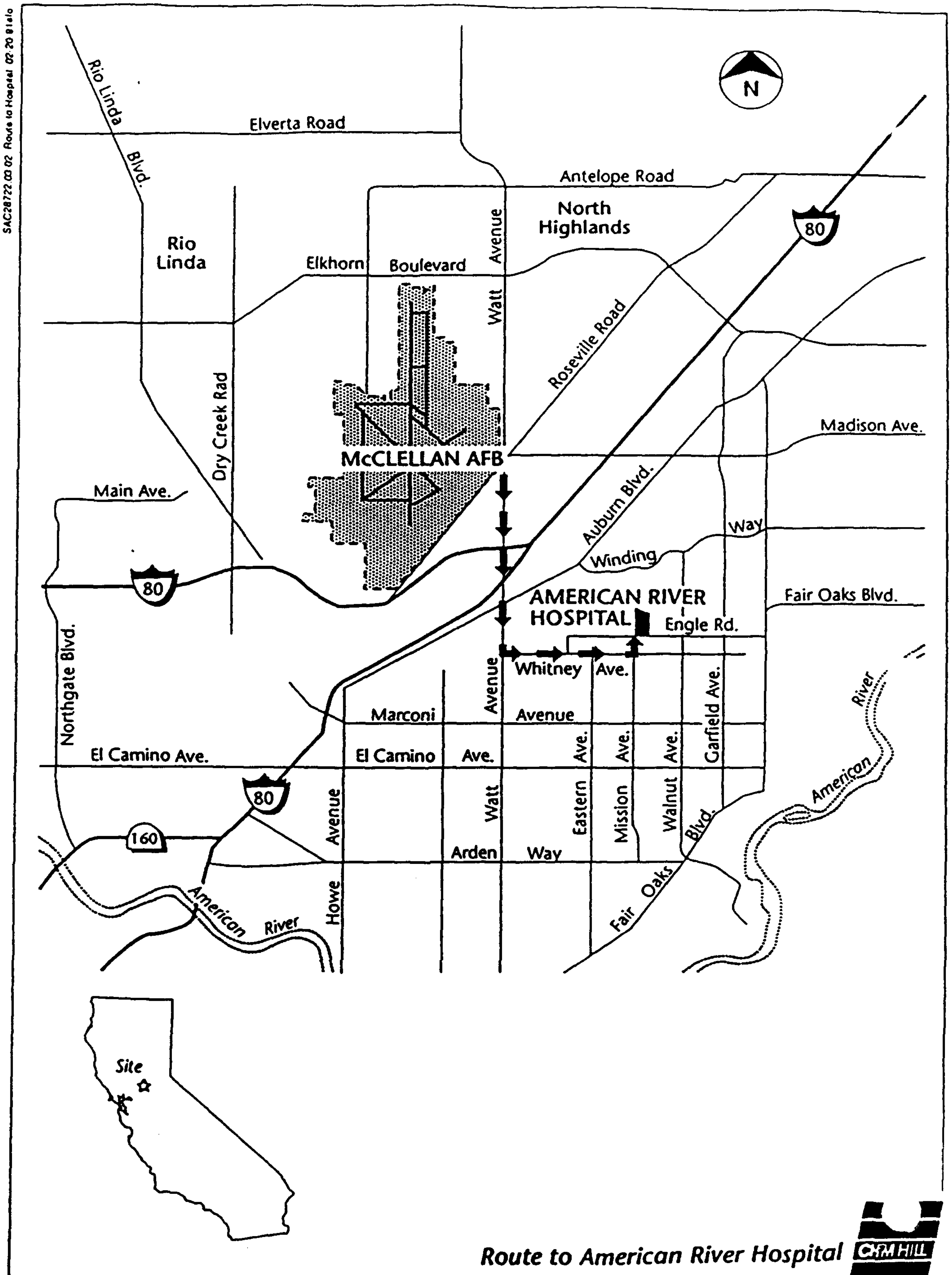
- Site Map
- Form 311, Emergency Phone Numbers
- Form 533, Record of Hazardous Waste Field Activity
- MSDS where applicable
- Attachment A--Descriptions of Planned Activities
- Attachment B--Heat Stress/Cold Stress Hazards
- Attachment C--Health and Safety Site Meeting
- Site Safety Plan Addendum

Distribution of approved plan:

Project Manager (responsible for distribution to team members and client)
Health and Safety Manager



Location of McClellan AFB
CH2M HILL



Route to American River Hospital

FORM 311
EMERGENCY TELEPHONE NUMBERS

Police Department	Address:	Phone: Contact:
Fire Department	Address:	Phone: Contact:
Paramedic	Address:	Phone: Contact:
Fire Report	Address:	Phone: Contact:
Ambulance Service	Address:	Phone: Contact:
Water Department	Address:	Phone: Contact:
Gas Utility	Address:	Phone: Contact:
Electric Utility	Address:	Phone: Contact:
Telephone Utility	Address:	Phone: Contact:
Hospital	Address:	Phone: Contact:
Owner	Address:	Phone: Contact:

This notice is located at : ______________________________

FORM 533
RECORD OF HAZARDOUS WASTE FIELD ACTIVITY

SITE NAME:
SITE SAFETY COORDINATOR:
PROJECT NUMBER:
RECORD OF ACTIVITIES FOR (DATES):

EMPLOYEE NAME / NUMBER	TOTAL DAYS ONSITE	DAYS IN LEVEL B	DAYS IN LEVEL C	DAYS IN LEVEL D	DAYS AS SSC LEVEL B	DAYS AS SSC LEVEL C	DAYS AS SSC LEVEL D	ACTIVITIES PERFORMED

Attachment A
DESCRIPTION OF PLANNED ACTIVITIES

This Description of Planned Activities encompasses a broad range of possible tasks to be issued as task orders against contract No. F04699-90-D-0035. This section defines the range of tasks CH2M HILL shall be responsible to perform as per Section 4.0 (Technical Requirements) of the above contract.

•Conduct field sampling of drums, spill sites, tanks (above and underground), monitoring wells, past waste disposal sites, etc., and perform sample characterization studies to include analysis of a wide variety of contaminants in complex matrices, including up to 297 compounds listed as hazardous by EPA.

•Perform laboratory and field tests of environmental monitoring and testing equipment, to include validation of manual/instrumental methods, continuous monitors, analytical support and Mathematical models using EPA, ASTM, NR, and/or equivalent procedures specified by the Air Force.

•Perform photogrammetric analyses of environmental and infrared photographs.

•Perform geophysical studies to include, but not be limited to, studies involving magnetometer, metal detection, earth resistivity, terrain conductivity, seismic, gravity, ground penetrating radar and shallow (less than 400 feet, in most cases) borehole logging.

•Perform hydrogeological investigations to determine the magnitude and extent of groundwater contamination.

•Determine the direction and rate of movement of contaminants and estimate the degree of risk associated with contaminant migration.

•Develop methods to mitigate the adverse environmental effects of pollutant migration.

•Develop leachate monitoring and analysis programs to comply with state or EPA regulations required for landfills and other hazardous waste treatment and disposal sites which are currently operated or have been operated in the past by the U.S. Air Force.

•Perform onsite geological/hydrological investigations required to assist the Air Force in selecting proper locations for new solid/hazardous waste treatment, storage, or disposal sites or other facilities.

•Perform sampling of soil and water in the unsaturated (vadose) zone above the water table using techniques recommended by the National Water Well Association (NWWA).

•Perform aquifer tests to determine the porosity, permeability, specific yield, drawdown and extent of cones of depression developed in aquifers in which contamination has been found or is suspected.

•Conduct comprehensive water supply and water distribution studies.

•Perform evaluations of domestic water, industrial wastewater, domestic wastewater, and groundwater treatment plants.

•Perform water and wastewater characterization, to include ambient short-term and continues water monitoring.

•Conduct inflow/infiltration studies into industrial, reclamation and groundwater extract/treatment systems at McClellan AFB and its Satellite Locations.

•Perform treatability studies, pilot plant investigations, and toxicity and bioassay determinations.

•Prepare evaluations and analyses providing sufficient detail to allow development of National Pollutant Discharge Elimination Systems (NPDES) permit applications, certifications and discharge monitoring reports.

•Conduct instream biological monitoring and fish-kill investigations.

•Perform laboratory analyses of potable water, groundwater, wastewater, soil, sludges, biologicals, fuels or commercial products and other environmental samples.

•Perform studies to ensure personnel safety, including the use of explosimeters, gas detectors, and survey meters and other equipment necessary to monitor air quality during site operations.

•Prepare evaluations and analyses, providing sufficient details to aid development of state or EPA-mandated permit applications, certifications, discharge monitoring reports and groundwater monitoring reports.

•Perform necessary analyses and reduction of any physical/chemical samples or data acquired under activities outlined herein.

•Provide analytical results in both hard copy and other formats suitable for archiving, including computer format.

•When required and specified in the delivery order, prepare sites for sampling/ monitoring and restore sites upon completion of work.

•Identify, evaluate, design and prototype processes, equipment, and facilities which minimize the generation of hazardous wastes or improve environmental quality.

•Develop permits and various applications as required by the guidance documents.

•Conduct Community Relations Program requirements in accordance with SARA.

•Prepare Site-Specific Spill Plans, maintain and reviewed annually in accordance with Air Force policy, guidance and directives.

•Develop Base Spill Prevention and Response Plans.

•Conduct quarterly review of regulatory requirements regarding the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Superfund amendments and on-going RCRA and CERCLA/SARA Programs and other background documents as required.

•Prepare Statements of Work.

•Perform waste minimization assessments and recommend process modifications that eliminate or reduce the use, generation, and disposal of hazardous materials within production process. The assessments shall include:

- Analyze the results of waste audits to identify the most promising areas for waste minimization.

- Identify, devise, and prototype new approaches to reduce and minimize hazardous wastes through process modification of emission/effluent control.

- Investigate process technology and develop conceptual system designs to prevent and reduce industrial pollution and hazardous waste generation.

- Determine the environmental consequences of present and proposed environmental regulations of any recommended process or equipment changes.

- Recommend control technology for toxics and pollutants to address recovery/recycle and reduction, optimization treatment (chemical and biological), onsite treatment, and substitution with less toxic/hazardous materials.

- Prepare detailed drawing packages, plans, and designs for waste minimization pilot projects relative to equipment design and modifications including charts, graphs, return on investments, and cost estimates.

- Document, evaluate, and integrate the results of pilot projects in ongoing industrial processes operations through process modifications or prototype development.

•Conduct and administer the Hazardous Waste Training Program to Base employees including requirements under 29 CFR 1910.120.

•Conduct Underground Storage Tank Annual Precision Leak Testing.

•Conduct Environmental Audit Assessment of base facilities and operation in accordance with Air Force and SM-ALC/EM policy, guidance, and directives.

•Perform Inspection Services and Construction Management for Environmental Investigations, construction Project or Remedial Action Implementation.

•Develop and maintain a computer data base for tracking hazardous waste generator/management data and all delivery order project information.

•Maintain an inventory of McClellan Air permits. Develop tracking system to monitor environmental compliance. This inventory and tracking system will be maintained in a microcomputer within the Directorate of Environmental Management.

•Provide engineering and services to operate and maintain interim Remedial Measures and Remedial Actions implemented by McClellan AFB in accordance with CERCLA/SARA. This includes the McClellan Groundwater and Treatment Plant and existing and future groundwater extractor systems. Operation and maintenance shall be conducted in accordance with existing procedures.

•Prepare Environmental Assessments for proposed Air Force activities in water usage, wastewater discharge, solid waste disposal, hazardous waste cleanup, and contaminated groundwater cleanup.

•Document performance of existing and future McClellan water, wastewater, solid waste, and groundwater treatment facilities (including groundwater extraction systems) to include performance evaluations of individual unit processes within a treatment facility.

•Prepare comprehensive studies to determine potable water supply, storage and distribution requirements for McClellan AFB and its Satellite Locations.

Appendix B

Well Logs

Attachment B
HEAT STRESS/COLD STRESS HAZARDS

Heat Stress

Wearing PPE puts a hazardous waste worker at considerable risk of developing heat stress. This can result in health effects ranging from transient heat fatigue to serious illness or death. Heat stress is caused by a number of interacting factors, including environmental conditions, clothing, workload, and the individual characteristics of the worker. Because heat stress is probably one of the most common (and potentially serious) illnesses at hazardous waste sites, regular monitoring and other preventive precautions are vital.

Monitoring Heat Stress. Because the incidence of heat stress depends on a variety of factors, all workers, even those not wearing protective equipment, should be monitored.

Workers wearing semipermeable or impermeable protective clothing should be monitored when the temperature in the work area is above 70°F (21°C).

To monitor the worker, measure:

- Heart Rate--Count the radial pulse during a 30-second period as early as possible in the rest period.
  - If the heart rate exceeds 110 beats per minute at the beginning of the rest period, shorten the next work cycle by one-third and keep the rest period the same.
  - If the heart rate still exceeds 110 beats per minute at the next rest period, shorten the following work cycle by one-third.
- Oral temperature--Use a clinical thermometer (3 minutes under the tongue) or similar device to measure the oral temperature at the end of the work period (before drinking).
  - If oral temperature exceeds 99.6°F (37°C), shorten the next work cycle by one-third without changing the rest period.
  - If oral temperature still exceeds 99.6°F (37.6°C) at the beginning of the next rest period, shorten the following work cycle by one-third.
  - Do not permit a worker to wear a semipermeable or impermeable garment when his/her oral temperature exceeds 100.6°F (38.1°C).

- Body water loss, if possible. Measure weight on a scale accurate to ±0.25 lb at the beginning and end of each work day to see if enougl fluids are being taken to prevent dehydration. Weights should be taken while the employee wears similar clothing or, ideally, is nude. The body water loss should not exceed 1.5 percent total body weight loss in a work day.

Initially, the frequency of physiological monitoring depends on the air temperature adjusted for solar radiation and the level of physical work (see Table 1). The length of the work cycle will be governed by the frequency of the required physiological monitoring.

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

Adjusted Temperature[b]	Normal Work Ensemble[c]	Impermeable Ensemble
90°F (32.2°C) or above	After each 45 minutes of work	After each 15 minutes of work
87.5°-90°F (30.8°C-32.2°C)	After each 60 minutes of work	After each 30 minutes of work
77.5°-82.5°F (25.3°-28.1°C)	After each 120 minutes of work	After each 90 minutes of work
72.5°-77.5°F (22.5°-25.3°C)	After each 150 minutes of work	After each 120 minutes of work

[a]For work levels of 250 kilocalories/hour.
[b]Calculate the adjusted air temperature (ta adj) by using this equation: ta adj °F = ta °F + (13 x % sunshine). Measure air temperature (ta) with a standard mercury-in-glass thermometer, with the bulb shielded from radiant heat. Estimate percent sunshine by judging what percent time the sun is not covered by clouds that are thick enough to produce a shadow. (100 percent sunshine = no cloud cover and a sharp, distinct shadow; 0 percent sunshine = no shadows.)
[c]A normal working ensemble consists of cotton coveralls or other cotton clothing with long sleeves and pants.

Prevention of Heat Stress. Proper training and preventive measures will help avert serious illness and loss of work productivity. Preventing heat stress is particularly important because once someone suffers from heat stroke or heat exhaustion, that person may be predisposed to additional heat injuries. To avoid heat stress, management should take the following steps:

- Adjust work schedules:
  - Modify work/rest schedules according to monitoring requirements
  - Mandate work slowdowns as needed
  - Rotate personnel: alternate job functions to minimize overstress or overexertion at one task

- Add additional personnel to work teams.

- Perform work during coolers hours of the day if possible or at night if adequate lighting can be provided.

• Provide shelter (air-conditioned, if possible) or shaded areas to protect personnel during rest periods.

• Maintain workers' body fluids at normal levels. This is necessary to ensure that the cardiovascular system functions adequately. Daily fluid intake must approximately equal the amount of water lost in sweat, i.e., 8 fluid ounces (0.23 liters) of water must be ingested for approximately every 8 ounces (0.32 kg) of weight lost. The normal third mechanism is not sensitive enough to ensure that enough water will be drunk to replace lost sweat. When heavy sweating occurs, encourage the worker to drink more. The following strategies may be useful:

  - Maintain water temperature at 50° to 60°F (10° to 15.6°C).

  - Provide small disposable cups that hold about 4 ounces (0.1 liter).

  - Have workers drink 16 ounces (0.5 liters) of fluid (preferably water or dilute drinks) before beginning work.

  - Urge workers to drink a cup or two every 15 to 20 minutes, or at each monitoring break. A total of 1 to 1.6 gallons (4 to 6 liters) of fluid per day are recommended, but more may be necessary to maintain body weight.

  - Weigh workers before and after work to determine if fluid replacement is adequate.

• Encourage workers to maintain an optimal level of physical fitness:

  - Where indicated, acclimatize workers to site work conditions: temperatures, protective clothing, and workload.

  - Urge workers to maintain normal weight levels.

• Provide cooling devices to aid natural body heat exchange during prolonged work or severe heat exposure. Cooling devices include:

  - Field showers or hose-down areas to reduce body temperature and/or to cool off protective clothing.

  - Cooling jackets, vests, or suits.

- Train workers to recognize and treat heat stress. As part of trainin identify the signs and symptoms of heat stress (see Table 2).

Table 2 SIGNS AND SYMPTOMS OF HEAT STRESS
• Heat rash may result from continuous exposure to heat or humid air
• Heat cramps are caused by heavy sweating with inadequate electrolyte replacement. Signs and symptoms include: - Muscle spasms - Pain in the hands, feet, and abdomen
• Heat exhaustion occurs from increased stress on various body organs including inadequate blood circulation due to cardiovascular insufficiency or dehydration. Signs and symptoms include: - Pale, cool, moist skin - Heavy sweating - Dizziness - Nausea - Fainting
• Heat stroke is the most serious form of heat stress. Temperature regulation fails and the body temperature rises to critical levels. Immediate action must be taken to cool the body before serious injury and death occur. Competent medical help must be obtained. Signs and symptoms are: - Red, hot, usually dry skin - Lack of or reduced perspiration - Nausea - Dizziness and confusion - Strong, rapid pulse - Coma

Cold Stress

Although northern California is not prone to bitter-cold temperatures, cold stress may still be a potential problem. Cold stress is possible when work performed over water is at temperatures of 50°F or less. The ultimate effects of cold stress is hypothermia, which is a decrease in the deep core body temperature. At temperatures of 35°F, workers in water, or whose clothing becomes wet, should be provided with an immediate change of clothing. They may need to be treated for hypothermia. Workers who wear impermeable protective clothing are susceptible to chilling because their cotton underclothing may become wet with perspiration.

Windchill index. The windchill factor is the cooling effect of any combination of temperature and wind velocity of air movement. The windchill index is shown in Table 3. The windchill index does not take into account that part of the body which is exposed to cold, the level of activity and its effect on body heat production, and the amount of clothing being worn.

Table 3
WINDCHILL INDEX

ACTUAL THERMOMETER READING (F)										
Wind speed in mph	50	40	30	20	10	0	-10	-20	-30	-40
EQUIVALENT TEMPERATURE (F)										
calm	50	40	30	20	10	0	-10	-20	-30	-40
5	48	37	27	16	6	-5	-15	-26	-36	-47
10	40	28	16	4	-9	-21	-33	-46	-58	-70
15	36	22	9	-5	-18	-36	-45	-58	-72	-85
20	32	18	4	-10	-25	-39	-53	-67	-82	-96
25	30	16	0	-15	-29	-44	-59	-74	-88	-104
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109
35	27	11	-4	-20	-35	-49	-67	-82	-98	-113
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116
Over 40 mph (little added effect)	LITTLE DANGER (for properly clothed person)				INCREASING DANGER (danger from freezing of exposed flesh)			GREAT DANGER (Danger from freezing of exposed flesh)		

Note: The human body senses "cold" as a result of both the air temperature and the wind velocity. Cooling of exposed flesh increases rapidly as the wind velocity goes up. Frostbite can occur at relatively mind temperatures if wind penetrates the body insulation. For example, when the actual air temperature of the wind is 40°F (4.4°C) and its velocity is 30 mph (48 km/h), the exposed skin would perceive this situation as an equivalent still air temperature of 13°F (-11°C).

Attachment C
HEALTH AND SAFETY SITE MEETING

We the undersigned have read this Site Safety Plan and fully understand its contents and will adhere to procedures set forth in this document.

Name	Affiliation	Title	Date

CH2M HILL Site Safety Plan
Addendum for Well Abandonment-Phase II
Addendum for field activities and site personnel
Addendum should be accompanied by the MAFB Master Site Safety Plan

McClellan Air Force Base
Sacramento, California

Client: McClellan Air Force Base
Project No.: SAC28722.31
Project Manager: Chuck Elliott
Site Name: McClellan Air Force Base
Dates of Field Visit: January through December, 1992

Purpose of Field Visit: During this phase of the project, CH2M HILL personnel will supervise subcontractors in the decommissioning of five base wells (BW-7, BW-13, BW-17, BW-20, and BW-28), two laundry wells (LW-1 and LW-2), and two seismic wells. CH2M HILL personnel will also supervise subcontractors in the modification to BW-8. Decommissioning involves the following tasks: pull existing pumps from the wells, bail waste oil from the wells, perform downhole television surveys, perforate the casing, and inject cement grout under pressure to fill the well from bottom to top.

Hazard Evaluation: Onsite activities involve potential hazards of heat stress; vehicular traffic on roadways; and a slight possibility of exposure to the bacteria that causes Lyme disease through contact with the rabbit population in the area.

Well abandonment activities pose safety hazards to personnel in the immediate vicinity of heavy equipment such as the drill rig and cement mixers. To protect personnel from overhead falling objects (i.e., bolts, wrenches, pieces of pipe), hard hats must be worn in the immediate vicinity of the drill rig. Safety glasses are also required to protect against flying projectiles that could be caused by hammering fittings/connections and driving casing. Drilling activities near overhead electrical lines will be avoided. The drill rig mast shall remain as far as practical from all overhead utility lines. Continuous monitoring with an HNu will be performed to identify potential inhalation hazards.

A summary of hazards from chemical constituents found at one or more of the well sites is presented below.

Chlorinated Solvents: Possible low levels of chlorinated compounds may be encountered in groundwater from the well. The primary avenue of exposure is inhalation and dermal contact. Some of these compounds act as central nervous system depressants that produce visual disturbances, mental confusion, fatigue, and nausea. The OSHA PELs for chlorinated solvents can be as low as 1 ppm, depending on the solvent.

Metals: Heavy metals typically have a high affinity for soil particles, creating potential for both inhalation and dermal contact from dust created during drilling operations. Metals are absorbed in the bloodstream and produce fever, dizziness, mental confusion, and nausea. The OSHA PELs for several heavy metals are: arsenic 0.5 mg/m^3, cadmium 0.2 mg/m^3, lead 50 micrograms per cubic meter (ug/m^3), antimony 0.5 mg/m^3, and barium 0.5 mg/m^3.

Solvents and Paints: Organic chemicals in general act as anesthetics and irritants to the eyes, respiratory system, and skin. Eye contact may cause irritation, dermatitis, cell damage, and necrosis. Chronic toxicities include kidney, liver, heart, and lung damage. The OSHA PELs for common solvents and paint constituents are: toluene 100 ppm, xylene 100 ppm, acetone 750 ppm, and benzene 1 ppm.

During Phase I of this project, the Explosimeter, the Rad-mini and the HNU were used for monitoring purposes. The only "hits" were observed on the HNU when monitoring inside the well.

Site Personnel:

Team Member	Responsibility
Chuck Elliott	SSC Level C
Rob Pexton	Field Scientist
Chuck Ouellette	Field Engineer
Suzanne Davis	Field Engineer
Karla Ebert	Field Scientist

Level of Protection:

A ______ **B** ______ **C** __X__ **D** __X__

Poly coated Tyvek coveralls with nitrile outer gloves and latex inner gloves will be worn when splash protection is needed. Nitrile outer gloves and latex inner gloves will be worn during sampling and when handling samples. Safety glasses, hard hat, and neoprene steel toe/shank boots will be worn while onsite. A TLD or equivalent badge must be worn by all team members.

Monitoring Equipment: The HNU with the 11.7 eV lamp will be used at the site for monitoring purposes. The 11.7 eV lamp will be used because many of the chlorinated solvents have ionization potentials above 10.2 and are therefore not detected by the 10.2 eV bulb. Readings will be recorded every half hour. Continuous monitoring will occur while drilling or performing intrusive activities. The following action levels will be used:

Reading	Action
0-1 ppm	Level D; Continue Monitoring
1-5 ppm	Level C; Full facepiece respirator with GMC-H Cartridges. Continue Monitoring.
>5 ppm	Call Safety Plan Approver

Equipment will be calibrated offsite and upwind before the start of daily activities. Reading will be taken in the breathing zone over a 5-minute period.

Personal Restrictions: The cementers are not 40-hour health and safety trained for hazardous waste work. Because they do not have the appropriate training, they will not be allowed to work within the exclusion zone. The cementers will set up their operations at least 25 feet upwind from the well head and will not enter the exclusion zone at any time. A 25-foot radius circle will be established as the exclusion zone around each well. It will be delineated with flagging tape, cones, and barricades. It is the responsibility of the SSC to enforce the policy that non-trained personnel will remain outside this zone.

Any equipment that is used in the exclusion zone must be decontaminated prior to the cementers handling the equipment.

Addendum Written By: Karla Ebert/SAC

Date: 12/3/91

Addendum Approved By: Allen Macenski/LAO

Date: 12/3/91

Appendix C
Cement Bond Logs

7N/5E·1N1 — 1N1 —

USGS-CAL-T1
May 1948

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

No. 9/5E-1N1
Other Nos. 24[illegible]

WELL LOG

State Calif. County Sacramento Subarea Arcade

Owner McClellan Field Well 1

Location 1550 feet north, 4650 feet west of SE corner of section 1 (USGS-FK)

Drilled by Eaton Address Woodland

Date April 1937 Casing diam. 24" Land-surf. alt. 74

Source of data U.S.Army - Mr. Knapton

(Enter type of well, perforations, yield, and drawdown at end of log)

Correlation	Material	Thickness (feet)	Depth (feet)
	clay and hardpan		30
	sand (water)		36
	hardpan		83
	sand (water)		89
	clay, gray		133
	sand, gray packed		174
	hardpan and sandstone		232
	sand (water)		236
	hardpan		247
	sand (water)		252
	sand and gravel		266
	clay		268
	sand and gravel		294
	hardpan		311
	sand		315
	hardpan (broken by sand and gravel)		378
	sand and gravel		396
	hardpan		400

C-2

Record by FK Date 9-27-48 Sheet 1 of 1

9N/5E·1N2
-1N2-

USGS-CAL-T1
May 1948

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

No. 9/5E-1N2
Other Nos. 24

WELL LOG

State Calif. County Sacramento Subarea Arcade

Owner McClellan Field Well 2

Location 2100 feet north, 4650 feet west of SE corner of section 1 (USGS) FK

Drilled by Eaton Address

Date April 1937 Casing diam. 24" Land-surf. alt. 75

Source of data U. S. Army

(Enter type of well, perforations, yield, and drawdown at end of log)

Correlation	Material	Thickness (feet)	Depth (fee
	clay and hardpan, red sandy		33
	sand		38
	hardpan		54
	hardpan, broken		68
	hardpan		30
	sand		84
	hardpan		104
	sand		110
	clay		143
	sand		155
	hardpan		170
	clay		176
	sand		178
	hardpan		186
	sand		197
	hardpan		214
	clay		217
	clay and hardpan		276
	sand		298
	hardpan		309
	sand		315
	hardpan		342
	sand		363
	hardpan		372
	sand		405

C-3

Record by ... Date ...

USGS-CAL-T1
May 1948

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

-1P1-

No. 9/5E-1L1

Other Nos. 37½

WELL LOG

State Calif. County Sacramento Subarea Arcade

Owner McClellan Field Well 8

Location 1350 feet north, 2750 feet west of SE corner of section 1 (USGS) FK

Drilled by not stated Address

Date July 1942 Casing diam. 24" Land-surf. alt. 80

Source of data U. S. Army - Mr. Knapton

(Enter type of well, perforations, yield, and drawdown at end of log)

Correlation	Material	Thickness (feet)	Depth (feet)
	fill		6
	hardpan		24
	sand		41
	clay, hard		54
	hardpan and clay		97
	clay, sandy gray		115
	sand and gravel, fine		130
	clay, sandy		159
	lava and hardpan		181
	sand and gravel		192
	hard cemented formation		198
	sand and fine gravel		224
	hard lava sand		255
	gravel, fine		261
	cemented formation, hard		269
	gravel and sand, fine		277
	cemented formation, hard		281
	cobbles and gravel		325
	sand and gravel		398
	perf; 170-398		

USGS-CAL-T1
May 1948

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

No. 9/5E-11A1
Other Nos. 25

WELL LOG

State California County Sacramento Subarea Arcade Well #7

Owner War Department, Quartermaster Corp., McClellan Field, Contract 787 qm 55CIN Ite

Location

Drilled by Aulman Address

Date July 1941 Casing diam. Land-surf. alt. 70'

Source of data Driller

(Enter type of well, perforations, yield, and drawdown at end of log)

Correlation	Material	Thickness (feet)	Depth (feet)
	Red soil		1
	Hard pan		8
	Hard brittle lava sand		9
	Hard pan		1
	Hard brittle lava sand		18
	Clay, yellow		22
	Hard sand		24
	Loose sand		25
	Hard sand		26
	Fine gravel		30
	Hard lava		305
	Fine gravel		31
	Hard pan		33
	Sand and fine gravel		33
	Hard pan		37
	Sand and fine gravel		38
	Hard pan		

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Record by ok Date 9-20-48 Sheet of

USGS-CAL-T1
May 1948

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

No. 9/5E-11A2

Other Nos. 258

WELL LOG

State California County Sacramento Subarea Arcade

Owner U.S. Engineer Office McClellan Field - Rubber Conservation Bldg.

Location 4300 feet north, 900 feet west of SE corner of section 11 (USGS) FK

Drilled by Kirchgater Address

Date 1943 Casing diam. 12" Land-surf. alt. 70'

Source of data

(Enter type of well, perforations, yield, and drawdown at end of log)

Correlation	Material	Thickness (feet)	Depth (feet)
	soil		2
	hardpan		12
	sand, brown		14
	clay		38
	sand, fine		41
	clay, white		87
	clay and sand mixed		102
	sand, (Water Temp. 68°)		104
	clay, yellow		135
	clay, brick		148
	sand, muck		155
	clay, white		176
	sandstone		210
	clay, brown		245
	sand, brown heavy with mica		256
	sand, coarse and gravel fine		270
	clay, soft and sand, fine, mixed		298
	clay, white sticky		305
	W. L. 31'		
	Perf: 245-270		
	1000 GPM @ 71'		

Record by Date t/hm 5-13-49 Sheet of

9N/5E-11E1

USGS-CAL-T1
May 1948

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

No. 9/5E-11E1

Other Nos. 35

WELL LOG

State Calif. County Sacramento Subarea Arcade

Owner McClellan Field, Well 17

Location 3450 feet north, 5100 feet west of SE corner of section 11 (USGS) FK

Drilled by Address

Date Casing diam. 14" Land-surf. alt. 60'

Source of data Mr. Knapton - McClellan Field

(Enter type of well, perforations, yield, and drawdown at end of log)

Correlation	Material	Thickness (feet)	Depth (feet)
	clay, red		2
	hardpan		39
	sand		45
	clay		53
	hardpan		53
	sand, lava sand		171
	cemented hard		179
	hardpan		216
	sand and fine rock		230
	cement hard		262
	sand, lava sand		275
	hardshell		276
	hardpan		284
	find gravel		290
	hardpan		300
	fine gravel		311
	hardpan, red		376
	sand, lava		390
	hardpan, red		441
	sand, lava		463
	hardpan		507
	sand, lava		530
	hard cement		532
	fine rocks		540
	hardpan		571
	sand, lava		595
	cement		597
	sand and rock		655
	lava		695
	clay, yellow		725
	hardpan		
	hard cement		
	hard gravel		
	gravel		
	clay, blue		881

(This well has high iron content below 300' and has been sealed off below that depth.)

C-7

ORIGINAL
File with DWR

CONFIDENTIAL LOG
Water Code Sec. 13752

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do Not Fill In

№ 58851

State Well No. 9N/5E-11M

Other Well No.

(1) OWNER:

Name McClellan AFB

Address Sacramento

(2) LOCATION OF WELL:

County

Owner's number, if any Well No. 18

Township, Range, and Section 09N 05E-11M

Distance from cities, roads, railroads, etc.

(3) TYPE OF WORK (check):

New Well ☒ Deepening ☐ Reconditioning ☐ Destroying ☐

If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☒ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☐
Cable ☐
Other ☐

(6) CASING INSTALLED:

STEEL: SINGLE ☒ DOUBLE ☐ OTHER:

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	From ft. (If gravel packed)	To ft. (If gravel packed)
0	408	14"		30"	0	408

Size of shoe or well ring: Size of gravel:

Describe joint

(7) PERFORATIONS OR SCREEN:

Type of perforation or name of screen

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.
169	185			
210	260			
304	349			
378	387			

(8) CONSTRUCTION:

Was a surface sanitary seal provided? Yes ☒ No ☐ To what depth 50 ft.

Were any strata sealed against pollution? Yes ☐ No ☒ If yes, note depth of strata

From ft. to ft.

From ft. to ft.

Method of sealing Cement Grout

(9) WATER LEVELS:

Depth at which water was first found, if known ft.

Standing level before perforating, if known ft.

Standing level after perforating and developing ft.

(10) WELL TESTS:

Was pump test made? Yes ☒ No ☐ If yes, by whom?

Yield: 1200 gal./min. with 59 ft. drawdown after — hrs.

Temperature of water Was a chemical analysis made? Yes ☐ No ☐

Was electric log made of well? Yes ☐ No ☐ If yes, attach copy

(11) WELL LOG:

Total depth ft. Depth of completed well ft.

Formation: *Describe by color, character, size of material, and structure*

ft. to ft.	
0 - 7	Hard Pan
7 - 11	Sandy Silt
11 - 14	Hard Pan
14 - 20	Fine Sand Gravel
20 - 30	Hard Sandy Clay
30 - 36	Fine Blue Sand
36 - 49	Sandy Clay
49 - 52	Sandy Clay Hard
52 - 65	Fine Sandy Clay
65 - 80	Fine Sand
80 - 90	Clay
90 - 92	Loose Shale
92 - 98	Hard "
98 - 136	Gray "
136 - 165	Hard Sandy Red Clay
165 - 192	Hard Shale [illegible]
192 - 207	Hard Red Sandy Clay
207 - 219	Yellow Clay
219 - 224	Clay Showing Sand
224 - 240	Sand
240 - 246	Cobble Stones (Gravel 2")
246 - 261	Sand
261 - 280	Cobble Stone (Gravel 2" Max)
280 - 318	Yellow Joint Clay
318 - 340	Red Sandy Clay
340 - 354	Clay
354 - 370	Fine Sand w/clay streaks
370 - 388	Fine Sand
388 - 404	Clay
404 - 408	Sand

Work started 10/18 1952, Completed 2/12 1953

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME J. B. Heard Co
(Person, firm, or corporation) (Typed or printed)

Address

[SIGNED]
(Well Driller)

License No. Dated 2/12/53, 19

SKETCH LOCATION OF WELL ON REVERSE SIDE

CONFIDENTIAL LOG
Water Code Sec. 13752

DWR 188 (REV. 9-68)

25179-950 9-68 30M TRIP OSP

STATE OF CALIFORNIA

(1) OWNER:

(2) LOCATION OF WELL:

2148

(3) TYPE OF WORK:

New well X

(4) PROPOSED USE: | (5) EQUIPMENT:

Other X | Rotary X

(6) CASING INSTALLED:

0 261 ft 6 Diam
0 71 12"

13 71
8 261

Describe joint welded

(7) PERFORATIONS:

Type of perforation mill

Size 3/18 in. length 1 1/2 in.

175 185
200 210
240 260

(8) CONSTRUCTION:

X Yes 71

From

Method of Sealing cement grout

(9) WATER LEVELS:

(10) WELL TESTS:

(11) WELL LOG:

0	4	top soil
4	40	hard shaley cla
40	130	shaley clay
130	135	coarse sand
135	175	shaley clay
175	185	coarse sand
185	204	shaley clay
204	208	coarse sand
208	254	shaley clay
254	260	sand & gravel

2 copies

6/19 62 6/29 6.

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Baton Drilling Co

Address P. O. Box 975

Woodland, California

[SIGNED] [illegible]

Well Driller

License No. 133713037 Dated

97729 6-57 80M GUIR SPO DWR 183 (REV. 3-64)

Appendix D
Response to Comments

RESPONSE TO COMMENTS

SUBJECT: Draft Well Closure Methods Report
Water Well Abandonment Phase II
McClellan AFB

REVIEWER: Alexander MacDonald, Regional Water Quality Control Board

DATE: June 30, 1992

Comment: Base Well BW-17 was drilled using the cable tool method. Thus, there is no gravel pack associated with the well. There are no special procedures provided in the report for dealing with this type of well. The current proposed procedures only deal with wells with an annulus and call for perforating the casing, along with pressure grouting. Staff does not recommend this procedure on a well without a gravel packed annulus. The well should be pressure grouted to the surface with no perforation of the casing.

Response: The main difference between a well drilled by the cable tool method and one drilled by the rotary method from a well abandonment perspective is that there is no gravel pack associated with the cable tool well. Base Well (BW-) 28 is also constructed by the cable tool method. Since there is no gravel pack, the calculation for cement volume must be adjusted. It is recommended that cement volumes be calculated based on the inside volume of the casing, plus an additional 10 percent to fill the micro-annulus outside the casing. This additional 10 percent is felt to be conservative since subsurface clays may be expected to have swelled up tightly against the well casing. The Well Closure Methods and Procedures Report (the Procedures) will be modified to reflect this approach. Otherwise the decommissioning approach should be the same as other wells, with grout applied under pressure in a series of lifts. This approach is felt to be necessary because of the heterogeneity of the subsurface geology in the vicinity of McClellan AFB. In this way, all zones outside the casing will be sealed for maximum protection against the possibility of contaminants migrating along the casing.

RESPONSE TO COMMENTS

SUBJECT: Draft Well Closure Methods Report
Water Well Abandonment Phase II
McClellan AFB

REVIEWER: Richard McJunkin and Will Rowe, Department of Toxic Substance Control, Technical and Support Services Branch

DATE: June 30, 1992

Comment: General

1) **Procedures**

The decommissioning methods outlined in the Procedures lack sufficient detail.

Recommendations

Each well addressed in the Procedures should have a detailed decommissioning plan tailored to local or well-specific lithology, yield, and construction features.

Response: It is not possible in this report to provide more details on the decommissioning approach with regard to well construction details because of the contradictory and often conflicting information that exists for the wells. Preliminary work on the wells will involve pulling pumps, cleaning the casing, jackhammering the pad to expose the gravel pack, and downhole television surveying. Following this work, it will be possible to describe in greater detail the decommissioning approach at individual wells (such as intervals that will be perforated, cement volume calculations, etc.) that are based on well construction details. This description will be written in a Technical Memorandum that will be prepared following the preliminary work. Regulatory agencies will have an opportunity to review this Technical Memorandum.

It is also not possible to account for well-specific lithology or yield in advance because of the complexity of the subsurface hydrogeology. The approach described in this report attempts to deal with these factors by field testing the approximate permeability of a given interval prior to cementing; varying the height of individual cemented intervals; and varying the composition of the cement and additives. These adjustments will be documented in the field notes and described in the Informational Field Report that will be prepared following the field work.

Comment: General

2) **Sample Wells Before Decommissioning**

Recommendation:

Before decommissioning, water levels should be measured and samples collected and analyzed. The water surface should be tested for floating product and, if present, a sample should be taken and analyzed.

Response: Water levels will be measured during the decommissioning of the wells. Floating products will be removed during preliminary work following removal of pumps from the wells. This product is expected to consist primarily of petroleum-based pump lubricating oil, and will be stored in 55-gallon drums. It will be tested as part of disposal, according to normal State of California procedures. Water in the wells will not be tested, because: (1) water will not be generated at the surface during normal abandonment procedures, and therefore will not have to be disposed; (2) appropriate sampling procedures would require that a large volume of water be pumped, and this water would require expensive disposal procedures; and (3) groundwater characterization samples to support the ongoing remedial investigation at McClellan AFB are best collected from monitoring wells, rather than these production wells with their lengthy perforated intervals.

Comment: General

3) **Decommission Uncomplicated Wells First**

Recommendation:

Before decommissioning complex wells, such as Base Well 7, decommission wells which are less likely to present technical problems. The experience gained from these wells will help with potentially troublesome wells like Base Well 7.

Response: The Procedures will be modified to reflect this approach. It is also hoped that experience gained during Phase I will prove valuable during the present work.

Comment: Well Decommissioning

These issues should be addressed in a work plan on a well-by-well basis. The following considerations should be applied to each well:

1) Identification of Low Permeability Zones

The Procedures do not discuss the locations of low permeability zones in the lithology of each well. Low permeability zones should be sealed to reestablish preexisting aquitards.

Recommendation:

Identification and sealing of low permeability zones in each well should be addressed in the Procedures. Well logs and geophysical logs should be presented with the description of decommissioning of each well. This information will dictate the location of perforating intervals.

Response: The Drillers Logs are often contradictory for base wells at McClellan AFB or are so inaccurate that they are almost unusable. Geologic and geophysical logs prepared in nearby monitoring wells are not usable because of the heterogeneity of the geology. This uncertainty is dealt with by pressure-grouting the entire well in a series of short lifts, and by varying the length of the lifts and the cement composition in response to observed conditions at a given well.

Comment: Well Decommissioning

2) Perforating the Casing

The Procedures do not discuss how casings will be perforated to assure sealing of the low permeability intervals and the filter pack.

Recommendation:

The Procedures should be amended to specify the methods for perforating blank casing in each well including perforation size, density, and depths, and interval lengths.

Response:

The Technical Memorandum will specify intervals of perforation in each well following the downhole television surveys that will indicate where the existing intervals of perforation lie. The entire casing will be perforated, with perforation of a given interval occurring immediately prior to cementing that interval. The Procedures specify that perforation will be with a mills knife perforator. Language will be added to show that perorations will be four per row, with one row per foot. Each perforation will be about one-third inch in thickness, and about 3 inches in length. The Technical Memorandum may also recommend that certain wells be perforated by explosive shot perforation, based on the conclusions drawn during the preliminary work.

Comment: Well Decommissioning

3) Grout Lifts

The Procedures insufficiently discuss how many lifts will be used. Insufficient criteria or rationale are provided for determining how many lifts will be used in well decommissioning. The section titled "Abandonment With a Packer" does not define how existing perforations, expected lithology, and the outcome of the previous lift will determine packer placement.

Recommendation:

The Procedures should include rationale and criteria for determining the number and placement of grout lifts in each well.

Response: The Procedures will be modified to provide more detail on this subject. It is expected that decommissioning at a given well will begin with a short lift of about 15 feet and that the lift size will increase if all goes well to a maximum of no more than 50 feet. As described in the comment above, the size of a lift will be influenced by the existing perforations, expected lithology, and outcome of the previous lift. More rationale and criteria will be included.

Comment: Well Decommissioning

4) Hydrofracting

The Procedures do not discuss how hydrofracting will be avoided during grouting. There is some discussion on page 48 of "rule of thumb" estimates of grout pressure; however, the Procedures do not describe how pressure will be monitored and controlled.

Recommendation:

The Procedures should be amended to include methods for determining appropriate pressure and pressure-control.

Response: Hydrofracting was discussed in the Procedures on page 47 under measures taken to avoid exceeding the fracture pressure of the formation. Pressure at the surface (downstream from the pump) will be monitored with a gauge. During Phase I, this pressure never exceeded 50 psi. Since this pressure is propagated evenly throughout the fluid, the pressure downhole should be equal to the pressure at the pump plus the pressure exerted by the column of fluid (0.458 psi/ft for water above the water table). The Halliburton "rule of thumb" says that hydrofracting will not occur if pressure does not exceed about 1 psi/ft beneath the ground surface. This pressure shculd not be exceeded at McClellan AFB, as long as gauge pressures at the surface do not exceed about 100 psi. The Procedures will be expanded to provide more discussion on these points.

Comment: Well Specific

1) Base Well 7

According to the Procedures, no information exists about the type of cement used, nor grout takes, during the original decommissioning of this well in the 1960s. Without this information, there is no way to gauge how effectively the filter pack was invaded by the original decommissioning.

Recommendation:

To assure and document that this well is properly decommissioned, it should be decommissioned after experience is gained by decommissioning a similar well in a non-contaminated area. Well LW-1 at Camp Kohler provides an opportunity to drill-out a grouted well and decommission by perforated casing and re-injecting. This experience will help in tackling the likely enormous technical problems presented by Base Well 7.

Response: The Technical Memorandum will propose an approach to decommissioning these wells after the television survey has been done. As suggested, BW-7 will be decommissioned after the Camp Kohler Laundry wells have been decommissioned.

Comment: Well Specific

2) Base Well 8

The Procedures explain that the upper zone of the well will be grouted, then rebored to allow continued use of the lower, uncontaminated interval. This approach may not completely seal the upper interval, especially when the emplaced grout is being drilled-out. During drilling, there is potential for the seal to be fractured, thereby introducing unseen contaminant pathways. This approach leaves too many potential problems unaddressed.

Recommendation:

The entire well should be completely decommissioned. Replacing it with a new well in a non-contaminated area assures the integrity of the seal which isolates the contaminated upper interval.

Response: McClellan AFB has decided to delay decommissioning BW-8 for about 6 to 12 months until water hook-ups with City of Sacramento have been accomplished. Until that time, BW-8 will remain inactive as a fire emergency well. After the water hook-up, BW-8 will be completely decommissioned as recommended. The Technical Memorandum will provide details on the approach to decommissioning.

RESPONSE TO COMMENTS

SUBJECT: Draft Well Closure Methods Report
Water Well Abandonment Phase II
McClellan AFB

REVIEWER: David Wang, Department of Toxic Substance Control

DATE: June 30, 1992

Comment: The workplan provides only general guidelines that may be followed for decommissioning base wells. A major element missing from the draft Well Closure Workplan is a description of the well perforation process. The Department believes the perforation technique applied to Base Well-1 (Well Closure - Phase I) may have caused the decommissioning problems encountered at Base Well-1. The Department recommends adding specific and detailed descriptions on the decommissioning procedures for each well.

Response: More detailed procedures will be provided in the Technical Memorandum that will be produced after the pumps are removed and the wells are television surveyed. Perforation procedures will depend on existing perforation intervals and an evaluation of the condition of the well casing based on the television survey. Perforations will be made only immediately prior to cementing a given lift of a well, and will typically be cut with a mills knife at four perforations per row and one row per foot of casing.

Comment: The Department does not support trying to keep Base Well-8 in operation for fire fighting. Nearby monitoring wells have found contaminated groundwater at 175-200 feet below ground surface. Partial decommissioning of the base well may not adequately prevent cross contamination of aquifers, and will impact the effectiveness of the lower section. The Department recommends using other base wells located further north for fire fighting reserves.

Response: McClellan AFB has decided to delay decommissioning BW-8 for about 6 to 12 months until water hook-ups with City of Sacramento have been accomplished. Until that time, BW-8 will remain inactive as a fire emergency well. After the water hook-up, BW-8 will be completely decommissioned as recommended. The Technical Memorandum will provide details on the approach to decommissioning.

RESPONSE TO COMMENTS

SUBJECT: Draft Well Closure Methods Report
Water Well Abandonment Phase II
McClellan AFB

REVIEWER: Mark Malinowski, Department of Toxic Waste Substances

DATE: June 30, 1992

Comment: General

The draft workplan should describe the well decommissioning process to be followed for each well. Previous perforation techniques applied to Base Well-1 (Well Closure - Phase I) may have caused the decommissioning problems encountered at Base Well-1. The perforation process, perforation intervals and number of lifts to be used should be described for each individual well.

If specific decommissioning information is not available or cannot be determined until after the well cleaning and video survey, the Department recommends a Technical Memo, describing the proposed decommissioning procedures for each well, be prepared and submitted to the agencies for review and comments.

The emphasis of well decommissioning should be placed on perforating and sealing the aquitard zones. Very little geologic information has been provided to ensure that the zones of interest are adequately determined prior to initiating decommissioning procedures. The Department recommends that nearby pilot boring and monitor well logs (lithologic and geophysical) be include during the discussion on zones considered for perforation.

The Department questions the necessity of running video surveys prior to cleaning the wells since the wells should be cleaned regardless of the video results. The video survey after the cleaning would serve to determine which well construction diagram is accurate.

Permits and regulatory requirements (State and local) should be included or referenced from Phase I workplan.

The Base Wells should be tested for water level, presence of floating product and sampled for contaminants prior to abandonment.

Decommissioning of BW-7 should be attempted after drilling-out the Camp Kohler well LW-1. The experience gained from the LW-1 well should help in the BW-7 effort.

The Department does not support trying to keep Base Well 8 in operation for fire fighting. Nearby monitoring wells have found contaminated groundwater at 175-200 feet below ground surface. Deeper aquifer zones have not been tested; however, con tamination is expected. The Department recommends using base wells located further north, if possible, for fire fighting reserves.

The Department requires that McAFB provide information on future efforts for Base Wells 4, 5, 9, 11, 14, 16, 22, 23, 24, Old BW-29 and the "Boy Scout Well".

Well construction diagrams should be included for each well and where possible lithologic logs from nearby pilot holes or monitor wells should be included for comparison to driller logs.

Response: It is not possible in this report to provide more details on the decommissioning approach with regard to well construction details because of the contradictory and often conflicting information that exists for the wells. Preliminary work on the wells will involve pulling pumps, cleaning the casing, jackhammering the pad to expose the gravel pack, and downhole television surveying. Following this work, it will be possible to describe in greater detail the decommissioning approach at individual wells (such as intervals that will be perforated, cement volume calculations, etc.) that are based on well construction details. This description will be written in a Technical Memorandum that will be prepared following the preliminary work. Regulatory agencies will have an opportunity to review this Technical Memorandum.

It is also not possible to account for well-specific lithology or yield in advance because of the complexity of the subsurface hydrogeology. The approach described in this report attempts to deal with these factors by field testing the approximate permeability of a given interval prior to cementing; varying the height of individual cemented intervals; and varying the composition of the cement and additives. These adjustments will be documented in the field notes and described in the Informational Field Report that will be prepared following the field work. Because of the continual variation characteristic of alluvial materials, it is best to pressure-grout the well casing throughout the entire saturated interval, rather than attempting to isolate aquitards and only sealing them.

It is recommended that television surveys be run both before and after cleaning the casing. For one thing, television surveys are relatively inexpensive to run. In addition, the first video may indicate that the casing is in poor enough condition that conventional wire brush cleaning would risk casing collapse and a more gentle cleaning or no cleaning may be warranted. Finally, in some cases the well casing may be found to be clean enough to allow adequate evaluation of the condition of the casing, and a second video may not need to be run.

It was found during the first phase that State and County permits were not necessary for well decommissioning at McClellan AFB, because the work is governed by the terms of the Inter Agency Agreement, which provides for supervision by representatives of the various agencies of the County and State.

Water levels will be measured during the decommissioning of the wells. Floating product will be removed during preliminary work following removal of pumps from the wells. This product is expected to consist primarily of petroleum-based pump lubricating oil, and will be stored in 55-gallon drums. It will be tested as part of disposal, according to normal State of California procedures. Water in the wells will not be tested, because: (1) water will not be generated at the surface during normal abandonment procedures, and therefore will not have to be disposed; (2) appropriate sampling procedures would require that a large volume of water be pumped, and this water would require expensive disposal procedures; and (3) groundwater characterization samples to support the ongoing remedial investigation at McClellan AFB are best collected from monitoring wells, rather than these production wells with their lengthy perforated intervals.

The Procedures will be modified to specify that LW-1 and LW-2 at Camp Kohler will be abandoned before BW-7. It is also hoped that experience gained during Phase I will prove valuable during the present work.

McClellan AFB has decided to delay decommissioning BW-8 for about six to twelve months until water hook-ups with City of Sacramento have been accomplished. Until that time, BW-8 will remain inactive as a fire emergency well. After the water hook-up, BW-8 will be completely decommissioned as recommended. The Technical Memorandum will provide details on the approach to decommissioning.

McClellan AFB will continue to evaluate other wells for decommissioning in the future. The Procedures attempted to facilitate this process by gathering information on well locations and construction details. It is expected that there will be a Phase III following completion of the present work.

Contradictory well logs and diagrams were obtained for various wells when gathering data for the preparation of the procedures, and therefore only the original Well Drillers Report was included for a given well when available. The Technical Memorandum that will be prepared following completion of the preliminary work will include actual information on well construction, as well as the appropriate geologic log, if available.

Comment: Page 4, paragraph 3, Permits and regulatory requirements should be included or referenced from Phase I workplan.

Response: It was found during Phase I that state and county permits were not necessary for well decommissioning at McClellan AFB, because the work is governed by the terms of the InterAgency Agreement, which provides for supervision by representatives of the various agencies of the county and state. However, because the regulatory requirements set standards that are met or exceeded in all phases of well decommissioning at McClellan AFB, Phase I work plan will be referenced in this context.

Comment: Page 18, Table 4 indicates a casing diameter of 16" while the drillers log indicates a 14". Correct or explain the discrepancy.

Response: The actual diameter is 16 inches, so the table is correct and the drillers log is incorrect.

Comment: Page 19, paragraph 3, The drillers log indicates a TD of 881 feet and the text indicates 930 feet. Correct or explain the discrepancy.

Response: The 930-foot depth was taken from McClellan AFB files. It is unknown which depth is correct. However, the actual original borehole depth will not affect the well decommissioning.

Comment: Page 20, The drillers log for a BW-20 should be included in the appendix. Logs form monitor wells 210 and 211 should also be presented.

Response: A drillers log was not located for BW-20. Available information was taken from McClellan AFB files. Geologic logs from wells 210 and 211 would serve no purpose since they are 500 feet away from BW-20.

Comment: Page 31, paragraph 4, BW-9. BW-9 should be further investigated and properly decommissioned in future efforts.

Response: Agreed. This well will be the object of future decommissioning efforts.

Comment: Page 35, paragraph 1, BW-15. BW-15 should be further investigated and properly decommissioned in future efforts.

Response: Agreed. This well will be the object of future decommissioning efforts.

Comment: Page 40, paragraph 5, Remedial efforts at the Davis site include implementation of a Remedial Investigation for groundwater contamination.

Response: The text will be modified to reflect this fact. The decommissioning of BW-26, however, is not a part of the Remedial Investigation.

Comment: Page 42, paragraph 2, What type of "licensed professional"?

Response: The text will be modified to read a "California Registered Geologist or Professional Engineer."

Comment: Page 42, paragraph 4, All equipment that comes into contact with groundwater should be decontaminated prior to arrival at each well.

Response: The text will be modified to reflect this statement.

Comment: Page 43, paragraph 1, Since the equipment used in cementing will be decontaminated, how will the equipment taken from base wells (pumps, bowls, strainers, etc.) be treated prior to sending to DRMO.

Response: All pump equipment will be steam-cleaned as it is pulled out of the well. Steam cleaning water will be allowed to run back down the well to avoid disposal problems. The text will be modified to reflect this statement.

Comment: Page 43, paragraph 4, The Department questions the necessity of running video surveys prior to cleaning the wells since the wells should be cleaned regardless of the video results. The video survey after the cleaning would serve to better determine which well construction diagram is accurate.

Response: It is recommended that television surveys be run both before and after cleaning the casing. First, television surveys are relatively inexpensive to run. In addition, the first video may indicate that the casing is in poor enough condition that conventional wire brush cleaning would risk casing collapse and a more gentle cleaning or no cleaning may be warranted. Finally, in some cases the well casing may be found to be clean enough to allow adequate evaluation of the condition of the casing, and a second video may not need to be run.

Comment: Page 44, paragraph 4, The technical memo should also include specific decommissioning information for each well (e.g. perforation interval, type of perforation tool-knife, bullet, explosive-, number of lifts needed and interval of lifts, etc.

Response: The Technical Memorandum will attempt to supply this information.

Comment: Page 47, paragraph 1, Perforation of the entire well and then cementing is probably the cause of the decommissioning problems encountered at BW-1 during Phase I. The Department does not support use of "perforation and cementing the entire casing in one lift" technique.

Response: This approach is only mentioned because it is the conventional method of decommissioning wells. The text goes on to say that the casing will be perforated just prior to cementing each lift (pages 48-49).

Comment: Page 48, Bullet 1. Describe the criteria to be used in determining if/when perforation of the casing is necessary.

Response: Blank sections of casing will be perforated prior to cementing unless the television survey reveals that the casing is too weak to sustain perforation.

Comment: Page 49, Bullet 4. The perforated interval(s) should be identified for each well.

Response: The Technical Memorandum will describe intervals to be perforated based on the results of the television survey, which will identify intervals of existing perforations. However, final decisions on perforation will be made in the field and be based on results of prior episodes of perforation for that well.

Comment: Page 49, paragraph 2. Specify if wells located within buildings will not be excavated 3 feet below grade.

Response: Wells located within buildings will not be excavated 3 feet below grade. Instead, the cement will be brought up flush with the floor surface. The Procedures will be modified to clarify this.

Comment: Page 50, BW-7. The Department recommends attempting to seal the lowe section of BW-7 and overwashing and removing the upper 170-200 feet.

Response: The Technical Memorandum will propose an approach to decommissioning BW-7. This approach will most likely be similar to the approach used in LW-1 and LW-2 at Camp Kohler. Decommissioning of BW-7 will also most likely follow the decommissioning of the Camp Kohler wells in order to benefit from the experience gained at Camp Kohler.

Comment: Page 51, paragraph 2, BW-8. Contamination has been found at 175' BGS. The Department recommends that BW-8 be completely decommissioned and not used as a fire fighting reserve well.

Response: McClellan AFB has decided to delay decommissioning BW-8 for about 6 to 12 months until water hook-ups with City of Sacramento have been accomplished. Until that time, BW-8 will remain inactive as a fire emergency well. After the water hook-up, BW-8 will be completely decommissioned as recommended. The Technical Memorandum will provide details on the approach to decommissioning.

Comment: Page 51, Camp Kohler Wells. Provide any of the driller or lithologic logs for the Seismic and Triax Holes. The Departments evaluation of the cement bond logs indicate that a poor seal (if any) exists. The Department recommends perforating the casing and squeezing the hole with cement.

Response: No driller or lithologic logs are available for the Seismic Well and Triax Holes. McClellan AFB agrees that the acoustic bond log for the Triax Hole contains contradictory signals and may indicate that the cement seal is poor or nonexistent. This well will be decommissioned through pressure-grouting. A detailed approach will be provided in the Technical Memorandum. The data from the acoustic bond log for the Seismic Well, however, are relatively unambiguous. Therefore it is recommended that this well be decommissioned as proposed in the Procedures.

Comment: Page 53, paragraph 3, All water generated during the decommissioning effort (not just decontamination water) should be pumped into a Baker tank and sent to the GWTP for disposal. Use of berms and evaporation is not acceptable.

Response: The decommissioning process has been designed so that no water will be generated and will therefore require no disposal. Decontamination will take place with a steam cleaner fitted with a circular sprayer mounted to the well head, with steam jets directed downward into the well. In this way decontamination water will flow back down the hole. If it should become necessary to generate wastewater for disposal through some unanticipated event during the field work, this water will be collected in a Baker Tank and disposed at the Groundwater Treatment Plant, as recommended here. The Procedures will be modified to reflect this language.

Comment: Page 9, paragraph 2, Edit. Should reference to BW-16 be BW-15?

Response: During the record search for this project, it was found that the well that was previously thought to be BW-16 was actually BW-15. BW-16 was located along Patrol Road in the western portion of McClellan AFB.

Comment: Page 31, paragraph 3, Base Well 6 is not identified on Figure 2.

Response: The presumed location of BW-6 will be plotted on Figure 2.

PREPARED FOR: Marc Garcia/SM-ALC/EMR
Greg Churchill/SM-ALC/EMR
Norman Orrick/SM-ALC/EMR

PREPARED BY: Chuck Elliott/SAC

COPIES: Starr Dehn/SAC

DATE: October 1, 1993

SUBJECT: McClellan AFB Well Abandonment Phase II Preliminary Field Activities

PROJECT: SAC28722.31.A4

Introduction

Task 2 of the Phase II Well Abandonment Program at McClellan AFB involved the preparation of wells for decommissioning. This preliminary work included the removal of existing turbine pumps from five inactive wells, a downhole television survey in those wells, removal of lubricating oil from four wells, cleaning of the casings in four wells, coring into the gravel packs in five wells, and a second television survey in the four wells that were cleaned. In addition, formerly abandoned wells at Camp Kohler were located by digging with a backhoe, and two seismic wells at Camp Kohler were given acoustic bond log surveys. This Technical Memorandum describes the preliminary work accomplished at McClellan AFB and summarizes the findings of the television surveys and coring into the gravel pack. Recommendations for completing the decommissioning are also included.

Preliminary Work

Pump Removal

Pumps were removed from base wells BW-8, BW-13, BW-17, BW-20, and BW-28 between April 20 and May 3, 1992. The work was performed by Layne-Western Company under the supervision of CH2M HILL. Safety and ambient air conditions during this and all field work were monitored by CH2M HILL using a photoionization detector, an explosimeter, and a radiation meter. No elevated readings above background were observed during pump removal. All pump equipment and parts were steam-cleaned for decontamination as they were pulled from the wells, and water was allowed to run back down the holes. Pumps and piping were temporarily stored at

BW-13 and then moved to the McClellan AFB Defense Reutilization and Marketing Office (DRMO) at Building 700. Pumps and piping from BW-8 have been temporarily stored at the Contractor's Staging Area pending reinstallation in the well.

Base Well No. 8

Pump removal at BW-8 took place between April 21 and 24, 1992. Removed were a U.S. Motors 100-horsepower (hp) electric motor with a U.S. Hollowshaft gear drive connected to a diesel auxiliary motor and a Peerless 10-stage bowl assembly set at a depth of 160 feet below the ground surface. It was necessary to jackhammer the concrete pedestal on which the head assembly rested because this assembly was cemented in place. It was also necessary to cut the head tube that distributes lubricating oil through the discharge head assembly to the main oil tube that enclosed the line shaft and bearings. This tube is set under tension with a tension nut, which was frozen and had to be cut to release the tension.

During work at BW-8, a 10-inch-diameter casing liner was found inside the regular 12-inch-diameter casing. Because the pump column was 8 inches in diameter and the pump bowls were 9-5/8 inches in diameter, the pump bowls were tightly wedged against the side of the liner and were difficult to pull.

Base Well No. 13

The pump was removed from BW-13 between April 20 and 22, 1992. The motor was a U.S. Motors 100-hp electric motor, with a Randolph right-angle gear drive attached to a diesel auxiliary motor and a Peerless eight-stage bowl assembly set at a depth of 150 feet below the ground surface. The diameter of the pipe column decreased from 10 inches to 8 inches at a depth of 60 feet.

Base Well No. 17

Pump removal at BW-17 took place on May 2 and 3, 1992. Because power lines run directly above Building 699, in which BW-17 is located, it was necessary for McClellan AFB to turn off the power and take down the lines, so work took place on a weekend. Pump parts consisted of a U.S. Hollowshaft 75-hp electric motor with a Floway gear drive and a Floway three-stage bowl assembly set at a depth of about 140 feet. The former auxiliary motor had been removed previously. The pump column consisted of 8-inch diameter pipe in 10-foot sections, with the exception of the first section, which was 8 feet long. As with BW-8, it was necessary to cut the head tube to release the tension on the main oil tube before pulling out the pump column materials.

Base Well No. 20

The pump in BW-20 was removed on April 27, 1992. The motor was a General Electric 7.5-hp induction motor, with no auxiliary motor, and a Johnston eight-stage bowl assembly set a depth of 100 feet below the ground surface. Apparently, the original pump was removed from this well in 1968 and replaced with this smaller pump, and BW-20 changed from a base supply well to a backup supply well serving Building 200 only. The pump column in BW-20 was 4 inches in diameter. Pump removal went smoothly except that the air line fell to the bottom of the well (it was not banded to the column pipe) when cut.

Base Well No. 28

Pump removal at BW-28 took place on April 20, 1992. The pump was a Franklin Electric 2-hp submersible pump set at a depth of 105 feet below the ground surface on five sections of 21-foot-long, 2-inch-diameter discharge pipe. This well was not part of the base water supply system but served Building 1082 only. In 1991 the groundwater level fell below the pump intake. Pump removal was simple and uneventful.

Initial Television Surveys

Following removal of the pumps, downhole television surveys were performed in each well to be decommissioned or modified during Phase II. The television surveys were conducted by Layne-Western Company under CH2M HILL's supervision. BW-8, BW-13, and BW-28 were surveyed on April 29, 1992, and BW-7, BW-17, and BW-20 on May 6, 1992. The purpose of the surveys was to obtain initial evaluations of the conditions of the casings prior to any further work. The survey also identified wells that contained lubricating oil and that required cleaning, and provided basic confirmation of well construction details. As the camera and cable were withdrawn from each well they were steam-cleaned and the water allowed to flow down the well. Main findings of the surveys follow.

Base Well No. 7

BW-7 was first located in 1982 during the Phase II Installation Restoration Program at McClellan AFB. The well lay below grade in a buried vault and was located with a magnetic flux indicator, then excavated. An extension was welded onto the casing to bring it above grade, and the excavation was filled in. Sounding of the well revealed the presence of an obstruction at a depth of approximately 80 feet. McClellan AFB staff attempted to drill out the obstruction using a "rotary wash" method, but was unsuccessful.

It was hoped that a television survey in BW-7 would reveal the nature of the obstruction. However, the camera contacted silty fill material at a depth of 73 feet below the top of the casing (70.5 feet below grade) and was unable to reveal the nature of the obstruction. The casing above that point was dry and appeared to be in good condition. The casing was in 4-foot sections, normally suggestive of cable-tool construction. However, base records and the report from the 1982 investigation both state that the well was constructed by rotary drilling and contains a gravel pack annulus.

Base Well No. 8

The television survey revealed that BW-8 was 779 feet deep below the top of the casing (the well lies within a vault about 10 feet below grade). A 1966 television survey had previously noted that the well was 785 feet deep. A 10-inch-diameter liner was found to run from the well head to a depth of 666 feet. At various depths, the liner was heavily encrusted with iron bacteria that obscured views of its condition. Below the liner was open hole, corresponding to the "large cavity" noted on Base records. Pump lubricating oil to a depth of 7 feet (about 29 gallons) was found floating on the water in the well.

A 12-inch-diameter casing is present at the surface and may be the original well casing for the 400-foot well noted in Base well records. Gravel feed pipes are also present suggesting a rotary drilled well. However, the television video revealed joints in the casing liner every 5 feet, suggestive of a cable-tool well. Presumably, the original well was drilled by rotary methods to a depth of about 389 feet, and 12-inch-diameter casing was installed. Perforations extended from a depth of 170 feet to 389 feet, according to records. At some later time, the well was deepened by driving 10-inch-diameter casing through the existing well by the cable-tool method. This casing was drilled to a depth of 779 feet, then withdrawn to a depth of 666 feet, leaving a large cavity in the semi-consolidated rock. There are no perforations in the casing liner, and water is drawn into the well from the open cavity below. The current water level is 90 feet below the top of the casing (about 100 feet below the ground surface).

Base Well No. 13

The television survey found the total depth of BW-13 to be 374 feet rather than the originally reported 391 feet, suggesting that the lower 17 feet of the casing was filled with sediment. The 14-inch-diameter casing reduces to 12 inches between 141 and 143 feet in depth. The water level was found to be about 97 feet below the top of the casing (about 107 feet below grade, as the well lies inside a subsurface vault). About 1-1/2 feet of pump lubricating oil floated on the water (about 8 gallons of oil).

The main conclusion drawn from the television survey was that the casing is in very poor condition. Fortunately, relatively little iron bacteria obscured the view of the casing. Numerous breaks were visible in the casing, primarily open vertical seams, but also polygonal crack patterns, breaks along joints, and holes. Because of the fragile condition of the casing, no attempt was made to clean it or bail the sediment from the bottom of the well.

Base Well No. 17

The television survey contacted sediment on the bottom of BW-17 at a depth of 317 feet. According to Base records, this well was originally drilled to a depth of 930 feet but then sealed in 1947 at a depth of 390 feet. However, perforations extended only to a depth of 307 feet (312 feet was the depth given in the records), and a

1971 photographic survey found the well to be 344 feet deep. It contained a 16-inch-diameter casing, as expected. Joints were visible in the casing every 4 feet, indicating that the well was drilled by the cable-tool method. This also conformed to Base records. In places, unusually large perforations were visible that may have allowed the entry of sediment. Encrustation of iron bacteria obscured the casing through much of the well. The water level was about 105 feet below the top of the casing and about 2 feet (11 gallons) of oil floated on the water.

Base Well No. 20

The bottom of BW-20 was contacted at a depth of 561 feet below the top of the casing. The well lay in a subsurface vault about 7.5 feet below the ground surface. According to Base records, the reported original depth of BW-20 was 600 feet. If these records are correct, a little more than 30 feet of sediment lies in the bottom of the well. BW-20 contains 14-inch-diameter steel casing that is set inside a 32-inch-diameter conductor casing at the well head. The water level lay at a depth of about 110 feet below grade. About 3 feet (24 gallons) of pump lubricating oil was floating on the water. BW-20 was found to contain heavy encrustations of iron bacteria obscuring the view of the casing throughout much of the well. The air line that fell into the well during pump removal was visible from a depth of 479 feet to a depth of 561 feet.

Base Well No. 28

The television survey contacted bottom in BW-28 at a depth of 240 feet although the depth indicated on Base records is 248 feet. The well casing diameter is 8 inches (set inside a 14-inch-diameter, cement-filled conductor casing). Groundwater was contacted at a depth of 106 feet. No lubricating oil was present, which was as expected because BW-28 contained a submersible pump rather than a turbine pump. Because of iron bacteria fouling the well casing and near opacity of the water due to apparent lack of groundwater movement through the well, it was very difficult to evaluate the condition of the casing.

Removal of Pump Lubrication Oil

Oil was found during initial television surveys in wells BW-8, BW-13, BW-17 and BW-20, the four wells that contained turbine pumps. This oil was bailed out between May 11 and 16, 1992, and stored in 55-gallon drums at the wellhead. Fifty to 100 gallons of oil/water mixture was dipped from each of the four wells.

RAMOS Environmental Services was contracted to recycle the oil being stored in the drums. Removal was accomplished on May 20, 1992, after chloro-detect and flammability tests were performed to confirm that the oil was nonhazardous according to California regulations. A total of 239 gallons of oil/water mixture was removed. The empty 55-gallon drums were then disposed to a drum recycler.

Well Rehabilitation

After the pump lubricating oil had been removed, some rehabilitation of the wells was necessary. With the exception of BW-7, which contained no water, all the McClellan AFB wells were fouled with gelatinous masses of iron bacteria and encrusted with iron oxide deposits. Rehabilitation consisted of cleaning with a steel brush fabricated for each well diameter, in order to allow improved evaluation of the condition of the well casing. BW-13 was excluded from this brushing because of the fragile condition of the well casing detected during the initial television survey and the fear of casing collapse. For wells BW-8, BW-17, BW-20, and BW-28, cleaning consisted of slowly lowering and raising the brush through the entire length of the casing until it was judged to be clean. The cable and brush were steam-cleaned as they were pulled from the well. Cleaning took place between May 12 and 16, 1992, with about 1 day devoted to cleaning at each well. It was necessary to work on BW-17 on the weekend because of the need to remove power lines.

Each well was sounded after the cleaning of the casing, and an additional 7 feet of sediment was found to have settled to the bottom of BW-17. Apparently, the movement of the bailer past the zones of large perforations in this well caused additional material to enter the well. After some consideration, it was decided to bail the sediment from BW-17. BW-13 and BW-20 may also be candidates for sediment removal. However, BW-13 was considered too fragile to risk bailing. BW-20 contained about 30 feet of sediment, but the bottom of this well lay at a depth of 600 feet below the ground surface. At this great depth, groundwater flow gradients are reported to be vertically upward, and so removal of the relatively small amount of material was considered unnecessary. Cement volumes will be observed during decommissioning to evaluate whether this portion of the well is successfully sealed.

Sediment was bailed from BW-17 over the weekend of June 13 and 14, 1992. Sediment was placed in a metal bin adjacent to the wellhead. Progress was fairly rapid to a depth of 356 feet below grade. From that point, additional bailing proved impossible. This depth was below the bottom of the well noted in the 1971 photographic survey but above the depth noted in the Base records. Bailing past this depth was attempted for about 2 hours. Presumably, the base of the well lies at 356 feet. The lower portion of the casing in BW-17 exposed after bailing the sediment was then cleaned by brushing, as in other wells. During this operation, 5 additional feet of sediment entered the well and was subsequently removed by bailing. Sediment was later disposed to the McClellan AFB soils-holding area at the direction of Base disposal personnel.

Exposure of the Gravel Pack

Portions of the concrete pads at the wellheads were removed by jackhammering to expose the underlying gravel pack. The objective of this work was to allow an evaluation of the diameter of the annular space surrounding the casing and the composition of the gravel pack. This information is needed to reduce uncertainty during cement volume calculations when the wells are being decommissioned. BW-17 and BW-28 were drilled by the cable-tool method so removal of the pads confirmed that no gravel pack was present in these wells.

As previously described, BW-8 has a 10-inch-diameter liner inside the 12-inch-diameter well casing. During removal of a portion of the concrete pad, a 2-inch-diameter submerged pipe was discovered that was apparently used to feed sand into the annular space between the casing and liner. When exposed, the annular space appeared to be filled with sand; the annular space between the well casing and the conductor casing was filled with pea gravel.

At BW-20 a steel plate welded onto the 32-inch-diameter conductor casing covered the space between the conductor and the 14-inch-diameter well casing, covering the gravel pack. However, the composition of the gravel could be seen in the two feeding pipes, which were filled with 1/2-inch pea gravel to the top.

Final Television Survey

A second television survey was performed in the wells that had been cleaned. BW-8, BW-17, and BW-20 were videotaped on May 21, 1992 and BW-28 on May 26, 1992. It was necessary to reclean BW-28 on June 8, 1992, after the television survey revealed that the casing was still obscured by iron bacteria. As described above, BW-17 was recleaned on June 14, 1992, after sediment was bailed from the bottom of the hole on June 13 and 14, 1992. Downhole television surveys were then taken in BW-17, BW-20, and BW-28 on June 20, 1992, and in the Triax Hole at Camp Kohler on June 25, 1992.

The surveys revealed that the casings in BW-8, BW-17, BW-20, BW-28, and the Triax Hole were sound enough to withstand pressure grouting. Void spaces of unknown diameter were observed for 2 feet in the open borehole beneath the casing liner in BW-8 and at depths of 679 and 680 feet, and 722 and 723 feet. Large perforations were observed in BW-17 at depths of 281 to 288 feet and 297 to 306 feet. These perforations were presumably the source of the sediment that migrated into the well.

Camp Kohler Laundry Wells No. 1 and 2

In December 1991 an effort had been made to locate Laundry Wells No. (LW-) 1 and 2 by surveying the locations from old maps and then digging down with a backhoe. The southernmost of these wells, LW-1, was located at that time with a mushroom-shaped plug of concrete extending above casing that had been cut about 4 feet below grade. However, field personnel were unsuccessful at locating LW-2. Since that time, old aerial photographs found in Base files have offered an improved opportunity to locate LW-2. On June 16 through 18, 1992, a second attempt was made to locate LW-2, and LW-1 was dug up again.

When LW-1 was exposed, the concrete plug was removed, and a 12-inch-diameter steel casing was revealed. Further excavation to a depth of about 9 feet failed to expose any conductor casing or gravel pack. In the opinion of field personnel, this well was constructed by cable-tool methods and therefore did not contain a gravel pack. An extension was then welded onto the casing to bring it above grade, and the hole was backfilled with dirt.

It took about 4 hours to locate LW-2, even with the assistance of aerial photographs. Finally, the well was found about 4 feet below grade, filled with cement. Further excavation revealed a 32-inch-diameter conductor casing. After the cement was jackhammered, a 14-inch-diameter well casing was exposed. Between the well casing and the conductor casing was a loose pea gravel filter pack. An extension was then welded to this well to bring it above grade, and the hole was backfilled with dirt.

Conclusions and Recommendations

Table 1 summarizes well construction details pertinent to the well decommissioning that were obtained during preliminary work on McClellan AFB wells. The preliminary work revealed some previously unknown information regarding certain wells that will affect the decommissioning approach. In addition, regulatory agencies have expressed some concerns that will also affect the approach. This section summarizes the main conclusions drawn during the preliminary work and describes necessary changes to the approach outlined in the Well Closure Methods and Procedures Report (the Report).

Table 1
Summary of Well Construction Data
Pertinent to Decommissioning

Well	Well Casing Diameter (in.)	Conductor Casing Diameter (in.)	Filter Pack Composition	Existing Perforated Intervals (ft)	Proposed Perforated Intervals (ft)	Grout Volume Required (ft^3/ft)	Depth of Well (ft)
BW-7	12	24	Pea gravel	N/A	Will be determined	1.73	398
BW-8	10 (inner) 12 (outer)	26	Pea gravel	Uncertain	Will be determined	1.81 (liner) 1.95 (casing	779
BW-13	14 (0-142 ft) 12 (142-374 ft)	24	¼-pea gravel	178-391	80-170	1.90 (0-142 (ft) 1.73 (142-374 ft)	391
BW-17	16	24	N/A	212-214; 281-288; 297-306	85-200; 225-270; 315-356	1.54	356
BW-20	14	32	½-inch pea gravel	168-178; 219-258; 338-374; 494-506	90-155; 190-210; 270-325; 385-485; 515-569	2.88	569
BW-28	8	14	N/A	143-147; 202-204; 233-236	90-130; 160-190; 215-225	0.38	248
LW-1	12	N/A	N/A	NA	Will be determined	Uncertain	420
LW-2	14	32	Pea gravel	N/A	Will be determined	Uncertain	514
Triax Hole	11¾	13⅜	N/A	N/A	0-190	1.03	190
Seismic	7	N/A	N/A	N/A	N/A	0.27	500

Base Well No. 7

There is an obstruction in BW-7 at a depth of about 71 feet below grade that reportedly resisted drilling in 1982. A television survey performed as part of the preliminary work for this project did not reveal what the obstruction may be. However, it is possibly the top of the well's original pump column. When the well was abandoned, the workers may have removed the motor and cut the column, allowing it to fall to the bottom of the well. However, if the well is really 398 feet deep, then the original pump bowls must have been set at a depth of 327 feet. This seems unreasonably deep. On the other hand, if the casing had been filled with cement, rotary drilling should have penetrated beyond a depth of 71 feet.

Because of the uncertainty surrounding this well, the proposed first step is an attempt to further evaluate the well by core-drilling a 6-inch-diameter hole through air-rotary methods. If no resistance is met, the hole should be continued to the bottom of the well. The well can then be perforated by shot perforation and grout injected under pressure in stages as described in the Report. If no cement is encountered but the top of the pump column is found, an effort should be made to fish out the column. The casing can then be evaluated by means of a television survey and the well decommissioned as specified in the Report. If no cement is found but the well is filled with gravel or sand, it should be drilled out by mud or air techniques and decommissioned as specified in the Report. Finally, if the pump column is found encased in cement, it will be necessary to develop a new approach. This may involve drilling out the column with a mill bit or constructing an "overwash" bit and drilling outside the casing to remove the gravel pack. In the former approach, the well would be perforated and pressure-grouted. In the latter approach, cement would be tremmied down to replace the gravel pack. The regulatory agencies (DTSC and RWQCB) should be consulted as decisions are made in this process. Because of the similarities between this well and LW-2 at Camp Kohler, it is proposed that LW-2 be decommissioned first to refine the approach before attempting to decommission BW-7.

Base Well No. 8

Based on additional information collected during Phase II in 1992, BW-8 was found to have two well casings; a 12-inch well casing (assumed to be the original well which extended down to 389 feet) and a solid 10-inch casing or liner that extended to 662 feet. The total depth of the well was 779 feet. Three voids were noted during a 1992 television survey between 662 and 779 feet.

The lower portion of BW-8 extending from approximately 779 feet to 662 feet will be filled with a sand slurry cement to seal the three large voids. The 10-inch inner casing will then be perforated from 662 fee 410 feet and sealed with another lift of sand slurry cement. From 380 to 410 feet iner casing will be perforated to induce sand which might be in the annular space between the 10 and 12-inch casing to flow into the well.

The inner casing will then be cut at the bottom of the original well (around 389 feet) with a Mills knife. An attempt will be made to pull the 10 inch casing from the well. If the 10-inch casing is successfully removed, then the well will be bailed out and another downhole television survey will be performed. Depending on the conditions of the 12-inch casing, it may be necessary to clean the casing and perform a second television survey. The well would then be pressure grouted from 170 to 389 feet and then perforated and pressure grouted from 170 to 85 feet.

If the attempt to pull the liner is unsuccessful, it may be possible to cut shorter lengths of the casing and to pull these segments out using borehole "fishing" tools. If this method is unsuccessful, it may be necessary to shot-perforate through the liner and casing. BW-8 will then be decommissioned by pressure-grouting according to the procedures described in the Well Closure Methods and Procedures for Phase II.

Base Well No. 13

Because the well casing in BW-13 was found to be in very weak condition, it would be too risky to attempt pressure-grouting the well. Instead, BW-13 should be decommissioned in stages, using a low-viscosity cement according to procedures specified in the Report. Fortunately, existing perforations in the well extend from a depth of 178 feet to the total depth of the well, so it would be unnecessary to perforate in that interval. Above that interval, the casing appears to be sound, according to the television survey. Therefore the casing would be perforated from about 80 feet to 170 feet and grout injected under pressure in a minimum of two lifts. The remaining procedures would be as described in the Report.

Base Wells No 17, 20, and 28

Preliminary ev[illegible]ions of BW-17, BW-20, and BW-28 indicate that the casing in these wells are in relatively good condition. Therefore, decommissioning can proceed as specified in the Report. Intervals proposed for perforation are listed in Table 1. If intervals exceed 50 feet, they will be grouted in more than one lift. As described in the Report, grouting will begin with short intervals and gradually move to longer intervals.

Laundry Well No. 1

LW-1 at Camp Kohler is believed to have been drilled by the cable-tool method, in which well casing is driven into the ground and no gravel pack is installed. Excavation to a depth of 9 feet at this well failed to reveal gravel pack. The well does appear to have been filled with cement. However, it is possible that a plug was set at a relatively shallow depth and cement emplaced above the plug, as sometimes practiced in the past. Therefore, it is proposed that a 6-inch-diameter core be drilled into the cement to a depth of about 50 feet to determine whether the cement extends throughout the casing. If so, the core hole should be backfilled with cement, and the well cut below grade and buried to return it to its previous condition. If for some reason the cement does not entirely fill the well, it should be filled with a sand/cement slurry placed in the well through a tremmie pipe. Because LW-1 does not contain a gravel pack, extraordinary measures, such as shot-perforation and pressure-grouting, are not needed to decommission this well.

Laundry Well No. 2

During preliminary work at Camp Kohler LW-2 was excavated and determined to contain a pea gravel filter pack surrounding the original casing that is presently filled with cement. Therefore, this well should be decommissioned by filling the void spaces in the gravel pack with grout. However, a previous investigation suggested that the pump column may have been cut and allowed to fall into the well prior to cementing (Radian Corporation, 1985. Camp Kohler Investigation). LW-2 is therefore similar in circumstance to BW-7 at McClellan AFB.

Because of the uncertainty surrounding this well, it is proposed that a similar approach be followed as at BW-7. The first step should be to attempt to further evaluate the well by core-drilling a six-inch-diameter hole through air-rotary methods. If no resistance is met, then the hole will be continued to the bottom of the well. The well will then be perforated by shot perforation, and grout injected under pressure in stages as described in the Report. If the cement is restricted to a small interval above a plug, but the top of the pump column is found, then an effort will be made to fish out the column. The well will then be given a television survey to evaluate the casing, and decommissioned as specified in the Report. Finally, if the pump column is found encased in cement, then it will be necessary to develop a new approach. This may involve drilling out the column with a mill bit, or constructing a an "overwash" bit and drilling away outside of the casing to remove the gravel pack. In the former approach, the well would be perforated and pressure-grouted. In the latter approach, cement would be tremmied down to replace the gravel pack. The regulatory agencies will be consulted as decisions are made in this process. LW-1 will be decommissioned before BW-7 to refine the approach before moving to a setting that may be more difficult, both from a contamination and from an access standpoint.

Triax Hole

As a preliminary activity, the Triax Hole was given an acoustic bond survey to evaluate the condition of the cement seal surrounding the casing. A discussion of the survey and its conclusions and a copy of the original log for the survey were provided in the Report. Because the survey revealed that the seal may be inadequate and because of agency concern that no surface seal is in place, McClellan AFB staff have decided to perforate and seal the Triax Hole throughout its entire depth. The approach will be as described in the Report, with grout applied in stages under pressure from the bottom to within about 5 feet of the ground surface. The casing will then be cut, the cement allowed to overflow the casing and form a plug, and the hole backfilled with dirt.

Seismic Well

The seismic well was also given an acoustic bond survey as a preliminary activity. However, results for this well indicated that the cement seal was in good condition. Therefore, decommissioning will be as described in the Report, that is, a sand/cement slurry will be tremmied into the well in one lift from bottom to top. The casing will be cut about 5 feet below grade, cement allowed to overflow the casing and form a plug, and the hole backfilled with dirt.

Appendix A
Response to Comments

CH2M HILL

RESPONSE TO COMMENTS

SUBJECT: Technical Memorandum
McClellan AFB Well Abandonment Phase II
Preliminary Field Activities

REVIEWER: Mark Malinowski, Department of Toxic Substances Control

DATE: October 1, 1993

Comment: Base Well 13. Given the fragile nature of the lower section of BW-13, the Department agrees with the proposal to use a low viscosity cement. However, the proposal to perforate from 80 feet to 170 feet below ground surface (BGS) goes counter to previous verbal agreements and the approved grouting procedures specified in the "Well Closure Methods and Procedures" workplan. The workplan specifies that grouting intervals will be done in lifts "to a minimum of no more than 50 feet" (page 50, paragraph 4). Perforating nearly 100 feet and then grouting the section may cause a recurrence of what happened when Base Well 1 was decommissioned. The section of casing from 80 to 170 feet should be perforated and grouted with a minimum of two lifts.

Response: It was feared that subjecting the casing to two episodes of perforation and pressure-grouting could increase the risk of casing damage or collapse. Although the television survey did not show any obvious signs of deterioration in the casing in the upper depth interval, the poor condition of the casing at greater depth increases the risk that hidden problems may exist in the upper interval as well. However, the text has been modified to specify that the casing from 80 to 170 feet BGS will be perforated and grouted with a minimum of two lifts.

Comment: Base Wells 17, 20, and 28. Line four says that the "lengthy intervals will not necessarily be grouted in one lift." Again, the Department and McAFB have agreed that lifts will not exceed 50 feet. The 85-200 foot BGS proposed perforated interval for BW-17 and the 385-485 foot BGS interval for BW-20 should be completed with a minimum of two lifts.

Response: It was never intended that lifts should exceed 50 feet in these wells. The text has been modified to remove the confusing language and clearly state that lifts will not intentionally exceed 50 feet.

BUDGET ESTIMATE/TECHNICAL PROPOSAL

FOR

HORIZONTAL EXTRACTION WELLS

AT

MCCLELLAN AIR FORCE BASE - SACRAMENTO, CA

SUBMITTED TO:

CH2M HILL

BY:

DRILEX SYSTEMS, INC.

NOVEMBER 4, 1993

DRILEX

DRILEX SYSTEMS, INC.

15151 Sommermeyer
Houston, Texas 77041
P.O. Box 801114, 77280-1114
Tel: (713) 937-8888
Fax: (713) 849-2390

November 2, 1993

Mr. Umesh Lalwani
CH2M Hill
2525 Airpark Drive
Redding, California 96049-2478

RE: Horizontal Extraction Well
McClellan Air Force Base - Sacramento, CA

Dear Mr. Lalwani:

Drilex Systems, Inc. respectfully submits the following Budget Estimate/Technical Proposal for the above referenced site.

The estimate is based on the installation of one well and the mobilization of the drilling equipment from Houston, Texas. The mobilization/demobilization cost will change based on the final number of wells and the travel distance. If additional wells are added to the project, the mobilization costs will have a smaller impact on the overall project cost.

This estimate should be used as a "ballpark" cost only. A more detailed proposal will be submitted after the final project parameters are determined.

Thank you for the opportunity to submit an estimate for this project. If you have any questions or require additional information, please call.

Sincerely,

David S. Bardsley

David S. Bardsley
Geologist/Project Manager

DSB/ccc
Quotation Number 10096-ENV

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SECTION I

DRILEX ENVIRONMENTAL SERVICES RIG

The DSI 140 horizontal drill rig was designed with several key factors in mind. Paramount in its conception is the ability to provide a mud rotary drilling system while keeping the rig site protected from the inherent spilling of mud during normal operations. Secondly, the rig is designed to be totally self-sufficient with the exception of water for mixing drilling fluid. Finally, the rig is engineered with enough power and versatility to complete wells from a true vertical depth of 10' to 250'.

The rig is constructed on four truck trailers that are non-permit loads. It is designed to pull up on location and be rigged up for drilling in a matter of hours. A normal location pad would require only an area of approximately 50 x 100 ft. A functional description of the operating components of the rig follows:

DRILLING RIG TRAILER

The actual drilling operations are accomplished with the diesel/hydraulic power unit. All push, pull, pipe makeup/breakout and entry angle functions are on the trailer and controlled at the driller's console (on the pipe handling trailer). Additionally, the rig has pollution pans installed to capture any drilling fluids that may escape during pipe connections. Other features of this trailer are the wireline steering tool connections for directional drilling monitoring, air purge system, water washdown system and a high pressure, hot water washer with 100' hose.

PIPE HANDLING/DRILLER CONTROL TRAILER

This trailer has an air conditioned driller control enclosure, hydraulic crane, and drill pipe transport trays. The driller's control cabin has all controls necessary for the monitoring and control of drilling operations. Hydraulic functions on the drilling rig trailer are controlled by the driller through 12 volt electrical sensors in the control panel. The steering tool connection from the downhole instrument is located next to the driller's console for close communication with the directional driller. All communications with the crew are carried out with individual wireless headsets to minimize miscommunications. The hydraulic crane is mounted directly aft of the control cabin and can be operated manually or with a remote control umbilical cord. The pipe racks are designed such that any drilling fluid that may drain is captured and controlled with pollution pans. The driller can also control the mud circulation pump at his console.

DRILLING FLUIDS RECIRCULATION TRAILER

The major components of this trailer are a 5000 gallon capacity mud system separated into 5 tanks, two solids separation cycles to ensure clean fluids are pumped downhole, a diesel-powered triplex mud pump capable of over 400 gallons per minute and a mud mixing hopper. The solids removal system includes both a shale shaker and a desander/desilter. Centrifugal pumps circulate drilling fluid returns through the mud cleaners three times before being pumped back downhole. Solids removed from the drilling fluid are diverted into a container or roll off on the ground next to the trailer. Drilling fluids returning to the surface are diverted through a conductor pipe to a mud pan on the surface. This mud is then lifted to the shale shaker by a hydraulically powered centrifugal pump. The ability to clean and recirculate drilling fluids keeps the volume of drilling fluids needed to minimum.

AUXILIARY TRAILER

This unit houses a diesel-powered 175KW generator, a large 20 hp air, 75 cfm at 120 psi compressor and the rig workshop with spare parts. A 150' umbilical cord enables this trailer to be placed remote from the drilling units allowing a compact rig site. Electricity and air are distributed to all other trailers from this unit.

CREW TRUCK

The six man crew travels to location daily in a support vehicle. This truck has additional tool boxes and a 100 gallon diesel tank for fueling the rig. Utilizing our pickup to transport fuel keeps the amount of fuel on location to a minimum.

Actual rig specifications are outlined on the following pages of this section.

PROPOSED RIG SITE SETUP

Drilex proposes entering the ground at an angle 14° above horizontal. This angle will provide for safe working conditions, higher success rate in our objectives and a convenient borehole accessibility for future use.

The exact layout of the site and rig pad will have to be determined once an actual survey is conducted.

The location of the bore entry point will be approximately 474 ft. from the horizontal section.

Overview

Drilex Environmental Services intends to perform all work on this project within the limitations set by CH2M Hill. All well construction, location preparation and rig and equipment decontamination will conform to the final specifications as agreed. All safety requirements will be followed. To insure complete compliance with site regulations, we request a safety inspection of our rig site prior to commencing work.

The following detailed drilling plan is based on these criteria:

- We will use a 2-7/8" pilot string with 5" drill pipe for washover technique to enable more accurate placement of the borehole.
- We will be drilling with a D237 (2-3/8" O.D.) DRILEX Positive Displacement (Mud) Motor with a 3-1/2" O.D. drag bit, if motors are required.

Surface Conductor Hole

The initial entry into the ground will be drilled with 20" O.D. auger. We will install a 20' section of 16" HDPE conductor casing to 5 - 7 ft. true vertical depth (TVD) and cement in place. A mud diverter will be placed at the open end of the surface casing to control and direct mud returns to the mud pan. The mud returns are pumped to circulation system trailer by means of a hydraulically powered centrifugal pump.

Intermediate Casing through the Build Section

After surface casing is installed and grouted, a bit will be run in the surface casing to drill out any cement in the bottom of the hole. The intermediate section will then be drilled with a 2-7/8" drillstring with a motor assembly. The motor assembly will allow accurate placement of the borehole while minimizing mud flow rates. The pilot string will be directionally controlled with a three axis magnetic steering tool that gives constant directional information to the driller's console. A True Tracker system will be used as a second means of verifying the wellbore placement.

The hole will be drilled according to plan with true vertical depth of 100'.

Once the pilot hole is drilled up to 3-1/2" O.D., the wash pipe will be concentrically rotated in the build section to open the hole to a diameter of 14-3/4". After opening, the hole, the 5" drill pipe will be laid down, leaving the 2-7/8" drill pipe as a guide to run 10.75" HDPE. The casing will be cemented in place throughout the build section.

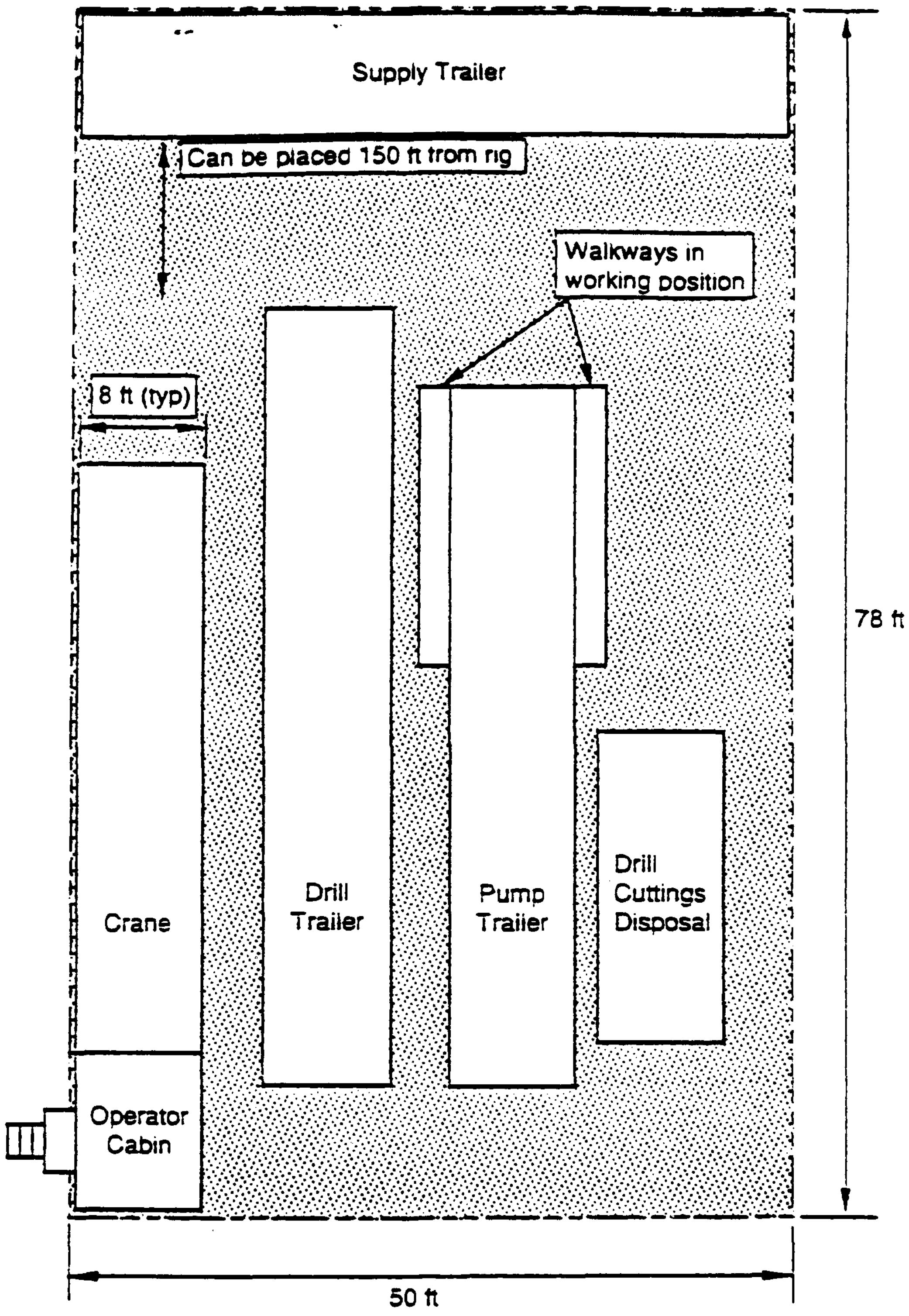
Horizontal Section

After the cement has set up we will then pickup the 5" drill pipe and a 6-3/4" O.D. DRILEX Mud Motor fully stabilized with a 9-3/4" O.D. bit to drill out the cement. This configuration will allow for a smooth transition from the casing in the build section to the slotted liner in the horizontal section. We will pull out of the hole to lay down the 6-3/4" motor. We will continue with pilot string/washover technique through the 500' horizontal section. Particular attention will be paid to the mud properties to ensure good hole stability and cuttings removal. We will have onsite a Bariod miniature mud lab, methylene blue test kit, mud balance kit, Marsh funnel kit, sand content percent by volume kit and retort kit with competent personnel to maintain specific chemical and mechanical properties of the drilling fluids. With the pilot string in place, the 5" drill pipe with a 9-3/4" washover bit will be concentrically rotated in the horizontal section to open the hole for running the screen then both strings of pipe will be removed. With the hole opened to 9-3/4" diameter, 500' section of prepacked HDPE pipe will be pushed to bottom using the 2-7/8" drill pipe to provide the pushing force.

The 2-7/8" drill pipe will then be used to clean out any wall cake and circulated the HDPE screen clean.

Final Decontamination

Final decontamination will be performed prior to demobilizing from the base. Final decontamination of equipment shall include, but not be limited to, the drill rig, drill rods, drill bits, threads, casing, sampling equipment and all other tools that might have been contaminated during the work.



Typical Rigsite Layout

DRILEX ENVIRONMENTAL SERVICES

SECTION II

CH2M HILL

MCCLELLAN A.F.B. - HORIZONTAL EXTRACTION WELL

I.	Mobilization/Demobilization		
	A. Drill Rig		
	B. Pipe Trailer		
	C. Mud System		
	D. Generator Trailer		
	E. Support Truck		
	F. Steam Cleaner		
	G. Well Materials		
	H. Initial and Final Decon		
		Lump Sum	$ 56,672.00
II.	Drilling and Well Construction		
	974' @ $61.00/ft.		$ 59,414.00
		Total Drilling	$ 59,414.00
III.	Materials		
	A. 20' - 16" Steel Conductor Casing @ $32.00/ft.		$ 640.00
	B. 476' - 10 HDPE Intermediate Casing @$27.00/ft.		$12,852.00
	C. 9 - 10-3/4" x 14-3/4" Centralizers @ $55.00 ea.		$ 495.00
	D. 200 - bags Cement @ $10.00 ea.		$ 2,000.00
	E. 10 - bags Bentonite Gel @ $12.00 ea.		$ 120.00
	F. 505' - 3.97" I.D. x 6.625" O.D. HDPE Prepacked Screen @ $59.00/ft.		$29,795.00
	G. 10 - 6.625" x 9-3/4" Centralizers @ $45.00 ea.		$ 450.00
	H. 1 - 4" Locking Cap @ $50.00		$ 50.00
	I. 2 - HDPE Heads @ $300.00 ea.		$ 600.00
	J. 1- Packer @ $250.00 ea.		$ 250.00
		Total Materials	$ 47,252.00
IV.	Development		
	12 hrs. @ $350.00/hr.		$ 4,200.00
		Total Development	$ 4,200.00
V.	Cuttings & Fluids Handling		By Others
VI.	Standby 0 hrs. @ $350.00/hr.		$ 0.00
		Total Estimate	$167,538.00

The above cost is based on the following assumptions:

- Permits and utility clearances will be obtained by others.
- The work will be performed in level "D" PPE.
- Rig standby will be charged at $350.00/hr.
- The containment, transport and disposal of all cuttings and fluids, including decon and development water, will be performed by others. All disposal of potentially contaminated PPE and visquene will be provided by others.
- Estimated cutting and fluids volume:

Drill Cuttings	38 yds
Fluids	22,000 gallons

SECTION III

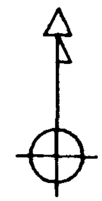
DRILEX

ENVIRONMENTAL SERVICES

CH2M HILL

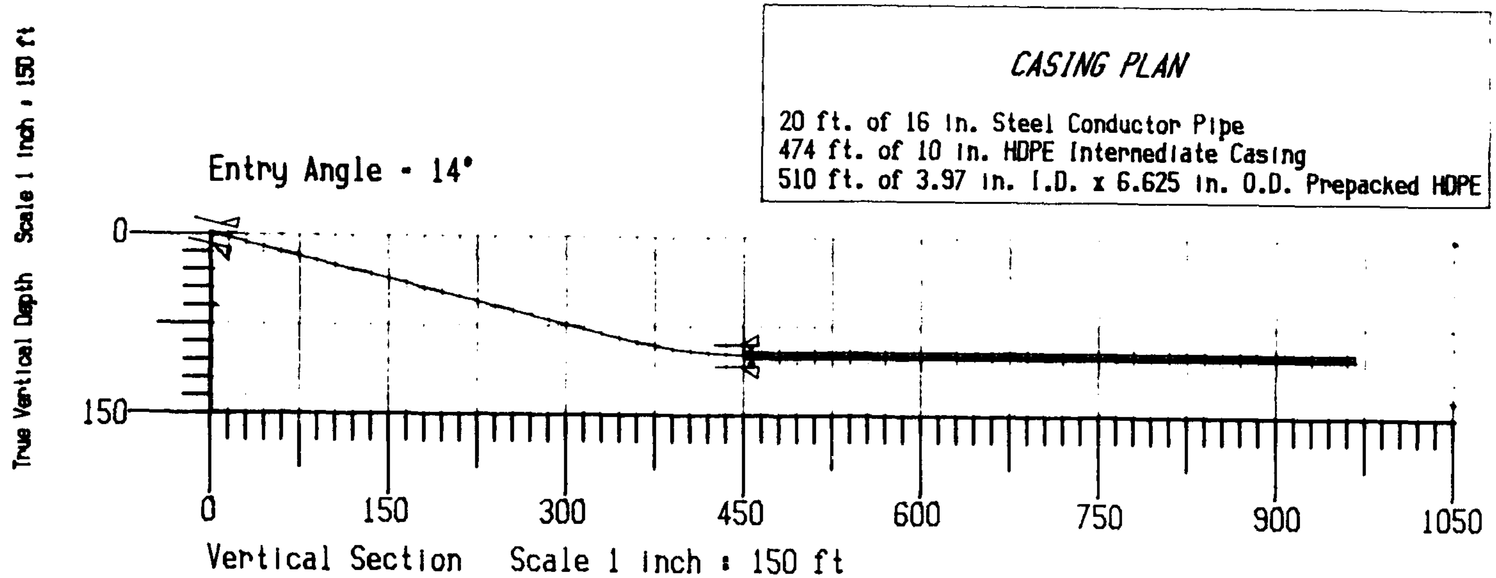
HORIZONTAL EXTRACTION WELL
AT
MCCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

All directional rel. to True North



CASING PLAN

20 ft. of 16 in. Steel Conductor Pipe
474 ft. of 10 in. HDPE Intermediate Casing
510 ft. of 3.97 in. I.D. x 6.625 in. O.D. Prepacked HDPE



PLANE OF VERT SECTn 0.00°
PLOT DATE 11-03-1993

TARGET DETAILS

No	TVD	Lat	Dep
1	100.0	462.3	0.0

BORE PROPOSAL

Sec	MD	TVD	VS	INC	DIR	LAT	DEP	TGT
1	0.0	0.0	0.0	76.0	0.00	0.0	0.0	
2	351.8	85.1	341.3	76.0	0.00	341.3	0.0	
3	473.9	100.0	462.3	90.0	0.00	462.3	0.0	1
4	973.9	100.0	962.3	90.0	0.00	962.3	0.0	

Enter the ground at 14°
Above Horizontal
Tangent for 351 ft.
Start 11.5°/100 ft. Build Rate
Until reaching 90° Inclination
Drill 500 ft. Horizontal Reach
At 100 ft. TVD

SECTION IV

VERTICAL AND HORIZONTAL PRECISION

The vertical accuracy of the specified well will be +/- 2' from the target depth. The horizontal accuracy will be +/- 2° from the target. The horizontal and vertical precision will be verified through subsurface and surface measurements obtained utilizing a steering tool system.

Two tracking systems will be utilized. One system will consist of a downhole steering tool system. The secondary system will utilize the existing downhole tools as well as a surface system.

The downhole steering tool system consists of four components:

Probe:

The probe consists of magnetic and gravitational sensors, digitizing circuitry, modulating circuitry and control circuitry. The probe is placed above the bit or motor, in a non-magnetic drill collar. Once the probe is screwed into the collar, it cannot be removed without the tools being brought to the surface. When the probe unit is powered up, continuous transmission of raw date is sent through the 12 volt wire leading to the interface unit.

Interface Unit:

The interface unit contains the power control, demodulating and interface circuitry. The unit sends power to the probe. Signals sent from the probe are demodulated by the interface unit and sent to the computer. The computer interprets the data and sends the information to the drillers console via the interface unit.

Computer:

The unit is an IBM compatible 386 computer with a minimum of 640K of memory, serial and parallel port. The computer receives data from the interface unit, interprets the data and sends the information to the drillers console via the interface unit.

Printer:

The printer is a parallel unit which prints a "hard copy" of the directional data.

The surface tracking system will utilize the components described above as well as the following:

Wire:

No. 8 or 6 wire is used to create a box or coil of wire at the surface.

DC Power Unit:

A DC power unit is connected to coil and a current is induced into the ground. The steering tool probe will "read" the current and send the information to the computer and interface unit for interpretation. Accurate survey information is required (elevation and distance) for the surface system to be accurate.

SECTION V

Mud Program

Drilex Systems, Inc. plans to use the following products on an as needed basis to maintain drilling fluids with these properties:

Marsh Funnel	45 - 60
Weight	8.6 #/gal.
Water Loss	≤ 7 ML/30 min.
PV	25 - 45 cp
YP	5 - 10 cp
Solids % by Volume	< 2 %
PH	9.0 - 8.5
Gels	20 int. 10 min 20 #/100 ft.^{2}
Sand	≤ 1%

Proposed additives to maintain wellbore stability and minimum fluid loss:

Beta Plus	Inorganic
Alpha Plus	Inorganic
CMS	Organic (Sodium Carboxymethyl Starch) (NaH12C8O7)
Gel Gold Seal	

No Residuals

Drilex Systems, Inc. understands the successful completion of this well will be directly related to drilling fluid control. We have designed a fluid handling system specifically for horizontal drilling applications.

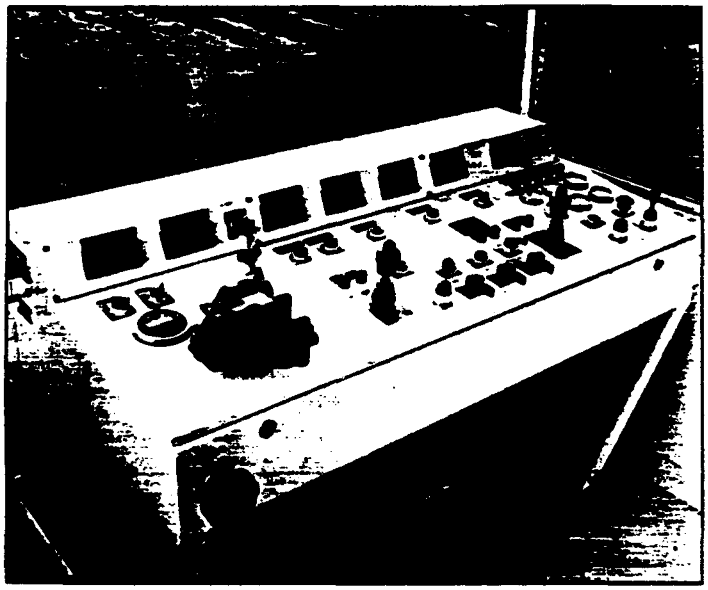
The volume of the system is 5000 gallons. The solids removal equipment consists of both a shale shaker and desanding/desilting cones. Drilling mud is circulated through the solids removal equipment three times before being pumped downhole. All removed solids are diverted into roll off containers or bins.

In addition to the mechanical mud system, one crew members only responsibility is to insure the mud properties are correct and that the system is functioning properly.

SECTION VI

AMERICAN DIRECTIONAL DRILL

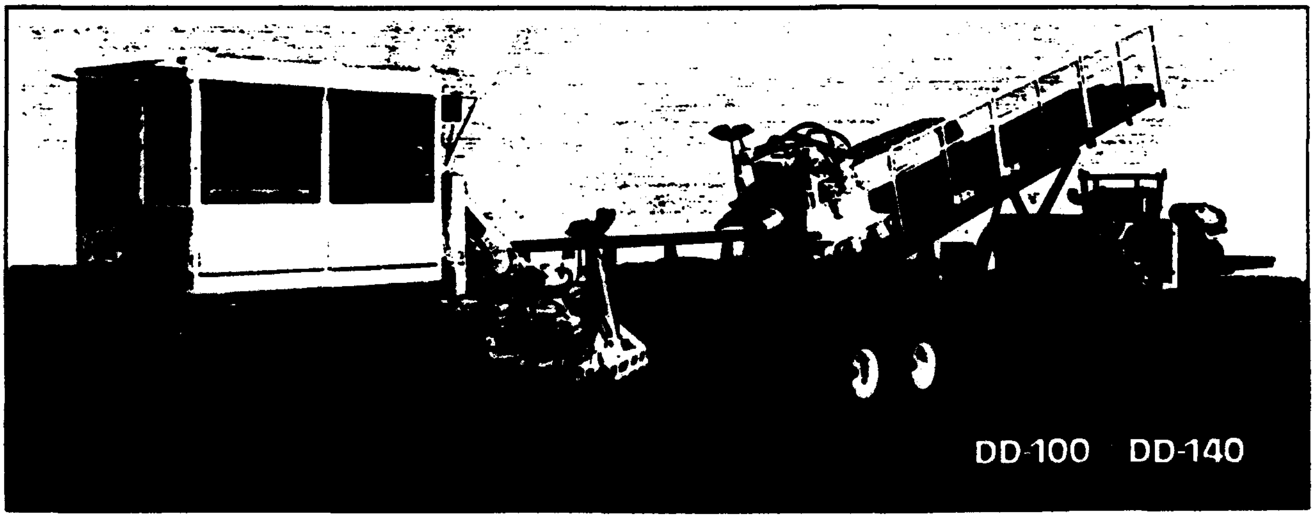
DD-100 / DD-140 Directional drills that you can keep busy year-round



Operators console featuring optional digital readout displays.

Feature List

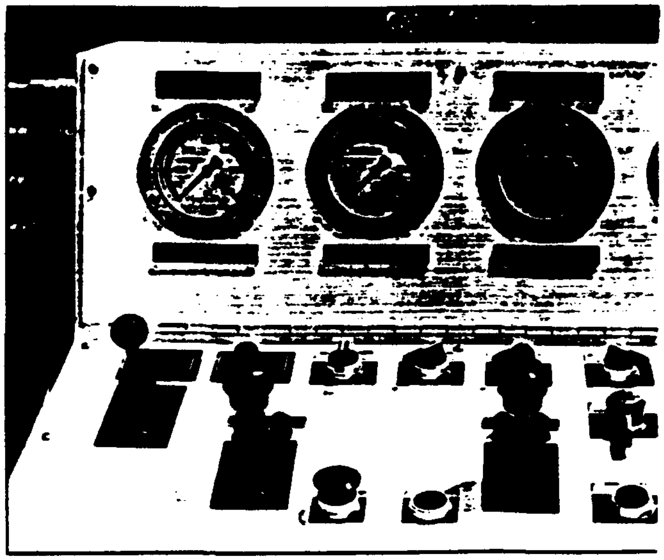
- ☐ Trailer mounted rig arranged for backing into site; eliminates lifting and hookup beside entrance pit.
- ☐ Self-erecting. Hydraulic cylinders raise rig to exact entry angle.
- ☐ Rack and pinion design for rugged, dependable, and positive carriage drive.
- ☐ Fully hydraulic wrench and fixed clamp for pipe makeup and breakout.
- ☐ Adjustable quartz floodlights on wrench and carriage.
- ☐ Wire gland and commutator for use with state-of-the-art downhole instrumentation.
- ☐ Rig fitted with full length, non-skid walkways with handrail.
- ☐ Carriage travel length to handle 30 foot *(9.1 m)* pipe lengths.
- ☐ Heavy-duty roller bearings to withstand thrust and pullback forces incorporated into rotary drive gearbox.
- ☐ All hydraulic hoses and cable to the moving drill carriage enclosed in rolling type carrier.
- ☐ Made in the U.S.A.



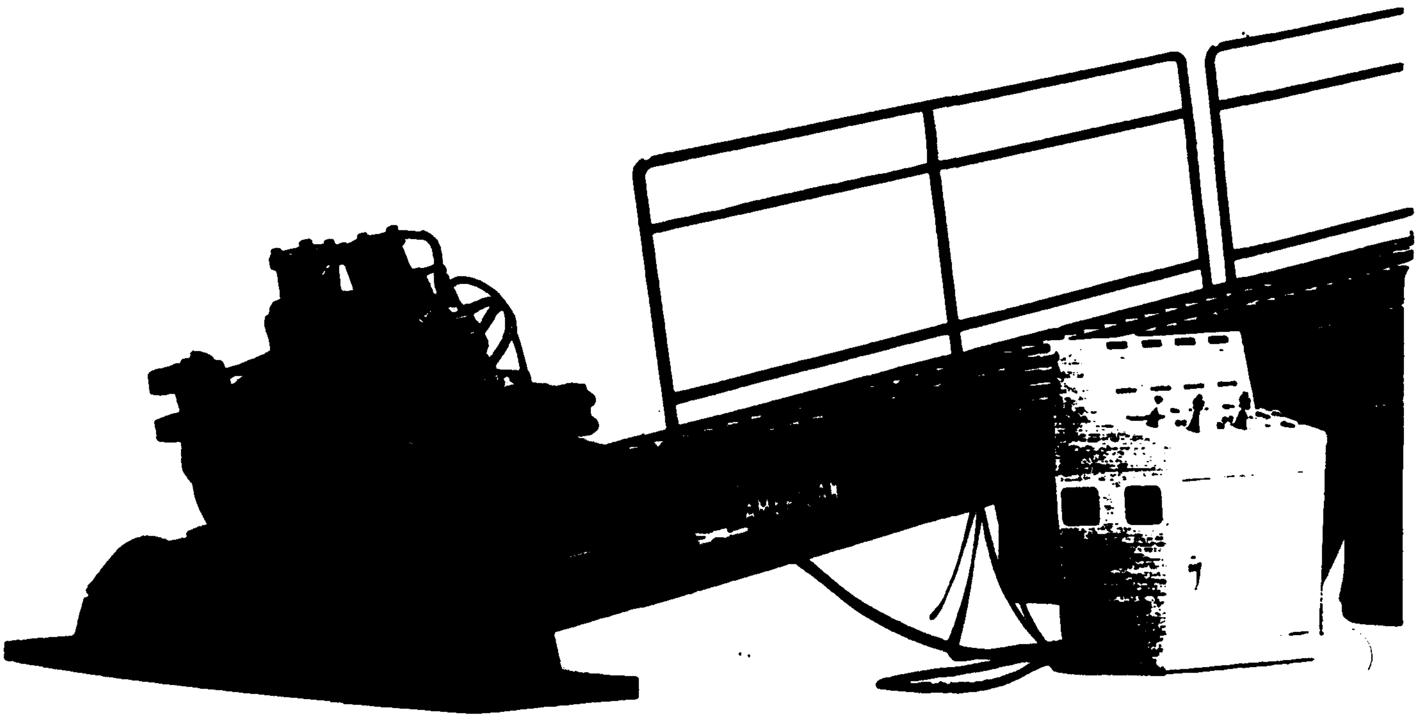
DD-140 with optional drillers cabin.

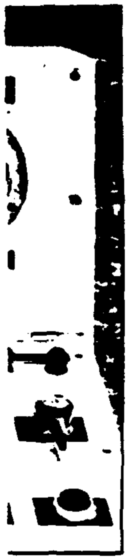
DD-100 / DD-140
The smallest of the big rigs

Only American Directional Drill offers a fully hydraulic wrench/clamp assembly featuring operator adjustable pressure settings.



Operators console with pressure gauges as standard equipment.





The American Directional Drill DD-100 and DD-140 are the smallest of the big rigs and are designed to do the majority of the crossings being designed and bid in todays growing market. The rigs are particularly equipped to handle crossings of less than 3,000 feet in length and with less than 24-inch diameter product lines.

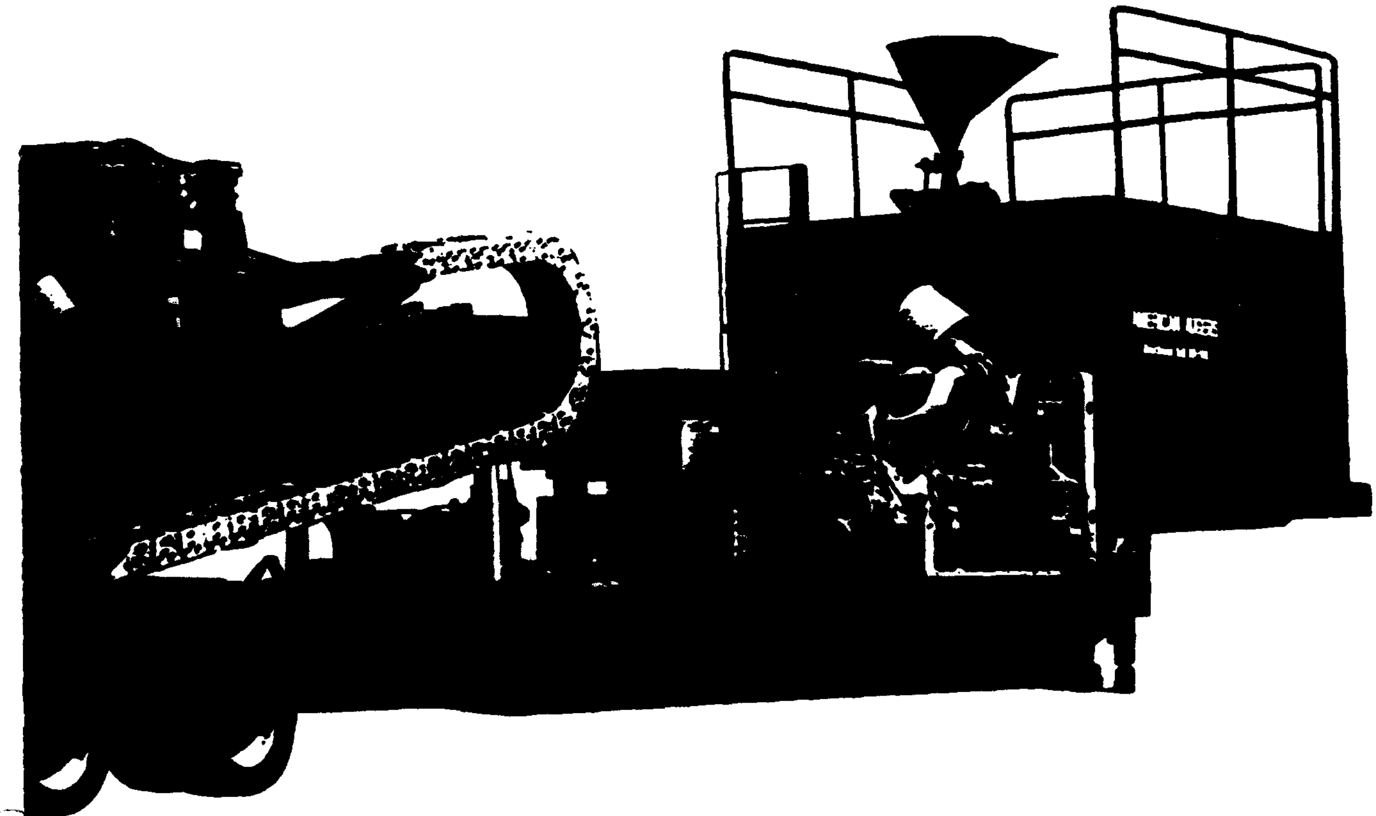
The DD-100 and DD-140 are directional drills you can keep busy year-round — no more waiting on the "big jobs" to bid. Both rigs are capable of larger diameters for short runs, however. In fact, a DD-140 drilled and reamed a 48-inch hole and pulled a 36-inch gas line 600 feet under the Trans-Canada Highway.

The rack and pinion design of the drill carriage eliminates the need for chains, cables or cylinders. There's power to spare without sacrificing precision for high-speed rotary drilling in hard rock formations. Sensitive turntable controls allow the precise rotation needed to set the direction of the down hole navigation instruments.

Pipe make up and breakout is easy work with the fully hydraulic wrench and fixed clamp assembly. The wrench and fixed clamp separate 8" to allow easy lineup of the tool joint in the clamps. The optional mud pump system gives you a compact drilling package on a single trailer for mobility and fast set-up.

Visit our Wooster, Ohio plant anytime. You'll see rigs under construction, talk to our engineering staff and see blueprints, components and parts, operators manuals and our technical support department. With rigs in service around the world, we have the knowledge and experience to keep you drilling.

American Directional Drill: "The World's Foremost Manufacturer of Directional Drills."



AMERICAN DIRECTIONAL DRILL

AMERICAN DIRECTIONAL DRILL SPECIFICATIONS	**DD-100**	**DD-140**
Drilling Torque - 4 Speed/Torque Ranges		
Lo Range - Maximum Torque	20,000 Ft-Lbs *(27,120 N-m)*	25,000 Ft-Lbs (33,900 N-m)
Lo Range - Maximum Speed	23 RPM	21 RPM
Mid-Lo Range - Maximum Torque	11,500 Ft-Lbs *(15,600 N-m)*	12,000 Ft-Lbs *(16,270 N-m)*
Mid-Lo Range - Maximum Speed	40 RPM	44 RPM
Mid-Hi Range - Maximum Torque	5,900 Ft-Lbs *(8,000 N-m)*	7,500 Ft-Lbs *(10,170 N-m)*
Mid-Hi Range - Maximum Speed	85 RPM	70 RPM
Hi Range - Maximum Torque	3,300 Ft-Lbs *(4,475 N-m)*	3,600 Ft-Lbs *(4,880 N-m)*
Hi Range - Maximum Speed	135 RPM	140 RPM
Drilling Carriage Drive - Force/Speed Ranges		
Lo Range - Maximum Thrust or Pullback	100,000 Lb *(445 kN)*	140,000 Lb *(623 kN)*
Lo Range - Maximum Speed	30 Ft Per Min *(9.1 m)*	25 Ft per Min *(7.6 m)*
Hi Range - Maximum Thrust or Pullback	30,000 Lb *(133 kN)*	28,000 Lb *(124 kN)*
Hi Range - Maximum Speed	100 Ft per Min *(30.5 m)*	125 Ft per Min *(38.1 m)*
Drill Angle: Includes Hydraulic Lifting and Pinned Outriggers	10 to 18 Degrees	10 to 25 Degrees
Wrench/Fixed Clamp Assembly		
Maximum Breakout Torque	49,000 Ft-Lbs *(66,400 N-m)*	70,000 Ft-Lbs *(95,000 N-m)*
Maximum Makeup Torque	35,000 Ft-Lbs *(47,500 N-m)*	40,000 Ft-Lbs *(54,200 N-m)*
Clamps Grip Range	2¾" to 7⅞" O.D. *(70 - 180 mm)*	2¾" to 12⅜" O.D. *(70 - 315 mm)*
Power Source Engines	175 HP *(131 kW)* Diesel 250 HP *(187 kW)* Diesel Optional	250 HP *(187 kW)* Diesel
Pumps	2 Hydrostatic Drive Pumps 1 Each for Drill Torque and for Thrust/Pullback 1 Pressure Compensated Piston Pump for Pipe Joint Clamping and Wrench Functions Gear Pumps as required for Auxiliary Functions	
Hydraulic Oil Cooler in Front of Engine Radiator		
Note: While accurate at publication, all specifications are subject to change without notice or obligation to retrofit units.		

UNDERGROUND TECHNOLOGY, INC.

The Leader in Trenchless Technology

AMERICAN AUGERS

AMERICAN DIRECTIONAL DRILL

AMERICAN TUNNELING EQUIPMENT

CORPORATE HEADQUARTERS:
3310 Columbus Road • P. O. Box 460 • Wooster, Ohio 44691 U.S.A. • Phone: 216-264-5666 • 800-321-4930 • Fax: 216-264-5514

CALIFORNIA PLANT:
23591 Robertson Blvd. • Chowchilla, CA 93610 U.S.A. • Phone: 209-665-1345 • 800-345-3023 • Fax: 209-665-2388

134 3-92

TECHNICAL MEMORANDUM Q CH2M HILL

PREPARED FOR: McClellan Air Force Base

DATE: June 9, 1994

SUBJECT: Evaluation of End-Use Options
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.FS

Purpose and Scope

This technical memorandum develops and evaluates several potential end-use options and recommends two end-use systems that would provide a beneficial use for treated groundwater from McClellan Air Force Base (McClellan AFB). One of these end-use systems will be included as part of the remedial actions that will be implemented to reduce the cost and duration of clean up of the contaminated groundwater. The remedial action will consist of a groundwater extraction system, a treatment system, and an end-use system.

This technical memorandum covers background information on the existing end-use system, treated groundwater characteristics, end-use screening, development of four end-use options, and implementation of two recommended end-use systems. The end-use options, consisting of the existing greywater system, selling to neighboring water utilities, onsite groundwater recharge, and discharging to Magpie Creek, are developed in detail and include site descriptions, water usage, facilities required, and institutional issues. The four end-use options become components of the recommended end-use systems. The development of the two recommended end-use systems includes order-of-magnitude capital and annual cost estimates without contingencies or allowances.

Background

McClellan AFB has been operating a groundwater extraction system and treatment plant on the west side of McClellan AFB since 1985. The treatment process includes air stripping, heat exchangers, and granular activated carbon to remediate approximately 200 gallons per minute (gpm) of contaminated groundwater. The primary groundwater contaminants are volatile organic compounds (VOCs) with the main contaminant being trichloroethene (TCE).

The effluent from the treatment plant is currently discharged into Magpie Creek. The discharge is regulated by National Pollutant Discharge Eliminating System (NPDES) Permit No. CA0081850 issued by the California Regional Water Quality Control Board (RWQCB), Central Valley Region Order No. 91-171. The permit requires that the treated water quality meet nondetectible levels for pesticides and VOCs, except that acetone should not exceed 1 mg/l, methylethyl ketone should not exceed 1 mg/l, and methylisobutyl ketone should not exceed 1 mg/l.

Treated Groundwater Characteristics

In this technical memorandum it has been assumed that the water quality standards applied to the discharge of the existing groundwater treatment plant will be applied to the water treated in this remedial investigation/feasibility study (RI/FS).

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, the following four flow rate scenarios were developed to account for the range of flows associated with the background target volume, risk target volume, and MCL target volume developed in Appendix J.

- Scenario No. 1—Low flow at the east treatment unit of 400 gpm or 640 acre-feet (ac-ft) per year.
- Scenario No. 2—High flow at the east treatment unit of 720 gpm or 1,160 ac-ft per year.
- Scenario No. 3—Low flow at the west treatment unit of 600 gpm or 960 ac-ft per year.
- Scenario No. 4—High flow at the west treatment unit of 1,600 gpm or 2,560 ac-ft per year.

These flow rate scenarios provide the basis for developing facility requirements and estimating capital and annual costs.

End-Use Screening

The end-use options that were suggested by McClellan AFB, the regulatory agencies, CH2M HILL, or outside groups were screened to limit the number of possible end uses for detailed evaluation. This section presents the end-use screening criteria, the initial screening of end-use options, and the final screening of end-use options.

Screening Criteria

Table Q-1 presents the screening criteria and their measurable factors.

Table Q-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., 1,600 gpm for 1 day is 2.5 MG) or no storage
		Robustness	1. Ability to take treated water year round 2. Ability to have a backup 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

Screening Process

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. Final screening took place at the August 25, 1993 Alternatives Development Workshop.

Initial Screening

Initial screening of the end-use options occurred at the August 10, 1993 Contaminated Groundwater Cleanup Workshop. Participants included McClellan AFB, CH2M HILL, Radian Corporation, Mitre, and neighboring water utilities including Sacramento County, Caltrans, Rio Linda Water District, Sacramento Metropolitan Water Authority, Arcade Water District, Citizens Utilities, City of Sacramento, Northridge Water District, and Natomas Central Mutual Water District. The following end-use options were discussed with the results in parenthesis:

1. Onsite Groundwater Injection—Has potential; however, it may push contamination offsite into production wells, and it may split a contaminated plume. (Carried forward.)

2. Offsite Groundwater Injection—Would be hard for McClellan AFB to manage, and conveyance costs would be high. (Dropped.)

3. 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.)

4. Recharge Basins—Probably not feasible due to a hardpan under most of McClellan AFB. (Dropped.)

5. Discharge to Sacramento Regional Public 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.)

6. Discharge to Local Golf Courses—Perhaps feasible; however, it would be a seasonal usage with high summer demand and no winter demand. (Dropped.)

7. Discharge to McClellan AFB Existing Greywater System—System has a limited capacity; however, McClellan AFB is interested in reusing as much as possible. (Carried forward.)

8. 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

Final screening took place at the August 25, 1993 Alternatives Development Workshop. Participants included McClellan AFB, U.S. Environmental Protection Agency (EPA), California Department of Toxic Substance Control (DTSC), RWQCB, Clean Sites, CH2M HILL, Radian Corporation, Mitre, City of Sacramento, and neighboring water utilities including Sacramento County, Caltrans, Rio Linda Water Agency, Sacramento Metropolitan Water Authority, and Northridge Water District. The discussions resulted in the following two end-use systems being put forward as the two systems of choice:

1. System 1 would convey the first 200 gpm of treated groundwater to McClellan AFB existing greywater system. The remaining flow would be sold to the

neighboring water districts. In the event of maintenance requirements, the backup system would discharge the treated groundwater to Magpie Creek.

2. System 2 would convey the first 200 gpm of treated groundwater to McClellan AFB existing greywater system. The remaining flow would be injected into the groundwater at the northeast end of McClellan AFB. In the event of maintenance requirements, the backup system would discharge the treated groundwater to Magpie Creek.

The components of these two systems are discussed separately and then as systems in the following sections.

Further Development of End-Use Options

As a result of the screening effort, the end-use options that were more completely developed include: (1) existing greywater system; (2) sell to neighboring water utilities; (3) onsite groundwater injection; and (4) discharge to Magpie Creek. Further development of the end-use options include a site description, water usage, facilities required, and institutional issues.

Water usage is the estimated amount of water expected to be reused by implementing the option. Facilities required for each option were developed using the following four groundwater pumping scenarios: (1) East Treatment Unit low flow at 400 gpm; (2) East Treatment Unit high flow at 720 gpm; (3) West Treatment Unit low flow at 600 gpm; and (4) West Treatment Unit high flow at 1,600 gpm. Institutional issues were identified through the screening workshops.

Pipeline alignments were developed for each end-use option. These alignments have been field checked solely for general constructability, but not for utility interferences or right-of-way width. It should be expected that these alignments may change during preliminary design as more detailed engineering data becomes available.

Option 1—Existing Greywater System

McClellan AFB presently uses some water from the existing groundwater treatment plant in a greywater system. The greywater system consists of an extensive network of piping to cooling towers. The cooling towers are located on building roofs and are part of the heating, ventilation, and air conditioning units.

Site Description

The existing greywater system was originally completed in 1978 with pipes ranging from 14-inch to 1/2-inch diameter. Modifications completed in the spring of 1993, including a 250,000-gallon storage tank near the existing groundwater treatment plant, have been made that should allow the system to be operable. However, a pressure leak test still has to be made by McClellan AFB to ensure the viability of the older pipes and appurtenances. The system covers much of McClellan AFB with the exception of the Northeast corner. The system is connected primarily to cooling towers (approximately 22) and jet engine test cells. No irrigation use is planned with this system. The system also includes a discharge point to Don Julio Creek riparian area near Building 1205 off of Patrol Road.

Water Usage

The system has not been used to date, since the pressure leak test is still needed, so actual flow demand with this system is unknown. Personnel at McClellan AFB believe the system can handle at least 200 gpm. A flowmeter located at the storage tank near the groundwater treatment plant will be used to obtain flowrates and cumulative flow quantities.

Facilities Required

The reliability of the existing greywater system is unknown. Additional facilities to be required will depend on the status of the existing system. An extensive pipe network could potentially be required.

Since developing a new greywater system plan is beyond the scope of this study, the assumption is made that existing known operable parts of the system will be used. This assumption limits the water usage to approximately 200 gpm. Only water from the west treatment unit site will be used for the greywater system, since connections are located at that site.

Facilities required for this option are listed in Table Q-2 and include pipeline and pumps. The assumption was made that approximately 400 feet of pipe will be required to connect the west groundwater treatment unit to the 250,000-gallon grey-water storage tank.

Table Q-2
Facilities Required for Greywater System

	Groundwater Pumping Scenario		
	East Treatment Unit		West Treatment Unit
Facilities	Low Flow (400 gpm)	High Flow (720 gpm)	Flow (200 gpm)
1. Pipeline			
-- Diameter (in)	--	--	6
-- Length (ft)	--	--	400
2. Pump Station			
-- Design flow	--	--	200
-- Total dynamic head	--	--	60
-- Delivery pressure	--	--	5
-- Motor size	--	--	5

Institutional Issues

There are two main issues that limit the desirability of this end-use option. It is unknown when the existing greywater system will be operational, and the existing greywater system is unable to take a large volume of treated groundwater on a continuous basis.

Option 2 – Sell to Neighboring Water Utilities

This end use option involve selling treated groundwater to neighboring water utilities. Four water purveyors that have shown an interest in obtaining this water, if the cost is comparable to that of their present water supply. These purveyors include Arcade Water District, Northridge Water District, Rio Linda Water District, and Citizens Utilities.

Site Description

A connection to Northridge Water District was selected for the east treatment unit site since the District has an 8-inch and a 20-inch service connection that are already established for McClellan AFB, in the vicinity of the proposed east treatment unit site. The 20-inch service connection was selected for the east treatment unit site. A connection to Rio Linda Water District's 8-inch water mains appeared to be the most economical connection for the west treatment unit site.

The conveyance pipeline alignments from the treatment unit sites to the proposed connections are shown in Figure Q-1.

Water Usage

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 proposed supply. It is assumed that all available water could be used by the Districts on an as-generated basis. From discussions with the Districts, no flow equalization will be required. Rio Linda Water District has a nearby storage tank that could serve for flow equalization. Northridge Water District believes that it could install a small tank for flow equalization, if necessary.

Facilities Required

The facilities required for Northridge Water District and Rio Linda Water District connections are presented in Table Q-3 and are shown in Figure Q-1. The Northridge Water District has a 20-inch service connection that will require slight modifications. Additional facilities required for the Northridge Water District connection will include approximately 1,600 feet of 8-inch-diameter pipe for low flow scenario and approximately 1,600 feet of 10-inch pipe for the high flow scenario. Pumping systems will be required to supply pressurized water to the Districts. Water will be delivered to Northridge Water District at 65 psi and 52 psi to Rio Linda Water District, since that is the pressure of their systems at the connection points.

Table Q-3
Facilities Required to Sell to Neighboring Water Utilities

	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. Pipeline				
-- Diameter (in)	8	10	10	12
-- Length (ft)	1,600	1,600	7,100	7,100
2. Pump Stations				
-- Design flow (gpm)	400	650	750	1,600
-- Total dynamic head (ft)	170	170	185	85
-- Delivery pressure (psi)	65	65	52	52
-- Motor size (hp)	25	40	50	110

Major features of the pipeline alignment for the connection to Northridge Water District are described as follows:

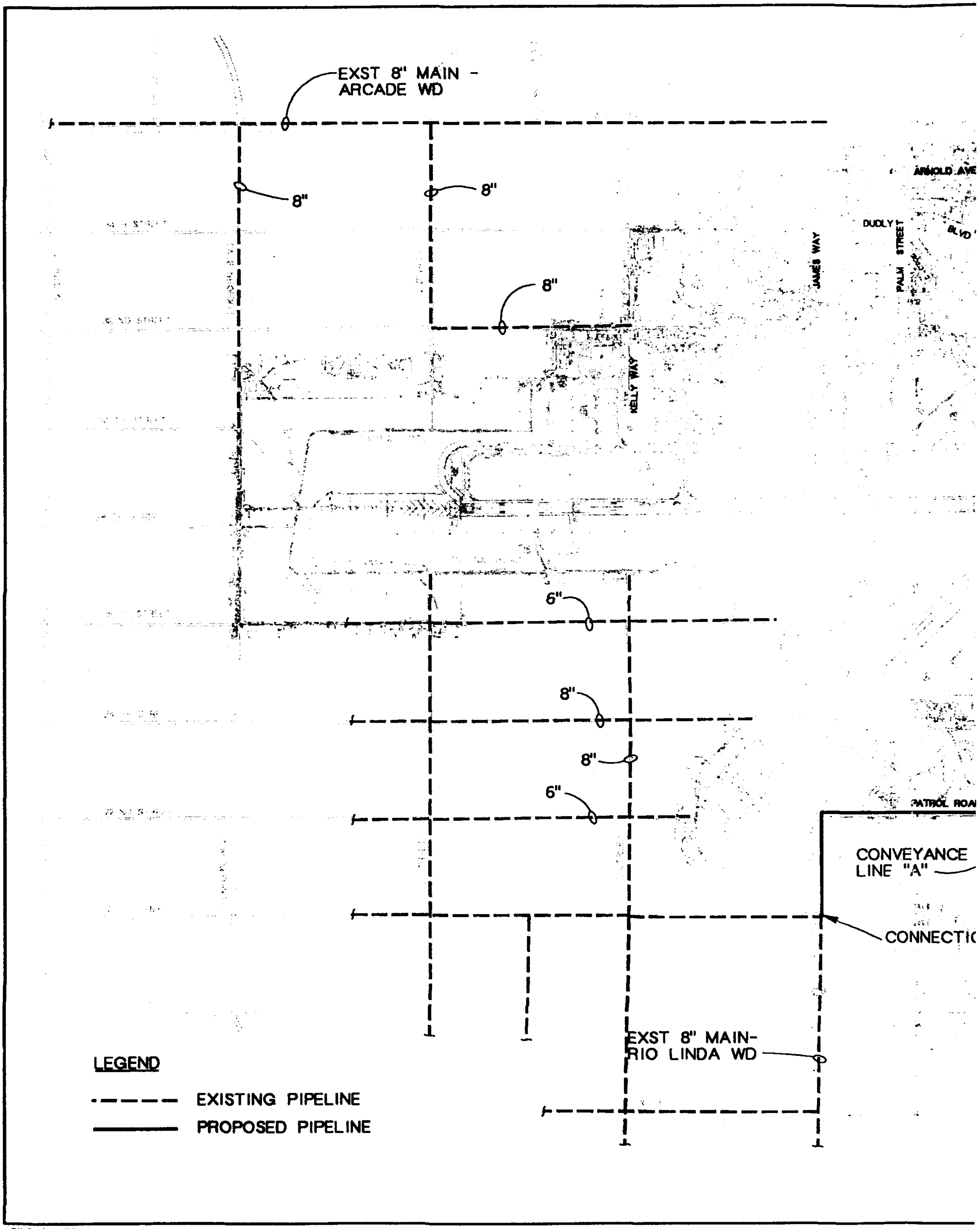
- Pipeline routing for the connection to Northridge Water District begins at the east treatment unit site and extends about 300 feet across the lot to Dudley Boulevard. The only apparent utility interference identified in the field was one sanitary sewer line.

- The alignment then turns northeast onto Dudley Boulevard. This section of pipe is about 1,100 feet long. Dudley Boulevard is a four-lane street with heavy traffic. Overhead power lines are several feet from both sides of the pavement. Sewer and water pipelines appear to be on the north side of the road.

- A 90 degree turn south is taken across the parking lot adjacent to Magpie Creek. This section of pipe is approximately 200 feet long.

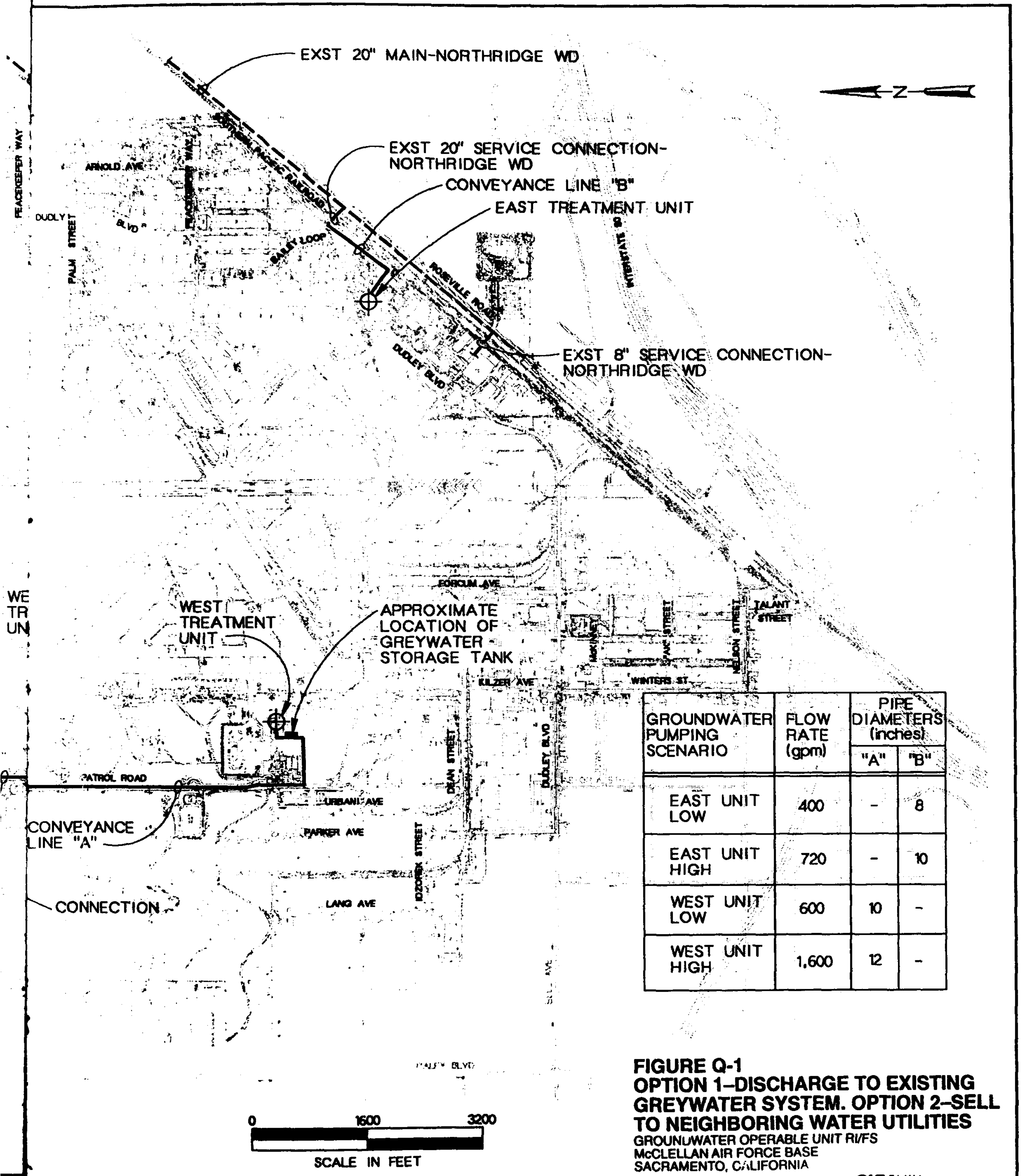
The Rio Linda Water District service connection will require approximately 7,100 feet of 10-inch-diameter pipe for low flow and approximately 7,100 feet of 12-inch-diameter pipe for high flows. The connection will be made to the existing 8-inch water main on the corner of Ascot and 20th Streets.

Major features of the pipeline alignment for the Rio Linda Water District connection are described in the following paragraphs:



EXST 8" MAIN -
ARCADE WD
8"
8"
8"
ARNOLD AVE
DUDLY
BLVD
PALM STREET
JAMES WAY
KELLY WAY
6"
8"
8"
6"
PATROL ROAD
CONVEYANCE
LINE "A"
CONNECTIC
EXST 8" MAIN-
RIO LINDA WD
LEGEND
EXISTING PIPELINE
PROPOSED PIPELINE

GWOU/Q-1.DGN



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 Q-1
OPTION 1–DISCHARGE TO EXISTING GREYWATER SYSTEM. OPTION 2–SELL TO NEIGHBORING WATER UTILITIES
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

- The pipeline alignment is routed for approximately 1,300 feet from the west treatment unit site west to Patrol Road through the treatment unit access road. The pipe then follows Patrol Road north for approximately 4,400 feet. Patrol Road consists of two lanes, with water lines on the west edge for much of this alignment. Overhead power lines are on the west edge. This route has two creek crossings, one for Magpie Creek and one for Don Julio Creek.

- The pipe takes a 90 degree turn west onto Ascot Avenue and follows Ascot Avenue for approximately 1,400 feet until 20th Street. Ascot Avenue and 20th Street both have wide shoulders in an almost rural setting and are lightly traveled. A connection will be made here to the 8-inch-diameter mainline for Rio Linda.

Institutional Issues

Interest in obtaining the treated water for a supplemental source of potable water is high. Northridge Water District is strongly interested in obtaining the treated groundwater for a drinking water source, provided the water quality meets the required potable water standards. The District would have to provide public information to sell the idea to its customers; however, the District does not see this as a problem (personal communication, Jerry Ness, August 10, 1993). Rio Linda Water District has also shown a strong interest in the water.

One limitation to this option may be the current regulations of the State Department of Health Services (DHS) concerning contaminated water. Currently, the DHS regulations state 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.

In a letter dated December 6, 1993, to Doris Varnadore/SM-ALC-EMR from A. L. Ellsworth/DHS, the DHS requested that this alternative be deleted from further consideration (see Attachment D-1 to Appendix D).

The cost of the water should not be a limitation because the Water Districts are amenable to paying up to their existing pumping costs.

The Water Districts are also interested in a reasonable assurance of a continuous source of treated groundwater prior to putting their production wells on standby. McClellan AFB has not guaranteed a steady supply of treated groundwater.

Option 3—Onsite Groundwater Injection

Groundwater injection would involve pumping treated groundwater from both treatment units to injection wells at the north side of McClellan AFB. The wells would be perforated into the regional aquifer to an approximate depth of 600 feet below ground surface.

Site Description

The preferred area for the groundwater injection site is at the north end of McClellan AFB. This site may be accessible by Gate 1010. Presently this area is undeveloped and appears to be unused.

The conveyance pipeline alignment from the treatment unit sites to the groundwater injection site is shown in Figure Q-2 (Option 3—Onsite Groundwater Injection).

Water Usage

All water generated by both the west and the east treatment units would be injected into the wells. It has been assumed for this analysis that a minimum of two and a maximum of three injection wells would be required to accommodate the flow ranges. One of these wells would be required as a standby well for maintenance purposes.

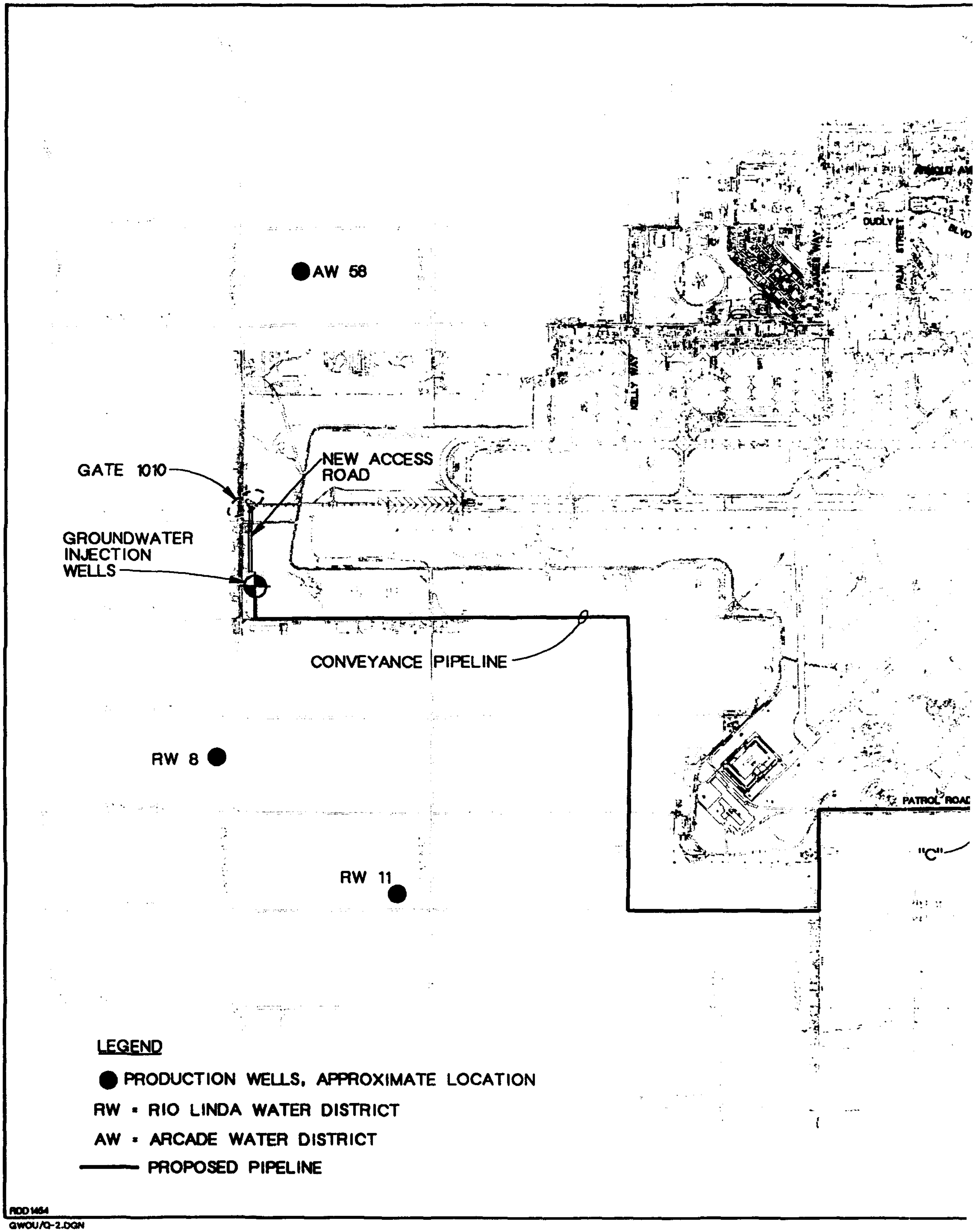
Facilities Required

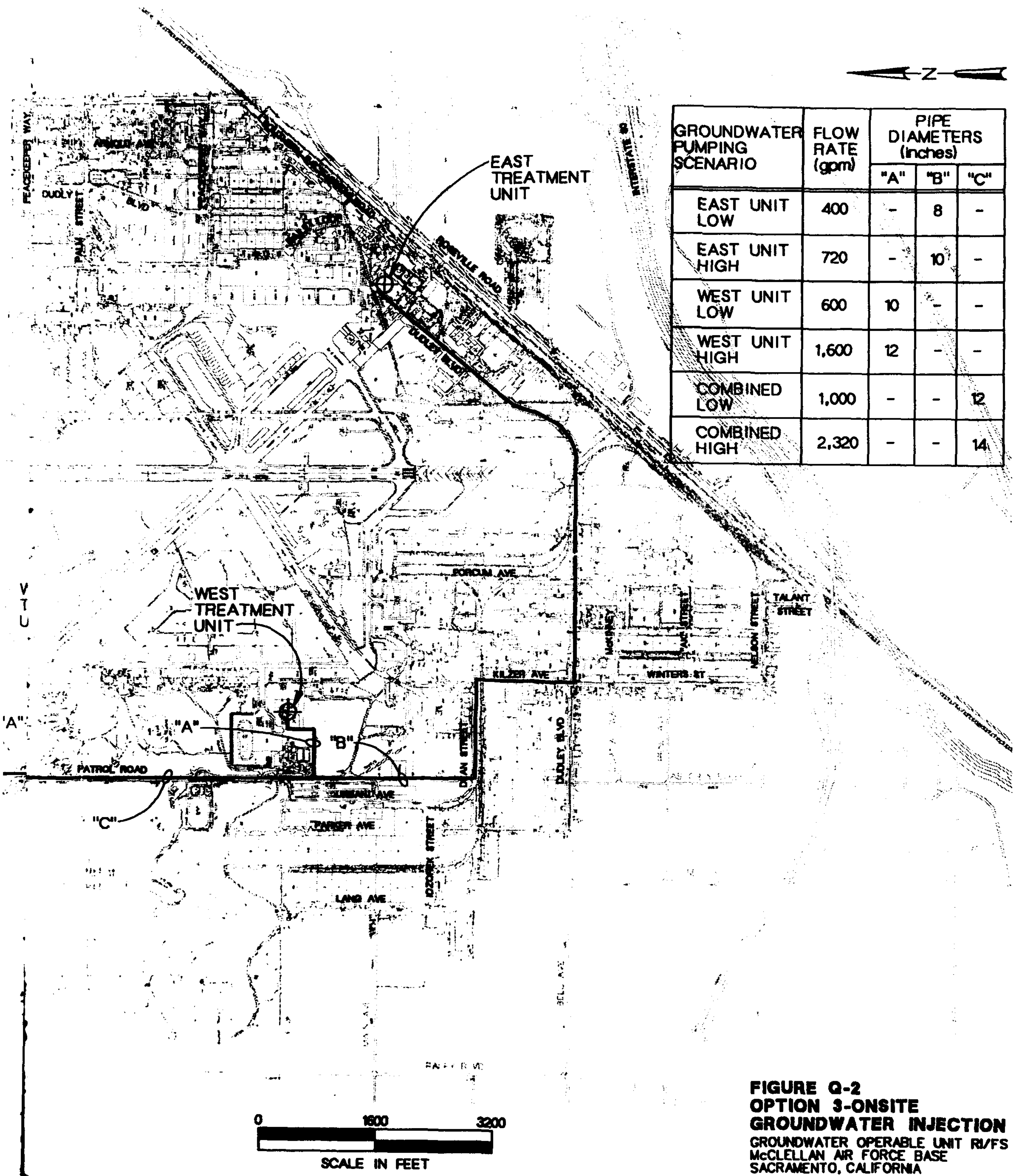
Facilities required for this option are listed in Table Q-4 and include approximately 30,900 feet of pipe, a 1,400-foot access road from Gate 1010 to the well field, injection wells, and booster pumps at each treatment unit site. For facility development, it has been assumed that both treatment units would discharge into a common conveyance pipeline north of the west treatment unit.

Major features of the pipeline alignment are described in the following paragraphs. All pipe will be in paved roads with the exception of the section east from 26th Street to the groundwater injection site.

- Beginning at the east treatment unit site, the pipeline is routed for about 6,600 feet along Dudley Blvd. This four-lane street is fairly busy, since it is a main access road on the Base. The sewer and water lines appear to be to the north edge of the road. The shoulders are wide and there are no overhead electrical lines along much of the route. This route has at least one railroad crossing.

- The alignment follows Kilzer Avenue north for about 1,400 feet to the intersection with Dean Street. Kilzer has two lanes, with overhead lines along the west shoulder. Water appears to be on the west side of the street. One bore and jack will be required to go underneath four sets of railroad tracks just prior to the intersection with Dean Street.


AW 58
ARNOLD AV
DUDLY
BLVD
PALM STREET
KELLY WAY
NEW ACCESS ROAD
GATE 1010
GROUNDWATER INJECTION WELLS
CONVEYANCE PIPELINE
RW 8
PATROL ROAD
"C"
RW 11
LEGEND
PRODUCTION WELLS, APPROXIMATE LOCATION
RW = RIO LINDA WATER DISTRICT
AW = ARCADE WATER DISTRICT
PROPOSED PIPELINE
RDD1464
GWOU/Q-2.DGN



GROUNDWATER PUMPING SCENARIO	FLOW RATE (gpm)	PIPE DIAMETERS (inches)		
		"A"	"B"	"C"
EAST UNIT LOW	400	-	8	-
EAST UNIT HIGH	720	-	10	-
WEST UNIT LOW	600	10	-	-
WEST UNIT HIGH	1,600	12	-	-
COMBINED LOW	1,000	-	-	12
COMBINED HIGH	2,320	-	-	14

FIGURE Q-2
OPTION 3-ONSITE GROUNDWATER INJECTION
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

Table Q-4 Facilities Required for Onsite Groundwater Injection		
	Low Flow	**High Flow**
Facilities	**(400 gpm + 600 gpm = 1,000 gpm)**	**(720 gpm + 1,600 gpm = 2,320 gpm)**
1. Pipeline Length (ft)		
-- 8-inch	11,600	--
-- 10-inch	1,300	11,600
-- 12-inch	18,000	1,300
-- 14-inch	--	18,000
2. Combined Pump Station Capacities		
-- Design flow (gpm)	1,150	2,250
-- Total dynamic head (ft)	170	210
-- Delivery pressure (psi)	10	10
-- Motor size (hp)	75	170
3. Injection Wells		
-- Number of wells	2	3
-- Casing size (in.)	12	12
-- Depth (ft)	600	600
4. Access Road (ft)	1,400	1,400

- The alignment turns west onto Dean Street for about 1,400 feet. Dean Street has two lanes, with overhead lines on the south shoulder. The sewer appears to be located along the north edge of the street.

- Continuing north on Patrol Road, the route covers about 2,200 feet prior to the intersection of Patrol Road and the west treatment unit access road. Patrol Road has two lanes with water and overhead powerlines located on the west edge.

- Beginning at the west treatment plant, the pipeline is routed for about 1,300 feet along the treatment unit access road across to Patrol Road.

- The alignment then follows Patrol Road to the north for about 4,400 feet. Patrol Road is still two lanes. This route has two creek crossings, one for Magpie Creek and one for Don Julio Creek. The alignment will also cross one sewer pipe and one natural gas pipe (RCRA Part B).

- The alignment turns west onto Ascot Avenue and follows that road for about 1,400 feet until it reaches 20th Street. Ascot and 20th both have wide shoulders in an almost rural setting and are lightly traveled. The alignment continues north on 20th Street to E Street for about 2,600 feet. 20th Street has overhead powerlines on the west shoulder, and water valves located on the west edge.

- At the intersection of E Street, the alignment is routed east on E Street for about 4,000 feet to the intersection with 26th Street. Water is on the south edge of E Street. This street is lightly traveled and runs through a residential area.

- The alignment follows 26th Street north for about 5,200 feet, then turns due east for 400 feet to end at the proposed groundwater injection site location. This section of the alignment crosses Robla Creek. One section of pipe will have to cross under the security fence at McClellan AFB, and due to security reasons will probably have to be constructed within 1 day's time.

Institutional Issues

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 contaminated plume. Such effects could include breaking the plume up, thus making the cleanup more difficult and possibly contaminating the existing uncontaminated supplies. This issue is being evaluated as part of the RI/FS.

A Report of Waste Discharge will be required by RWQCB for developing injection installations and requirements. The EPA does not require a permit for injection of a non-hazardous waste (i.e., treated groundwater) into a usable aquifer.

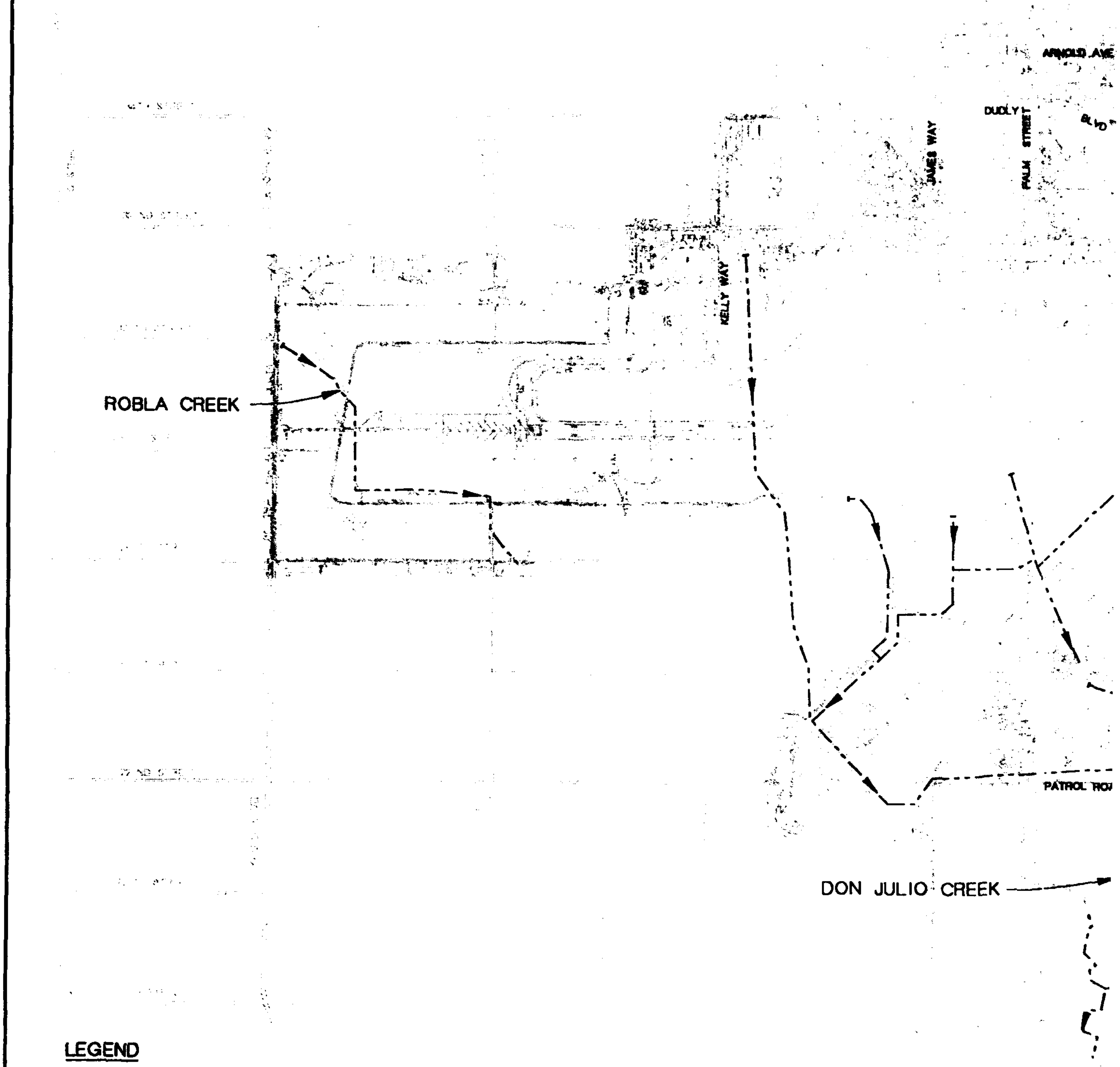
Option 4—Discharge to Magpie Creek

Currently, the groundwater treatment plant discharges its water (approximately 200 gpm) into Magpie Creek. Although a pipe and discharge structure are presently installed for the existing treatment unit, the assumption was made that new facilities would be required. Magpie Creek is a concrete-lined canal through much of the McClellan AFB. Its existing design capacity is 700 cubic feet per second (cfs) or 314,160 gpm (Jerry Reitz, personal communication, July 22, 1993).

Site Description

Discharge to Magpie Creek from the west treatment unit will use a pipeline paralleling the existing discharge pipe along the treatment unit access road. Discharge to Magpie Creek from the east treatment unit will use a pipeline through a congested area of McClellan AFB to the closest available point of discharge.

The relative locations of the treatment unit sites and the associated pipeline routing for this option are shown in Figure Q-3 (Option 4—Discharge to Magpie Creek).

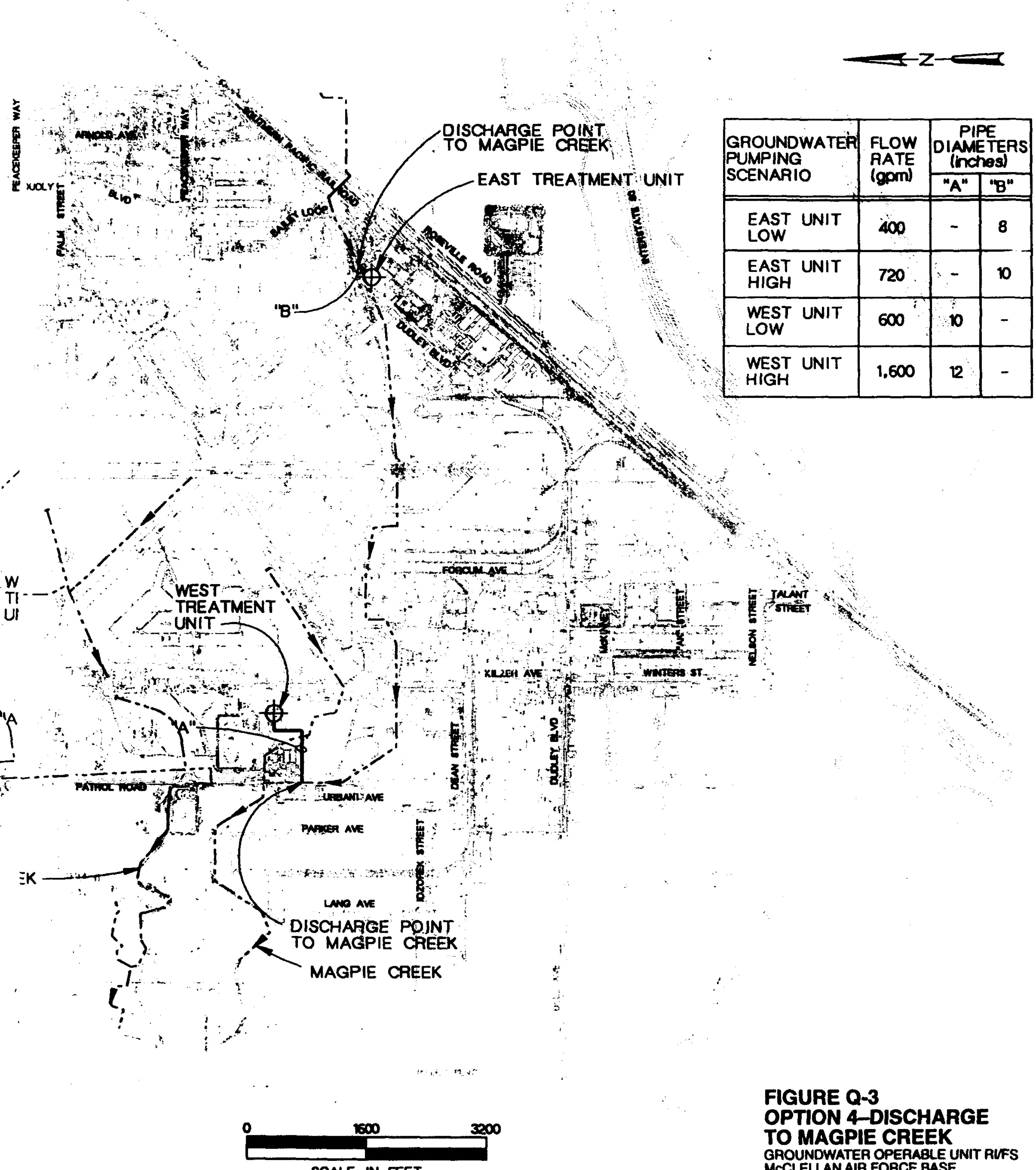


LEGEND

SURFACE DRAINAGE CHANNEL

PROPOSED PIPELINE

GWOU/Q-3.DGN



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 Q-3
OPTION 4–DISCHARGE TO MAGPIE CREEK
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Water Usage

For this study, it is assumed that all generated flow can be discharged to Magpie Creek regardless of the season. However, the creek capacity should be evaluated in detail during the preliminary design because the creek does overflow at some locations during storm events.

Facilities Required

New facilities required for this option are listed in Table Q-5 and include the discharge pipeline from each treatment unit site to the creek, a discharge structure, and a pumping system. The discharge structure is assumed to be corrugated metal pipe with a flap gate at the end to dissipate the energy. The discharge structure would be similar to the one currently used by the groundwater treatment plant.

Table Q-5
Facilities Required for Discharge to Magpie Creek

	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. Pipeline				
-- Diameter (in)	8	10	10	12
-- Length (ft)	200	200	1,400	1,400
2. Pump Station				
-- Design flow (gpm)	400	650	750	1,600
-- Total dynamic head (ft)	25	25	25	30
-- Delivery pressure (psi)	5	5	5	5
-- Motor size (hp)	5	7.5	7.5	20
3. Discharge Structure	1	1	1	1

Institutional Issues

Discharge to Magpie Creek may create additional riparian habitat that McClellan AFB may be responsible for after cleanup is completed. For this reason McClellan AFB does not look at discharge to Magpie Creek as a primary end use. However, if other alternatives do not prove to be feasible, Magpie Creek could become a primary end use.

An NPDES permit will be required and may be similar to the existing NPDES permit requirements for the existing groundwater treatment unit (NPDES No. CA0081850, Order No. 91-171). Each new treatment will not be required to monitor its own discharge. Additional testing and monitoring of Magpie Creek will not be required prior to discharge of any new treated groundwater. However, initial sampling at the groundwater treatment units will be intensive until the system is proven viable (personal communication, Alex McDonald, RWQCB, July 22, 1993).

Implementation of End-Use Options

The end-use options as described above will not be sufficient on an individual basis in terms of operational flexibility. Therefore, the options were combined into two complete systems, with primary and secondary end uses. These two systems were evaluated for each of the four groundwater pumping scenarios, assuming that the entire remedial action program will be designed around one or a combination of these scenarios.

System 1 – Description

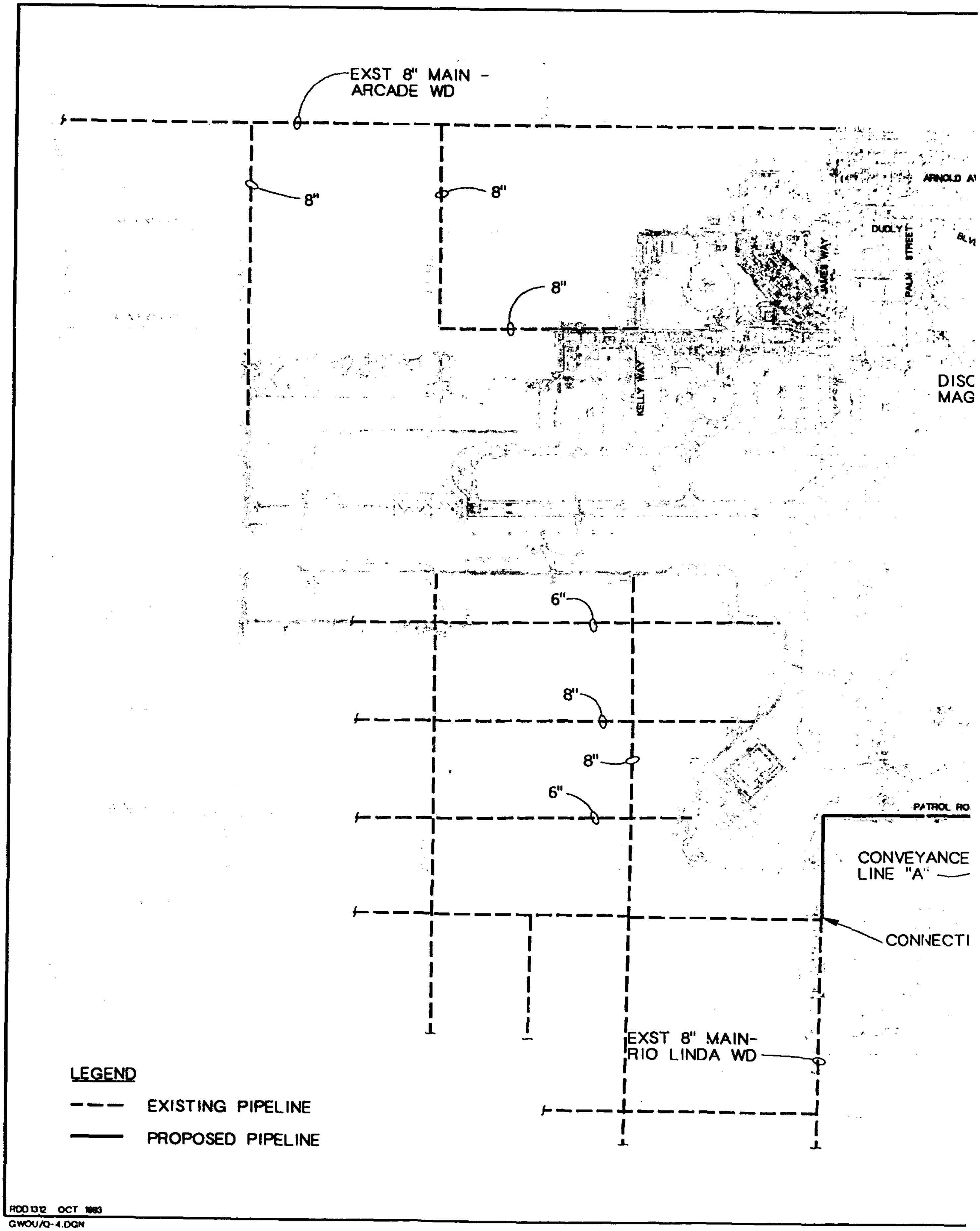
System 1 would convey the first 200 gpm of treated groundwater to McClellan AFB existing greywater system. The remaining flow would be sold to the neighboring water districts. In the event of maintenance requirements, the backup system would discharge the treated groundwater to Magpie Creek. Facilities required for this system are listed in Table Q-6. The pump motor size is based on the maximum size required for a given groundwater pumping scenario. System 1 is shown in Figure Q-4.

Table Q-6
Facilities Required for System 1

Facilities	*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. Pipe Lengths (ft)				
-- 6 in	-------	-------	400	400
-- 8 in	1,800	-------	-------	-------
-- 10 in	-------	1,800	8,500	-------
-- 12 in	-------	-------	-------	8,500
2. Pump Stations				
-- Design flow (gpm)	400	650	750	1,600
-- Total dynamic head (ft)	170	170	185	185
-- Delivery pressure (psi)	65	65	52	52
-- Motor size (hp)	25	40	50	110
3. Discharge Structure at Magpie Creek	1	1	1	1

System 2 – Description

System 2 would convey the first 200 gpm of treated groundwater to McClellan AFB existing greywater system. The remaining flow would be injected into the groundwater at the northeast end of McClellan AFB. In the event of maintenance requirements, the backup system would discharge the treated groundwater to Magpie Creek.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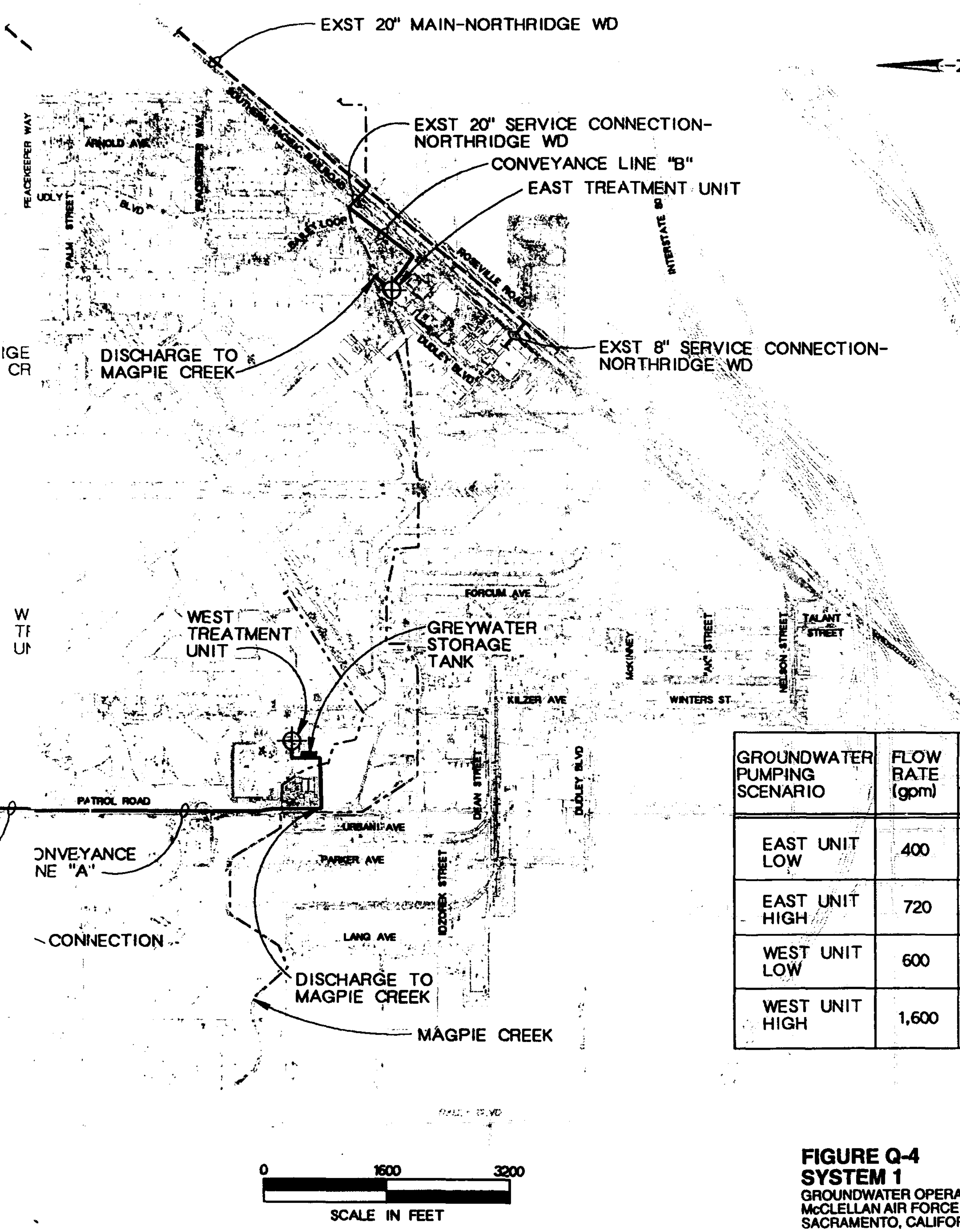
8"
8"
8"
ARNOLD A
DUDLY
JAMES WAY
PALM STREET
KELLY WAY
DISC
MAG
6"
8"
8"
6"
PATROL RO
CONVEYANCE LINE "A"
CONNECTI
EXST 8" MAIN- RIO LINDA WD
LEGEND
EXISTING PIPELINE
PROPOSED PIPELINE
RDD 1312 OCT 1993
GWOU/Q-4.DGN



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 Q-4
SYSTEM 1
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2MHILL

Facilities required for this system are listed in Table Q-7. The pump motor size is based on the maximum size required for a given groundwater pumping scenario. System 2 is shown in Figure Q-5.

Table Q-7
Facilities Required for System 2

Facilities	Groundwater Pumping Scenario	
	Low Flow	High Flow
	(400 gpm + 600 gpm = 1,000 gpm)	(720 gpm + 1,600 gpm = 2,320 gpm)
1. Pipe Lengths (ft)		
-- 6 in	400	400
-- 8 in	11,800	-------
-- 10 in	2,700	11,800
-- 12 in	18,000	2,700
-- 14 in	------	18,000
2. Combined Pump Station Capacities		
-- Design flow (gpm)	1,150	2,250
-- Total dynamic head (ft)	170	210
-- Delivery pressure (psi)	10	10
-- Motor size (hp)	75	170
3. Discharge Structure at Magpie Creek	2	2
4. Injection Wells		
-- Number of wells	3	4
-- Casing size (in.)	12	12
-- Depth (ft)	600	600
5. Access Road (ft)	1,400	1,400

Order-of-Magnitude Costs

Order-of-magnitude cost opinions were prepared for each system in accordance with the guidelines of the American Association of Cost Engineers. These are approximate estimates made without detailed engineering data. The estimates were founded on cost curves, bid tabs from similar water conveyance projects, and preliminary estimated quantities of major facility components. It is normally expected that an estimate of this type would be accurate within +50 percent to -30 percent.

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, and other variable factors. As a result, the final project costs will vary from the estimates presented here. Because of these factors, project feasibility, benefit cost ratios, risks, and funding needs must be carefully reviewed prior to making specific financial decisions or establishing project budgets to help ensure proper evaluation and adequate funding. Both capital and annual costs have been developed for each system evaluated.

Estimated Capital Costs for Systems 1 and 2

Assumptions

Estimated capital costs for Systems 1 and 2 are based on the following assumptions:

- Facilities are independent for each groundwater pumping scenario.
- Pipe diameters are based on a maximum velocity of 5 feet per second (fps) and an allowable friction loss of 7 feet per 1,000 feet of pipe.
- Pipe capital cost is based on $5 per diameter inch per linear foot (materials and installation included).
- Pump capital cost is based on $1,500 per hp.
- Discharge structure to Magpie Creek capital cost is based on the existing structure and an approximate cost of $2,000 each.
- Groundwater injection wells are $90,000 each, assuming a depth of 600 feet.
- One standby groundwater injection well is required for each scenario.
- Access Road is 6-inch gravel base, 12 feet wide.

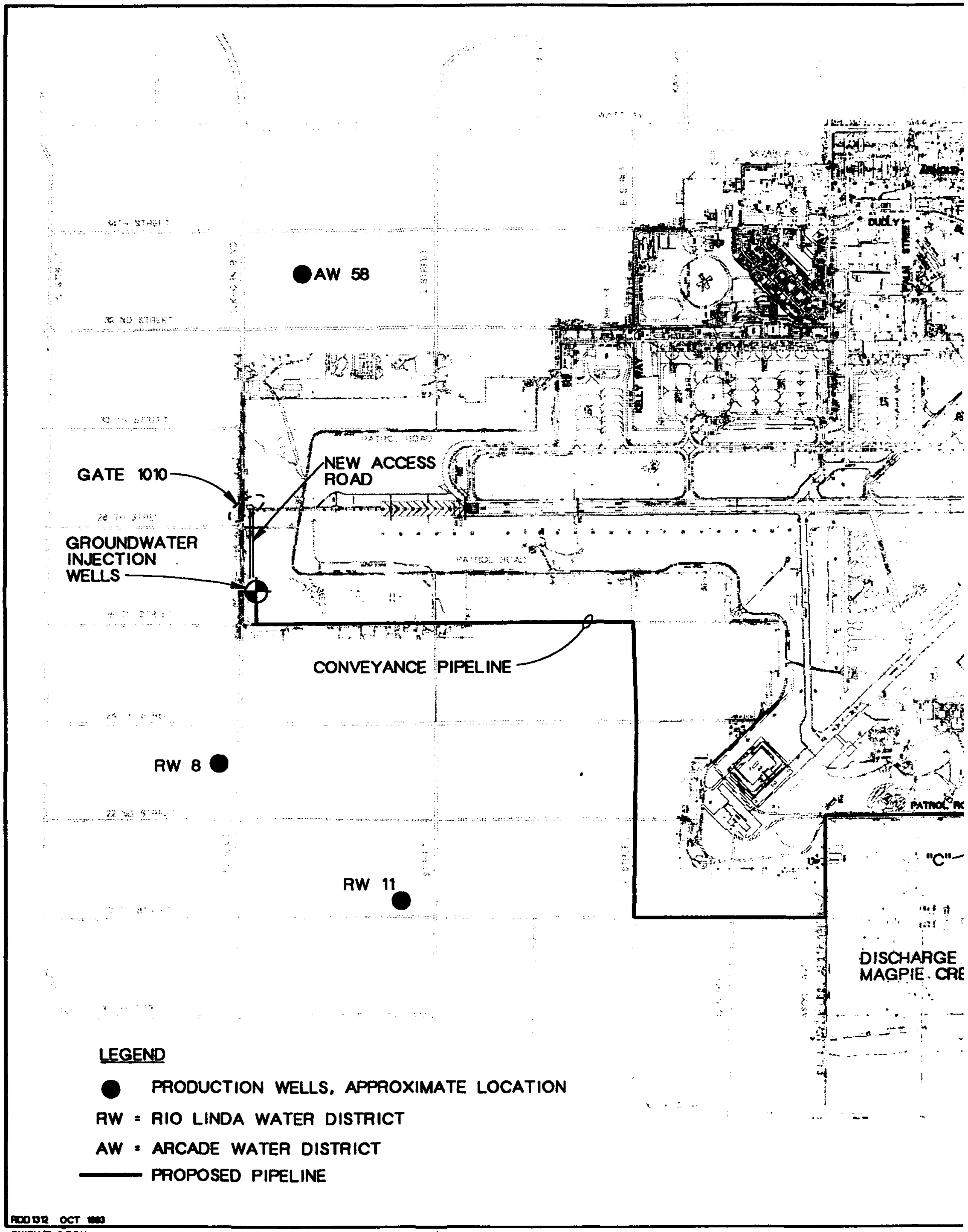
Table of Costs

Capital costs are presented in Table Q-8 for both groundwater pumping systems of low flow and high flow at each treatment unit. As shown in the table, estimated capital costs range from $626,000 (low flows) to $856,000 (high flows) for System 1, and $2,270,000 (low flows) to $2,669,000 (high flows) for System 2. The cost treatment unit portion of System 2 would not be built without the west treatment unit portion of System 2.

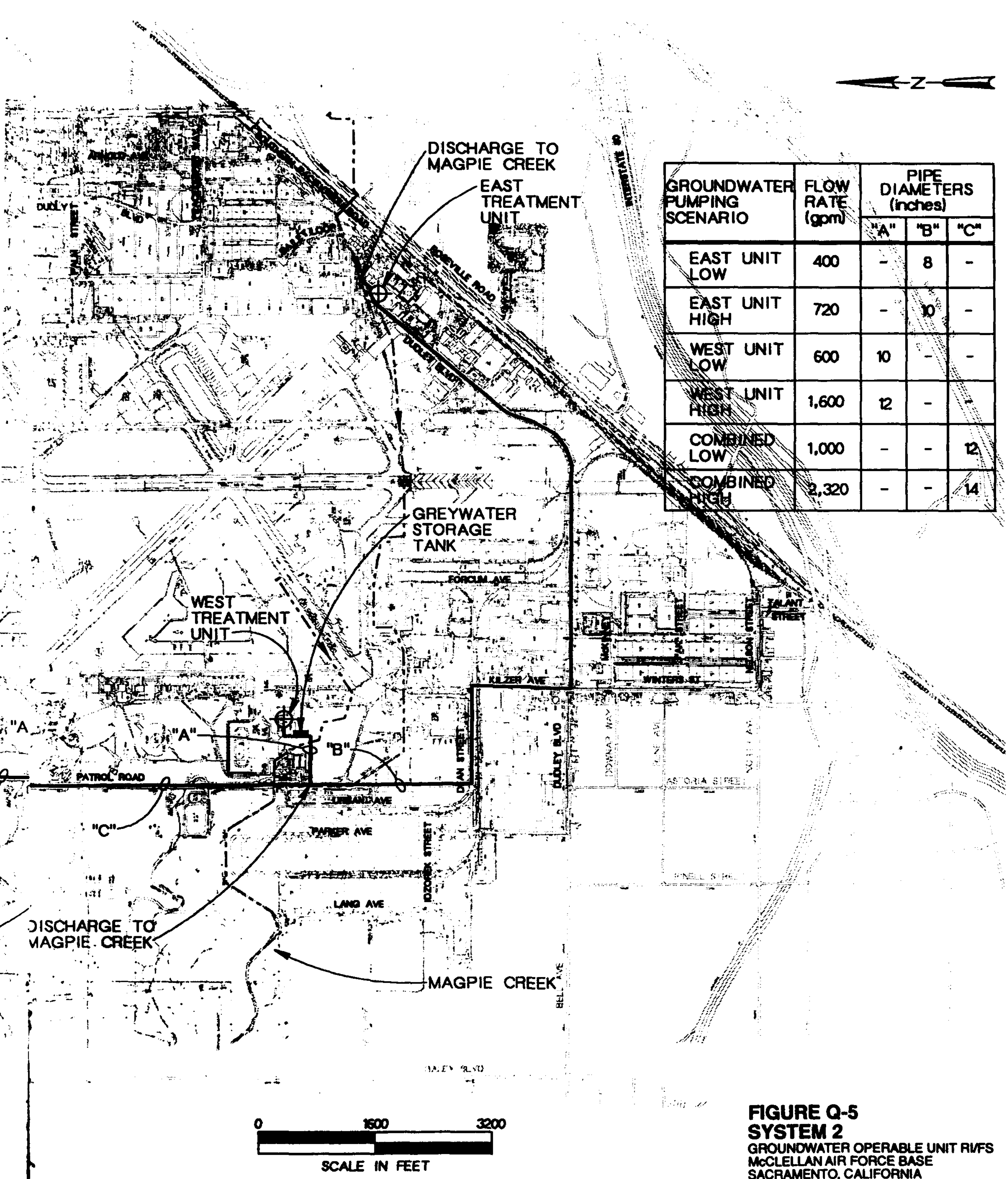
Estimated Annual Costs for Systems 1 and 2

Assumptions

Annual costs include operation and maintenance and pumping requirements. Labor is not included. Annual costs were estimated for both systems using the following assumptions:


AW 58
GATE 1010
NEW ACCESS ROAD
GROUNDWATER INJECTION WELLS
PATROL ROAD
CONVEYANCE PIPELINE
RW 8
RW 11
"C"
DISCHARGE
MAGPIE CRE
LEGEND
PRODUCTION WELLS, APPROXIMATE LOCATION
RW = RIO LINDA WATER DISTRICT
AW = ARCADE WATER DISTRICT
PROPOSED PIPELINE
RDD1312 OCT 1993
GWOU/Q-5.DGN

(1)



GROUNDWATER PUMPING SCENARIO	FLOW RATE (gpm)	PIPE DIAMETERS (inches)		
		"A"	"B"	"C"
EAST UNIT LOW	400	-	8	-
EAST UNIT HIGH	720	-	10	-
WEST UNIT LOW	600	10	-	-
WEST UNIT HIGH	1,600	12	-	-
COMBINED LOW	1,000	-	-	12
COMBINED HIGH	2,320	-	-	14

FIGURE Q-5
SYSTEM 2
GROUNDWATER OPERABLE UNIT RI/FS
McCLELLAN AIR FORCE BASE
SACRAMENTO, CALIFORNIA

CH2M HILL

Table Q-8 System Capital Costs					
		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

- Facilities are independent for each groundwater pumping scenario.
- Pipe friction head losses were based on a Hazen Williams coefficient of friction of 120, which is representative of a rough pipe (conservative).
- Pump elevations are at ground surface in general vicinity of treatment unit site as based on United States Geological Survey (USGS) map.
- Discharge elevations are at ground surface in general vicinity of discharge point as based on USGS map.
- Pump discharge assembly losses (losses through fittings and valves) are approximately 10 feet.
- A discharge head of approximately 5 psi is required for the existing greywater system, approximately 65 psi for Northridge Water District, approximately 52 psi for Rio Linda Water District, approximately 10 psi for groundwater injection, and approximately 5 psi for Magpie Creek.
- The combined pump and motor efficiency will be 70 percent.
- Pumps will operate 24 hours a day, 365 days a year.
- Power cost will be @ $0.06/kilowatt hour (kWh).
- Operation and maintenance costs are based on a percent of capital cost as follows:

-	Pipes	0.5
-	Pumps	5.0
-	Discharge Structures	10.0
-	Groundwater Injection Wells	20.0
-	Access Road	10.0

Annual Costs

Annual costs for both systems are identified in Table Q-9 for each groundwater pumping scenario. As shown in the table, total annual costs range from approximately $36,000 (low flows) to $82,000 (high flows) for System 1, and from approximately $98,000 (low flows) to $156,000 (high flows) for System 2.

Table Q-9
System Annual Costs

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

Works Cited

McDonald, Alex. 1993. Personal communication. July 22.

Ness, Jerry. 1993. Personal communication. August 10.

Reitz, Jerry. 1993. Personal communication. July 22.

PREPARED FOR: McClellan Air Force Base

DATE: March 27, 1994

SUBJECT: Methodology for Budget-Level Cost Estimates
Groundwater OU RI/FS Report
Delivery Order No. 5066

PROJECT: SAC28722.66.FS

Introduction

This technical memorandum describes the assumptions and methodology used to develop budget-level cost estimates for the each of the six remedial action alternatives in the Groundwater OU RI/FS. Capital costs and O&M costs are provided for the proposed extraction, treatment, and end-use systems that comprise each remedial action alternative. Capital costs are expenditures required to initiate and install a remedial action. They are exclusive of costs required to maintain the action throughout its lifetime. Annual operating and maintenance costs are the post-construction costs necessary to ensure continued effectiveness of a remedial action and achievement of its objective.

Capital and O&M costs were developed based on the anticipated tasks and activities required to implement and operate the remedial action. Complete listings of the tasks and activities are presented in Appendix S. The engineer responsible for a specific activity estimated the necessary level of effort and materials required to complete that activity. Costs were then calculated based on quotes from equipment vendors, bid tabs, estimates from similar projects at McClellan AFB or elsewhere, standard costing guidance references, and standard labor rates. The cost for each task was computed by totaling the activities necessary to complete that task. Cost summary tables located at the end of this technical memorandum provide a listing of each task and its estimated budget-level cost. Budget-level costs are considered to be accurate within plus 30 percent or minus 15 percent.

Annual O&M costs were developed for two time periods. Since construction of the remedial action will occur in phases, an initial cost was calculated that included operation of the existing treatment plant and the offbase monitoring wells with wellhead treatment. This initial phase was conservatively estimated at 5 years. When the remedial action is completely installed, the wellhead treatment units will be taken offline, and the O&M costs then reflect the operation of the entire facility.

Extraction System

Capital costs were generated based on all activities related to the completion of the monitoring wells, extraction wells, wellhead treatment units, instrumentation and control (I&C), and collection piping. Major tasks related to the wells include planning, obtaining permits, subcontracting, drilling and logging, sampling, lab analysis, and data interpretation. Activities related to the collection piping include design, utility mapping, obtaining permits, and construction. Annual O&M costs consist of power for the extraction wells and instrumentation, pump and piping maintenance, and sampling and analytical testing.

Capital Cost Estimates

Extraction Wells and Monitoring Wells

Installation of the monitoring wells and extraction wells was estimated to be completed in three phases, each resulting in a separate task order. Table R-1 summarizes the number of proposed wells to be installed offbase, in hot spot locations, and within the remainder of the onbase areas.

Costs for both the extraction wells and monitoring wells were estimated on the basis of cost per foot of depth. Drilling methods will depend on the depth of well, for example:

- A-zone wells (average depth of 140 feet)—Dual tube percussion with cyclone
- B-zone wells (average depth of 200 feet)—Mud-rotary rig with mud pit, pump, flow ditch, and shaker
- C-zone wells (average depth of 300 feet)—Mud-rotary rig with mud pit, pump, flow ditch, and shaker

For A- and B-zone wells, 4 days will be required to mobilize equipment to the boring location, drill the hole, install the well materials including a 2-hp submersible pump, monument at the surface, and decontaminate materials and equipment. For C-zone wells, 5 days will be required for this work. Well screens will consist of 50-foot lengths of flush-jointed, 6-inch-diameter, Type 304 stainless steel, with 0.040-inch slots.

Three-person drilling crews will be used with Level D protective gear required. Derived drilling wastes will require containerization. Drilling mud will be contained in 6,500-gallon Baker tanks. Drill cuttings will be contained in 10-cubic-yard rolloff boxes. Waste materials will be disposed at an onbase facility within 60 days, and the containers will be reused at another boring or returned to the vendor. Costs for chemically characterizing drilling mud and soil cuttings are not included. Decontamination wastewater will be disposed at an onbase treatment facility.

Table R-1
Summary of Groundwater Monitoring and Extraction Wells

	A					B				C				Totals		
	Offbase		Hot Spot	Onbase		Offbase		Onbase		Offbase		Onbase				
	EW	MW	EW	MW	EW	MW	EW	MW	EW	MW	EW	MW	EW	EW	MW	Wells
MCL Target Volume																
Task Order																
1	4	3	15	0	0	5	1	0	0	2	1	0	0	21	10	31
2	11	2	14	0	0	2	3	0	0	1	1	0	0	29	5	34
3	0	0	0	32	42	0	0	20	19	0	0	9	12	73	61	134
Totals	**15**	**5**	**29**	**32**	**42**	**7**	**4**	**20**	**19**	**3**	**2**	**9**	**12**	**123**	**76**	**199**
Risk Target Volume																
Task Order																
1	6	10	15	0	0	7	2	0	0	2	0	0	0	23	19	42
2	16	7	14	0	0	2	5	0	0	1	1	0	0	36	10	46
3	0	0	0	34	53	0	0	21	25	0	0	13	16	94	68	162
Totals	**22**	**17**	**29**	**34**	**53**	**9**	**7**	**21**	**25**	**3**	**1**	**13**	**16**	**153**	**97**	**250**
Background Target Volume																
Task Order																
1	17	15	15	0	0	10	5	0	0	3	0	0	0	37	28	65
2	35	9	14	0	0	3	7	0	0	2	1	0	0	57	14	71
3	0	0	0	36	61	0	0	26	38	0	0	10	12	111	72	183
Totals	**52**	**24**	**29**	**36**	**61**	**15**	**12**	**26**	**38**	**5**	**1**	**10**	**12**	**205**	**116**	**319**

Note: EW = extraction wells; MW = monitoring wells.

Wellhead treatment is proposed for temporary use (about 3 to 5 years) at the offbase extraction wells until the remedial action is fully implemented. Costs include the treatment unit only; no costs were estimated for piping required to convey the discharge water.

Instrumentation and Control

I&C costs were computed for each alternative based on the need for flow measurements and water level measurements for the extraction wellls and monitoring wells, respectively. Data will be collected from all of the proposed monitoring wells plus all of the existing monitoring wells that have been designated to be on the monitoring system. Table R-2 summarizes the I&C requirements.

Table R-2
Summary of I&C Requirements

Case	Monitoring Wells		Extraction Wells		Total Wells	I/O Locations	PLCs	I/O Drops
	Existing	Proposed	Existing	Proposed				
MCL	40	76	9	123	248	83	11	70
Risk	50	97	9	153	309	103	13	87
Background	65	116	9	205	395	132	17	112

Water level data will be collected from the monitoring wells at a maximum frequency of 1 sample per hour per well. The system will be capable of sampling all wells within a one-hour period. Monitoring of the output flow from the extraction wells will enable the operator to determine the well performance and operating status. Cost estimates are based on power being available at the extraction wells for the I&C units and no flow controls being required for the pumps.

The well data will be hardwired to an input/output (I/O) location consisting of a programmable logic controller (PLC) I/O module that can accommodate analog inputs. Well data will be collected from the monitoring wells and extraction wells with level probes or flow meters, respectively. It is assumed that one I/O location (probably at an extraction well having a power source) will service three wells within a radius of 400 feet. The I/O units, in turn, are hardwired to a PLC from where the data are transmitted via modem to a computer control station (PC) located at each of the treatment plants. One PLC should be able to accommodate eight I/O units; thus, the monitoring system needs one PLC for every 24 wells.

The network consists of the following:

- DH-485 network between the PLCs and modems with 16,000 feet of cable

- Six modems and convertors

- RS-232 network between the modems and the PCs with 15,000 feet of conduit

- Two personal computers

- Process monitoring software

Collection Piping

Costs for the collection piping depend upon the length and diameter of pipes as well as the type of pipe. The diameter and length of pipes were developed using a computerized piping network model. The collection piping network varies depending on the target volumes for the alternative.

Design of the collection system was performed using available Microstation base mapping. A software package developed by CH2M HILL, named LYNX, was used as the interface between the Microstation base mapping, a database, and NETWK, the hydraulic analysis software used for piping networks. The collection system piping network was laid out in Microstation over the base mapping to ensure that pipes were located appropriately. LYNX was used to translate the graphical information from Microstation to a database, and then to write input files from the database for use by NETWK After the hydraulic analysis was completed, LYNX was used to generate output reports summarizing the pipe sizes and quantities necessary for this system. LYNX was also used to graphically display the results from NETWK for a visual check of the results. Table R-3 summarizes the pipe quantities for each collection system.

The collection system will consist of both dual-wall containment pipelines and single-wall pipelines. Dual-wall containment pipe will only be used to convey the extracted water from wells located in hot spots to the mainline. Otherwise, costs were based on single-wall pipes. Costs were calculated using C-900 polyvinyl chloride pipe (PVC) suitable for conveying potable water.

Land use in the area surrounding the pipeline construction corridor has a significant impact on the cost of the installation. Pipeline construction in open country typically has little or no utility interference or traffic control requirements, while construction in urban areas can be significantly complicated by these types of additional work. The EPA published a technical report in 1978 entitled *Construction Costs for Municipal Wastewater Conveyance System: 1973-1977* that adjusts sanitary sewer construction costs for various land use categories by a multiplier.

Table R-3 Pipe Quantities for Collection Systems						
Pipe Diam (inches)	Pipe Length (feet)					
	MCL		Risk		Background	
	East	West	East	West	East	West
2	15,312	19,979	20,821	20,016	18,998	29,972
3	22,329	6,538	11,126	21,251	18,619	25,298
4	3,835	3,397	5,115	9,433	2,071	13,986
6	4,315	6,505	4,114	3,292	5,229	11,451
8	1,902	5,945	846	1,127	10,045	3,632
10				2,945	1,952	5,805
12				2,308	143	3,101
14						1,178
16						920
Total	**47,693**	**42,364**	**42,022**	**60,372**	**57,057**	**95,343**

Quantities of pipe generated by the network model were divided into two categories—dense residential and commercial/industrial. For all piping, the estimate includes provision for moderate utility interference (dense residential) or heavy utility interference (commercial/industrial). Excavation and backfill costs were developed for piping in a light residential street and adjusted for the above factors. The adjustments are dense residential times 1.19 and commercial/industrial times 1.32. Earthwork costs include sawcutting and removing the asphalt concrete pavement, excavating, backfilling with pipe zone material and general backfill material, locator tape, and paving. Estimated costs include the installation of pipeline crossings under railroads and taxiways with directional drilling.

O&M Cost Estimates

O&M costs were developed for labor, power, data sampling and analysis, wellhead treatment, as well as maintenance.

Power

Costs for power were calculated using the total horsepower of the extraction well pumps, with the 2-hp pumps operating 24 hours per day, 365 days per year. The cost of power was calculated at $0.06/kWh, the rate provided by McClellan AFB.

Sampling and Analyses

Well sampling is expected to occur twice per year with a total of 40 percent of the wells being sampled yearly. The total number of wells monitored per year at each target volume is:

- MCL–47
- 10^{-6} Cancer Risk–59
- Background–73

The cost per sample is based on a two-person crew sampling 5 wells per day and standard labor rates.

Laboratory analysis costs were included to analyze each sample for VOCs, minerals, and inductively coupled plasma (ICP) metals. Data interpretation and reports will also be generated twice yearly.

Wellhead Treatment and General Maintenance

Costs were also added for replacing the carbon in the wellhead treatment unit during the year by a vendor. Maintenance of the system was assumed to be 5 percent of construction cost per year and includes service, painting, and repairs.

Treatment System

Capital costs were developed for all tasks and activities required to complete the modification of the existing west treatment plant and the construction of the proposed east treatment plant. Major tasks include planning, acquiring necessary permits, design and construction. Annual O&M costs consist of operating and administrative labor, pumping, and processing power, natural gas usage, maintenance, and analytical testing.

Proposed East Treatment Plant

Capital Cost Estimates

Table R-4 lists the east plant flows and concentrations for the six alternatives being evaluated in the Groundwater OU FS.

The estimated influent concentrations of groundwater are summarized in Appendix M. The concentrations were determined using database queries to search and average the monitoring well analytical data over the target areas for each alternative. Significant contaminants were those which had average calculated concentrations above MCL concentrations. Nondetects were averaged into the series of data as zero

Table R-4 East Treatment Plant Requirements		
Alternative No.	Groundwater Flow (gpm)	Treatment Requirement ($\mu g/l$)
1	460	<0.5[a]
2	590	<0.5[a]
3	710	<0.5[a]
4	460	<0.5[a]
5	460	<0.5
6	460	<0.5[a]

[a]With granular activated carbon.

concentration values. While some average metals concentrations were higher than MCLs, they were not included as significant contaminants in this evaluation. The historical sampling of filtered and nonfiltered samples and the relationship of these data to the actual extracted groundwater concentrations indicate that extracted concentrations will be less than MCL values. This data analysis and the metals treatment requirements are discussed in Chapter 4 of the Groundwater OU FS.

Air Stripper. As in the order-of-magnitude cost estimations, preliminary air stripper sizing for the three target volumes was performed using STRIPR, an in-house CH2M HILL program. In all three cases, MCL, risk, and background, air stripping towers were sized to remove TCE to required levels. This, in turn, provided adequate removal for all other contaminants. Each STRIPR capital cost is based on fiberglass-reinforced plastic external construction and includes all packing and internals. Tower height was limited to 40 feet for aesthetic and air traffic reasons with air flow adjusted to provide required removals. All air strippers were combined with either CatOx or VGAC for offgas control.

Liquid Phase Carbon. Liquid phase carbon equipment sizing and costs are based on vendor-supplied quotes. Equipment capital costs are based on flow rates only, and therefore the cost outlay is the same for all 500-gpm flow alternatives. Alternative 3, however, requires treatment of 700 gpm of groundwater, and therefore two vendors estimated costs for two units, each operating at 350 gpm. These two vendors require two units for the 700-gpm flow rate case because the maximum flow rate through their largest carbon unit is 500 gpm.

Vapor Phase Carbon. The vapor phase carbon capital cost for Alternative 4 has been deferred to O&M costs because the most reasonable vendor price is that of a rental unit.

Catalytic Oxidation. Capital cost estimates for a catalytic oxidizer and auxiliary equipment were prepared from vendor budget-level quotations. Sizing criteria were prepared from STRIPR outputs for the three different target volumes (MCL, risk, background). Three vendors were contacted to request budget-level estimates.

O&M Cost Estimates (General)

Labor. Labor requirements for each alternative were determined through a comparison of labor usage at the existing GWTP. Three full-time equivalents (FTEs) are estimated for the GWTP to operate; therefore, it was determined that three FTEs would be required to operate alternatives involving air stripping with offgas control and LGAC polishing. It then follows that for Alternative 5, which involves two technologies, only two FTEs will be required for operation, and so on for remaining alternatives. General labor represents 80 percent of the total labor hours, and supervisory labor accounts for 20 percent of the total. Hourly labor rates are supplied by the Hazardous Waste Remediation Operations and Maintenance Cost Estimating Guidance Manual developed by CH2M HILL for the State of California (CAL O&M).

Administrative costs will be approximately twice that of the existing GWTP including McClellan AFB personal labor for meetings, oversight, tours, and optimization.

Power. Pump sizes and power requirements were determined using standard engineering methods, accounting for given flow rates and expected head losses through the piping and equipment. Blower sizes and power requirements were determined by vendor suggestions and standard engineering methods.

Power cost was calculated on an energy cost of $0.06/kWh, the rate provided by McClellan AFB. It was assumed that the treatment plant would operate 24 hours per day, 365 days per year.

Natural Gas. Estimates of natural gas usage were calculated from vendor-provided heat requirements. Vendors provided heat input required in British thermal units (Btus) per hour. Natural gas usage and cost are calculated assuming 8,760 operating hours per year, 1,050 Btus per cubic foot of natural gas, and $0.003 per cubic foot of natural gas.

Maintenance Materials. Maintenance costs include piping modifications, painting, and other maintenance materials. Maintenance material costs were estimated as 5 percent of the total capital cost, with installation costs not included. This percentage is an average factor for maintenance provided by vendors.

Analytical Testing. Sampling costs for monitoring treated water are included. The assumptions used to calculate the cost of analytical requirements include twice-weekly testing for organics, and weekly analytical testing for sodium, chlorine, total suspended solids, dissolved oxygen, and turbidity.

O&M Cost Estimates (Technology-Specific)

Vapor Phase Carbon. The most financially feasible vapor phase carbon unit was available only as a rental unit and therefore had only operating costs associated with it. The rental cost includes general maintenance and carbon recharging costs incurred during operation. One vapor phase carbon unit, 12,500 pounds of carbon, is estimated to be required. This system would have an estimated capacity to adsorb the off-gas contaminants for one 5-month period. Fuel costs incurred during vapor preheat were determined using guidelines described in the CAL O&M. Natural gas usage and cost were calculated assuming 8,760 operating hours per year; 1,050 Btus per cubic foot of natural gas, and $0.003 per cubic foot of natural gas.

Liquid Phase Carbon. Carbon regeneration costs were determined using in-house carbon usage estimation programs and several vendor quotes. Air stripper performance and influent carbon concentrations for the three flow and concentration scenarios are included in Tables R-5 through R-7. Carbon cost is calculated based on $1.10 per pound of carbon.

Table R-5
Proposed East Treatment Plant
Background Target Volume (Alternative 3)
Flow 710 gpm

Contaminant	Influent Concentration (ppb)	Removal (%)	Exiting Stream Concentration (ppb)
TCE	935	99.95	0.468
Carbon Tetrachloride	2.06.13	99.86	0.003
1,2-DCA	0.11.08	95.92	0.005
Benzene	34	99.86	0.048
cis-1,2-DCE	9	99.31	0.062
Methylene Chloride	1.89	99.42	0.011

Table R-6 Proposed East Treatment Plant 10^{-6} Cancer Risk Target Volume (Alternative 2) Flow 600 gpm			
Contaminant	Influent Concentration (ppb)	Removal (%)	Exiting Stream Concentration (ppb)
TCE	1,122	99.96	0.449
Carbon Tetrachloride	2.5	99.95	0.001
1,2-DCA	1.32	96.26	0.049
Benzene	41	99.89	0.045
1,1-DCE	0.52	99.98	0.000
Methylene Chloride	2.1	99.74	0.006
cis-1,2-DCE	11	99.41	0.065

Table R-7 Proposed East Treatment Plant MCL Target Volume (Alternatives 1, 4, and 5) Flow 500 gpm			
Contaminant	Influent Concentration (ppb)	Removal (%)	Exiting Stream Concentration (ppb)
TCE	1,870	99.97	0.500
Carbon Tetrachloride	4	99.97	0.001
1,2-DCA	2.2	96.82	0.070
Benzene	63	99.92	0.005
1,1-DCE	0.64.1	99.98	0.000
Methylene Chloride	3.0	99.81	0.006
cis-1,2-DCE	21	99.55	0.095

Existing West Treatment Plant

Capital Cost Estimates

The purpose of this section is to provide cost backup for the capital and O&M cost estimates for the existing GWTP at McClellan AFB under future flow scenarios, as described in the six alternatives developed in the GW OU RI/FS. The GWTP flows and concentrations described in the alternatives are listed in Table R-8.

Table R-8 Existing West Treatment Plant Flows and Treatment Requirements		
Alternative No.	**Groundwater Flow (gpm)**	**Treatment Requirement (μg/l)**
1	630	<0.5[a]
2	820	<0.5[a]
3	1,300	<0.5[a]
4	630	<0.5[a]
5	630	<0.5
6	630	<0.5[a]

[a]With granular activated carbon.

The concentration of groundwater to be treated in the six alternatives was also estimated. The significant concentrations of all compounds are given in Appendix M. The methods used to determine concentrations and criteria used to define significant contaminants are the same as those listed for the east treatment plant.

As discussed in Appendix A, stripping compounds typically found in McClellan AFB groundwater (specifically 1,2-DCA) is dependant on temperature. Calculations performed as part of the groundwater treatment plant evaluation showed that there is an economic breakpoint which centers on stripper temperature of about 100°F. At water temperatures below 100°F, 1,2-DCA tends to stay in the water and require removal in the carbon beds. This causes a dramatic rise in carbon consumption and therefore total O&M cost. At temperatures above 100°F, the 1,2-DCA is stripped and destroyed in the offgas control incinerator, with negligible impact on O&M cost over typical operating expenses. While economic optimization of the design is a detailed, involved task that should best take place at the predesign stage, we have attempted to find an approximate optimum as part of this cost-estimating task. To determine the capital cost required to expand the existing GWTP for future flows, the following assumptions were made:

- The optimum stripper water temperature is approximately 99° to 101°F.
- The scrubber inlet gas temperature shall be 490° to 515°F to avoid problems with internals being damaged by high temperature.
- The air/water heat exchanger will be replaced or supplemented with larger units to allow the first two conditions to be met at higher flow rates.

To determine the required air/water heat exchanger area and related cost, the GWTP was evaluated using a heat balance model developed by CH2M HILL. This model is described in Appendix A. In addition to air/water heat exchanges, additional capital items are required to allow the GWTP to accommodate the hydraulic flow of Alternatives 1 through 6. The additional major equipment items with each alternative are summarized in Table R-9.

Table R-9
Capital Items Required for GWTP Expansion

Item	Alternatives 1, 4, 5, and 6	Alternative 2	Alternative 3
Air/water heat exchanger	Add 361 ft^2 Exchanger	Add 1,000 ft^2 Exchanger	Add 1,500 ft^2 Exchanger
Water/water heat exchangers	No change	Add one 3,500 ft^1 Exchanger	Add two 3,500 ft^2 Exchangers
LGAC units	No change	Add one pair of 20,000-lb vessels (in series)	Add three pairs of 20,000-lb vessels (in series)
Stripper pumps	No change	No change	Replace pumps with 1,600-gpm capacity models
LGAC pumps	No change	No change	Replace pumps with 1,600-gpm capacity models
Liquid distributor	No change	No change	Replace with trough-type distributor
Piping	Minor changes ($62,000 installed)	Minor changes–scrubber may require repositioning to allow new air/water exchanger	Major changes–diameters increase for hydraulic capacity increase, scrubber may require repositioning

O&M Cost Estimates

LGAC. One principal variable factor in O&M costs for the west treatment plant is carbon usage. As discussed above, an optimum stripper feedwater temperature has been estimated. Capital items have been included in the cost estimates of the various alternatives to allow operation at this temperature. Stripper performance and resulting carbon influent concentrations that result from stripper operation estimates at approximately 100°F are given in Tables R-10 through R-12.

Table R-10
West Treatment Plant
Stripper Performance—Alternatives 1, 4, 5, and 6
Conditions: Flow = 766 gpm, Air Flow = 2,000 scfm,
Water Temperature = 99°F, Air Temperature = 90° to 98°F

Compound	Extracted Groundwater Feed Concentration (μg/l)	Removal (%)	Stripped Effluent (Carbon Feed) Concentration (μg/l)
TCE	1,220	99.99	0.012
1,1-DCE	415	99.99	0.05
1,1-DCA	7	99.99	0.00
1,2-DCA	4	93.34	1.27
PCE	51	99.9	0.01
1,1,1-TCA	39	99.99	0.00
Methylene Chloride	24	99.89	0.02
Vinyl Chloride	6	99.99	0.00
cis-1,2-DCE	7.4	99.80	0.01
Benzene	0.04	99.99	0.00

Note: In accordance with the estimated effluent concentrations, carbon usage for Alternatives 1, 4, 5, and 6 is estimated at 300,000 pounds per year.

Table R-11
West Treatment Plant
Stripper Performance—Alternative 2
Conditions: Flow = 1,095 gpm, Air Flow = 2,500 scfm,
Water Temperature = 101°F, Air Temperature = 90° to 100°F

Compound	Extracted Groundwater Feed Concentration (μg/l)	Removal (%)	Stripped Effluent (Carbon Feed) Concentration (μg/l)
TCE	1,052	99.99	0.10
1,1-DCE	355	99.99	0.04
1,1-DCA	6.1	99.99	0.00
1,2-DCA	3.3	91.32	0.29
PCE	44	99.99	0.01
1,1,1-TCA	33	99.99	0.00
Methylene Chloride	21	99.81	0.02
Vinyl Chloride	5.5	99.99	0.00
cis-1,2-DCE	6	99.69	0.03
Benzene	0.04	99.99	0.00

Note: In accordance with the estimated effluent concentrations, carbon usage for Alternative 2 is estimated at 460,000 pounds per year.

Table R-12
West Treatment Plant
Stripper Performance—Alternative 3
Conditions: Flow = 1,599 gpm, Air Flow = 3,000 scfm,
Water Temperature = 100°F, Air Temperature = 90° to 99°F

Compound	Extracted Groundwater Feed Concentration (µg/l)	Removal (%)	Stripped Effluent (Carbon Feed) Concentration (µg/l)
TCE	825	99.99	0.08
1,1-DCE	281	99.99	0.03
1,1-DCA	4.8	99.97	0.001
1,2-DCA	2.6	4.08	0.42
PCE	34	99.99	0.003
1,1,1-TCA	26	99.99	0.003
Methylene Chloride	16	99.35	0.10
Vinyl Chloride	4	99.99	0.00
cis-1,2-DCE	5	99.01	0.05
Benzene	0.03	99.95	0.00

Note: In accordance with the estimated effluent concentrations, carbon usage for Alternative 3 is estimated at 610,000 pounds per year.

Labor/Administration. Annual operations labor has been estimated assuming three to four FTEs are required for operation of the GWTP. This basis is substantiated through estimates made by OMI, a subsidiary of CH2M HILL, during a site visit to the existing plant in 1993. Twenty-four hours per day operations staffing is not provided. It is assumed that McClellan AFB will modify the operations contract in the future to only require three to four FTEs. Operations labor is therefore equivalent to the assumptions made in developing O&M costs for the east treatment plant. Administration costs are assumed to remain constant.

Power. Electrical costs have been estimated from power consumption of the pumps and fans at the increased flow rates for the alternatives, as described in the air stripper performance Tables R-10, R-11, and R-12. A base electrical cost per year has been estimated from historical data for the GWTP. This cost represents power requirements for equipment other than the pumps or the air stripper fan, such as lights, compressors, and instrumentation.

Natural Gas. Natural gas costs were developed by comparing estimated heat loads in the heat balance calculations performed in the capital cost section against the existing case and future alternatives. The 1992 natural gas costs were then adjusted to the costs for each alternative using a ratio of heat required in the incinerator.

Maintenance Materials. A cost was incurred in 1992 for material other than carbon at the existing GWTP. The cost included piping modifications, painting, and other maintenance materials. This cost was held constant and applied to the future alternatives.

Analytical Testing. The cost for analytical testing cost was held constant and applied to the proposed alternatives.

End-Use System

Components include the end-use piping, pump stations, discharge structures, reinjection wells, chlorine injection system, and miscellaneous appurtances such as equalization tanks, air valves, drains, and connections with the utilities. Capital costs include all costs required to plan, design, obtain the necessary permits and agreements, and construct the facilities. Annual O&M costs were developed for the labor, power, and materials required to operate and maintain the end-use system.

Capital Cost Estimates

As with the collection piping, the end-use piping costs depend upon the length and diameter of pipes, as well as the type of pipe. Costs were calculated using C-900 PVC pipe which is suitable for potable water conveyance. Pipe sizing was accomplished using the same methodology as described in the collection piping discussion. Table R-13 summarizes the end-use piping components.

Table R-13
Summary of End-Use System Piping

Diameter (inches)	Utilities						Reinjection (MCL Target Volume Only)
	MCL Target Volume		10^{-6} Cancer Risk Target Volume		Background Target Volume		
	East	West	East	West	East	West	
6	0	400	0	400	0	400	400
8	1,800	--	--	--	1,800	--	11,800
10	--	8,500	1,800	--	--	--	2,700
12	--	--	--	8,500	--	8,500	18,000
Total	**1,800**	**8,900**	**1,800**	**8,900**	**1,800**	**8,900**	**32,900**

The emergency discharge structures to Magpie Creek were assumed to be similar to the existing discharge structure located at the treatment plant, complete with 24-inch corrugated metal pipe and flap gate.

A chlorine injection system is also required at each treatment plant. Disinfection is required for protection of public health for those alternatives that provide water to the utilities. Disinfection is also required to prevent algae growth and subsequent plugging of the well. Because of this distinction, costs for the chlorination system are included in the end-use calculations. The chlorination system is assumed to be use liquid hypochlorite to disinfect TCE-laden groundwater, at a dose of between 0.5 and 2.5 ppm of chlorine, enabling a residual of 0.5 to 1.0 ppm.

Downstream of each chlorine injection system is a pump station sized to convey the treated water to either the reinjection well or the utilities. A large clearwell will be required to allow 1 hour of contact time for disinfection. A discharge head of approximately 20 psi is required for the existing greywater system, 65 psi for the Northridge Water District, 52 psi for Rio Linda Water District, 10 psi for groundwater reinjection, and 5 psi for Magpie Creek. Combined motor and pump efficiency will be 70 percent. Total power requirements vary from 75 hp to 160 hp depending upon the alternative.

Also included at each treatment plant is a flow equalization tank that is sized for 1 hour of storage. Size of the storage tank varies between 25,000 and 100,000 gallons, depending on the alternative. The tanks are assumed to be bolted steel with normal coatings and linings.

A reinjection well is basically a production well in reverse. It was assumed that three wells would be required to accommodate any of the projected flows. A new 12-foot-wide gravel (6-inch-thick) access road is required adjacent to a portion (700 linear feet) of the reinjection pipeline.

O&M Cost Estimates

O&M costs for the end-use systems were developed based on the same methodology and data previously described in the collection piping section. Added costs include replenishing the hypochlorite in the chlorine injection system.

Summary

Tables R-14 through R-19 present the capital cost summaries for Alternatives 1 through 6. Tables R-20 through R-25 summarize the O&M costs anticipated during the implementation of each remedial action alternative (conservatively estimated at 5 years) and after implementation is complete. Costs are in 1994 dollars. Construction costs include a 5 percent field detail allowance to account for any unquantified items. A 20 percent contingency has also been added to account for unforeseeable elements of cost within the defined scope of this project. This contingency is used as a means to reduce the risk of possible cost overruns, but does not change the confidence limits of the estimate.

The cost estimates presented have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of this project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final project schedule, the firm selected for final engineering design, and other variable factors.

As a result, the final project costs will vary from the estimates presented herein. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

Table R-14
Alternative 1

ID	Activity	Man-Days: Sr. Level Professional	Man-Days: Mid Level Professional	Man-Days: Jr. Level Professional	Man-Days: Technician	Man-Days: Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
1	Master Plan/Work Plan of Remedial Action										
2	Develop Remedial Action Master Plan										
3	Extraction System	4	24	25	4	4	8,245.12		49,470.72	9,894.14	59,364.86
4	Treatment System	1	2	6	2	2	1,571.39		9,428.35	1,885.67	11,314.02
5	End-Use System	2	15	25	25	4	8,390.03		50,340.19	10,068.04	60,408.23
6	Collection System	6	20	20	40	8	10,996.35		65,978.11	13,195.62	79,173.73
7	Prepare DQOs	3	15	15	6	2	5,446.34		32,678.02	6,535.60	39,213.62
8	Prepare Rationale	1	5	2	0	2	1,378.53		8,271.17	1,654.23	9,925.40
9	Prepare Health and Safety Plan	0	1	0	0	0	158.53		951.17	190.23	1,141.40
10	Prepare QAPP	2	20	20	0	0	5,950.85		35,705.09	7,141.02	42,846.11
11	Prepare SAP	5	20	20	0	0	6,484.80		38,908.80	7,781.76	46,690.56
12	Develop Remedial Action Work Plan	5	50	125	25	15	27,504.16		165,024.96	33,004.99	198,029.95
13	Prepare Draft Copy	1	12	40	10	10	8,674.24		52,045.44	10,409.09	62,454.53
14	Prepare Draft Final	1	2	8	2	10	2,475.71		14,854.27	2,970.85	17,825.13
15	Prepare Final Remedial Action Master Plan and Work Plan	1	2	5	2	10	2,112.06		12,672.38	2,534.48	15,206.86
	Subtotal	32	188	311	116	67	89,388.11	0.00	536,328.67	107,266.73	643,594.41
16	Utility Mapping	67	138	0	254	60	98,988.00		409,393.60	81,878.72	491,272.32
	Subtotal	67	138	0	254	60	98,988.00	0.00	409,393.60	81,878.72	491,272.32
21	Onbase/Offbase Production Wells										
22	Prepare Base Well 18 Abandonment Program	2	12	20	5	8	5,803.47		34,820.83	6,964.17	41,785.00
23	Prepare Production Well Contingency Plans	2	0	5	10	2	2,045.44		12,272.64	2,454.53	14,727.17
	Subtotal	4	12	25	15	10	7,848.91	0.00	47,093.47	9,418.69	56,512.17
24	Extraction System										
25	Subcontractor Procurement										
26	Specify System Requirements	2	15	30	4	40	10,046.98		60,281.86	12,056.37	72,338.23
27	Identify Performance Criteria	2	5	5		5	2,168.37		13,010.21	2,602.04	15,612.25
28	Procure BOAs w/3 Subs for Basewide EW/MW	2	15	2	2	15	4,400.94		26,405.66	5,281.13	31,686.80
	Subtotal	6	35	37	6	60	16,616.29	0.00	99,697.73	19,939.56	119,637.27
29	Phase 1--Well Installation/Investigations										
30	Offbase Monitoring Wells/HydroPunch(10)										
31	Offbase Extraction Wells (6) w/Well Head Treatment										
32	Hot Spot Extraction Wells (10)										
33	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
34	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
35	Install Wells/Interpret Data	10	250	250	50	50	96,934.24	1,141,000.00	1,640,145.44	328,029.09	1,968,174.53
36	Phase 1 Report/Phase 2 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
37	Abandon Base Well 18	1	2	15	15	3	3,938.37	25,000.00	48,630.21	9,726.04	58,356.25
	Subtotal	47	597	525	484	133	238,568	1,166,000	2,614,948	502,990	3,017,938
38	Phase 2--Well Installation										
39	Offbase Monitoring Wells (8)										
40	Offbase Extraction Wells (18) w/Well Head Treatment										
41	Hot Spot Extraction Wells (14)										
42	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
43	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
44	Install Wells/Interpret Data	10	250	250	50	50	98,530.24	1,745,000.00	2,245,741.44	449,148.29	2,694,889.73
45	Phase 2 Report/Phase 3 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	46	595	510	469	130	236,225.71	1,745,000.00	3,071,914.27	614,382.85	3,686,297.13
46	Phase 3--Well Installation/Investigation										
47	Onbase Monitoring Wells (61)										
48	Onbase Extraction Wells (73)										
49	Prepare Final Layout of Wells	9	43	87	12	55	24,616.34		147,698.02	29,539.60	177,237.62
50	Prepare for Installation	9	87	87	41	45	33,426.18		200,557.06	40,111.41	240,668.47
51	Install Wells/Interpret Data	29	725	725	125	140	302,320.98	3,825,000.00	5,282,485.86	1,056,497.17	6,338,983.03
52	Phase 3 Report	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	77	1,156	1,099	578	285	477,944.53	3,825,000.00	6,336,227.17	1,267,245.43	7,603,472.60
53	Treatment/End-Use/Collection Systems										
54	Procure Turnkey Contractor	2	20	20	5	20	8,064.53		48,387.17	9,677.43	58,064.60
55	Western Area										
56	Collection Piping										

Table E-44
Alternative 1

ID	Activity	Man-Days: Sr. Level Professional	Mid Level Professional	Jr. Level Professional	Technician	Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
57	Prepare Preliminary Design	20	55	62	35	40	26,316.27		157,897.63	31,579.53	189,477.16
58	Prepare Final Design	30	60	25	60	42	26,864.03		161,184.19	32,236.84	193,421.03
59	Prepare for Construction	20	40			8	10,562.69		63,376.13	12,675.23	76,051.35
60	Construct Collection Piping	25	120			25	25,541.36	1,150,100.00	1,303,348.16	260,669.63	1,564,017.79
	Subtotal	97	295	107	100	135	97,348.88	1,150,100.00	1,734,193.28	346,838.66	2,081,031.94
61	Treatment Plant										
62	Prepare Preliminary Design	9	20	9	4	3	6,478.74		38,872.42	7,774.48	46,646.90
63	Prepare Final Design	5	20	5	14	5	6,365.33		38,191.97	7,638.39	45,830.36
64	Prepare for Construction		40			2	6,506.59		39,039.55	7,807.91	46,847.46
65	Construct Treatment Plant	5	20			20	5,715.20	182,000.00	216,291.20	43,258.24	259,549.44
66	Startup/Shakedown										
67	Conduct Startup/Shakedown	2	2			1	755.76		4,534.56	906.91	5,441.47
68	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
69	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	21	102	14	18	31	25,821.62	182,000.00	336,929.70	67,385.94	404,315.64
70	End-Use Piping										
71	Prepare Preliminary Design	15	25	17	25	5	11,402.11		68,412.67	13,682.53	82,095.21
72	Prepare Final Design	5	25	22	50	5	12,523.15		75,138.91	15,027.78	90,166.69
73	Prepare for Construction	20	40		2	12	11,077.22		66,463.30	13,292.66	79,755.96
74	Construct End-Use Piping	10	45			20	10,568.32	585,000.00	648,409.92	129,681.98	778,091.90
	Subtotal	50	135	39	77	42	45,570.80	585,000.00	858,424.80	171,684.96	1,030,109.76
75	Eastern Area										
76	Collection Piping										
77	Prepare Preliminary Design	20	60	67	40	40	28,173.95		169,043.71	33,808.74	202,852.45
78	Prepare Final Design	30	60	32	70	42	28,630.46		171,782.78	34,356.56	206,139.34
79	Prepare for Construction	20	40			8	10,562.69		63,376.13	12,675.23	76,051.35
80	Construct Collection Piping	25	125			25	26,334.00	1,287,300.00	1,445,304.00	289,060.80	1,734,364.80
	Subtotal	95	285	99	110	115	93,701.10	1,287,300.00	1,849,506.62	369,901.32	2,219,407.95
81	Treatment Plant										
82	Prepare Preliminary Design	30	30	23	18	10	15,362.94		92,177.66	18,435.53	110,613.20
83	Prepare Final Design	15	30	35	40	10	16,167.20		97,003.20	19,400.64	116,403.84
84	Prepare for Construction	20	40			20	11,555.52		69,333.12	13,866.62	83,199.74
85	Construct Treatment Plant	5	30			5	6,059.44	783,600.00	819,956.64	163,991.33	983,947.97
86	Startup/Shakedown										
87	Conduct Startup/Shakedown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
88	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
89	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	75	135	58	58	46	50,910.40	783,600.00	1,089,062.40	217,812.48	1,306,874.88
90	End-Use Piping										
91	Prepare Preliminary Design	5	10	10	5	4	4,477.26		26,863.58	5,372.72	32,236.30
92	Prepare Final Design	3	15	10	5	4	4,913.94		29,483.62	5,896.72	35,380.34
93	Prepare for Construction	10	20			5	5,364.08		32,184.48	6,436.90	38,621.38
94	Construct End-Use Piping	3	15			5	3,325.55	251,800.00	271,753.31	54,350.66	326,103.97
	Subtotal	21	60	20	10	18	18,080.83	251,800.00	360,284.99	72,057.00	432,341.99
	Alternative 1 Total	638	3,732	2,844	2,295	1,132	1,497,013.26	10,975,800.00	19,244,005.18	3,848,801.04	23,092,806.22

Costs are in 1994 dollars and include a 5 percent field detail allowance for unquantified items.

Table R-15
Alternative 2

ID	Activity	Man-Days: Sr. Level Professional	Mid Level Professional	Jr. Level Professional	Technician	Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
1	Master Plan/Work Plan of Remedial Action										
2	Develop Remedial Action Master Plan										
3	Extraction System	4	24	25	4	4	8,245.12		49,470.72	9,894.14	59,364.86
4	Treatment System	1	2	6	2	2	1,571.39		9,428.35	1,885.67	11,314.02
5	End-Use System	2	15	25	25	4	8,390.03		50,340.19	10,068.04	60,408.23
6	Collection System	6	21	20	40	8	10,996.35		65,978.11	13,195.62	79,173.73
7	Prepare DQOs	3	15	15	6	2	5,446.34		32,678.02	6,535.60	39,213.62
8	Prepare Rationale	1	5	2	0	2	1,378.53		8,271.17	1,654.23	9,925.40
9	Prepare Health and Safety Plan	0	1	0	0	0	158.53		951.17	190.23	1,141.40
10	Prepare QAPP	2	20	20	0	0	5,950.85		35,705.09	7,141.02	42,846.11
11	Prepare SAP	5	20	20	0	0	6,484.80		38,908.80	7,781.76	46,690.56
12	Develop Remedial Action Work Plan	5	50	125	25	15	27,504.16		165,024.96	33,004.99	198,029.95
13	Prepare Draft Copy	1	12	40	10	10	8,674.24		52,045.44	10,409.09	62,454.53
14	Prepare Draft Final	1	2	8	2	10	2,475.71		14,854.27	2,970.85	17,825.13
15	Prepare Final Remedial Action Master Plan and Work Plan	1	2	5	2	10	2,112.06		12,672.38	2,534.48	15,206.86
	Subtotal	32	180	311	116	67	89,388.11	0.00	536,328.67	107,265.73	643,594.41
16	Utility Mapping	75	151	0	280	66	107,890.00		450,134.32	90,026.86	540,161.18
	Subtotal	75	151	0	280	66	107,890.00	0.00	450,134.32	90,026.86	540,161.18
21	Onbase/Offbase Production Wells										
22	Prepare Base Well 18 Abandonment Program	2	12	20	2	8	5,528.10		33,168.58	6,633.72	39,802.29
23	Prepare Production Well Contingency Plans	2	0	5	2	2	1,311.10		7,866.62	1,573.32	9,439.95
	Subtotal	4	12	25	4	10	6,839.20	0.00	41,035.20	8,207.04	49,242.24
24	Extraction System										
25	Subcontractor Procurement										
26	Specify System Requirements	2	15	30	4	40	10,046.98		60,281.86	12,056.37	72,338.23
27	Identify Performance Criteria	2	5	5		5	2,168.37		13,010.21	2,602.04	15,612.25
28	Procure BOAs w/3 Subs for Basewide EW/MW	2	15	2	2	15	4,400.94		26,405.66	5,281.13	31,686.80
	Subtotal	6	35	37	6	60	16,616.29	0.00	99,697.73	19,939.55	119,637.27
29	Phase1--Well Installation/Investigation										
30	Offbase Monitoring Wells (19)										
31	Offbase Extraction Wells (8) w/Well Head Treatment										
32	Hot Spot Extraction Wells (15)										
33	Prepare Final Layout of Wells	4	20	40	5	30	11,672.18		70,033.06	14,006.61	84,039.67
34	Prepare for Installation	4	40	40	20	20	15,392.26		92,353.54	18,470.71	110,824.24
35	Install Wells/Interpret Data	13	340	340	65	65	131,115.07	1,438,000.00	2,112,970.43	422,594.09	2,535,564.52
	Phase 1 Report/Phase 2 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
37	Abandon Base Well 18	1	2	15	15	3	3,938.37	25,000.00	48,630.21	9,726.04	58,356.25
	Subtotal	52	702	635	505	163	279,698.91	1,463,000.00	3,029,473.47	605,894.69	3,635,368.17
38	Phase 2--Well Installation/Investigation										
39	Offbase Monitoring Wells (10)										
40	Offbase Extraction Wells (22) w/Well Head Treatment										
41	Hot Spot Extraction Wells (14)										
42	Prepare Final Layout of Wells	4	20	40	5	30	11,672.18		70,033.06	14,006.61	84,039.67
43	Prepare for Installation	4	40	40	20	20	15,392.26		92,353.54	18,470.71	110,824.24
44	Install Wells/Interpret Data	13	340	340	65	65	133,243.07	2,200,000.00	2,877,098.43	575,419.69	3,452,518.12
45	Phase 2 Report/Phase 3 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	51	700	620	490	160	277,888.54	2,200,000.00	3,744,971.26	748,994.25	4,493,965.52
46	Phase 3--Well Installation										
47	Onbase Monitoring Wells (60)										
48	Onbase Extraction Wells (94)										
49	Prepare Final Layout of Wells	15	75	150	18	110	43,494.98		260,969.86	52,193.97	313,163.83
50	Prepare for Installation	15	150	150	75	75	57,720.96		346,325.76	69,265.15	415,590.91
51	Install Wells/Interpret Data	50	1,275	1,275	240	240	493,643.52	4,822,000.00	7,352,941.12	1,470,588.22	8,823,529.34
52	Phase 3 Report	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	110	1,800	1,775	733	470	712,440	4,822,000	8,665,722.98	1,733,144.60	10,398,867.57
53	Treatment/End-Use/Collection Systems										
54	Procure Turnkey Contractor	2	20	20	5	20	8,064.53		48,387.17	9,677.43	58,064.60
55	Western Area										
56	Collection Piping										
57	Prepare Preliminary Design	22	65	75	44	45	31,073.14		186,438.82	37,287.76	223,726.58
58	Prepare Final Design	37	75	30	75	45	32,719.01		196,314.05	39,262.81	235,576.86
59	Prepare for Construction	25	46			8	12,403.78		74,422.66	14,884.53	89,307.19

Table R-15
Alternative 2 [a]

ID	Activity	Man-Days: Sr. Level Professional	Mid Level Professional	Jr. Level Professional	Technician	Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
60	Construct Collection Piping	31	140			25	29,779.82	1,597,800.00	1,776,478.94	355,295.79	2,131,774.73
	Subtotal	117	346	125	124	143	114,040.27	1,597,800.00	2,282,041.63	456,408.33	2,738,449.96
61	Treatment Plant										
62	Prepare Preliminary Design	15	30	18	6	5	10,571.92		63,431.52	12,686.30	76,117.82
63	Prepare Final Design	7	30	10	21	8	9,803.41		58,820.45	11,764.09	70,584.54
64	Prepare for Construction		40			3	6,589.33		39,535.97	7,907.19	47,443.16
65	Construct Treatment Plant	7	30			30	8,483.81	581,400.00	632,302.85	126,460.57	758,763.42
66	Startup/Shutdown										
67	Conduct Startup/Shutdown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
68	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
69	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	34	135	28	27	47	37,213.76	581,400.00	804,682.56	160,936.51	965,619.07
70	End-Use Piping										
71	Prepare Preliminary Design	15	25	17	25	5	11,402.11		68,412.67	13,682.53	82,095.21
72	Prepare Final Design	5	25	22	50	5	12,523.15		75,138.91	15,027.78	90,166.69
72	Prepare for Construction	20	40		2	12	11,077.22		66,463.30	13,292.66	79,755.96
74	Construct End-Use Piping	10	45			20	10,568.32	710,300.00	773,709.92	154,741.98	928,451.90
	Subtotal	50	135	39	77	42	45,570.80	710,300.00	983,724.80	196,744.96	1,180,469.76
75	Eastern Area										
76	Collection Piping										
77	Prepare Preliminary Design	18	55	60	36	36	25,478.72		152,872.32	30,574.46	183,446.78
78	Prepare Final Design	25	55	25	63	36	24,960.43		149,762.59	29,952.52	179,715.11
79	Prepare for Construction	18	35			7	9,331.34		55,988.06	11,197.61	67,185.68
80	Construct Collection Piping	18	110			23	22,544.72	1,137,900.00	1,273,168.32	254,633.66	1,527,801.98
	Subtotal	79	255	85	99	102	82,315.22	1,137,900.00	1,631,791.30	326,358.26	1,958,149.56
81	Treatment Plant										
82	Prepare Preliminary Design	30	30	23	18	10	15,362.94		92,177.66	18,435.53	110,613.20
83	Prepare Final Design	15	30	35	40	10	16,167.20		97,003.20	19,400.64	116,403.84
84	Prepare for Construction	20	40			20	11,555.52		69,333.12	13,866.62	83,199.74
85	Construct Treatment Plant	5	30			5	6,059.44	783,600.00	819,956.64	163,991.33	983,947.97
86	Startup/Shutdown										
87	Conduct Startup/Shutdown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
88	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
89	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	75	135	58	58	46	50,910.40	783,600.00	1,089,062.40	217,812.48	1,306,874.88
90	End-Use Piping										
91	Prepare Preliminary Design	6	12	12	7	5	5,481.06		32,886.35	6,577.27	39,463.60
92	Prepare Final Design	4	17	12	7	5	5,917.73		35,506.37	7,101.27	42,607.64
93	Prepare for Construction	12	22			5	6,037.10		36,222.62	7,244.52	43,467.15
94	Construct End-Use Piping	4	17			5	3,820.59	349,900.00	372,823.55	74,564.71	447,388.26
	Subtotal	26	68	24	14	20	21,256.40	349,900.00	477,438.80	95,487.70	572,926.66
	Alternative 2 Total	711	4,662	3,762	2,533	1,396	1,842,068.40	13,645,900.00	23,836,105.20	4,767,221.04	28,603,326.24

[a] Costs are in 1994 dollars and include a 5 percent field detail allowance for unquantified items.

Table B-16
Alternative 1

ID	Activity	Man-Days					Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
		Sr. Level Professional	Mid Level Professional	Jr. Level Professional	Technician	Administrative Assistant					
1	Master Plan/Work Plan of Remedial Action										
2	Develop Remedial Action Master Plan										
3	Extraction System	4	24	25	4	4	8,245.12		49,470.72	9,894.14	59,364.86
4	Treatment System	1	2	6	2	2	1,571.39		9,428.35	1,885.67	11,314.02
5	End-Use System	2	15	25	25	4	8,390.03		50,340.19	10,068.04	60,408.23
6	Collection System	6	20	20	40	8	10,996.35		65,978.11	13,195.62	79,173.73
7	Prepare DQOs	3	15	15	6	2	5,446.34		32,678.02	6,535.60	39,213.62
8	Prepare Rationale	1	5	2	0	2	1,378.53		8,271.17	1,654.23	9,925.40
9	Prepare Health and Safety Plan	0	1	0	0	0	158.53		951.17	190.23	1,141.40
10	Prepare QAPP	2	20	20	0	0	5,950.85		35,705.09	7,141.02	42,846.11
11	Prepare SAP	5	20	20	0	0	6,484.80		38,908.80	7,781.76	46,690.56
12	Develop Remedial Action Work Plan	5	50	125	25	15	27,504.16		165,024.96	33,004.99	198,029.95
13	Prepare Draft Copy	1	12	40	10	10	8,674.24		52,045.44	10,409.09	62,454.53
14	Prepare Draft Final	1	2	8	2	10	2,475.71		14,854.27	2,970.85	17,825.13
15	Prepare Final Remedial Action Master Plan and Work Plan	1	2	5	2	10	2,112.06		12,672.38	2,534.48	15,206.86
	Subtotal	32	188	311	116	67	89,388.11	0.00	536,328.67	107,265.73	643,594.41
16	Utility Mapping	67	138	0	254	60	98,988.00		409,393.60	81,878.72	491,272.32
	Subtotal	67	138	0	254	60	98,988.00	0.00	409,393.60	81,878.72	491,272.32
21	Onbase/Offbase Production Wells										
22	Prepare Base Well 18 Abandonment Program	2	12	20	5	8	5,803.47		34,820.83	6,964.17	41,785.00
23	Prepare Production Well Contingency Plans	2	0	5	10	2	2,045.44		12,272.64	2,454.53	14,727.17
	Subtotal	4	12	25	15	10	7,848.91	0.00	47,093.47	9,418.69	56,512.17
24	Extraction System										
25	Subcontractor Procurement										
26	Specify System Requirements	2	15	30	4	40	10,046.98		60,281.86	12,056.37	72,338.23
27	Identify Performance Criteria	2	5	5		5	2,168.37		13,010.21	2,602.04	15,612.25
28	Procure BOAs w/3 Subs for Basewide EW/MW	2	15	2	2	15	4,400.94		26,405.66	5,281.13	31,686.80
	Subtotal	6	35	37	6	60	16,616.29	0.00	99,697.73	19,939.55	119,637.27
29	Phase 1--Well Installation/Investigations										
30	Offbase Monitoring Wells /HydroPunch(10)										
31	Offbase Extraction Wells (6) w/Well Head Treatment										
32	Hot Spot Extraction Wells (18)										
33	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
34	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
35	Install Wells/Interpret Data	10	250	250	50	50	96,934.24	1,641,150.00	2,140,295.44	428,059.09	2,568,354.53
36	Phase 1 Report/Phase 2 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
37	Abandon Base Well 18	1	2	15	15	3	3,938.37	25,000.00	48,630.21	9,726.04	58,356.25
	Subtotal	47	597	525	484	133	238,568	1,666,150	3,015,098	603,020	3,618,118
38	Phase 2--Well Installation										
39	Offbase Monitoring Wells (8)										
40	Offbase Extraction Wells (18) w/Well Head Treatment										
41	Hot Spot Extraction Wells (14)										
42	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
43	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
44	Install Wells/Interpret Data	10	250	250	50	50	98,530.24	1,969,380.00	2,470,121.44	494,024.29	2,964,145.73
45	Phase 2 Report/Phase 3 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	46	595	510	469	130	236,225.71	1,969,380.00	3,296,294.27	659,258.85	3,955,553.13
46	Phase 3--Well Installation/Investigation										
47	Onbase Monitoring Wells (61)										
48	Onbase Extraction Wells (73)										
49	Prepare Final Layout of Wells	9	43	87	12	55	24,616.34		147,698.02	29,539.60	177,237.62
50	Prepare for Installation	9	87	87	41	45	33,426.18		200,557.06	40,111.41	240,668.47
51	Install Wells/Interpret Data	29	725	725	125	140	302,320.98	2,954,070.00	4,411,555.86	882,311.17	5,293,867.03
52	Phase 3 Report	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	77	1,155	1,099	578	285	477,944.53	2,954,070.00	5,465,297.17	1,093,059.43	6,558,356.60

Table R-16
Alternative 1

ID	Activity	Man-Days: Sr. Level Professional	Man-Days: Mid Level Professional	Man-Days: Jr. Level Professional	Man-Days: Technician	Man-Days: Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
53	**Treatment/End-Use/Collection Systems**										
54	Procure Turnkey Contractor	2	20	20	5	20	8,064.53		48,387.17	9,677.43	58,064.60
55	Western Area										
56	Collection Piping										
57	Prepare Preliminary Design	20	55	62	35	40	26,316.27		157,897.63	31,579.53	189,477.16
58	Prepare Final Design	30	60	25	60	42	26,864.03		161,184.19	32,236.84	193,421.03
59	Prepare for Construction	20	40			8	10,562.69		63,376.13	12,675.23	76,051.35
60	Construct Collection Piping	25	120			25	25,541.36	1,032,360.00	1,185,608.16	237,121.63	1,422,729.79
	Subtotal	97	295	107	100	135	97,348.88	1,032,360.00	1,616,483.28	323,290.66	1,939,743.94
61	Treatment Plant										
62	Prepare Preliminary Design	9	20	9	4	3	6,478.74		38,872.42	7,774.48	46,646.90
63	Prepare Final Design	5	20	5	14	5	6,365.33		38,191.97	7,638.39	45,830.36
64	Prepare for Construction		40			2	6,506.59		39,039.55	7,807.91	46,847.46
65	Construct Treatment Plant	5	20			20	5,715.20	182,000.00	216,291.20	43,258.24	259,549.44
66	Startup/Shakedown										
67	Conduct Startup/Shakedown	2	2			1	755.76		4,534.56	906.91	5,441.47
68	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
69	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	21	102	14	18	31	25,821.62	182,000.00	336,929.70	67,385.94	404,315.64
70	End-Use Piping										
71	Prepare Preliminary Design	15	25	17	25	5	11,402.11		68,412.67	13,682.53	82,095.21
72	Prepare Final Design	5	25	22	50	5	12,523.15		75,138.91	15,027.78	90,166.69
73	Prepare for Construction	20	40		2	12	11,077.22		66,463.30	13,292.66	79,755.96
74	Construct End-Use Piping	10	45			20	10,568.32	714,435.00	777,844.92	155,568.98	933,413.90
	Subtotal	50	135	39	77	42	45,570.80	714,435.00	987,889.80	197,571.96	1,185,431.76
75	Eastern Area										
76	Collection Piping										
77	Prepare Preliminary Design	20	60	67	40	40	28,173.95		169,043.71	33,808.74	202,852.45
78	Prepare Final Design	30	60	32	70	42	28,630.46		171,782.78	34,356.56	206,139.34
79	Prepare for Construction	20	40			8	10,562.69		63,376.13	12,675.23	76,051.35
80	Construct Collection Piping	25	125			25	26,334.00	1,406,475.00	1,564,479.00	312,895.80	1,877,374.80
	Subtotal	95	285	99	110	115	93,701.10	1,406,475.00	1,968,681.62	393,736.32	2,362,417.95
81	Treatment Plant										
82	Prepare Preliminary Design	30	30	23	18	10	15,362.94		92,177.66	18,435.53	110,613.20
83	Prepare Final Design	15	30	35	40	10	16,167.20		97,003.20	19,400.64	116,403.84
84	Prepare for Construction	20	40			20	11,555.52		69,333.12	13,866.62	83,199.74
85	Construct Treatment Plant	5	30			5	6,059.44	475,000.00	511,356.64	102,271.33	613,627.97
86	Startup/Shakedown										
87	Conduct Startup/Shakedown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
88	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
89	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	75	135	58	58	46	50,910.40	475,000.00	780,462.40	156,092.48	936,554.88
90	End-Use Piping										
91	Prepare Preliminary Design	5	10	10	5	4	4,477.26		26,863.58	5,372.72	32,236.30
92	Prepare Final Design	3	15	10	5	4	4,913.94		29,483.62	5,896.72	35,380.34
93	Prepare for Construction	10	20			5	5,364.08		32,184.48	6,436.90	38,621.38
94	Construct End-Use Piping	3	15			5	3,325.55	357,315.00	377,268.31	75,453.66	452,721.97
	Subtotal	21	60	20	10	18	18,888.83	357,315.00	466,799.99	93,160.00	558,959.99
	Injection Site							385,875.00	385,875.00	77,175.00	463,050.00
	Alternative 1 Total	638	3,732	2,844	2,295	1,132	1,497,813.26	11,143,860.00	19,411,265.18	3,882,253.04	23,293,518.22

a Costs are in 1994 dollars and include a 5 percent field detail allowance for unquantified items.

Table R-17
Alternative 2

ID	Activity	Man-Days: Sr. Level Professional	Man-Days: Mid Level Professional	Man-Days: Jr. Level Professional	Man-Days: Technician	Man-Days: Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
1	Master Plan/Work Plan of Remedial Action										
2	Develop Remedial Action Master Plan										
3	Extraction System	4	24	25	4	4	8,245.12		49,470.72	9,894.14	59,364.86
4	Treatment System	1	2	6	2	2	1,571.39		9,428.35	1,885.67	11,314.02
5	End-Use System	2	15	25	25	4	8,390.03		50,340.19	10,068.04	60,408.23
6	Collection System	6	20	20	40	8	10,996.35		65,978.11	13,195.62	79,173.73
7	Prepare DQOs	3	15	15	6	2	5,446.34		32,678.02	6,535.60	39,213.62
8	Prepare Rationale	1	5	2	0	2	1,378.53		8,271.17	1,654.23	9,925.40
9	Prepare Health and Safety Plan	0	1	0	0	0	158.53		951.17	190.23	1,141.40
10	Prepare QAPP	2	20	20	0	0	5,950.85		35,705.09	7,141.02	42,846.11
11	Prepare SAP	5	20	20	0	0	6,484.80		38,908.80	7,781.76	46,690.56
12	Develop Remedial Action Work Plan	5	50	125	25	15	27,504.16		165,024.96	33,004.99	198,029.95
13	Prepare Draft Copy	1	12	40	10	10	8,674.24		52,045.44	10,409.09	62,454.53
14	Prepare Draft Final	1	2	8	2	10	2,475.71		14,854.27	2,970.85	17,825.13
15	Prepare Final Remedial Action Master Plan and Work Plan	1	2	5	2	10	2,112.06		12,672.38	2,534.48	15,206.86
	Subtotal	32	188	311	116	67	89,388.11	0.00	536,328.67	107,265.73	643,594.41
16	Utility Mapping	75	151	0	280	66	107,890.00		450,134.32	90,026.86	540,161.18
	Subtotal	75	151	0	280	66	107,890.00	0.00	450,134.32	90,026.86	540,161.18
21	Onbase/Offbase Production Wells										
22	Prepare Base Well 18 Abandonment Program	2	12	20	5	8	5,803.47		34,820.83	6,964.17	41,785.00
23	Prepare Production Well Contingency Plans	2	0	5	10	2	2,045.44		12,272.64	2,454.53	14,727.17
	Subtotal	4	12	25	15	10	7,848.91	0.00	47,093.47	9,418.69	56,512.17
24	Extraction System										
25	Subcontractor Procurement										
26	Specify System Requirements	2	15	30	4	40	10,046.98		60,281.86	12,056.37	72,338.23
27	Identify Performance Criteria	2	5	5		5	2,168.37		13,010.21	2,602.04	15,612.25
28	Procure BOAs w/3 Subs for Basewide EW/MW	2	15	2	2	15	4,400.94		26,405.66	5,281.13	31,686.80
	Subtotal	6	35	37	6	60	16,616.29	0.00	99,697.73	19,939.55	119,637.27
29	Phase1--Well Installation/Investigation										
30	Offbase Monitoring Wells (19)										
31	Offbase Extraction Wells (8) w/Well Head Treatment										
32	Hot Spot Extraction Wells (15)										
33	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
34	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
35	Install Wells/Interpret Data	10	250	250	50	50	102,786.24	2,057,816.25	2,562,813.69	512,562.74	3,075,376.43
	Phase 1 Report/Phase 2 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
37	Abandon Base Well 18	1	2	15	15	3	3,938.37	25,000.00	48,630.21	9,726.04	58,356.25
	Subtotal	47	597	525	484	133	244,420.08	2,082,816.25	3,437,616.73	687,523.35	4,125,140.08
38	Phase 2--Well Installation/Investigation										
39	Offbase Monitoring Wells (10)										
40	Offbase Extraction Wells (22) w/Well Head Treatment										
41	Hot Spot Extraction Wells (14)										
42	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
43	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
44	Install Wells/Interpret Data	10	250	250	50	50	104,914.24	2,469,379.50	2,976,504.94	595,300.99	3,571,805.93
45	Phase 2 Report/Phase 3 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	46	595	510	469	130	242,609.71	2,469,379.50	3,802,677.77	760,535.55	4,563,213.33
46	Phase 3--Well Installation										
47	Onbase Monitoring Wells (68)										
48	Onbase Extraction Wells (94)										
49	Prepare Final Layout of Wells	9	43	87	12	55	24,616.34		147,698.02	29,539.60	177,237.62
50	Prepare for Installation	9	87	87	41	45	33,426.18		200,557.06	40,111.41	240,668.47
51	Install Wells/Interpret Data	29	725	725	125	140	317,216.98	3,704,069.25	5,176,451.11	1,035,290.22	6,211,741.33
52	Phase 3 Report	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49

Table B-17
Alternative 2 a

ID	Activity	Man-Days: Sr. Level Professional	Mid Level Professional	Jr. Level Professional	Technician	Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
	Subtotal	77	1,156	1,099	570	285	492,841	3,704,069	6,230,192.42	1,246,038.48	7,476,230.90
53	Treatment/End-Use/Collection Systems										
54	Procure Turnkey Contractor	2	20	20	5	20	8,064.53		48,387.17	9,677.43	58,064.60
55	Western Area										
56	Collection Piping										
57	Prepare Preliminary Design	22	65	75	44	45	31,073.14		186,438.82	37,287.76	223,726.58
58	Prepare Final Design	37	75	30	75	45	32,719.01		196,314.05	39,262.81	235,576.86
59	Prepare for Construction	25	46			8	12,403.78		74,422.66	14,884.53	89,307.19
60	Construct Collection Piping	31	140			25	29,779.82	1,601,775.00	1,780,453.94	356,090.79	2,136,544.73
	Subtotal	117	346	125	124	143	114,040.27	1,601,775.00	2,286,016.63	457,203.33	2,743,219.96
61	Treatment Plant										
62	Prepare Preliminary Design	15	30	18	6	5	10,571.92		63,431.52	12,686.30	76,117.82
63	Prepare Final Design	7	30	10	21	8	9,803.41		58,820.45	11,764.09	70,584.54
64	Prepare for Construction		40			3	6,589.33		39,535.97	7,907.19	47,443.16
65	Construct Treatment Plant	7	30			30	8,483.81	581,400.00	632,302.85	126,460.57	758,763.42
66	Startup/Shakedown										
67	Conduct Startup/Shakedown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
68	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
69	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	34	135	28	27	47	37,213.76	581,400.00	804,682.86	160,936.51	965,619.07
70	End-Use Piping										
71	Prepare Preliminary Design	15	25	17	25	5	11,402.11		68,412.67	13,682.53	82,095.21
72	Prepare Final Design	5	25	22	50	5	12,523.15		75,138.91	15,027.78	90,166.69
73	Prepare for Construction	20	40		2	12	11,077.22		66,463.30	13,292.66	79,755.96
74	Construct End-Use Piping	10	45			20	10,568.32	755,235.00	818,644.92	163,728.98	982,373.90
	Subtotal	50	135	39	77	42	45,570.80	755,235.00	1,028,659.80	205,731.96	1,234,391.76
75	Eastern Area										
76	Collection Piping										
77	Prepare Preliminary Design	20	60	67	40	40	28,173.95		169,043.71	33,808.74	202,852.45
78	Prepare Final Design	30	60	32	70	42	28,630.46		171,782.78	34,356.56	206,139.34
79	Prepare for Construction	20	40			8	10,562.69		63,376.13	12,675.23	76,051.35
80	Construct Collection Piping	25	125			25	26,334.00	1,208,025.00	1,366,029.00	273,205.80	1,639,234.80
	Subtotal	95	285	99	110	115	93,701.10	1,208,025.00	1,770,231.62	354,046.32	2,124,277.95
81	Treatment Plant										
82	Prepare Preliminary Design	30	30	23	18	10	15,362.94		92,177.66	18,435.53	110,613.20
83	Prepare Final Design	15	30	35	40	10	16,167.20		97,003.20	19,400.64	116,403.84
84	Prepare for Construction	20	40			20	11,555.52		69,333.12	13,866.62	83,199.74
85	Construct Treatment Plant	5	30			5	6,059.44	788,400.00	824,756.64	164,951.33	989,707.97
86	Startup/Shakedown										
87	Conduct Startup/Shakedown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
88	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
89	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	75	135	58	58	46	50,910.40	788,400.00	1,093,862.40	218,772.48	1,312,634.88
90	End-Use Piping										
91	Prepare Preliminary Design	6	12	12	7	5	5,481.06		32,886.34	6,577.27	39,463.60
92	Prepare Final Design	4	17	12	7	5	5,917.73		35,506.37	7,101.27	42,607.64
93	Prepare for Construction	12	22			5	6,037.10		36,222.62	7,244.52	43,467.15
94	Construct End-Use Piping	4	17			5	3,820.59	395,115.00	418,038.55	83,607.71	501,646.26
	Subtotal	26	68	24	14	20	21,256.48	395,115.00	522,663.88	104,530.78	627,184.66
	Injection Site							574,875.00	574,875.00	114,975.00	689,850.00
	Alternative 2 Total	684	3,837	2,880	2,358	1,164	1,564,306.46	14,161,090.00	22,684,723.01	4,536,944.60	27,221,667.61

a Costs are in 1994 dollars and include a 5 percent field detail allowance for unquantified items.

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Table R-18
Alternative 3

ID	Activity	Man-Days: Sr. Level Professional	Man-Days: Mid Level Professional	Man-Days: Jr. Level Professional	Man-Days: Technician	Man-Days: Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
1	Master Plan/Work Plan of Remedial Action										
2	Develop Remedial Action Master Plan										
3	Extraction System	4	24	25	4	4	8,245.12		49,470.72	9,894.14	59,364.86
4	Treatment System	1	2	6	2	2	1,571.39		9,428.35	1,885.67	11,314.02
5	End-Use System	2	15	25	25	4	8,390.03		50,340.19	10,068.04	60,408.23
6	Collection System	6	20	20	40	8	10,996.35		65,978.11	13,195.62	79,173.73
7	Prepare DQOs	3	15	15	6	2	5,446.34		32,678.02	6,535.60	39,213.62
8	Prepare Rationale	1	5	2	0	2	1,378.53		8,271.17	1,654.23	9,925.40
9	Prepare Health and Safety Plan	0	1	0	0	0	158.53		951.17	190.23	1,141.40
10	Prepare QAPP	2	20	20	0	0	5,950.85		35,705.09	7,141.02	42,846.11
11	Prepare SAP	5	20	20	0	0	6,484.80		38,908.80	7,781.76	46,690.56
12	Develop Remedial Action Work Plan	5	50	125	25	15	27,504.16		165,024.96	33,004.99	198,029.95
13	Prepare Draft Copy	1	12	40	10	10	8,674.24		52,045.44	10,409.09	62,454.53
14	Prepare Draft Final	1	2	8	2	10	2,475.71		14,854.27	2,970.85	17,825.13
15	Prepare Final Remedial Action Master Plan and Work Plan	1	2	5	2	10	2,112.06		12,672.38	2,534.48	15,206.86
	Subtotal	32	188	311	116	67	89,388.11	0.00	536,328.67	107,265.73	643,594.41
16	Utility Mapping	100	190	0	370	90	160,500.00		607,140.00	121,428.00	728,568.00
	Subtotal	100	190	0	370	90	160,500.00	0.00	607,140.00	121,428.00	728,568.00
21	Onbase/Offbase Production Wells										
22	Prepare Base Well 18 Abandonment Program	2	12	20	5	8	5,803.47		34,820.83	6,964.17	41,785.00
23	Prepare Production Well Contingency Plans	2	0	5	10	2	2,045.44		12,272.64	2,454.53	14,727.17
	Subtotal	4	12	25	15	10	7,848.91	0.00	47,093.47	9,418.69	56,512.17
24	Extraction System										
25	Subcontractor Procurement										
26	Specify System Requirements	2	15	30	4	40	10,046.98		60,281.86	12,056.37	72,338.23
27	Identify Performance Criteria	2	5	5		5	2,168.37		13,010.21	2,602.04	15,612.25
28	Procure BOAs w/3 Subs for Basewide EW/MW	2	15	2	2	15	4,400.94		26,405.66	5,281.13	31,686.80
	Subtotal	6	35	37	6	60	16,616.29	0.00	99,697.73	19,939.54	119,637.27
29	Phase 1--Well Installation/Investigations										
30	Offbase Monitoring Wells (28)										
31	Offbase Extraction Wells (22) w/Well Head Treatment										
32	Hot Spot Extraction Wells (15)										
33	Prepare Final Layout of Wells	6	30	60	7	45	17,462.37		104,774.21	20,954.84	125,729.05
34	Prepare for Installation	6	60	60	30	30	23,088.38		138,530.30	27,706.06	166,236.36
35	Install Wells/Interpret Data	20	510	510	97	92	197,324.66	2,057,816.25	3,068,864.19	613,772.84	3,682,637.02
36	Phase 1 Report/Phase 2 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
37	Abandon Base Well 18	1	3	22	22	4	5,670.69	25,000.00	59,024.13	11,804.83	70,828.95
	Subtotal	63	903	852	556	216	361,127.14	2,082,816.25	4,076,679.07	815,335.81	4,892,014.88
38	Phase 2--Well Installation										
39	Offbase Monitoring Wells (14)										
40	Offbase Extraction Wells (43) w/Well Head Treatment										
41	Hot Spot Extraction Wells (14)										
42	Prepare Final Layout of Wells	6	30	60	7	45	17,462.37		104,774.21	20,954.84	125,729.05
43	Prepare for Installation	6	60	60	30	30	23,088.38		138,530.30	27,706.06	166,236.36
44	Install Wells/Interpret Data	20	510	510	97	92	200,516.66	2,469,379.50	3,483,619.44	696,723.89	4,180,343.32
45	Phase 2 Report/Phase 3 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	62	900	830	534	212	358,648.46	2,469,379.50	4,432,410.19	886,482.04	5,318,892.23
46	Phase 3--Well Installation/Investigation										
47	Onbase Monitoring Wells (72)										
48	Onbase Extraction Wells (111)										
49	Prepare Final Layout of Wells	17	82	165	20	120	47,789.82		286,738.94	57,347.79	344,086.73
50	Prepare for Installation	16	165	165	82	82	63,316.80		379,900.80	75,980.16	455,880.96
51	Install Wells/Interpret Data	55	1,425	1,425	260	260	551,157.60	3,704,069.25	6,524,234.85	1,304,846.97	7,829,081.82
52	Phase 3 Report	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49

Table R-18
Alternative 3 [a]

ID	Activity	Man-Days: Sr. Level Professional	Man-Days: Mid Level Professional	Man-Days: Jr. Level Professional	Man-Days: Technician	Man-Days: Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
	Subtotal	118	1,972	1,986	762	807	779,846	3,704,869	7,886,360.83	1,579,272.17	9,476,633.00
53	Treatment/End-Use/Collection Systems										
54	Process Turnkey Contractor	2	20	20	5	20	8,064.53		48,387.17	9,677.43	58,064.60
55	Western Area										
56	Collection Piping										
57	Prepare Preliminary Design	40	110	120	70	80	52,147.68		312,886.08	62,577.22	375,463.30
58	Prepare Final Design	60	120	50	120	80	53,397.12		320,382.72	64,076.54	384,459.26
59	Prepare for Construction	40	80			16	21,125.38		126,752.26	25,350.45	152,102.71
60	Construct Collection Piping	50	240			50	51,082.72	2,731,995.00	3,038,491.32	607,698.26	3,646,189.58
	Subtotal	192	570	190	196	246	185,817.42	2,731,995.00	3,846,899.54	769,379.91	4,616,279.46
61	Treatment Plant										
62	Prepare Preliminary Design	22	50	30	12	10	17,407.39		104,444.35	20,888.87	125,333.22
63	Prepare Final Design	12	50	20	33	12	16,508.50		99,050.98	19,810.20	118,861.17
64	Prepare for Construction		50			6	8,422.82		50,536.90	10,107.38	60,644.28
65	Construct Treatment Plant	12	50			45	13,785.33	1,672,900.00	1,755,611.97	351,122.39	2,106,734.36
66	Startup/Shutdown										
67	Conduct Startup/Shutdown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
68	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
69	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	51	205	80	46	74	87,889.33	1,672,900.00	2,020,236.97	404,047.19	2,424,283.16
70	End-Use Piping										
71	Prepare Preliminary Design	15	25	17	25	5	11,402.11		68,412.67	13,682.53	82,095.21
72	Prepare Final Design	5	25	22	50	5	12,523.15		75,138.91	15,027.78	90,166.69
73	Prepare for Construction	20	40		2	12	11,077.22		66,463.30	13,292.66	79,755.96
74	Construct End-Use Piping	10	45			20	10,568.32	838,985.00	902,394.92	180,478.98	1,082,873.90
	Subtotal	80	136	39	77	42	46,570.80	838,985.00	1,112,400.80	222,481.96	1,334,891.76
75	Eastern Area										
76	Collection Piping										
77	Prepare Preliminary Design	22	72	75	46	46	32,449.15		194,694.91	38,938.98	233,633.89
78	Prepare Final Design	32	72	35	80	46	32,501.28		195,007.68	39,001.54	234,009.22
79	Prepare for Construction	22	48			10	12,352.35		74,114.11	14,822.82	88,936.93
80	Construct Collection Piping	27	150			30	31,066.85	1,529,850.00	1,716,251.09	343,250.22	2,059,501.31
	Subtotal	103	342	110	126	132	108,369.63	1,529,850.00	2,180,887.79	436,013.86	2,616,801.35
81	Treatment Plant										
82	Prepare Preliminary Design	30	30	23	18	10	15,362.94		92,177.66	18,435.53	110,613.20
83	Prepare Final Design	15	30	35	40	10	16,167.20		97,003.20	19,400.64	116,403.84
84	Prepare for Construction	20	40			20	11,555.52		69,333.12	13,866.62	83,199.74
85	Construct Treatment Plant	5	30			5	6,059.44	1,154,400.00	1,190,756.64	238,151.33	1,428,907.97
86	Startup/Shutdown										
87	Conduct Startup/Shutdown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
88	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
89	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	78	138	58	58	46	90,910.40	1,154,400.00	1,489,862.40	291,972.48	1,751,834.88
90	End-Use Piping										
91	Prepare Preliminary Design	6	12	12	7	5	5,481.06		32,886.34	6,577.27	39,463.60
92	Prepare Final Design	4	17	12	7	5	5,917.73		35,506.37	7,101.27	42,607.64
93	Prepare for Construction	12	22			5	6,037.10		36,222.62	7,244.52	43,467.15
94	Construct End-Use Piping	4	17			5	3,820.59	477,015.00	499,938.55	99,987.71	599,926.26
	Subtotal	26	68	24	14	20	21,256.48	477,015.00	604,883.88	120,910.78	725,464.66
	Injection Site							763,875.00	763,875.00	152,775.00	916,650.00
	Alternative 3 Total	882	5,665	4,481	2,874	1,722	2,243,788.22	17,425,285.00	29,683,614.34	5,936,722.87	35,620,337.21

[a] Costs are in 1994 dollars and include a 5 percent field detail allowance for unquantified items.

Table R-19
Alternative 4

ID	Activity	Man-Days: Sr. Level Professional	Man-Days: Mid Level Professional	Man-Days: Jr. Level Professional	Man-Days: Technician	Man-Days: Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
1	Master Plan/Work Plan of Remedial Action										
2	Develop Remedial Action Master Plan										
3	Extraction System	4	24	25	4	4	8,245.12		49,470.72	9,894.14	59,364.86
4	Treatment System	1	2	6	2	2	1,571.39		9,428.35	1,885.67	11,314.02
5	End-Use System	2	15	25	25	4	8,390.03		50,340.19	10,068.04	60,408.23
6	Collection System	6	20	20	40	8	10,996.35		65,978.11	13,195.62	79,173.73
7	Prepare DQOs	3	15	15	6	2	5,446.34		32,678.02	6,535.60	39,213.62
8	Prepare Rationale	1	5	2	0	2	1,378.53		8,271.17	1,654.23	9,925.40
9	Prepare Health and Safety Plan	0	1	0	0	0	158.53		951.17	190.23	1,141.40
10	Prepare QAPP	2	20	20	0	0	5,950.85		35,705.09	7,141.02	42,846.11
11	Prepare SAP	5	20	20	0	0	6,464.80		38,908.80	7,781.76	46,690.56
12	Develop Remedial Action Work Plan	5	50	125	25	15	27,504.16		165,024.96	33,004.99	198,029.95
13	Prepare Draft Copy	1	12	40	10	10	8,674.24		52,045.44	10,409.09	62,454.53
14	Prepare Draft Final	1	2	8	2	10	2,475.71		14,854.27	2,970.85	17,825.13
15	Prepare Final Remedial Action Master Plan and Work Plan	1	2	5	2	10	2,112.06		12,672.38	2,534.48	15,206.86
	Subtotal	32	188	311	116	67	89,368.11	0.00	536,328.67	107,265.73	643,594.41
16	Utility Mapping	75	151	0	280	66	107,890.00		450,134.32	90,026.86	540,161.18
	Subtotal	75	151	0	280	66	107,890.00	0.00	450,134.32	90,026.86	540,161.18
21	Onbase/Offbase Production Wells										
22	Prepare Base Well 18 Abandonment Program	2	12	20	5	8	5,803.47		34,820.83	6,964.17	41,785.00
23	Prepare Production Well Contingency Plans	2	0	5	10	2	2,045.44		12,272.64	2,454.53	14,727.17
	Subtotal	4	12	25	15	10	7,848.91	0.00	47,093.47	9,418.69	56,512.17
24	Extraction System										
25	Subcontractor Procurement										
26	Specify System Requirements	2	15	30	4	40	10,046.98		60,281.86	12,056.37	72,338.23
27	Identify Performance Criteria	2	5	5		5	2,168.37		13,010.21	2,602.04	15,612.25
28	Procure BOAs w/3 Subs for Basewide EW/MW	2	15	2	2	15	4,400.94		26,405.66	5,281.13	31,686.80
	Subtotal	6	35	37	6	60	16,616.29	0.00	99,697.73	19,939.56	[illegible]
29	Phase 1–Well Installation/Investigations										
30	Offbase Monitoring Wells (19)										
31	Offbase Extraction Wells (8) w/Well Head Treatment										
32	Hot Spot Extraction Wells (18)										
33	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
34	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
35	Install Wells/Interpret Data	10	250	250	50	50	102,786.24	2,057,816.25	2,562,813.69	512,562.74	3,075,376.43
36	Phase 1 Report/Phase 2 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
37	Abandon Base Well 18	1	2	15	15	3	3,938.37	25,000.00	48,630.21	9,726.04	58,356.25
	Subtotal	47	597	525	484	133	244,420.88	2,082,816.25	3,437,616.73	687,523.36	4,125,140.08
38	Phase 2–Well Installation										
39	Offbase Monitoring Wells (10)										
40	Offbase Extraction Wells (22) w/Well Head Treatment										
41	Hot Spot Extraction Wells (14)										
42	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
43	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
44	Install Wells/Interpret Data	10	250	250	50	50	104,914.24	2,469,379.50	2,976,504.94	595,300.99	3,571,805.93
45	Phase 2 Report/Phase 3 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	46	595	510	469	130	242,609.71	2,469,379.50	3,802,677.77	760,535.55	4,563,213.33
46	Phase 3–Well Installation/Investigation										
47	Onbase Monitoring Wells (68)										
48	Onbase Extraction Wells (94)										
49	Prepare Final Layout of Wells	9	43	87	12	55	24,616.34		147,698.02	29,539.60	177,237.62
50	Prepare for Installation	9	87	87	41	45	33,426.18		200,557.06	40,111.41	240,668.47
51	Install Wells/Interpret Data	29	725	725	125	140	317,216.98	3,704,069.25	5,176,451.11	1,035,290.22	6,211,741.33
52	Phase 3 Report	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	77	1,155	1,099	578	285	492,840.53	3,704,069.25	6,230,192.42	1,246,038.48	7,476,230.90

Table R-19
Alternative 4 a

ID	Activity	Man-Days: Sr. Level Professional	Man-Days: Mid Level Professional	Man-Days: Jr. Level Professional	Man-Days: Technician	Man-Days: Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
53	Treatment/End-Use/Collection Systems										
54	Procure Turnkey Contractor	2	20	20	5	20	8,064.53		48,387.17	9,677.43	58,064.60
55	Western Area										
56	Collection Piping										
57	Prepare Preliminary Design	22	65	75	44	45	31,073.14		186,438.82	37,287.76	223,726.58
58	Prepare Final Design	37	75	30	75	45	32,719.01		196,314.05	39,262.81	235,576.86
59	Prepare for Construction	25	46			8	12,403.78		74,422.66	14,884.53	89,307.19
60	Construct Collection Piping	31	140			25	29,779.82	1,601,775.00	1,780,453.94	356,090.79	2,136,544.73
	Subtotal	117	346	125	124	143	114,048.27	1,601,775.00	2,286,016.63	457,203.33	2,743,219.96
61	Treatment Plant										
62	Prepare Preliminary Design	9	10	9	4	3	4,893.46		29,360.74	5,872.15	35,232.88
63	Prepare Final Design	5	10	5	14	5	4,780.05		28,680.29	5,736.06	34,416.35
64	Prepare for Construction		20			2	3,336.03		20,016.19	4,003.24	24,019.43
65	Construct Treatment Plant	5	20			20	5,715.20	581,400.00	615,691.20	123,138.24	738,829.44
66	Startup/Shakedown										
67	Conduct Startup/Shakedown	2	2			1	755.76		4,534.56	906.91	5,441.47
68	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
69	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	21	62	14	18	31	19,480.50	581,400.00	698,282.98	139,656.60	837,939.57
70	End-Use Piping										
71	Prepare Preliminary Design	13	22	14	20	4	9,665.22		57,991.30	11,598.26	69,589.56
72	Prepare Final Design	5	22	16	40	4	10,319.62		61,917.70	12,383.54	74,301.24
73	Prepare for Construction	17	32		2	10	9,109.57		54,657.41	10,931.48	65,588.89
74	Construct End-Use Piping	8	36			16	8,454.66	755,235.00	805,962.94	161,192.59	967,155.52
	Subtotal	43	112	30	62	34	37,549.06	755,235.00	980,529.34	196,105.87	1,176,635.20
75	Eastern Area										
76	Collection Piping										
77	Prepare Preliminary Design	20	60	67	40	40	28,173.95		169,043.71	33,808.74	202,852.45
78	Prepare Final Design	30	60	32	70	42	28,630.46		171,782.78	34,356.56	206,139.34
79	Prepare for Construction	20	40			8	10,562.69		63,376.13	12,675.23	76,051.35
80	Construct Collection Piping	25	125			25	26,334.00	1,208,025.00	1,366,029.00	273,205.80	1,639,234.80
	Subtotal	95	285	99	110	115	93,701.10	1,208,025.00	1,770,231.62	354,046.32	2,124,277.96
81	Treatment Plant										
82	Prepare Preliminary Design	25	31	24	20	11	15,019.09		90,114.53	18,022.91	108,137.43
83	Prepare Final Design	16	28	34	32	11	15,255.31		91,531.87	18,306.37	109,838.25
84	Prepare for Construction	10	10			22	5,185.31		31,111.87	6,222.37	37,334.25
85	Construct Treatment Plant	5	31			5	6,217.97	501,900.00	539,207.81	107,841.56	647,049.37
86	Startup/Shakedown										
87	Conduct Startup/Shakedown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
88	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
89	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	61	105	58	52	50	43,442.98	501,900.00	762,557.86	152,511.57	915,069.43
90	End-Use Piping										
91	Prepare Preliminary Design	6	12	12	7	5	5,481.06		32,886.34	6,577.27	39,463.60
92	Prepare Final Design	4	17	12	7	5	5,917.73		35,506.37	7,101.27	42,607.64
93	Prepare for Construction	12	22			5	6,037.10		36,222.62	7,244.52	43,467.15
94	Construct End-Use Piping	4	17			5	3,820.59	395,115.00	418,038.55	83,607.71	501,646.26
	Subtotal	26	68	24	14	20	21,256.48	395,115.00	522,653.88	104,530.78	627,184.66
95	Injection Site							574,875.00	574,875.00	114,975.00	689,850.00
	Alternative 4 Total	650	3,711	2,857	2,328	1,144	1,531,004.02	13,874,990.00	22,198,888.42	4,439,777.68	26,638,666.10

a Costs are in 1994 dollars and include a 5 percent field detail allowance for unquantified items.

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Table R-20
Alternative 5

ID	Activity	Man Days: Sr. Level Professional	Man Days: Mid Level Professional	Man Days: Jr. Level Professional	Man Days: Technician	Man Days: Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
1	**Master Plan/Work Plan of Remedial Action**										
2	Develop Remedial Action Master Plan										
3	Extraction System	4	24	25	4	4	8,245.12		49,470.72	9,894.14	59,364.86
4	Treatment System	1	2	6	2	2	1,571.39		9,428.35	1,885.67	11,314.02
5	End-Use System	2	15	25	25	4	8,390.03		50,340.19	10,068.04	60,408.23
6	Collection System	6	20	20	40	8	10,996.35		65,978.11	13,195.62	79,173.73
7	Prepare DQOs	3	15	15	6	2	5,446.34		32,678.02	6,535.60	39,213.62
8	Prepare Rationale	1	5	2	0	2	1,378.53		8,271.17	1,654.23	9,925.40
9	Prepare Health and Safety Plan	0	1	0	0	0	158.53		951.17	190.23	1,141.40
10	Prepare QAPP	2	20	20	0	0	5,950.85		35,705.09	7,141.02	42,846.11
11	Prepare SAP	5	20	20	0	0	6,484.80		38,908.80	7,781.76	46,690.56
12	Develop Remedial Action Work Plan	5	50	125	25	15	27,504.16		165,024.96	33,004.99	198,029.95
13	Prepare Draft Copy	1	12	40	10	10	8,674.24		52,045.44	10,409.09	62,454.53
14	Prepare Draft Final	1	2	8	2	10	2,475.71		14,854.27	2,970.85	17,825.13
15	Prepare Final Remedial Action Master Plan and Work Plan	1	2	5	2	10	2,112.06		12,672.38	2,534.48	15,206.86
	Subtotal	**32**	**188**	**311**	**116**	**67**	**89,388.11**	**0.00**	**536,328.67**	**107,265.73**	**643,594.41**
16	**Utility Mapping**	75	151	0	280	66	107,890.00	0.00	450,134.32	90,026.86	540,161.18
	Subtotal	**75**	**151**	**0**	**280**	**66**	**107,890.00**	**0.00**	**450,134.32**	**90,026.86**	**540,161.18**
21	**Onbase/Offbase Production Wells**										
22	Prepare Base Well 18 Abandonment Program	2	12	20	5	8	5,803.47		34,820.83	6,964.17	41,785.00
23	Prepare Production Well Contingency Plans	2	0	5	10	2	2,045.44		12,272.64	2,454.53	14,727.17
	Subtotal	**4**	**12**	**25**	**15**	**10**	**7,848.91**	**0.00**	**47,093.47**	**9,418.69**	**56,512.17**
24	**Extraction System**										
25	Subcontractor Procurement										
26	Specify System Requirements	2	15	30	4	40	10,046.98		60,281.86	12,056.37	72,338.23
27	Identify Performance Criteria	2	5	5		5	2,168.37		13,010.21	2,602.04	15,612.25
28	Procure BOAs w/3 Subs for Basewide EW/MW	2	15	2	2	15	4,400.94		26,405.66	5,281.13	31,686.80
	Subtotal	**6**	**35**	**37**	**6**	**60**	**16,616.29**	**0.00**	**99,697.73**	**19,939.55**	**119,637.27**
29	Phase 1--Well Installation/Investigations										
30	Offbase Monitoring Wells (19)										
31	Offbase Extraction Wells (8) w/Well Head Treatment										
32	Hot Spot Extraction Wells (15)										
33	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
34	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
35	Install Wells/Interpret Data	10	250	250	50	50	102,786.24	2,057,816.25	2,562,813.69	512,562.74	3,075,376.43
36	Phase 1 Report/Phase 2 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
37	Abandon Base Well 18	1	2	15	15	3	3,938.37	25,000.00	48,630.21	9,726.04	58,356.25
	Subtotal	**47**	**597**	**525**	**484**	**133**	**244,420.08**	**2,082,816.25**	**3,437,616.73**	**687,523.36**	**4,125,140.08**
38	Phase 2--Well Installation										
39	Offbase Monitoring Wells (10)										
40	Offbase Extraction Wells (22) w/Well Head Treatment										
41	Hot Spot Extraction Wells (14)										
42	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
43	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
44	Install Wells/Interpret Data	10	250	250	50	50	104,914.24	2,469,379.50	2,976,504.94	595,300.99	3,571,805.93
45	Phase 2 Report/Phase 3 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	**46**	**595**	**510**	**469**	**130**	**242,609.71**	**2,469,379.50**	**3,802,677.77**	**760,535.55**	**4,563,213.33**
46	Phase 3--Well Installation/Investigation										
47	Onbase Monitoring Wells (68)										
48	Onbase Extraction Wells (94)										
49	Prepare Final Layout of Wells	9	43	87	12	55	24,616.34		147,698.02	29,539.60	177,237.62
50	Prepare for Installation	9	87	87	41	45	33,426.18		200,557.06	40,111.41	240,668.47
51	Install Wells/Interpret Data	29	725	725	125	140	317,216.98	3,704,069.25	5,176,451.11	1,035,290.22	6,211,741.33
52	Phase 3 Report	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	**77**	**1,155**	**1,099**	**578**	**285**	**492,840.53**	**3,704,069.25**	**6,230,192.42**	**1,246,038.48**	**7,476,230.90**

Table R-20
Alternative 5 a

ID	Activity	Man Days: Sr. Level Professional	Man Days: Mid Level Professional	Man Days: Jr. Level Professional	Man Days: Technician	Man Days: Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
53	Treatment/End-Use/Collection Systems										
54	Procure Turnkey Contractor	2	20	20	5	20	8,064.53		48,387.17	9,677.43	58,064.60
55	Western Area										
56	Collection Piping										
57	Prepare Preliminary Design	22	65	75	44	45	31,073.14		186,438.82	37,287.76	223,726.58
58	Prepare Final Design	37	75	30	75	45	32,719.01		196,314.05	39,262.81	235,576.86
59	Prepare for Construction	25	46			8	12,403.78		74,422.66	14,884.53	89,307.19
60	Construct Collection Piping	31	140			25	29,779.82	1,601,775.00	1,780,453.94	356,090.79	2,136,544.73
	Subtotal	117	346	125	124	143	114,040.27	1,601,775.00	2,286,016.63	457,203.33	2,743,219.96
61	Treatment Plant										
62	Prepare Preliminary Design	9	20	9	4	3	6,478.74		38,872.42	7,774.48	46,646.90
63	Prepare Final Design	5	20	5	14	5	6,365.33		38,191.97	7,638.39	45,830.36
64	Prepare for Construction		40			2	6,506.59		39,039.55	7,807.91	46,847.46
65	Construct Treatment Plant	5	20			20	5,715.20	581,400.00	615,691.20	123,138.24	738,829.44
66	Startup/Shakedown										
67	Conduct Startup/Shakedown	2	2			1	755.76		4,534.56	906.91	5,441.47
68	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
69	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	21	102	14	18	31	25,821.62	581,400.00	736,329.70	147,265.94	883,595.64
70	End-Use Piping										
71	Prepare Preliminary Design	22	35	22	35	5	15,757.28		94,543.68	18,908.74	113,452.42
72	Prepare Final Design	5	37	33	75	5	18,053.66		108,321.98	21,664.40	129,986.38
73	Prepare for Construction	20	40		2	12	11,077.22		66,463.30	13,292.66	79,755.96
74	Construct End-Use Piping	15	67			20	14,945.86	714,915.00	804,590.14	160,918.03	965,508.16
	Subtotal	62	179	55	112	42	59,834.02	714,915.00	1,073,919.10	214,783.82	1,288,702.92
75	Eastern Area										
76	Collection Piping										
77	Prepare Preliminary Design	20	60	67	40	40	28,173.95		169,043.71	33,808.74	202,852.45
78	Prepare Final Design	30	60	32	70	42	28,630.46		171,782.78	34,356.56	206,139.34
79	Prepare for Construction	20	40			8	10,562.69		63,376.13	12,675.23	76,051.35
80	Construct Collection Piping	25	125			25	26,334.00	1,208,025.00	1,366,029.00	273,205.80	1,639,234.80
	Subtotal	95	285	99	110	115	93,701.10	1,208,025.00	1,770,231.62	354,046.32	2,124,277.94
81	Treatment Plant										
82	Prepare Preliminary Design	30	30	23	18	10	15,362.94		92,177.66	18,435.53	110,613.20
83	Prepare Final Design	15	30	35	40	10	16,167.20		97,003.20	19,400.64	116,403.84
84	Prepare for Construction	20	40			20	11,555.52		69,333.12	13,866.62	83,199.74
85	Construct Treatment Plant	5	30			5	6,059.44	788,400.00	824,756.64	164,951.33	989,707.97
86	Startup/Shakedown										
87	Conduct Startup/Shakedown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
88	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
89	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	75	135	58	58	46	50,910.40	788,400.00	1,093,862.40	218,772.48	1,312,634.88
90	End-Use Piping										
91	Prepare Preliminary Design	22	33	21	33	5	15,135.42		90,812.54	18,162.51	108,975.05
92	Prepare Final Design	5	35	32	70	5	17,156.43		102,938.59	20,587.72	123,526.31
93	Prepare for Construction	20	38		2	12	10,760.16		64,560.96	12,912.19	77,473.15
94	Construct End-Use Piping	15	65			18	14,463.33	337,890.00	424,669.97	84,933.99	509,603.96
	Subtotal	62	171	53	106	40	57,515.34	337,890.00	682,982.06	136,596.41	819,578.48
										0.00	0.00
	Alternative 5 Total	719	3,951	2,911	2,475	1,168	1,683,436.38	13,488,670.00	22,247,082.62	4,449,416.52	26,696,499.15

a Costs are in 1994 dollars and include a 5 percent field detail allowance for unquantified items.

Table R-21
Alternative 6

ID	Activity	Man-Days: Sr. Level Professional	Mid Level Professional	Jr. Level Professional	Technician	Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
1	Master Plan/Work Plan of Remedial Action										
2	Develop Remedial Action Master Plan										
3	Extraction System	4	24	25	4	4	8,245.12		49,470.72	9,894.14	59,364.86
4	Treatment System	1	2	6	2	2	1,571.39		9,428.35	1,885.67	11,314.02
5	End-Use System	2	15	25	25	4	8,390.03		50,340.19	10,068.04	60,408.23
6	Collection System	6	20	20	40	8	10,996.35		65,978.11	13,195.62	79,173.73
7	Prepare DQOs	3	15	15	6	2	5,446.34		32,678.02	6,535.60	39,213.62
8	Prepare Rationale	1	5	2	0	2	1,378.53		8,271.17	1,654.23	9,925.40
9	Prepare Health and Safety Plan	0	1	0	0	0	158.53		951.17	190.23	1,141.40
10	Prepare QAPP	2	20	20	0	0	5,950.85		35,705.09	7,141.02	42,846.11
11	Prepare SAP	5	20	20	0	0	6,484.80		38,908.80	7,781.76	46,690.56
12	Develop Remedial Action Work Plan	5	50	125	25	15	27,504.16		165,024.96	33,004.99	198,029.95
13	Prepare Draft Copy	1	12	40	10	10	8,674.24		52,045.44	10,409.09	62,454.53
14	Prepare Draft Final	1	2	8	2	10	2,475.71		14,854.27	2,970.85	17,825.13
15	Prepare Final Remedial Action Master Plan and Work Plan	1	2	5	2	10	2,112.06		12,672.38	2,534.48	15,206.86
	Subtotal	32	188	311	116	67	89,388.11	0.00	536,328.67	107,265.73	643,594.41
16	Utility Mapping	75	151	0	280	66	107,890.00		450,134.32	90,026.86	540,161.18
	Subtotal	75	151	0	280	66	107,890.00	0.00	450,134.32	90,026.86	540,161.18
21	Onbase/Offbase Production Wells										
22	Prepare Base Well 18 Abandonment Program	2	12	20	5	8	5,803.47		34,820.83	6,964.17	41,785.00
23	Prepare Production Well Contingency Plans	2	0	5	10	2	2,045.44		12,272.64	2,454.53	14,727.17
	Subtotal	4	12	25	15	10	7,848.91	0.00	47,093.47	9,418.69	56,512.17
24	Extraction System										
25	Subcontractor Procurement										
26	Specify System Requirements	2	15	30	4	40	10,046.98		60,281.86	12,056.37	72,338.23
27	Identify Performance Criteria	2	5	5		5	2,168.37		13,010.21	2,602.04	15,612.25
28	Procure BOAs w/3 Subs for Basewide EW/MW	2	15	2	2	15	4,400.94		26,405.66	5,281.13	31,686.80
	Subtotal	6	36	37	6	60	16,616.29	0.00	99,697.73	19,939.55	119,637.27
29	Phase 1–Well Installation/Investigations										
30	Offbase Monitoring Wells (19)										
31	Offbase Extraction Wells (8) w/Well Head Treatment										
32	Hot Spot Extraction Wells (15)										
33	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
34	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
35	Install Wells/Interpret Data	10	250	250	50	50	102,786.24	2,057,816.25	2,562,813.69	512,562.74	3,075,376.43
36	Phase 1 Report/Phase 2 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
37	Abandon Base Well 18	1	2	15	15	3	3,938.37	25,000.00	48,630.21	9,726.04	58,356.25
	Subtotal	47	597	525	484	133	244,420.08	2,082,816.25	3,437,616.73	687,523.35	4,125,140.08
38	Phase 2–Well Installation										
39	Offbase Monitoring Wells (10)										
40	Offbase Extraction Wells (22) w/Well Head Treatment										
41	Hot Spot Extraction Wells (14)										
42	Prepare Final Layout of Wells	3	15	30	4	20	8,570.24		51,421.44	10,284.29	61,705.73
43	Prepare for Installation	3	30	30	15	15	11,544.19		69,265.15	13,853.03	83,118.18
44	Install Wells/Interpret Data	10	250	250	50	50	104,914.24	2,469,379.50	2,976,504.94	595,300.99	3,571,805.93
45	Phase 2 Report/Phase 3 Plan	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	46	595	510	469	130	242,609.71	2,469,379.50	3,802,677.77	760,535.55	4,563,213.33
46	Phase 3–Well Installation/Investigation										
47	Onbase Monitoring Wells (68)										
48	Onbase Extraction Wells (94)										
49	Prepare Final Layout of Wells	9	43	87	12	55	24,616.34		147,698.02	29,539.60	177,237.62
50	Prepare for Installation	9	87	87	41	45	33,426.18		200,557.06	40,111.41	240,668.47
51	Install Wells/Interpret Data	29	725	725	125	140	317,216.98	3,704,069.25	5,176,451.11	1,035,290.22	6,211,741.33
52	Phase 3 Report	30	300	200	400	45	117,581.04		705,486.24	141,097.25	846,583.49
	Subtotal	77	1,155	1,099	578	285	492,840.53	3,704,069.25	6,230,192.42	1,246,038.48	7,476,230.90

Table R-21
Alternative 6 ª

ID	Activity	Man-Days: Sr. Level Professional	Mid Level Professional	Jr. Level Professional	Technician	Administrative Assistant	Expenses ($)	Construction Contracts ($)	Activity Subtotal ($)	20% Contingency ($)	Activity Total ($)
53	Treatment/End-Use/Collection Systems										
54	Procure Turnkey Contractor	2	20	20	5	20	8,064.53		48,387.17	9,677.43	58,064.60
55	Western Area										
56	Collection Piping										
57	Prepare Preliminary Design	22	65	75	44	45	31,073.14		186,438.82	37,287.76	223,726.58
58	Prepare Final Design	37	75	30	75	45	32,719.01		196,314.05	39,262.81	235,576.86
59	Prepare for Construction	25	46			8	12,403.78		74,422.66	14,884.53	89,307.19
60	Construct Collection Piping	31	140			25	29,779.82	1,601,775.00	1,780,453.94	356,090.79	2,136,544.73
	Subtotal	117	346	125	124	143	114,040.27	1,601,775.00	2,286,016.63	457,203.33	2,743,219.96
61	Treatment Plant										
62	Prepare Preliminary Design	9	20	9	4	3	6,478.74		38,872.42	7,774.48	46,646.90
63	Prepare Final Design	5	20	5	14	5	6,365.33		38,191.97	7,638.39	45,830.36
64	Prepare for Construction		40			2	6,506.59		39,039.55	7,807.91	46,847.46
65	Construct Treatment Plant	5	20			20	5,715.20	581,400.00	615,691.20	123,138.24	738,829.44
66	Startup/Shakedown										
67	Conduct Startup/Shakedown	2	2			1	755.76		4,534.56	906.91	5,441.47
68	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
69	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	21	182	14	18	31	25,821.62	581,400.00	736,329.70	147,265.94	883,596.64
70	End-Use Piping										
71	Prepare Preliminary Design	15	25	17	25	5	11,402.11		68,412.67	13,682.53	82,095.21
72	Prepare Final Design	5	25	22	50	5	12,523.15		75,138.91	15,027.78	90,166.69
73	Prepare for Construction	20	40		2	12	11,077.22		66,463.30	13,292.66	79,755.96
74	Construct End-Use Piping	10	45			20	10,568.32	755,235.00	818,644.92	163,728.98	982,373.90
	Subtotal	50	135	39	77	42	45,570.80	755,235.00	1,028,659.80	205,731.96	1,234,391.76
75	Eastern Area										
76	Collection Piping										
77	Prepare Preliminary Design	20	60	67	40	40	28,173.95		169,043.71	33,808.74	202,852.45
78	Prepare Final Design	30	60	32	70	42	28,630.46		171,782.78	34,356.56	206,139.34
79	Prepare for Construction	20	40			8	10,562.69		63,376.13	12,675.23	76,051.35
80	Construct Collection Piping	25	125			25	26,334.00	1,208,025.00	1,366,029.00	273,205.80	1,639,234.80
	Subtotal	95	285	99	110	115	93,701.10	1,208,025.00	1,770,231.62	354,046.32	2,124,277.95
81	Treatment Plant										
82	Prepare Preliminary Design	25	25	20	18	10	13,316.74		79,900.42	15,980.08	95,880.50
83	Prepare Final Design	15	25	30	36	10	14,401.31		86,407.87	17,281.57	103,689.45
84	Prepare for Construction	18	35			20	10,406.91		62,441.47	12,488.29	74,929.77
85	Construct Treatment Plant	5	25			5	5,266.80	320,600.00	352,200.80	70,440.16	422,640.96
86	Startup/Shakedown										
87	Conduct Startup/Shakedown	5	5			1	1,765.30		10,591.78	2,118.36	12,710.13
88	Implement Process Contingency Plan						0.00		0.00	0.00	0.00
89	Implement Capacity Contingency Plan						0.00		0.00	0.00	0.00
	Subtotal	68	115	50	54	46	45,157.06	320,600.00	591,542.34	118,308.47	709,850.80
90	End-Use Piping										
91	Prepare Preliminary Design	6	12	12	7	5	5,481.06		32,886.34	6,577.27	39,463.60
92	Prepare Final Design	4	17	12	7	5	5,917.73		35,506.37	7,101.27	42,607.64
93	Prepare for Construction	12	22			5	6,037.10		36,222.62	7,244.52	43,467.15
94	Construct End-Use Piping	4	17			5	3,820.59	395,115.00	418,038.55	83,607.71	501,646.26
	Subtotal	26	68	24	14	20	21,256.48	395,115.00	522,653.88	104,530.78	627,184.66
95	Reinjection Site							574,875.00	574,875.00	114,975.00	689,850.00
	Alternative 6 Total	664	3,784	2,858	2,346	1,148	1,547,160.96	13,693,290.00	22,114,050.08	4,422,810.02	26,536,860.10

ª Costs are in 1994 dollars and include a 5 percent field detail allowance for unquantified items.

Table R-22

Alternative 1--O&M Costs Summary

ITEM	QUANTITY	UNIT	$/UNIT	TOTAL ($)
EXTRACTION SYSTEM				
Power	1,607,600	KW/HRS	0.06	96,456
Sampling, Analyses & Interpretation	1	LS		62,524
Wellhead Treatment (1st 5 years)	21	EA	12,000	252,000
Maintenance (5% of Construction)	1	LS		273,400
TREATMENT FACILITY (Eastside Plant)				
Labor	1	LS		315,360
Power	1	LS		34,985
Natural Gas	1	LS		47,587
Materials	1	LS		21,370
Carbon	1	LS		206,250
Catalyst	1	LS		65,015
Sampling, Analyses & Interpretation	1	LS		37,560
TREATMENT FACILITY (Westside Plant)				
Labor	1	LS		311,200
Power	1	LS		51,000
Natural Gas	1	LS		58,000
Materials	1	LS		53,000
Carbon	1	LS		447,417
Sampling, Analyses & Interpretation	1	LS		35,360
CONVEYANCE & END USE				
Power	500,000	KW/HRS	0.06	30,000
Piping System Maintenance	1	LS		13,015
Pumping System Maintenance	1	LS		11,250
Chlorine System	1	LS		27,000
ANNUAL COST (1st 5 years)				1,208,000
ANNUAL COST (After 5 years)				2,198,000

Note: O&M costs for the first 5 years include wellhead treatment and the Westside treatment plant operation under revised plan.

O&M costs after 5 years include operation of all facilities but wellhead treatment.

All costs are in 1994 dollars.

Table R-23

Alternative 2--O&M Costs Summary

ITEM	QUANTITY	UNIT	$/UNIT	TOTAL ($)
EXTRACTION SYSTEM				
Power	1,999,698	KW/HRS	0.06	119,982
Sampling, Analyses & Interpretation	1	LS		70,828
Wellhead Treatment (1st 5 years)	32	EA	12,000	384,000
Maintance (5% of Construction)	1	LS		343,605
TREATMENT FACILITY (Eastside Plant)				
Labor	1	LS		315,360
Power	1	LS		34,965
Natural Gas	1	LS		47,587
Materials	1	LS		21,170
Carbon	1	LS		206,250
Catalyst	1	LS		65,015
Sampling, Analyses & Interpretation	1	LS		37,560
TREATMENT FACILITY (Westside Plant)				
Labor	1	LS		311,200
Power	1	LS		63,000
Natural Gas	1	LS		74,000
Materials	1	LS		53,000
Carbon	1	LS		688,686
Sampling, Analyses & Interpretation	1	LS		36,360
CONVEYANCE & END USE				
Power	787,000	KW/HRS	0.06	47,220
Piping System Maintenance	1	LS		15,054
Pumping System Maintenance	1	LS		17,700
Chlorine System	1	LS		41,000
ANNUAL COST (1st 5 years)				1,610,000
ANNUAL COST (After 5 years)				2,610,000

Note: O&M costs for the first 5 years include wellhead treatment and the Westside treatment plant operation under revised plan.

O&M costs after 5 years include operation of all facilities but wellhead treatment.

All costs are in 1994 dollars.

Table R-24

Alternative 3--O&M Costs Summary

ITEM	QUANTITY	UNIT	$/UNIT	TOTAL ($)
EXTRACTION SYSTEM				
Power	2,679,334	KW/HRS	0.06	160,760
Sampling, Analyses & Interpretation	1	LS		80,516
Wellhead Treatment (1st 5 years)	65	EA	12,000	780,000
Maintance (5% of Conctruction)	1	LS		499,025
TREATMENT FACILITY (Eastside Plant)				
Labor	1	LS		315,360
Power	1	LS		37,219
Natural Gas	1	LS		47,587
Materials	1	LS		31,400
Carbon	1	LS		45,885
Catalyst	1	LS		65,015
Sampling, Analyses & Interpretation	1	LS		37,560
TREATMENT FACILITY (Westside Plant)				
Labor	1	LS		384,000
Power	1	LS		80,500
Natural Gas	1	LS		91,100
Materials	1	LS		53,000
Carbon	1	LS		911,040
Sampling, Analyses & Interpretation	1	LS		35,360
CONVEYANCE & END USE				
Power	1,067,000	KW/HRS	0.06	64,020
Piping Syste Maintenance	1	LS		22,081
Pumping System Maintenance	1	LS		24,000
Chlorine System	1	LS		63,000
ANNUAL COST (1st 5 years)				2,335,000
ANNUAL COST (After 5 years)				3,048,000

Note: O&M costs for the first 5 years include wellhead treatment and the Westside treatment plant operation under revised plan.

O&M costs after 5 years include operation of all facilities but wellhead treatment.

All costs are in 1994 dollars.

Table R-25

Alternative 4--O&M Costs Summary

ITEM	QUANTITY	UNIT	$/UNIT	TOTAL ($)
EXTRACTION SYSTEM				
Power	1,607,600	KW/HRS	0.06	96,456
Sampling, Analyses & Interpretation	1	LS		62,524
Wellhead Treatment (1st 5 years)	21	EA	12,000	252,000
Maintance (5% of Consruction)	1	LS		273,400
TREATMENT FACILITY (Eastside Plant)				
Labor	1	LS		315,360
Power	1	LS		29,669
Natural Gas	1	LS		9,443
Materials	1	LS		13,770
Carbon	1	LS		281,250
VGAC Rental	1	LS		72,080
Sampling, Analyses & Interpretation	1	LS		37,550
TREATMENT FACILITY (Westside Plant)				
Labor	1	LS		311,200
Power	1	LS		51,000
Natural Gas	1	LS		58,000
Materials	1	LS		53,000
Carbon	1	LS		447,417
Sampling, Analyses & Interpretation	1	LS		35,360
CONVEYANCE & END USE				
Power	500,000	KW/HRS	0.06	30,000
Piping System Maintenance	1	LS		13,015
Pumping System Maintenance	1	LS		11,250
Chlorine System	1	LS		27,000
ANNUAL COST (1st 5 years)				1,208,000
ANNUAL COST (After 5 years)				2,229,000

Note: O&M costs for the first 5 years include wellhead treatment and the Westside treatment plant operation under revised plan.

O&M costs after 5 years include operation of all facilities but wellhead treatment.

All costs are in 1994 dollars.

Table R-26

Alternative 5--O&M Costs Summary

ITEM	QUANTITY	UNIT	$/UNIT	TOTAL ($)
EXTRACTION SYSTEM				
Power	1,607,600	KW/HRS	0.06	96,456
Sampling, Analyses & Interpretation	1	LS		62,524
Wellhead Treatment (1st 5 years)	21	EA	12,000	252,000
Maintance (5% of Construction)	1	LS		273,400
TREATMENT FACILITY (Eastside Plant)				
Labor	1	LS		234,240
Power	1	LS		31,746
Natural Gas	1	LS		47,587
Materials	1	LS		12,360
Catalyst	1	LS		55,015
Sampling, Analyses & Interpretation	1	LS		37,550
TREATMENT FACILITY (Westside Plant)				
Labor	1	LS		311,200
Power	1	LS		51,000
Natural Gas	1	LS		58,000
Materials	1	LS		53,000
Carbon	1	LS		447,417
Sampling, Analyses & Interpretation	1	LS		35,360
CONVEYANCE & END USE				
Power	500,000	KW/HRS	0.06	30,000
Piping System Maintenance	1	LS		18,721
Pump System Maintenance	1	LS		11,250
Reinjection Wells Maintenance	1	LS		12,000
Access Roads (10% of Construction)	1	LS		1,500
Chlorine System	1	LS		27,000
ANNUAL COST (1st 5 years)				1,208,000
ANNUAL COST (After 5 years)				1,907,000

Note: O&M costs for the first 5 years include wellhead treatment and the Westside treatment plant operation under revised plan.

O&M costs after 5 years include operation of all facilities but wellhead treatment.

All costs are in 1994 dollars.

Table R-27
Alternative 6--O&M Costs Summary

ITEM	QUANTITY	UNIT	$/UNIT	TOTAL ($)
EXTRACTION SYSTEM				
Power	1,607,600	KW/HRS	0.06	96,456
Sampling, Analyses & Interpretation	1	LS		62,524
Wellhead Treatment (1st 5 years)	21	EA	12,000	252,000
Maintance (5% of Consruction)	1	LS		273,400
TREATMENT FACILITY (Eastside Plant)				
Labor	1	LS		153,120
Power	1	LS		3,219
Materials	1	LS		9,010
Carbon	1	LS		1,285,487
Sampling, Analyses & Interpretation	1	LS		35,360
TREATMENT FACILITY (Westside Plant)				
Labor	1	LS		311,200
Power	1	LS		51,000
Natural Gas	1	LS		58,000
Materials	1	LS		53,000
Carbon	1	LS		447,417
Sampling, Analyses & Interpretation	1	LS		35,360
CONVEYANCE & END USE				
Power	500,000	KW/HRS	0.06	30,000
Piping System Maintenance	1	LS		13,015
Pumping System Maintenance	1	LS		11,250
Chlorine System	1	LS		27,000
ANNUAL COST (1st 5 years)				1,208,000
ANNUAL COST (After 5 years)				2,956,000

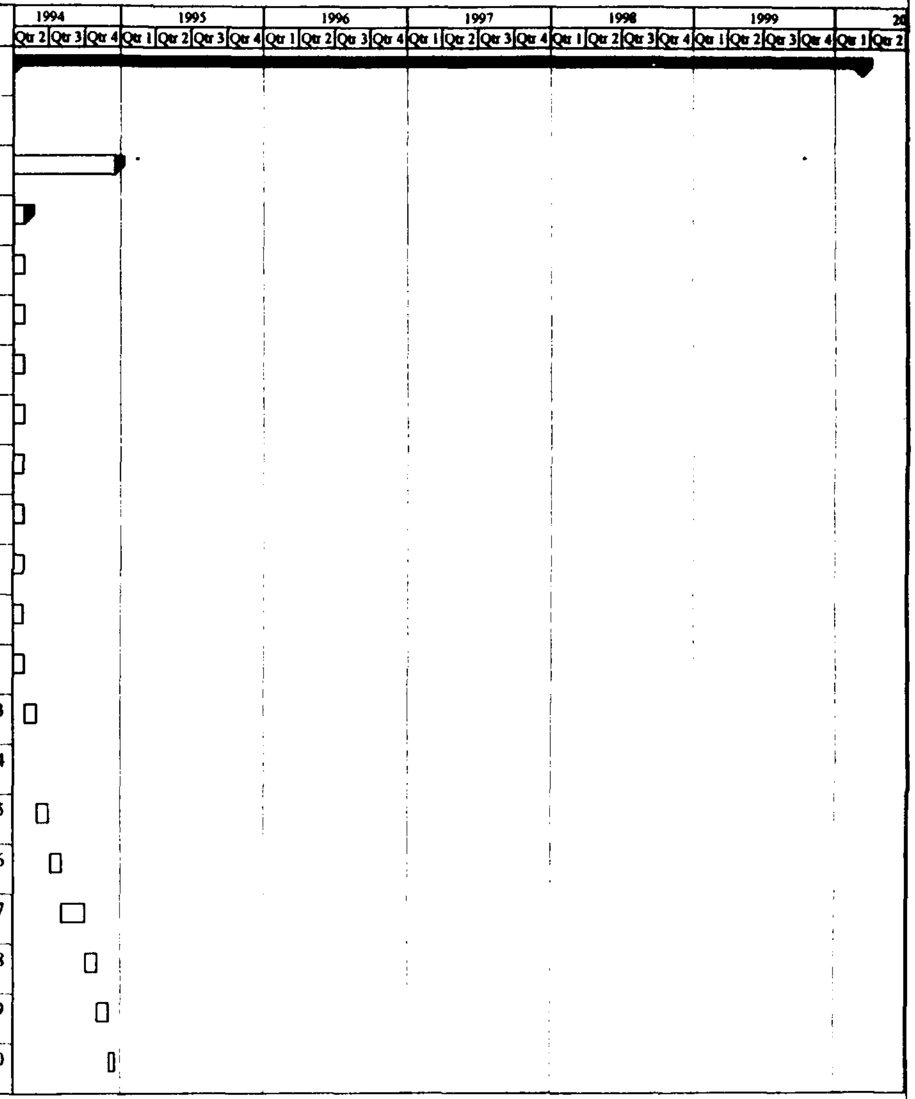
Note: O&M costs for the first 5 years include wellhead treatment and the Westside treatment plant operation under revised plan.

O&M after 5 years include operation of all facilities but wellhead treatment.

All costs are in 1994 dollars.

McClellan AFB GWOU RI/FS Alternative 1

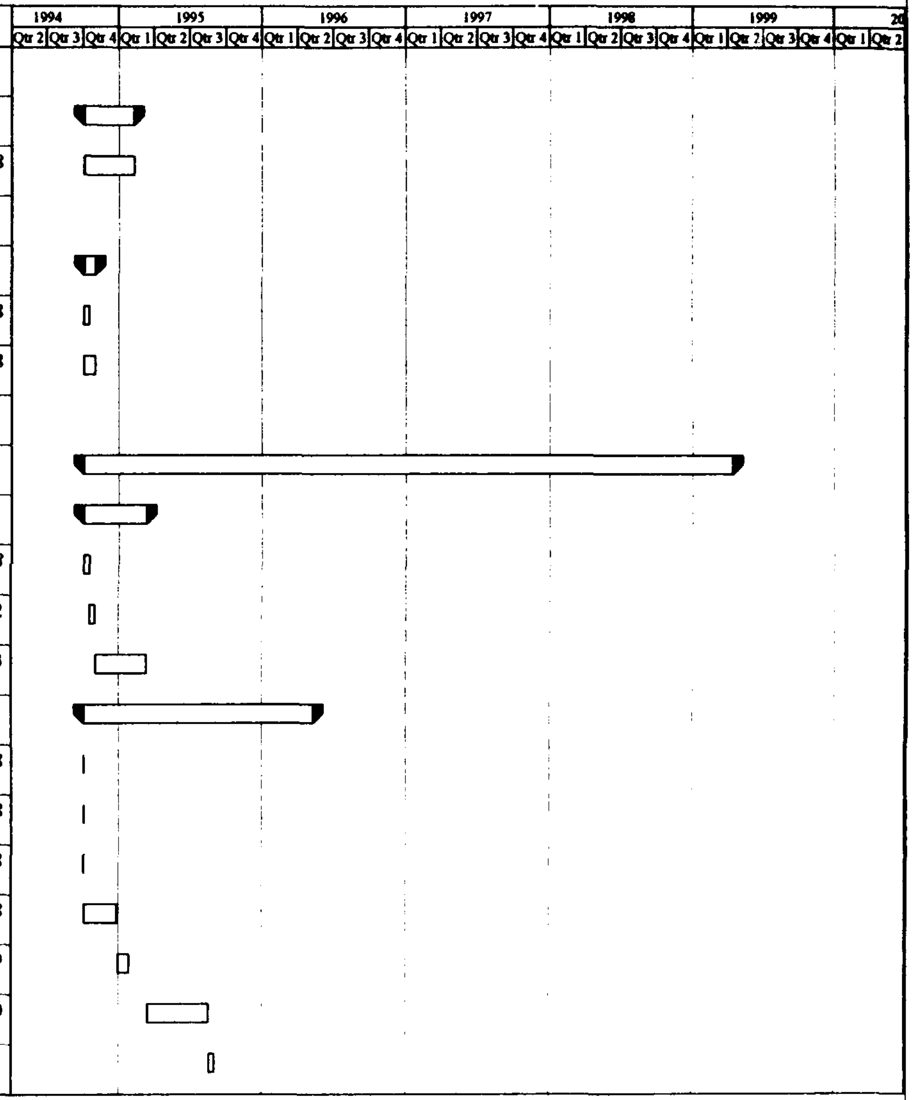
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
1	**Alternative 1 (MCL, AS/CATOX, UTILITIES) Draft final**	**1551d**	**4/1/94**	**3/12/00**	
2					
3	**Master Plan/Work Plan of Remedial Action**	**186d**	**4/1/94**	**12/17/94**	
4	**Develop Remedial Action Master Plan**	**21d**	**4/1/94**	**5/1/94**	
5	Extraction System	30ed	4/1/94	5/1/94	
6	Treatment System	30ed	4/1/94	5/1/94	
7	End Use System	30ed	4/1/94	5/1/94	
8	Collection System	30ed	4/1/94	5/1/94	
9	Prepare DQOs	20d	4/1/94	4/28/94	
10	Prepare rationale	20d	4/1/94	[illegible]8/94	
11	Prepare Health and Safety plan	20d	4/1/94	4/28/94	
12	Prepare QAPP	20d	4/1/94	4/28/94	
13	Prepare SAP	30ed	4/1/94	5/1/94	
14	Develop remedial action work plan	30ed	5/2/94	6/1/94	5,6,7,8,9,10,11,12,13
15	Submit RA Master Plan/Work Plan Working Copy	1d	6/1/94	6/1/94	14
16	McClellan AFB review working copy	30ed	6/2/94	7/2/94	15
17	Prepare draft copy	30ed	7/4/94	8/3/94	16
18	McClellan AFB and agencies review draft document	60ed	8/3/94	10/2/94	17
19	Prepare draft final	30ed	10/3/94	11/2/94	18
20	Agency review draft final	30ed	11/2/94	12/2/94	19
21	Prepare final Remedial Action Master Plan and Work Plan	15ed	12/2/94	12/17/94	20



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 1

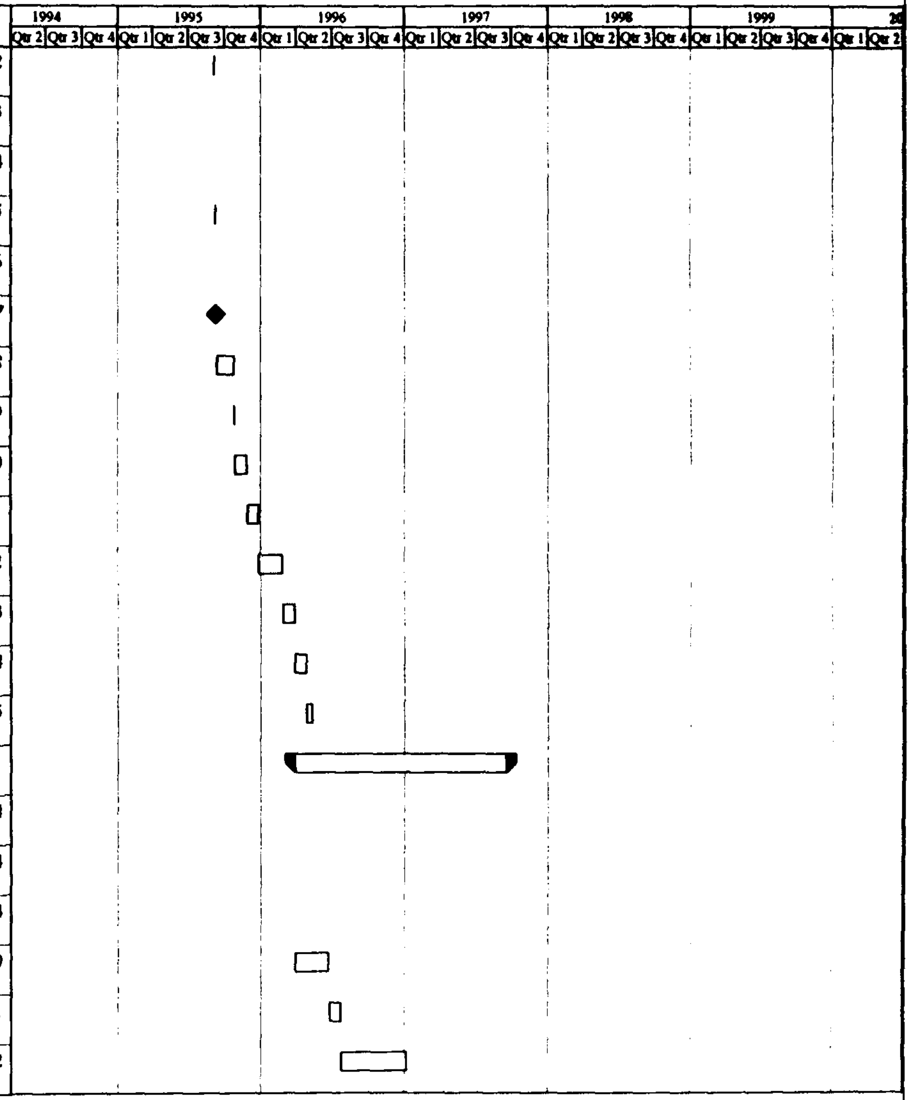
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
22					
23	**Utility Mapping**	**94d**	**10/3/94**	**2/9/95**	
24	Map Utilities (utilmap)	94d	10/3/94	2/9/95	18
25					
26	**On-base/Off-base production wells**	**22d**	**10/3/94**	**11/2/94**	
27	Prepare Base Well 18 abandonment program	15ed	10/3/94	10/18/94	18
28	Prepare production well contingency plans	30ed	10/3/94	11/2/94	18
29					
30	**Extraction System**	**1183d**	**10/3/94**	**4/15/99**	
31	**Subcontractor procurement**	**116d**	**10/3/94**	**3/13/95**	
32	Specify system requirements	15ed	10/3/94	10/18/94	18
33	Identify performance criteria	15ed	10/18/94	11/2/94	32
34	Procure BOAs w/ 3 subs for Basewide EW/MW (wellproc)	94d	11/2/94	3/13/95	33
35	**Phase 1**	**420d**	**10/3/94**	**5/11/96**	
36	Off base monitoring wells(10)	1d	10/3/94	10/3/94	18
37	Off base extraction wells(6) w/ well head treatment units	1d	10/3/94	10/3/94	18
38	Hot Spot extraction wells(15)	1d	10/3/94	10/3/94	18
39	Prepare final layout of wells (wellfides)	62d	10/4/94	12/28/94	36,37,38
40	Prepare for installation (wellprep)	22d	12/29/94	1/27/95	39
41	Install wells/Interpret data (wellins1)	113d	3/14/95	8/17/95	34,40
42	Abandon Base well 18	15ed	8/18/95	9/2/95	27,28,41



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 1

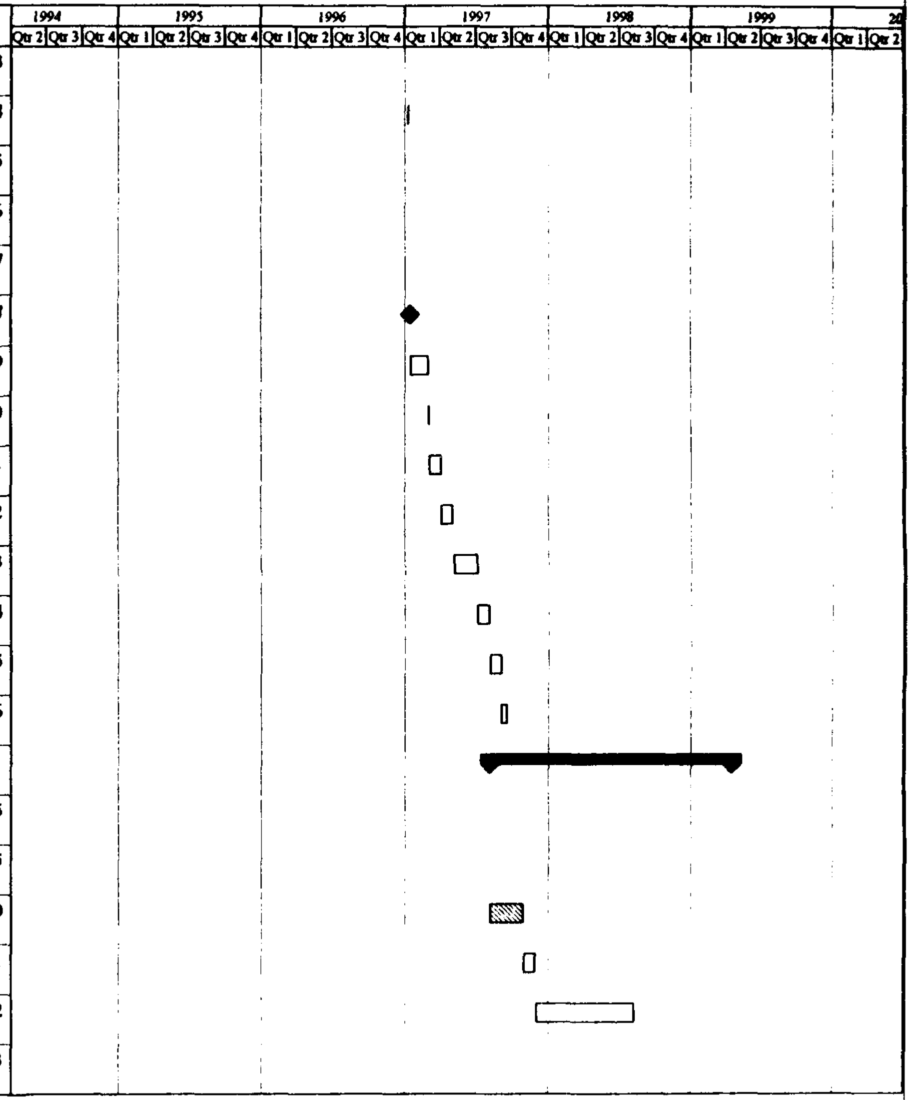
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
43	Reduce uncertainty in extent of contamination off base/hot spots	1d	9/4/95	9/4/95	42
44	Reduce uncertainty in off-base/hot spot flows to	1d	9/5/95	9/5/95	43
45	Reduce uncertainty of location and number of wells off base	1d	9/6/95	9/6/95	44
46	Reduce uncertainty in aquifer response	1d	9/7/95	9/7/95	45
47	Reduce uncertainty concerning potential innovative technologies	1d	9/8/95	9/8/95	46
48	***Implement contingency plan (if necessary)/revise model***	***0d***	***9/8/95***	***9/8/95***	47
49	Prepare Phase 1 Report/Phase 2 Plan	45ed	9/11/95	10/26/95	48
50	Submit Phase 1 Report/Phase 2 Plan Working Copy	1d	10/26/95	10/26/95	49
51	McClellan AFB review working copy	30ed	10/27/95	11/26/95	50
52	Prepare draft copy	30ed	11/27/95	12/27/95	51
53	McClellan AFB and agencies review draft document	60ed	12/27/95	2/25/96	52
54	Prepare draft final	30ed	2/26/96	3/27/96	53
55	Agency review draft final	30ed	3/27/96	4/26/96	54
56	Prepare final Phase 1 Report/Phase 2 Plan	15ed	4/26/96	5/11/96	55
57	**Phase 2**	**386d**	**3/27/96**	**9/18/97**	
58	Off base monitoring wells(5)	1d	3/27/96	3/27/96	54
59	Off base extraction wells(15) w/ well head treatment units	1d	3/27/96	3/27/96	54
60	Hot Spot extraction wells(14)	1d	3/27/96	3/27/96	54
61	Prepare final layout of wells (wellfides)	62d	3/28/96	6/21/96	58,59,60
62	Prepare for installation (wellprep)	22d	6/24/96	7/23/96	61
63	Install wells/Interpret data (wellins2)	120d	7/24/96	1/7/97	62



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 1

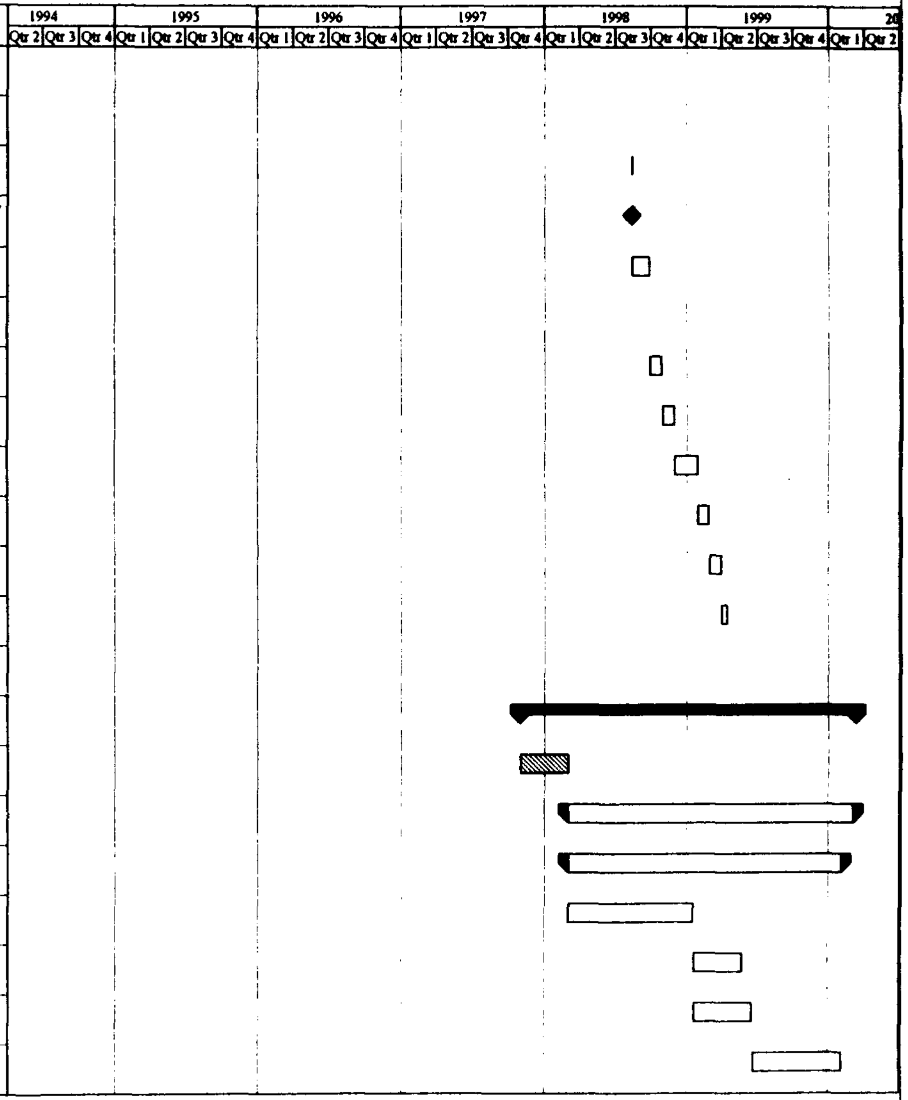
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
64	Resolve uncertainty in extent of contamination off base/hot spots	1d	1/8/97	1/8/97	63
65	Further reduce uncertainty in aquifer response	1d	1/9/97	1/9/97	64
66	Resolve uncertainty in location and number of extraction wells	1d	1/10/97	1/10/97	65
67	Resolve uncertainty in off-base/hot spot flows to	1d	1/13/97	1/13/97	66
68	Resolve uncertainty concerning potential innovative technologies	1d	1/14/97	1/14/97	67
69	***Implement contingency plan (if necessary)/revise model***	***0d***	***1/14/97***	***1/14/97***	***68***
70	Prepare Phase 2 Report/Phase 3 Plan	45ed	1/15/97	3/1/97	69
71	Submit Phase 2 Report/Phase 3 Plan Working Copy	1d	3/3/97	3/3/97	70
72	McClellan AFB review working copy	30ed	3/4/97	4/3/97	71
73	Prepare draft copy	30ed	4/3/97	5/3/97	72
74	McClellan AFB and agencies review draft document	60ed	5/5/97	7/4/97	73
75	Prepare draft final	30ed	7/4/97	8/3/97	74
76	Agency review draft final	30ed	8/4/97	9/3/97	75
77	Prepare final Phase 2 Report/Phase 3 Plan	15ed	9/3/97	9/18/97	76
78	**Phase 3**	**443d**	**8/4/97**	**4/15/99**	
79	On base monitoring wells(61)	1d	8/4/97	8/4/97	75
80	On base extraction wells(73)	1d	8/4/97	8/4/97	75
81	Prepare final layout of wells (wellfides)	62d	8/5/97	10/29/97	79,80
82	Prepare for installation (wellprep)	22d	10/30/97	11/28/97	81
83	Install/Interpret Data (wellins3)	180d	12/1/97	8/7/98	82
84	Resolve uncertainty in extent of contamination off base/hot spots	1d	8/10/98	8/10/98	83



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 1

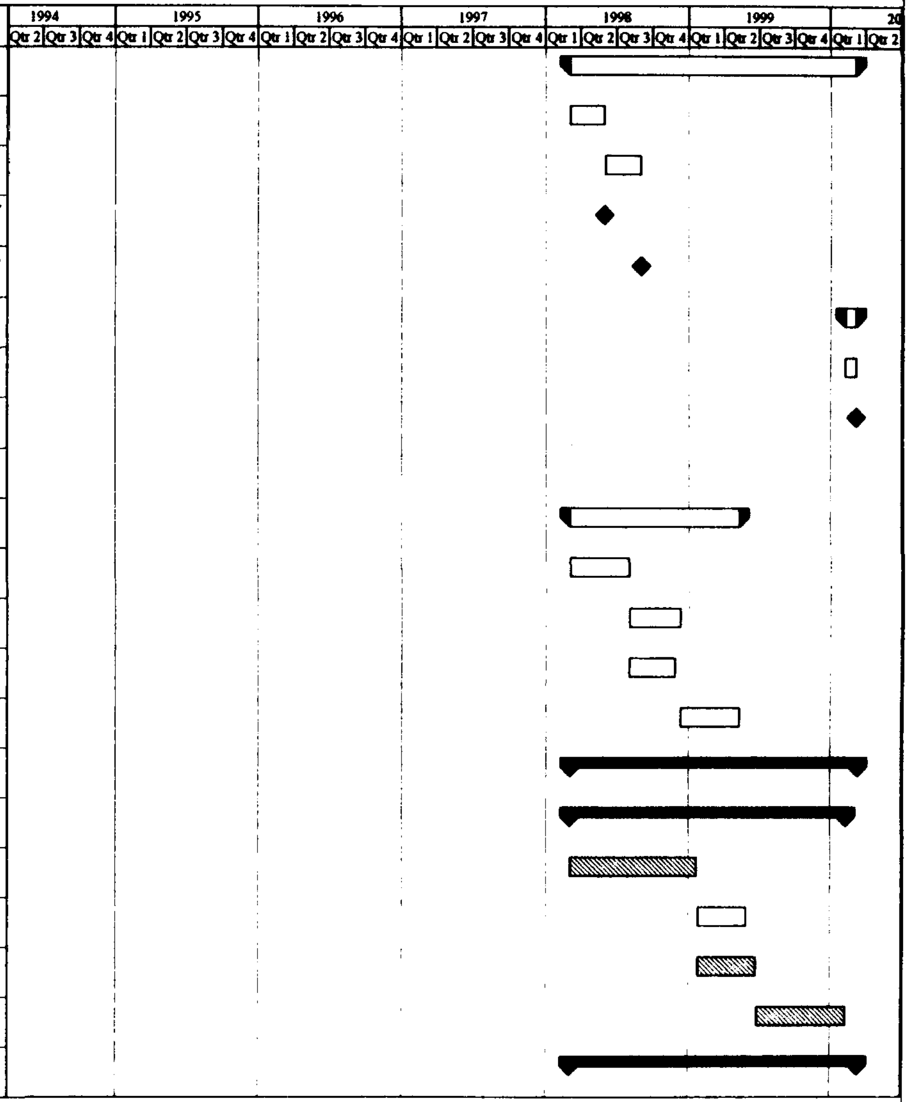
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
85	Resolve uncertainty in aquifer response	1d	8/11/98	8/11/98	84
86	Resolve uncertainty in location and number of extraction wells	1d	8/12/98	8/12/98	85
87	Resolve uncertainty in on base flow to treatment plants	1d	8/13/98	8/13/98	86
88	***Implement contingency plan (if necessary)/revise model***	***0d***	***8/13/98***	***8/13/98***	***87***
89	Prepare Phase 3 Report	45ed	8/14/98	9/28/98	88
90	Submit Phase 3 Report Working Copy	1d	9/28/98	9/28/98	89
91	McClellan AFB review working copy	30ed	9/29/98	10/29/98	90
92	Prepare draft copy	30ed	10/29/98	11/28/98	91
93	McClellan AFB and agencies review draft document	60ed	11/30/98	1/29/99	92
94	Prepare draft final	30ed	1/29/99	2/28/99	93
95	Agency review draft final	30ed	3/1/99	3/31/99	94
96	Prepare final Phase 3 Report	15ed	3/31/99	4/15/99	95
97					
98	**Treatment/End Use/ Collection Systems**	**617d**	**10/30/97**	**3/12/00**	
99	Procure turnkey contractor (contproc)	88d	10/30/97	3/2/98	24,81
100	**Western Area**	**526d**	**3/3/98**	**3/8/00**	
101	**Collection piping**	**504d**	**3/3/98**	**2/4/00**	
102	Prepare preliminary design (wcolde60)	231d	3/3/98	1/19/99	99
103	Prepare final design (wcolde95)	90d	1/20/99	5/25/99	102
104	Prepare for construction (wcolprep)	108d	1/20/99	6/18/99	102
105	Construct piping (wcollcon)	165d	6/21/99	2/4/00	88,103,104



Date: 3/26/94 | **Critical** | **Milestone** | **Summary** | **Noncritical**

McClellan AFB GWOU RI/FS Alternative 1

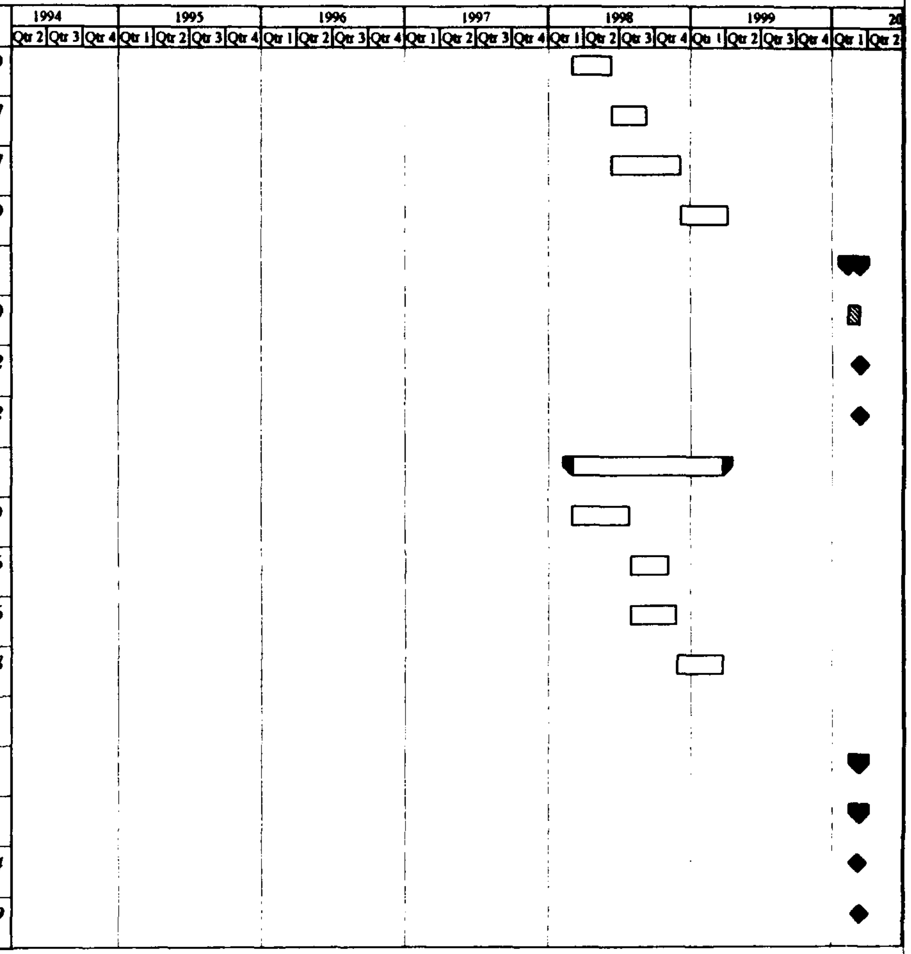
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
106	**Treatment plant**	**526d**	**3/3/98**	**3/8/00**	
107	Prepare preliminary design (wtrea60)	64d	3/3/98	5/29/98	99
108	Prepare final design (wtrea95)	66d	6/1/98	8/31/98	107
109	***Prepare for Construction (wtreapre)***	***0d***	***5/29/98***	***5/29/98***	***107***
110	***Construct treatment plant (wtreacon)***	***0d***	***8/31/98***	***8/31/98***	***108,109***
111	**Start-up/Shakedown**	**22d**	**2/7/00**	**3/8/00**	
112	Conduct Start-up/Shakedown	30ed	2/7/00	3/8/00	105,110
113	***Implement process contingency plan***	***0d***	***3/8/00***	***3/8/00***	***112***
114	Implement capacity contingency plan	0d	3/8/00	3/8/00	112
115	**End Use Piping**	**311d**	**3/3/98**	**5/11/99**	
116	Prepare preliminary design (wendu60)	108d	3/3/98	7/30/98	99
117	Prepare final design (wendu95)	95d	7/31/98	12/10/98	116
118	Prepare for construction (wendupre)	86d	7/31/98	11/27/98	116
119	Construct end use piping (wendcons)	108d	12/11/98	5/11/99	117,118
120	**Eastern Area**	**529d**	**3/3/98**	**3/12/00**	
121	**Collection piping**	**508d**	**3/3/98**	**2/10/00**	
122	Prepare preliminary design (ecolde60)	234d	3/3/98	1/22/99	99
123	Prepare final design (ecolde95)	90d	1/25/99	5/28/99	122
124	Prepare for construction (ecolprep)	108d	1/25/99	6/23/99	122
125	Construct collection piping (ecollcon)	166d	6/24/99	2/10/00	88,123,124
126	**Treatment plant**	**529d**	**3/3/98**	**3/12/00**	



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 1

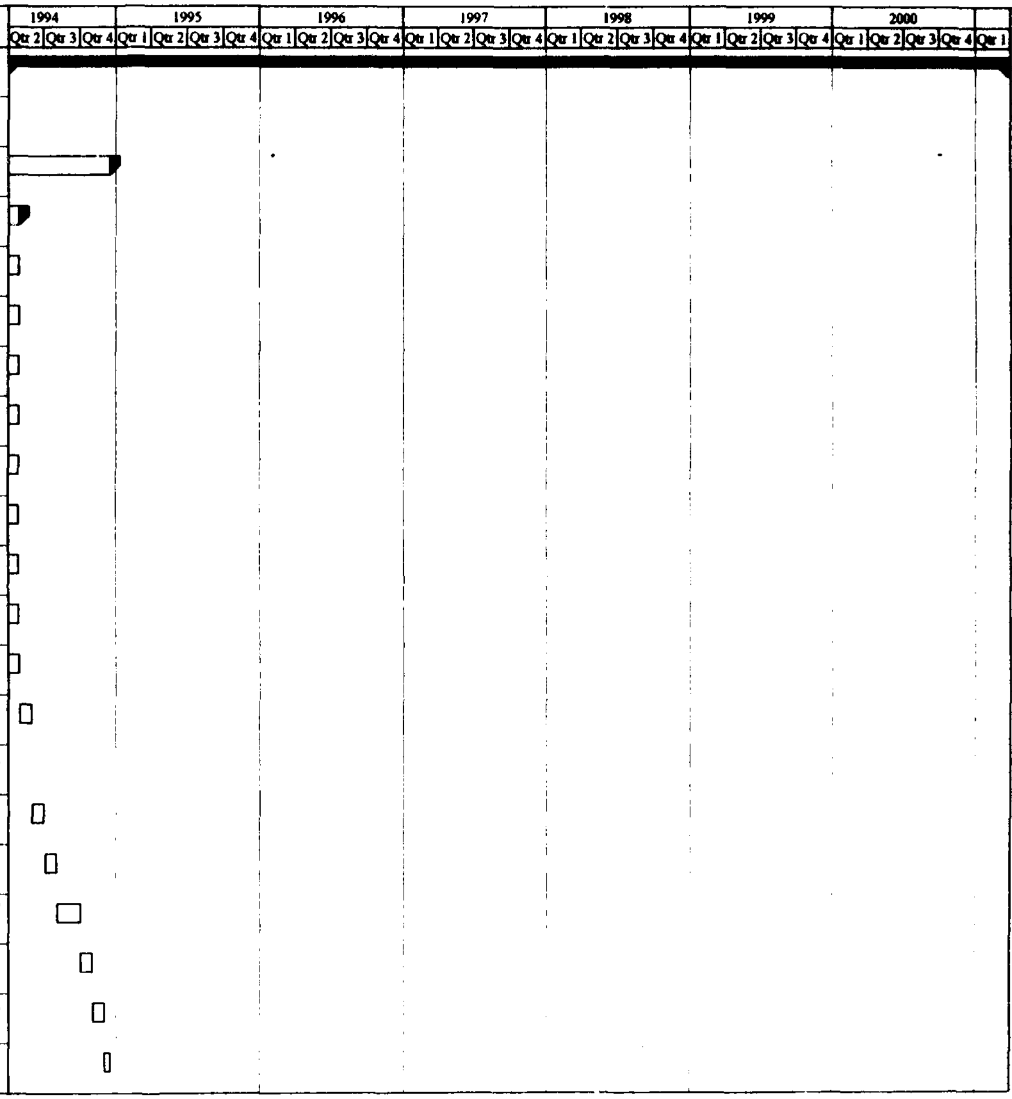
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
127	Prepare preliminary design (etrea60)	72d	3/3/98	6/10/98	99
128	Prepare final design (etrea95)	66d	6/11/98	9/10/98	127
129	Prepare for Construction (etreapre)	128d	6/11/98	12/7/98	127
130	Construct treatment plant (etreacon)	87d	12/8/98	4/7/99	128,129
131	**Start-up/Shakedown**	**21d**	**2/11/00**	**3/12/00**	
132	Conduct Start-up/Shakedown	30ed	2/11/00	3/12/00	125,130
133	***Implement process contingency plan***	***0d***	***3/12/00***	***3/12/00***	***132***
134	***Implement capacity contingency plan***	***0d***	***3/12/00***	***3/12/00***	***132***
135	**End Use Piping**	**278d**	**3/3/98**	**3/25/99**	
136	Prepare preliminary design (eendu60)	106d	3/3/98	7/28/98	99
137	Prepare final design (eendu95)	70d	7/29/98	11/3/98	136
138	Prepare for construction (eendupre)	86d	7/29/98	11/25/98	136
139	Construct end use piping (eendcons)	86d	11/26/98	3/25/99	137,138
140					
141	**Operation of Remedial Action**	**3d**	**3/8/00**	**3/12/00**	
142	**Containment of Contaminated Target Volume**	**3d**	**3/8/00**	**3/12/00**	
143	***West Base***	***0d***	***3/8/00***	***3/8/00***	***105,113,114***
144	***East Base***	***0d***	***3/12/00***	***3/12/00***	***125,133,134,139***



Date: 3/26/94 | **Critical** | **Milestone** ◆ | **Summary** | **Noncritical**

McClellan AFB GWOU RI/FS Alternative 4

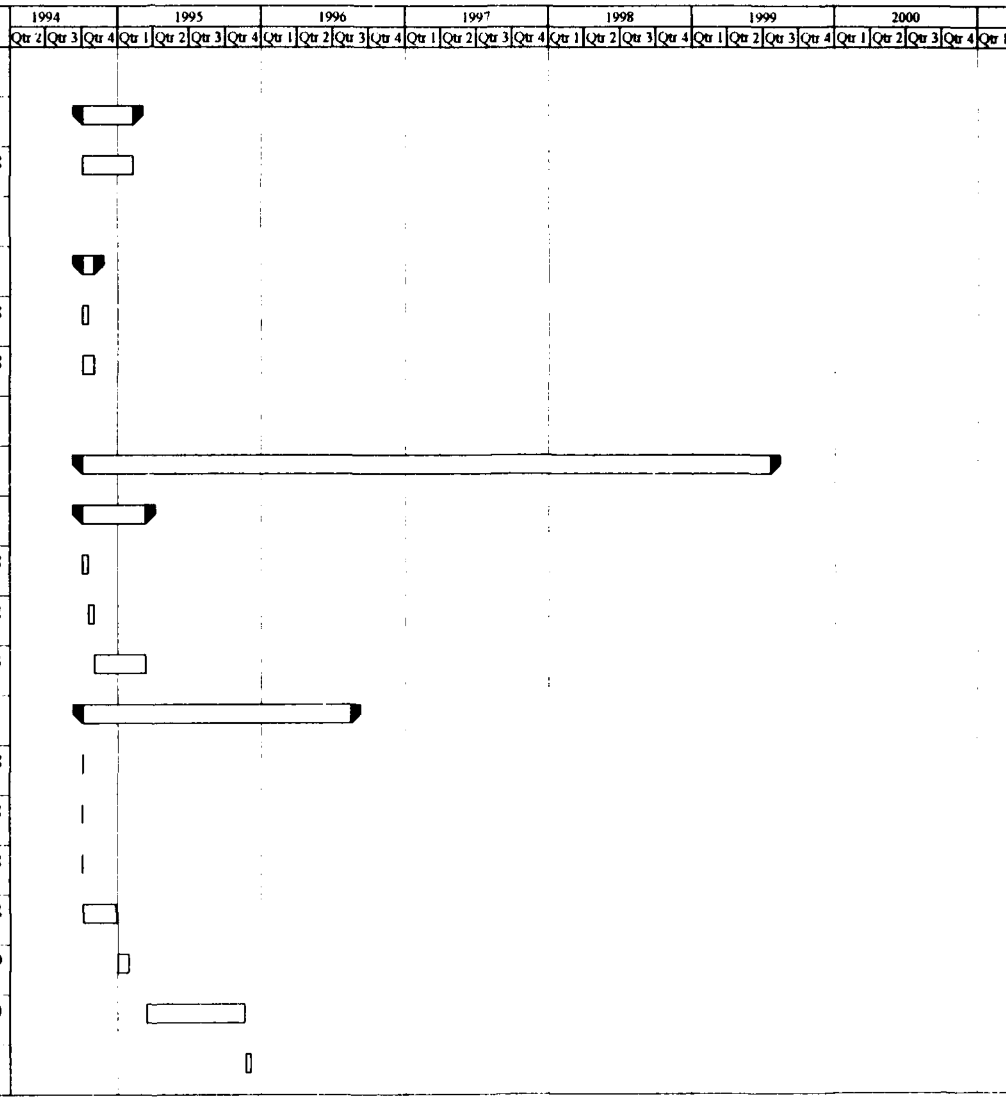
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
1	**Alternative 4 (MCL, AS/VGAC, UTILITIES)**	**1822d**	**4/1/94**	**3/26/01**	
2					
3	**Master Plan/Work Plan of Remedial Action**	**186d**	**4/1/94**	**12/17/94**	
4	**Develop Remedial Action Master**	**21d**	**4/1/94**	**5/1/94**	
5	Extraction System	30ed	4/1/94	5/1/94	
6	Treatment System	30ed	4/1/94	5/1/94	
7	End Use System	30ed	4/1/94	5/1/94	
8	Collection System	30ed	4/1/94	5/1/94	
9	Prepare DQOs	20d	4/1/94	4/28/94	
10	Prepare rationale	20d	4/1/94	4/28/94	
11	Prepare Health and Safety plan	20d	4/1/94	4/28/94	
12	Prepare QAPP	20d	4/1/94	4/28/94	
13	Prepare SAP	30ed	4/1/94	5/1/94	
14	Develop remedial action work plan	30ed	5/2/94	6/1/94	5,6,7,8,9,10,11,12,13
15	Submit RA Master Plan/Work Plan	1d	6/1/94	6/1/94	14
16	McClellan AFB review working	30ed	6/2/94	7/2/94	15
17	Prepare draft copy	30ed	7/4/94	8/3/94	16
18	McClellan AFB and agencies review	60ed	8/3/94	10/2/94	17
19	Prepare draft final	30ed	10/3/94	11/2/94	18
20	Agency review draft final	30ed	11/2/94	12/2/94	19
21	Prepare final Remedial Action	15ed	12/2/94	12/17/94	20



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 4

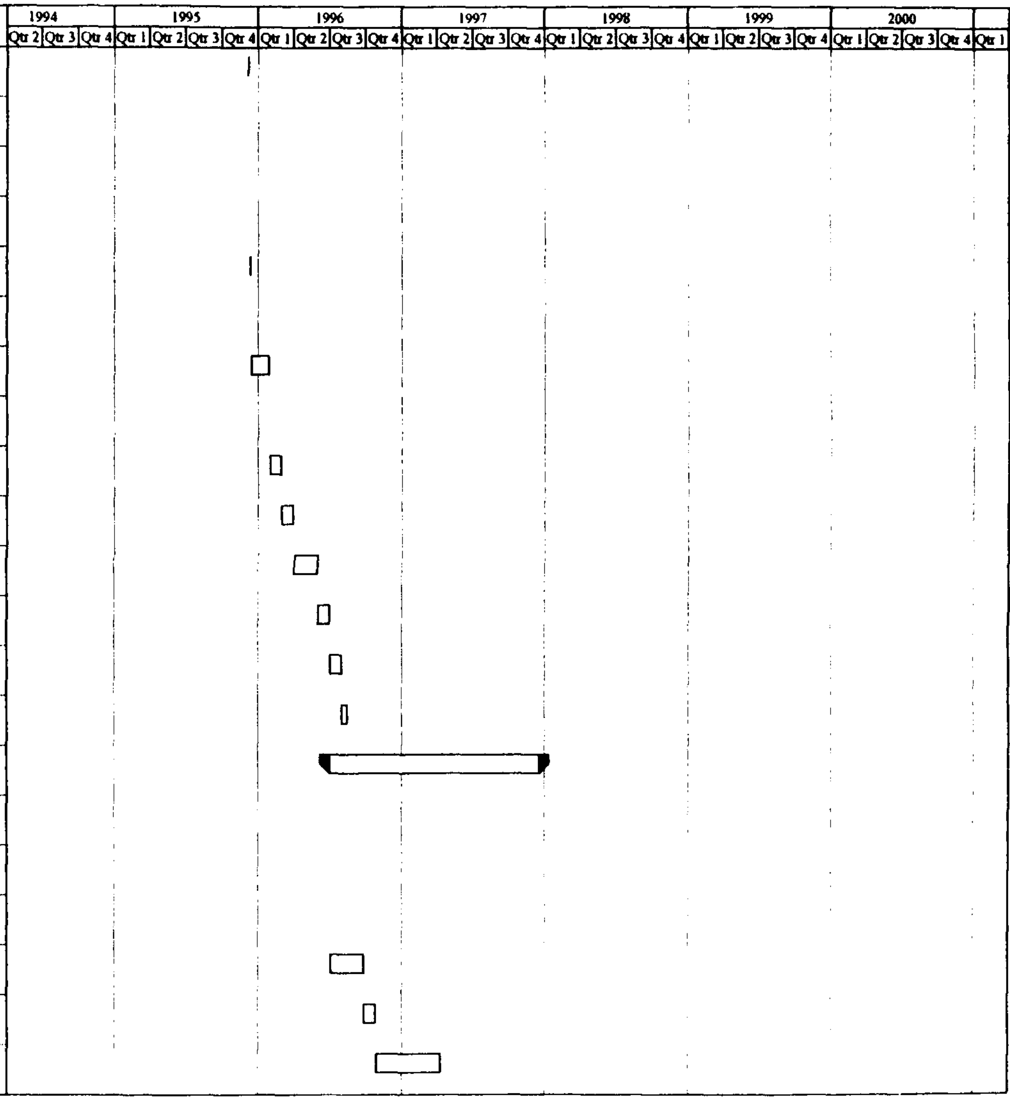
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
22					
23	**Utility Mapping**	**94d**	**10/3/94**	**2/9/95**	
24	Map Utilities (utilmap)	94d	10/3/94	2/9/95	18
25					
26	**On-base/Off-base production wells**	**22d**	**10/3/94**	**11/2/94**	
27	Prepare Base Well 18 abandonment	15ed	10/3/94	10/18/94	18
28	Prepare production well contingency	30ed	10/3/94	11/2/94	18
29					
30	**Extraction System**	**1251d**	**10/3/94**	**7/20/99**	
31	**Subcontractor procurement**	**116d**	**10/3/94**	**3/13/95**	
32	Specify system requirements	15ed	10/3/94	10/18/94	18
33	Identify performance	15ed	10/18/94	11/2/94	32
34	Procure BOAs w/ 3 subs for	94d	[illegible]	3/13/95	33
35	**Phase 1**	**488d**	**10/3/94**	**8/15/96**	
36	Off base monitoring	1d	10/3/94	10/3/94	18
37	Off base extraction	1d	10/3/94	10/3/94	18
38	Hot Spot extraction	1d	10/3/94	10/3/94	18
39	Final layout of wells	62d	10/4/94	12/28/94	36,37,38
40	Prepare for installation	22d	12/29/94	1/27/95	39
41	Installation/Int Data	180d	3/14/95	11/20/95	34,40
42	Abandon Base well 18	15ed	11/21/95	12/6/95	27,28,41



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 4

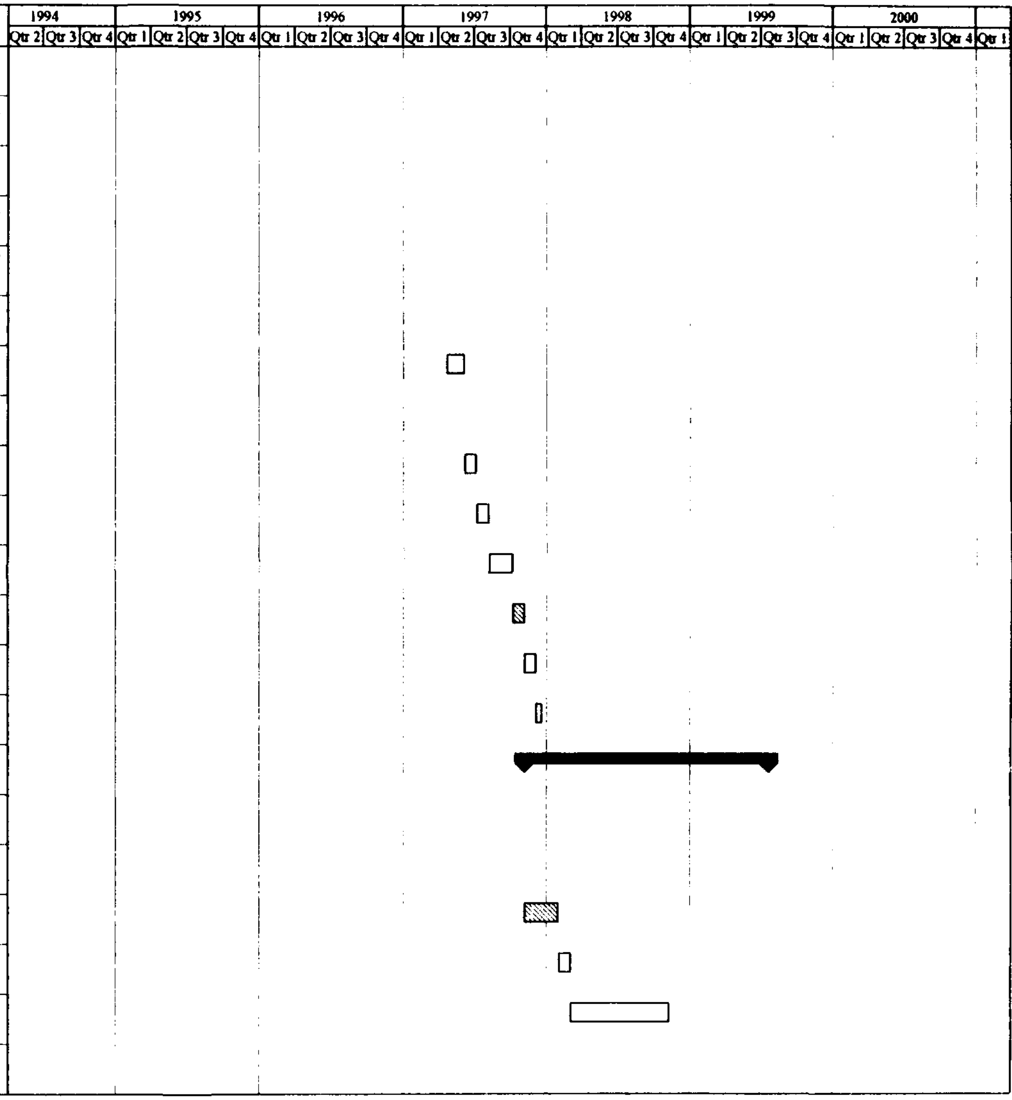
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
43	Reduce uncertainty in	1d	12/6/95	12/6/95	42
44	Reduce uncertainty in	1d	12/7/95	12/7/95	43
45	Reduce uncertainty of	1d	12/8/95	12/8/95	44
46	Reduce uncertainty in	1d	12/11/95	12/11/95	45
47	Reduce uncertainty	1d	12/12/95	12/12/95	46
48	Implement contingency	0d	12/12/95	12/12/95	47
49	Prepare Phase 1	45ed	12/13/95	1/27/96	48
50	Submit Phase 1	1d	1/29/96	1/29/96	49
51	McClellan AFB review	30ed	1/30/96	2/29/96	50
52	Prepare draft copy	30ed	2/29/96	3/30/96	51
53	McClellan AFB and	60ed	4/1/96	5/31/96	52
54	Prepare draft final	30ed	5/31/96	6/30/96	53
55	Agency review draft final	30ed	7/1/96	7/31/96	54
56	Prepare final Phase 1	15ed	7/31/96	8/15/96	55
57	**Phase 2**	**385d**	**7/1/96**	**12/20/97**	
58	Off base monitoring	1d	7/1/96	7/1/96	54
59	Off base extraction	1d	7/1/96	7/1/96	54
60	Hot Spot extraction	1d	7/1/96	7/1/96	54
61	Final layout of wells	62d	7/2/96	9/25/96	58,59,60
62	Prepare for installation	22d	9/26/96	10/25/96	61
63	Installation/Int Data	120d	10/28/96	4/11/97	62



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 4

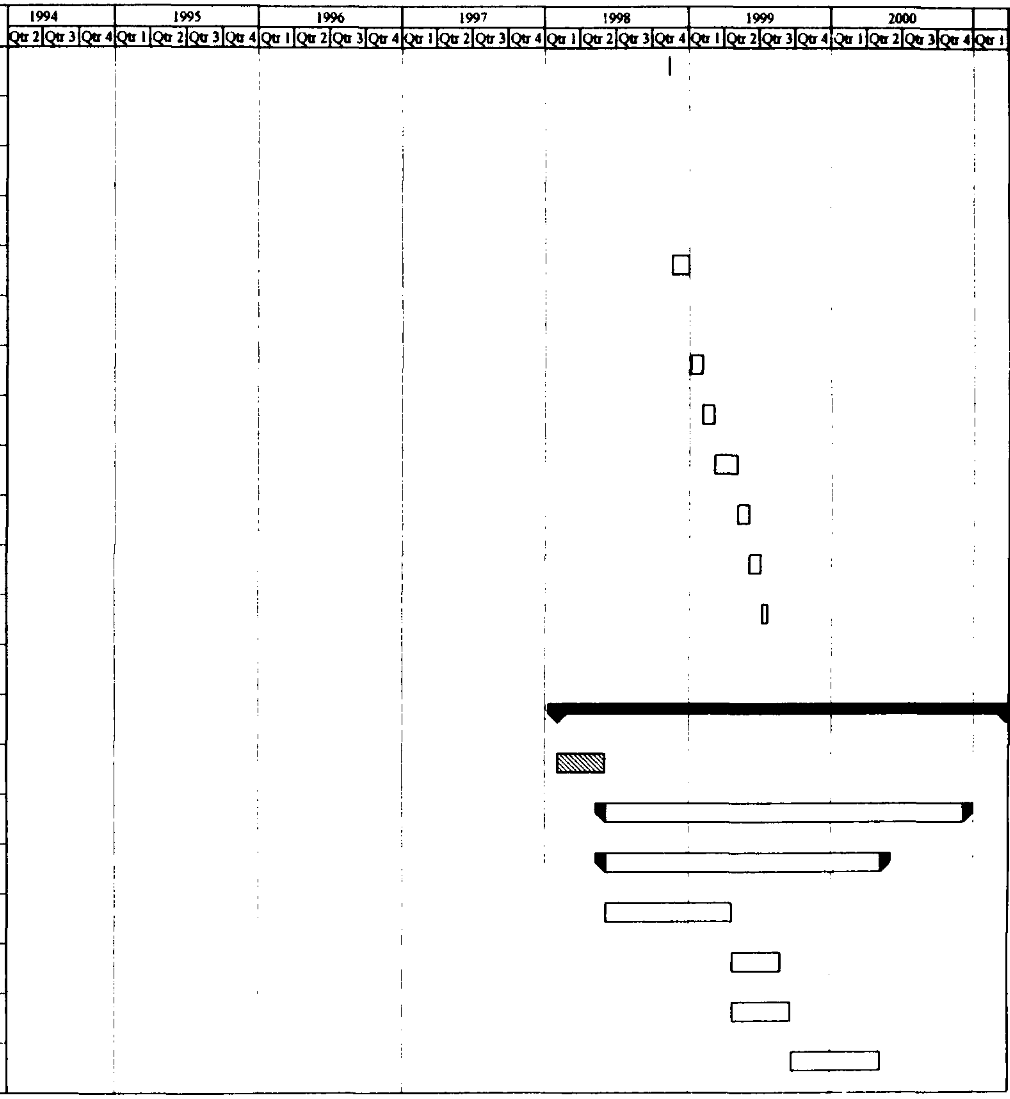
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
64	Resolve uncertainty in	1d	4/14/97	4/14/97	63
65	Further reduce uncertainty in	1d	4/15/97	4/15/97	64
66	Resolve uncertainty in	1d	4/16/97	4/16/97	65
67	Resolve uncertainty in	1d	4/17/97	4/17/97	66
68	Resolve uncertainty	1d	4/18/97	4/18/97	67
69	Implement contingency	0d	4/18/97	4/18/97	68
70	Prepare Phase 2	45ed	4/21/97	6/5/97	69
71	Submit Phase 2	1d	6/5/97	6/5/97	70
72	McClellan AFB review	30ed	6/6/97	7/6/97	71
73	Prepare draft copy	30ed	7/7/97	8/6/97	72
74	McClellan AFB and	60ed	8/6/97	10/5/97	73
75	Prepare draft final	30ed	10/6/97	11/5/97	74
76	Agency review draft final	30ed	11/5/97	12/5/97	75
77	Prepare final Phase 2	15ed	12/5/97	12/20/97	76
78	**Phase 3**	**444d**	**11/5/97**	**7/20/99**	
79	On base monitoring	1d	11/5/97	11/5/97	75
80	On base extraction	1d	11/5/97	11/5/97	75
81	Final layout of wells	62d	11/6/97	1/30/98	79,80
82	Prepare for installation	22d	2/2/98	3/3/98	81
83	Installation/Int Data	180d	3/4/98	11/10/98	82
84	Resolve uncertainty in	1d	11/11/98	11/11/98	83



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 4

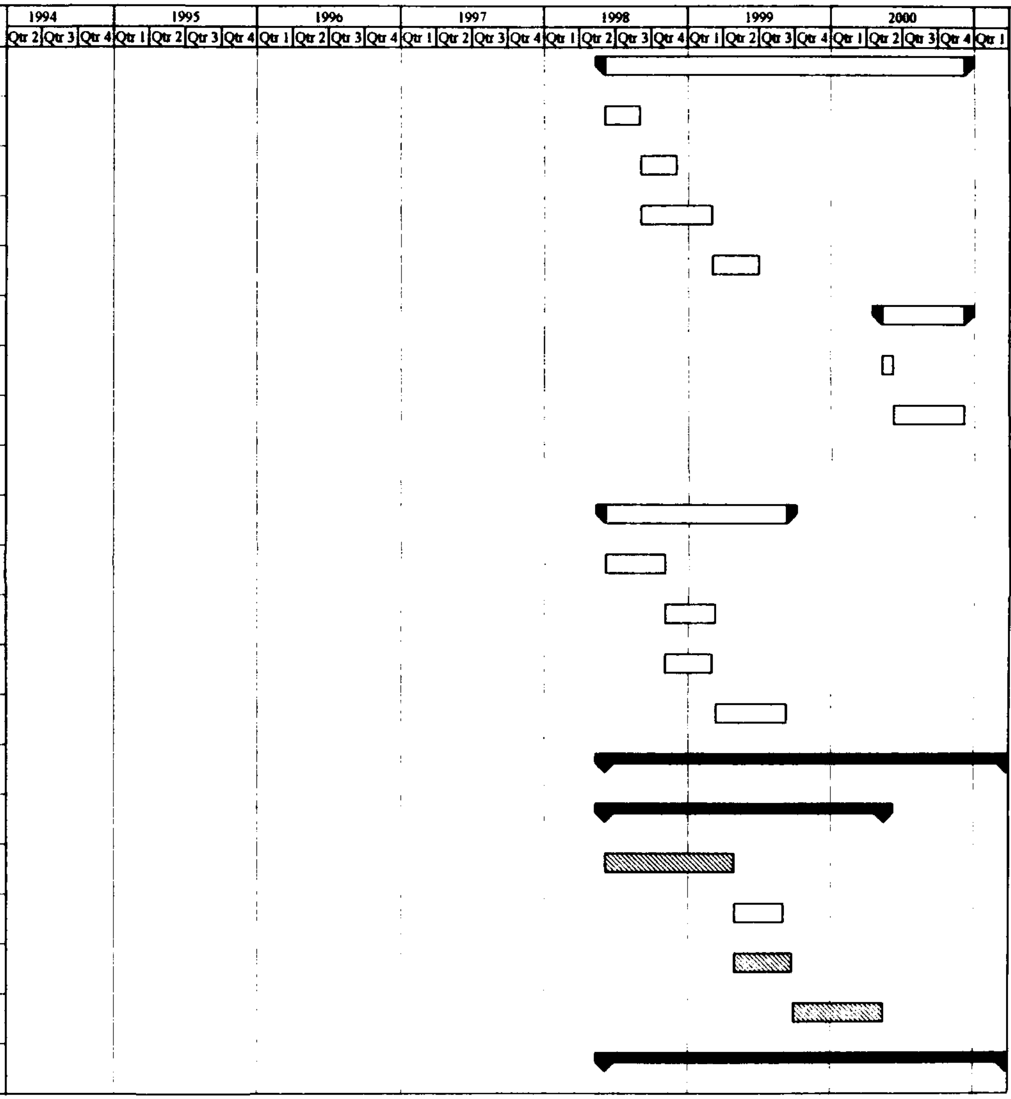
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
85	Resolve uncertainty in	1d	11/12/98	11/12/98	84
86	Resolve uncertainty in	1d	11/13/98	11/13/98	85
87	Resolve uncertainty in	1d	11/16/98	11/16/98	86
88	Implement contingency	0d	11/16/98	11/16/98	87
89	Prepare Phase 3 Report	45ed	11/17/98	1/1/99	88
90	Submit Phase 3 Report	1d	1/1/99	1/1/99	89
91	McClellan AFB review	30ed	1/4/99	2/3/99	90
92	Prepare draft copy	30ed	2/3/99	3/5/99	91
93	McClellan AFB and	60ed	3/5/99	5/4/99	92
94	Prepare draft final	30ed	5/4/99	6/3/99	93
95	Agency review draft final	30ed	6/3/99	7/3/99	94
96	Prepare final Phase 3	15ed	7/5/99	7/20/99	95
97					
98	**Treatment/End Use/ Collection Systems**	**821d**	**2/2/98**	**3/26/01**	
99	Procure turnkey contractor	88d	2/2/98	6/3/98	24,81
100	**Western Area**	**656d**	**6/4/98**	**12/7/00**	
101	**Collection piping**	**504d**	**6/4/98**	**5/9/00**	
102	Prelimin Design	231d	6/4/98	4/22/99	99
103	Final design	90d	4/23/99	8/26/99	102
104	Prepare for	108d	4/23/99	9/21/99	102
105	Construc	165d	9/22/99	5/9/00	88,103,104



Date: 3/26/94 **Critical** **Milestone** ◆ **Summary** **Noncritical**

McClellan AFB GWOU RI/FS Alternative 4

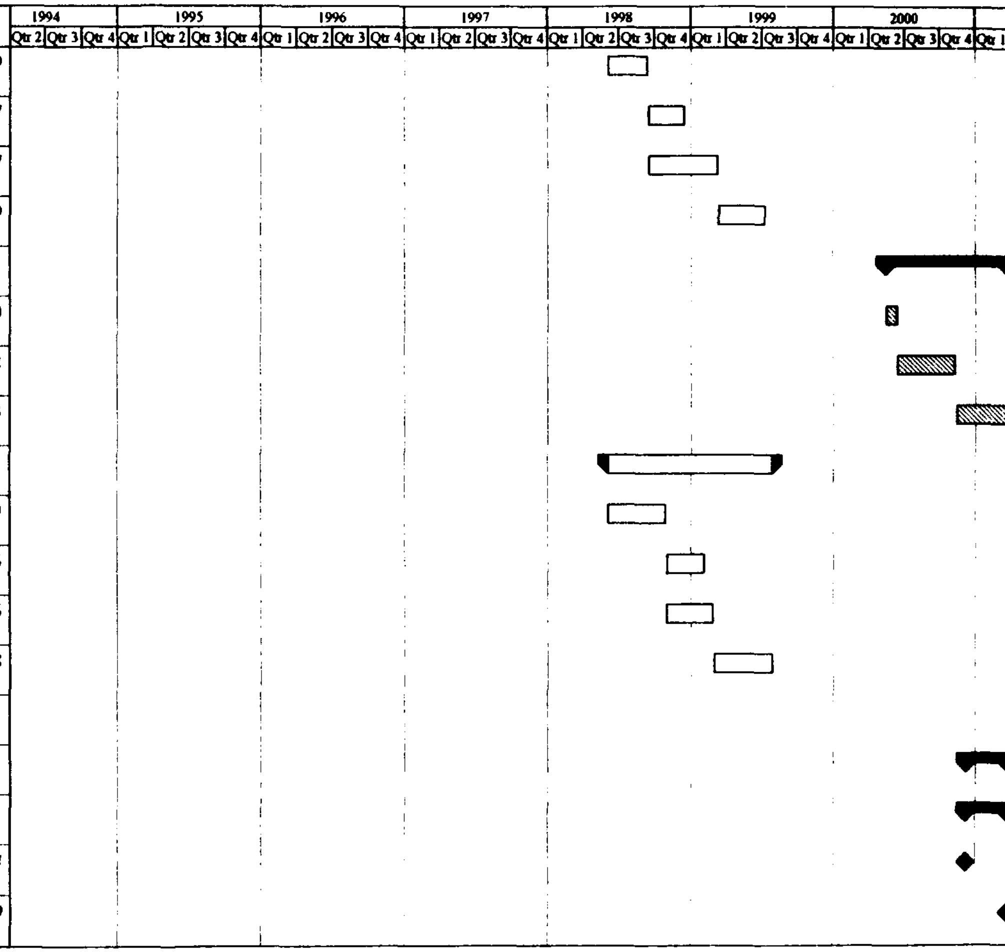
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
106	**Treatment plant**	**656d**	**6/4/98**	**12/7/00**	
107	Prelimin Design	64d	6/4/98	9/1/98	99
108	Final Design	66d	9/2/98	12/2/98	107
109	Prepare for	130d	9/2/98	3/2/99	107
110	Construc	86d	3/3/99	6/30/99	108,109
111	**Start-up**	**152d**	**5/10/00**	**12/7/00**	
112	Star	30ed	5/10/00	6/9/00	105,110
113	Pro con	130d	6/9/00	12/7/00	112
114	Cap con	0d	12/7/00	12/7/00	113
115	**End Use Piping**	**330d**	**6/4/98**	**9/8/99**	
116	Prelimin Design	108d	6/4/98	11/2/98	99
117	Final Design	92d	11/3/98	3/10/99	116
118	Prepare for	86d	11/3/98	3/2/99	116
119	Construc	130d	3/11/99	9/8/99	117,118
120	**Eastern Area**	**733d**	**6/4/98**	**3/26/01**	
121	**Collection piping**	**508d**	**6/4/98**	**5/15/00**	
122	Prelimin Design	234d	6/4/98	4/27/99	99
123	Final design	90d	4/28/99	8/31/99	122
124	Prepare for	108d	4/28/99	9/24/99	122
125	Construc	166d	9/27/99	5/15/00	88,123,124
126	**Treatment plant**	**733d**	**6/4/98**	**3/26/01**	



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 4

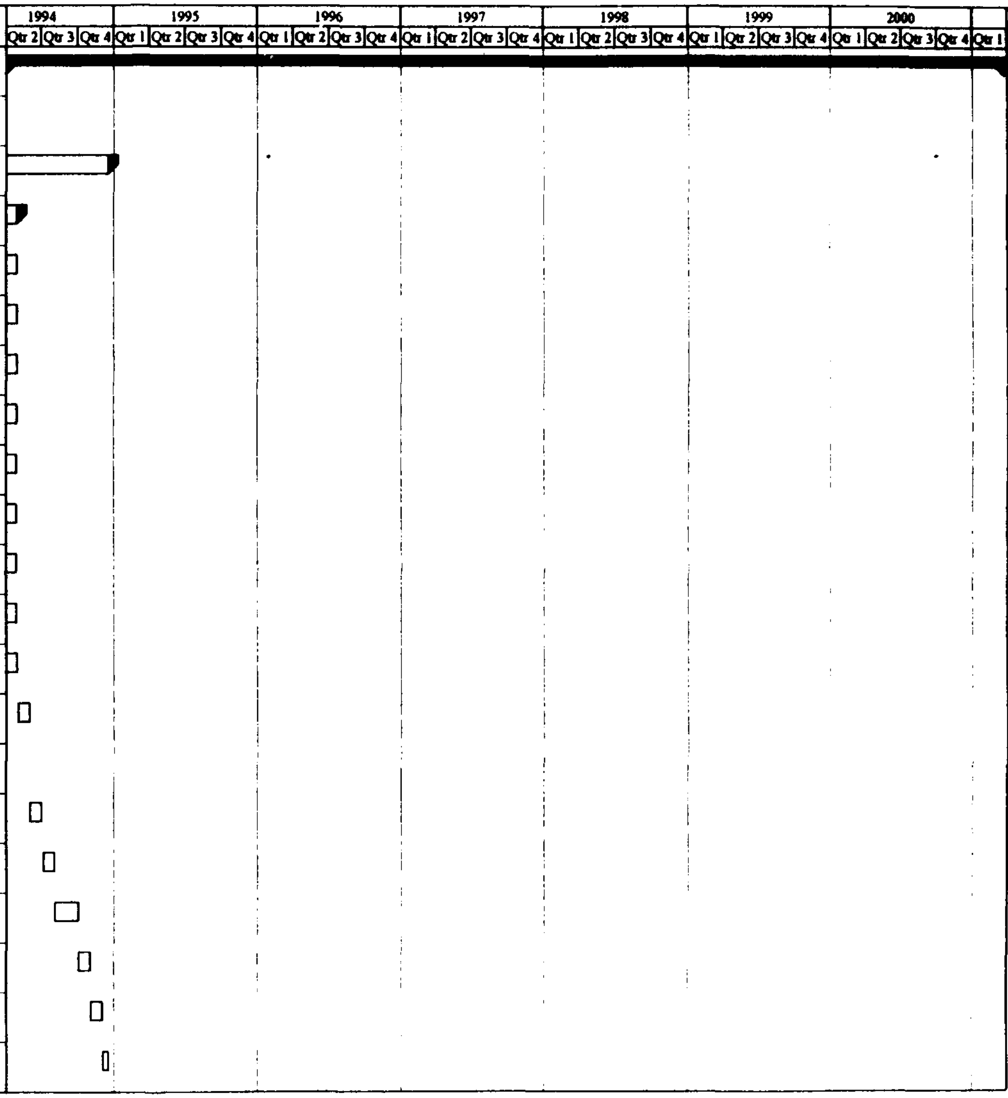
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
127	Prelimin Design	72d	6/4/98	9/11/98	99
128	**Final Design**	66d	9/14/98	12/14/98	127
129	**Prepare for**	128d	9/14/98	3/10/99	127
130	**Construc (etreacon**	87d	3/11/99	7/9/99	128,129
131	**Start-up**	**225d**	**5/16/00**	**3/26/01**	
132	**Star**	30ed	5/16/00	6/15/00	125,130
133	**Pro con**	107d	6/15/00	11/10/00	132
134	**Cap con**	96d	11/13/00	3/26/01	133
135	**End Use Piping**	**300d**	**6/4/98**	**7/28/99**	
136	Prelimin Design	106d	6/4/98	10/29/98	99
137	Final Design	69d	10/30/98	2/3/99	136
138	Prepare for	86d	10/30/98	2/26/99	136
139	Construc	108d	3/1/99	7/28/99	137,138
140					
141	**Operation of Remedial Action**	**77d**	**12/7/00**	**3/26/01**	
142	**Containment of Contaminated**	**77d**	**12/7/00**	**3/26/01**	
143	***West Base***	***0d***	***12/7/00***	***12/7/00***	***105,114***
144	***East Base***	***0d***	***3/26/01***	***3/26/01***	***125,134,139***



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 5

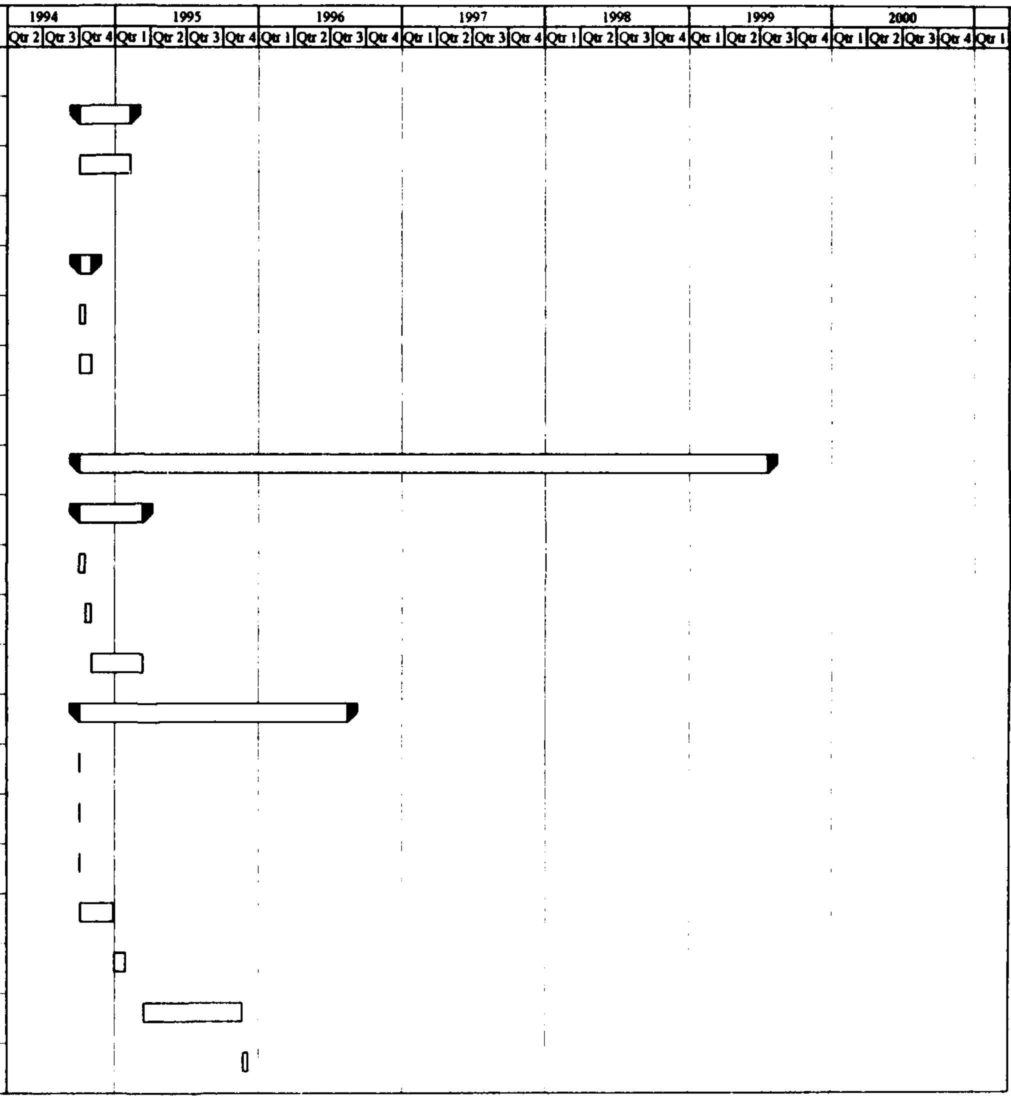
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
1	**Alternative 5 (MCL, AS/CATOX,**	**1822d**	**4/1/94**	**3/26/01**	
2					
3	**Master Plan/Work Plan of Remedial Action**	**186d**	**4/1/94**	**12/17/94**	
4	**Develop Remedial Action Master**	**21d**	**4/1/94**	**5/1/94**	
5	Extraction System	30ed	4/1/94	5/1/94	
6	Treatment System	30ed	4/1/94	5/1/94	
7	End Use System	30ed	4/1/94	5/1/94	
8	Collection System	30ed	4/1/94	5/1/94	
9	Prepare DQOs	20d	4/1/94	4/28/94	
10	Prepare rationale	20d	4/1/94	4/28/94	
11	Prepare Health and Safety plan	20d	4/1/94	4/28/94	
12	Prepare QAPP	20d	4/1/94	4/28/94	
13	Prepare SAP	30ed	4/1/94	5/1/94	
14	Develop remedial action work plan	30ed	5/2/94	6/1/94	5,6,7,8,9,10,11,12,13
15	Submit RA Master Plan/Work Plan	1d	6/1/94	6/1/94	14
16	McClellan AFB review working	30ed	6/2/94	7/2/94	15
17	Prepare draft copy	30ed	7/4/94	8/3/94	16
18	McClellan AFB and agencies review	60ed	8/3/94	10/2/94	17
19	Prepare draft final	30ed	10/3/94	11/2/94	18
20	Agency review draft final	30ed	11/2/94	12/2/94	19
21	Prepare final Remedial Action	15ed	12/2/94	12/17/94	20



Date: 3/26/94 | **Critical** | **Milestone** ◆ | **Summary** | **Noncritical**

McClellan AFB GWOU RI/FS Alternative 5

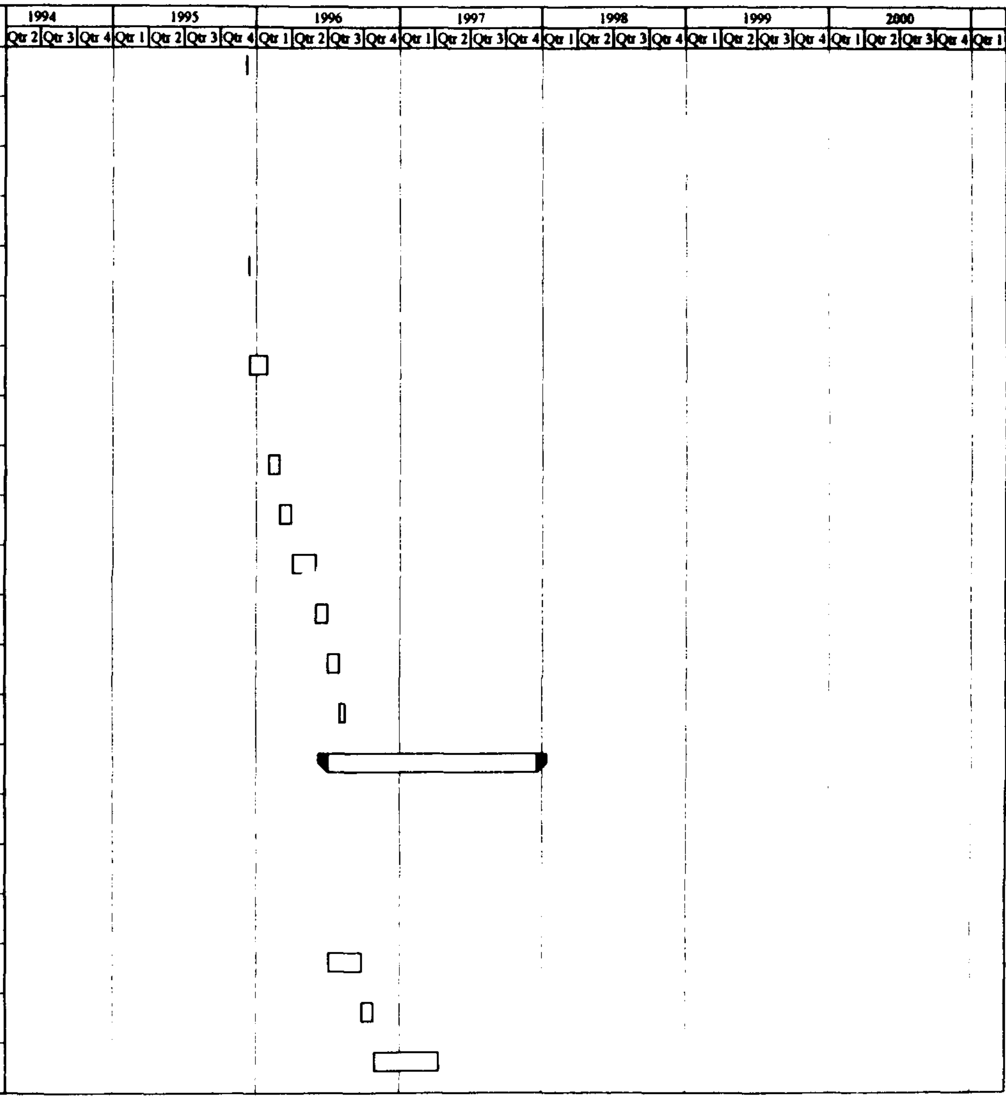
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
22					
23	**Utility Mapping**	**94d**	**10/3/94**	**2/9/95**	
24	Map Utilities (utilmap)	94d	10/3/94	2/9/95	18
25					
26	**On-base/Off-base production wells**	**22d**	**10/3/94**	**11/2/94**	
27	Prepare Base Well 18 abandonment	15ed	10/3/94	10/18/94	18
28	Prepare production well contingency	30ed	10/3/94	11/2/94	18
29					
30	**Extraction System**	**1251d**	**10/3/94**	**7/20/99**	
31	**Subcontractor procurement**	**116d**	**10/3/94**	**3/13/95**	
32	Specify system requirements	15ed	10/3/94	10/18/94	18
33	Identify performance	15ed	10/18/94	11/2/94	32
34	Procure BOAs w/ 3 subs for	94d	11/2/94	3/13/95	33
35	**Phase 1**	**488d**	**10/3/94**	**8/15/96**	
36	Off base monitoring	1d	10/3/94	10/3/94	18
37	Off base extraction	1d	10/3/94	10/3/94	18
38	Hot Spot extraction	1d	10/3/94	10/3/94	18
39	Final layout of wells	62d	10/4/94	12/28/94	36,37,38
40	Prepare for installation	22d	12/29/94	1/27/95	39
41	Installation/Int Data	180d	3/14/95	11/20/95	34,40
42	Abandon Base well 18	15ed	11/21/95	12/6/95	27,28,41



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 5

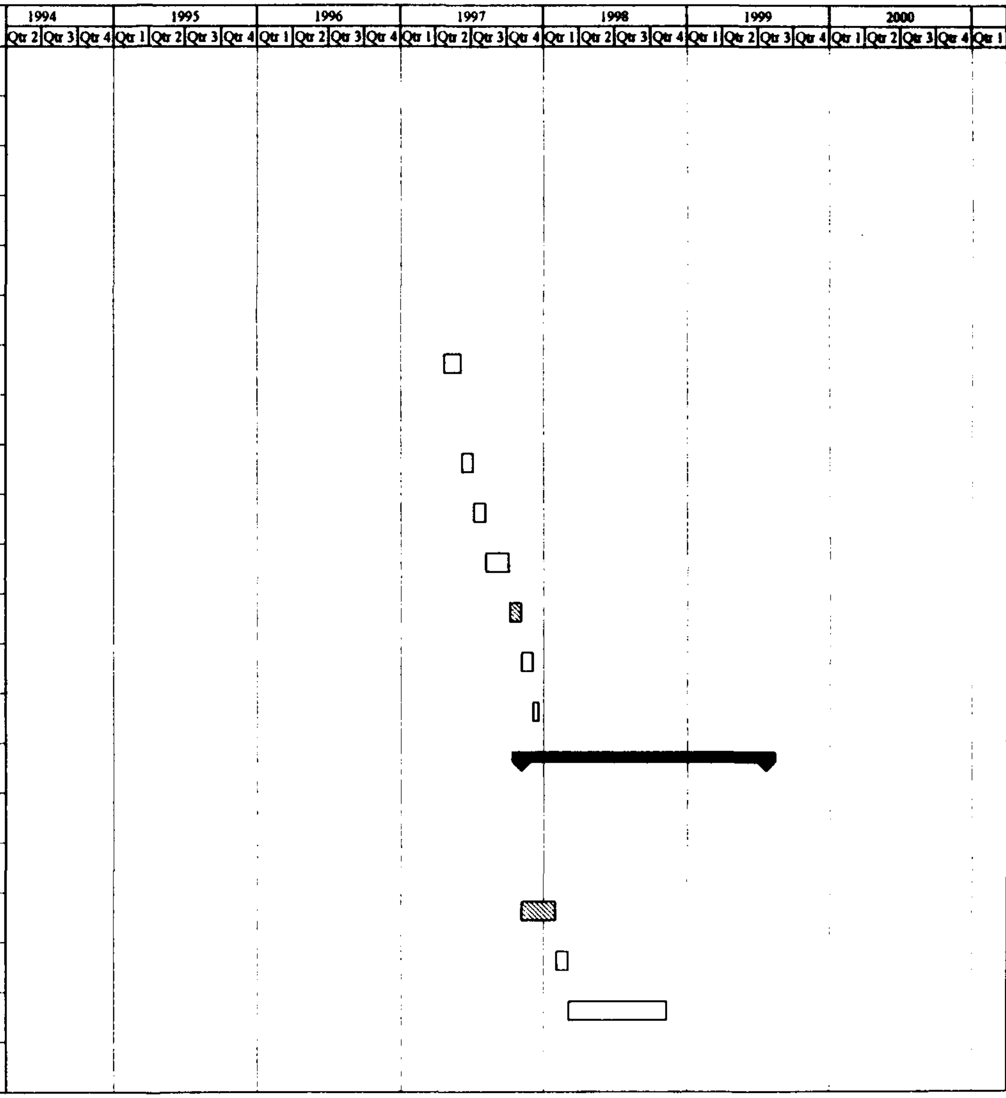
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
43	Reduce uncertainty in	1d	12/6/95	12/6/95	42
44	Reduce uncertainty in	1d	12/7/95	12/7/95	43
45	Reduce uncertainty of	1d	12/8/95	12/8/95	44
46	Reduce uncertainty in	1d	12/11/95	12/11/95	45
47	Reduce uncertainty	1d	12/12/95	12/12/95	46
48	Implement contingency	0d	12/12/95	12/12/95	47
49	Prepare Phase 1	45ed	12/13/95	1/27/96	48
50	Submit Phase 1	1d	1/29/96	1/29/96	49
51	McClellan AFB review	30ed	1/30/96	2/29/96	50
52	Prepare draft copy	30ed	2/29/96	3/30/96	51
53	McClellan AFB and	60ed	4/1/96	5/31/96	52
54	Prepare draft final	30ed	5/31/96	6/30/96	53
55	Agency review draft final	30ed	7/1/96	7/31/96	54
56	Prepare final Phase 1	15ed	7/31/96	8/15/96	55
57	**Phase 2**	**385d**	**7/1/96**	**12/20/97**	
58	Off base monitoring	1d	7/1/96	7/1/96	54
59	Off base extraction	1d	7/1/96	7/1/96	54
60	Hot Spot extraction	1d	7/1/96	7/1/96	54
61	Final layout of wells	62d	7/2/96	9/25/96	58,59,60
62	Prepare for installation	22d	9/26/96	10/25/96	61
63	Installation/Int Data	120d	10/28/96	4/11/97	62



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 5

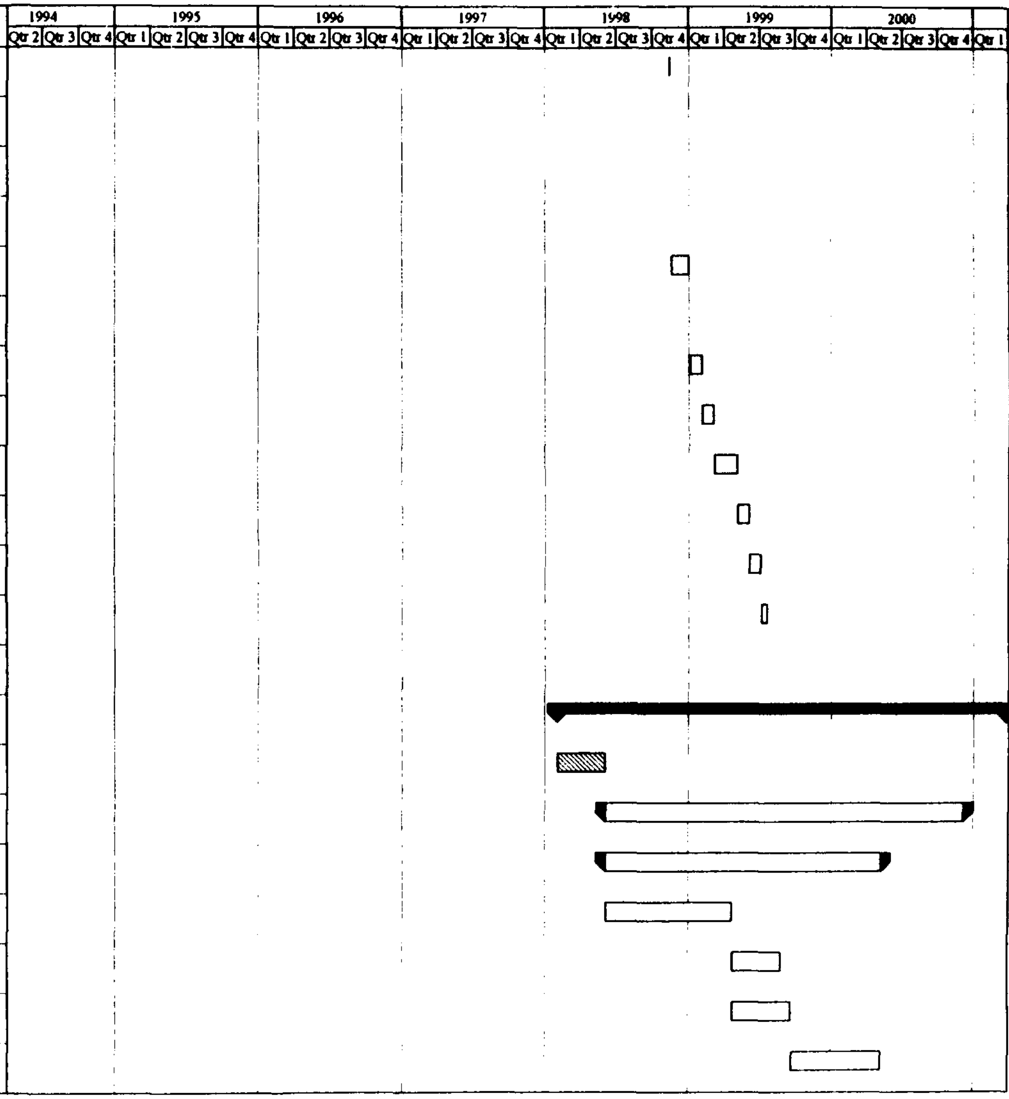
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
64	Resolve uncertainty in	1d	4/14/97	4/14/97	63
65	Further reduce uncertainty in	1d	4/15/97	4/15/97	64
66	Resolve uncertainty in	1d	4/16/97	4/16/97	65
67	Resolve uncertainty in	1d	4/17/97	4/17/97	66
68	Resolve uncertainty	1d	4/18/97	4/18/97	67
69	Implement contingency	0d	4/18/97	4/18/97	68
70	Prepare Phase 2	45ed	4/21/97	6/5/97	69
71	Submit Phase 2	1d	6/5/97	6/5/97	70
72	McClellan AFB review	30ed	6/6/97	7/6/97	71
73	Prepare draft copy	30ed	7/7/97	8/6/97	72
74	McClellan AFB and	60ed	8/6/97	10/5/97	73
75	Prepare draft final	30ed	10/6/97	11/5/97	74
76	Agency review draft final	30ed	11/5/97	12/5/97	75
77	Prepare final Phase 2	15ed	12/5/97	12/20/97	76
78	**Phase 3**	**444d**	**11/5/97**	**7/20/99**	
79	On base monitoring	1d	11/5/97	11/5/97	75
80	On base extraction	1d	11/5/97	11/5/97	75
81	Final layout of wells	62d	11/6/97	1/30/98	79,80
82	Prepare for installation	22d	2/2/98	3/3/98	81
83	Installation/Int Data	180d	3/4/98	11/10/98	82
84	Resolve uncertainty in	1d	11/11/98	11/11/98	83



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 5

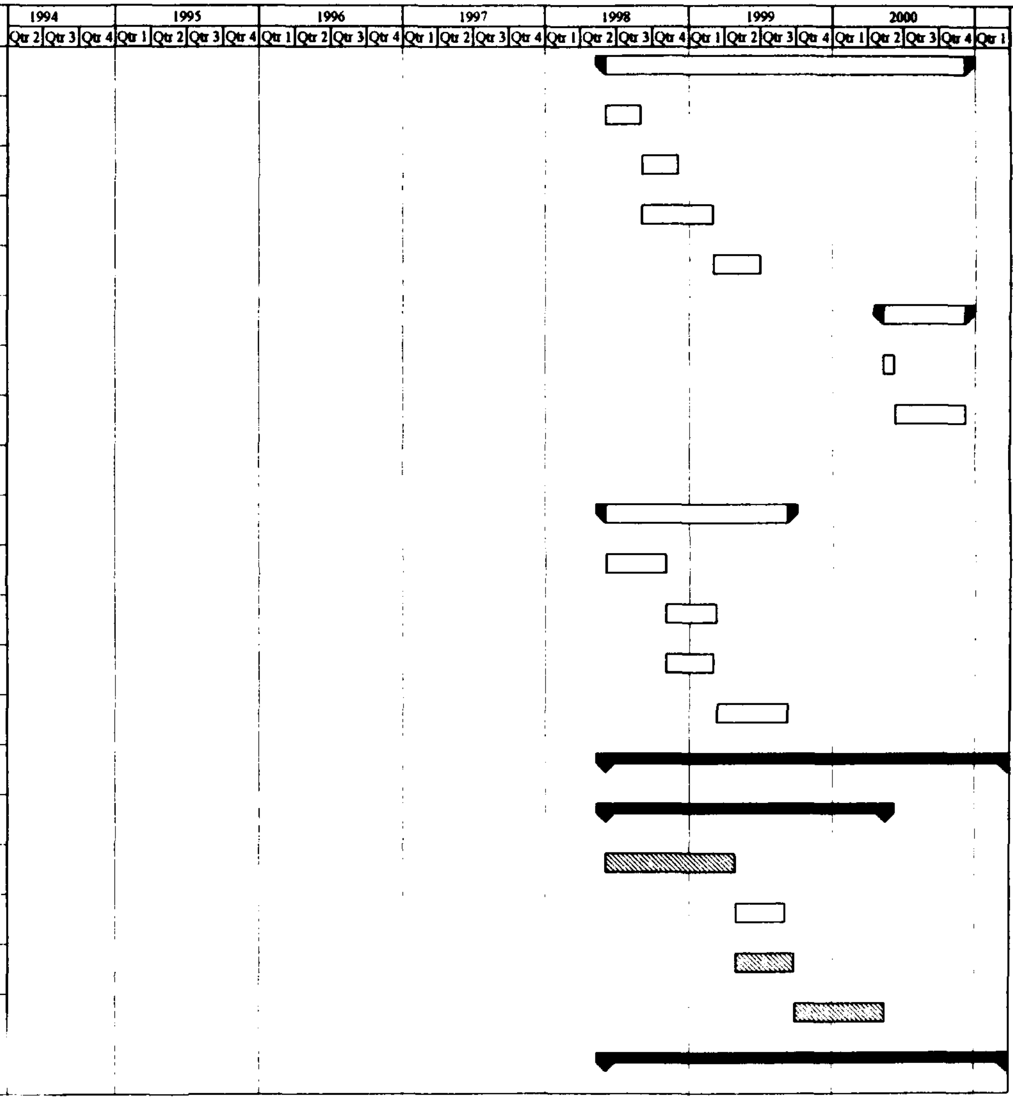
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
85	Resolve uncertainty in	1d	11/12/98	11/12/98	84
86	Resolve uncertainty in	1d	11/13/98	11/13/98	85
87	Resolve uncertainty in	1d	11/16/98	11/16/98	86
88	Implement contingency	0d	11/16/98	11/16/98	87
89	Prepare Phase 3 Report	45ed	11/17/98	1/1/99	88
90	Submit Phase 3 Report	1d	1/1/99	1/1/99	89
91	McClellan AFB review	30ed	1/4/99	2/3/99	90
92	Prepare draft copy	30ed	2/3/99	3/5/99	91
93	McClellan AFB and	60ed	3/5/99	5/4/99	92
94	Prepare draft final	30ed	5/4/99	6/3/99	93
95	Agency review draft final	30ed	6/3/99	7/3/99	94
96	Prepare final Phase 3	15ed	7/5/99	7/20/99	95
97					
98	**Treatment/End Use/ Collection Systems**	**821d**	**2/2/98**	**3/26/01**	
99	Procure turnkey contractor	88d	2/2/98	6/3/98	24,81
100	**Western Area**	**656d**	**6/4/98**	**12/7/00**	
101	**Collection piping**	**504d**	**6/4/98**	**5/9/00**	
102	Prelimin Design	231d	6/4/98	4/22/99	99
103	Final design	90d	4/23/99	8/26/99	102
104	Prepare for	108d	4/23/99	9/21/99	102
105	Construc	165d	9/22/99	5/9/00	88,103,104



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 5

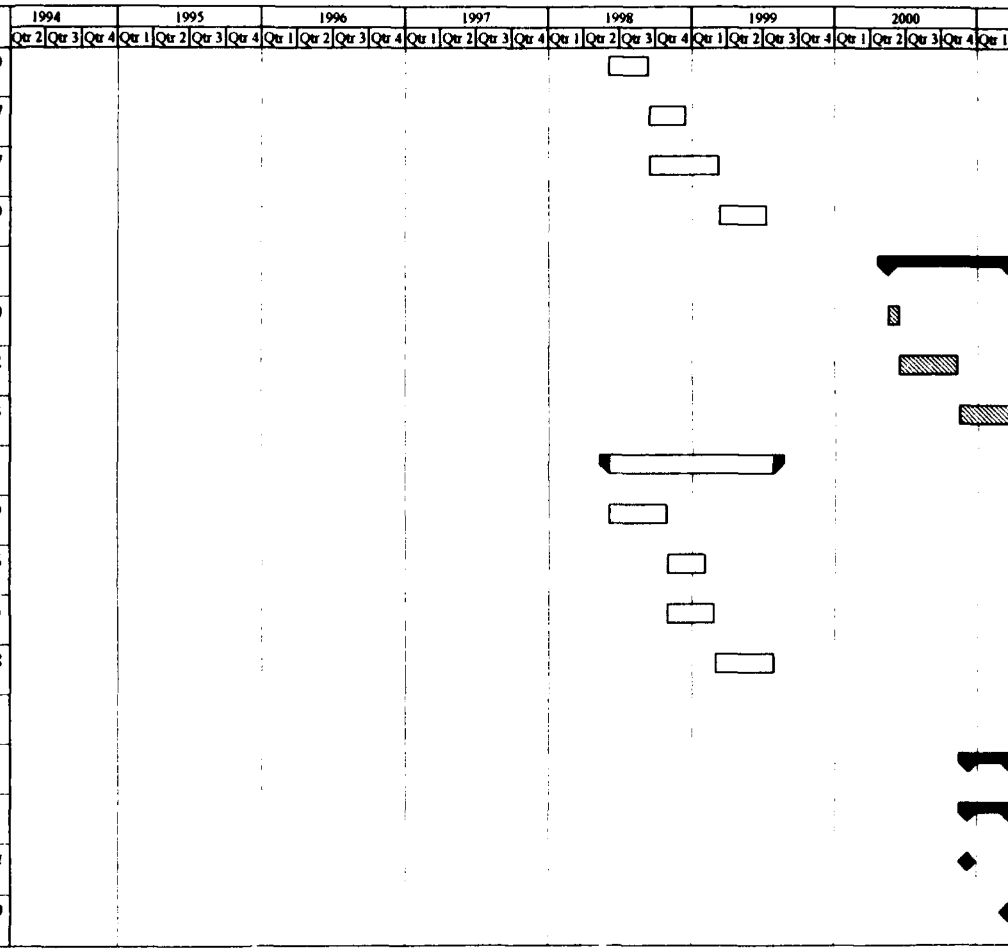
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
106	**Treatment plant**	**656d**	**6/4/98**	**12/7/00**	
107	Prelimin Design	64d	6/4/98	9/1/98	99
108	Final Design	66d	9/2/98	12/2/98	107
109	Prepare for	130d	9/2/98	3/2/99	107
110	Construc	86d	3/3/99	6/30/99	108,109
111	**Start-up**	**152d**	**5/10/00**	**12/7/00**	
112	Star	30ed	:/10/00	6/9/00	105,110
113	Pro con	130d	6/9/00	12/7/00	112
114	Cap con	0d	12/7/00	12/7/00	113
115	**End Use Piping**	**330d**	**6/4/98**	**9/8/99**	
116	Prelimin Design	108d	6/4/98	11/2/98	99
117	Final Design	92d	11/3/98	3/10/99	116
118	Prepare for	86d	11/3/98	3/2/99	116
119	Construc	130d	3/11/99	9/8/99	117,118
120	**Eastern Area**	**733d**	**6/4/98**	**3/26/01**	
121	**Collection piping**	**508d**	**6/4/98**	**5/15/00**	
122	Prelimin Design	234d	6/4/98	4/27/99	99
123	Final design	90d	4/28/99	8/31/99	122
124	Prepare for	108d	4/28/99	9/24/99	122
125	Construc	166d	9/27/99	5/15/00	88,123,124
126	**Treatment plant**	**733d**	**6/4/98**	**3/26/01**	



Date: 3/26/94 | **Critical** | **Milestone** ◆ | **Summary** | **Noncritical**

McClellan AFB GWOU RI/FS Alternative 5

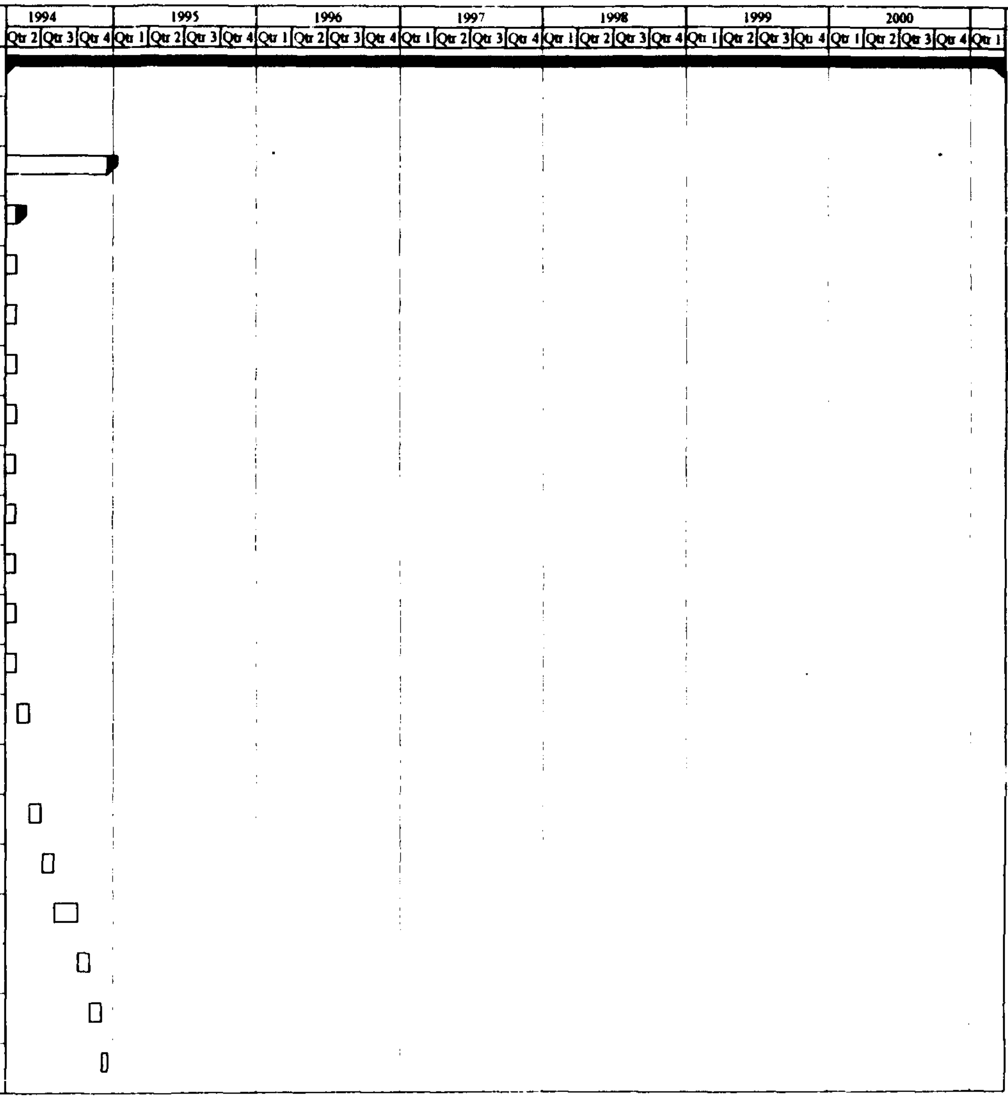
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
127	Prelimin Design	72d	6/4/98	9/11/98	99
128	Final Design	66d	9/14/98	12/14/98	127
129	Prepare for	128d	9/14/98	3/10/99	127
130	Construc (etreacon	87d	3/11/99	7/9/99	128,129
131	**Start-up**	**225d**	**5/16/00**	**3/26/01**	
132	Star	30ed	5/16/00	6/15/00	125,130
133	Pro con	107d	6/15/00	11/10/00	132
134	Cap con	96d	11/13/00	3/26/01	133
135	**End Use Piping**	**300d**	**6/4/98**	**7/28/99**	
136	Prelimin Design	106d	6/4/98	10/29/98	99
137	Final Design	69d	10/30/98	2/3/99	136
138	Prepare for	86d	10/30/98	2/26/99	136
139	Construc	108d	3/1/99	7/28/99	137,138
140					
141	**Operation of Remedial Action**	**77d**	**12/7/00**	**3/26/01**	
142	**Containment of Contaminated**	**77d**	**12/7/00**	**3/26/01**	
143	***West Base***	***0d***	***12/7/00***	***12/7/00***	***105,114***
144	***East Base***	***0d***	***3/26/01***	***3/26/01***	***125,134,139***



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 6

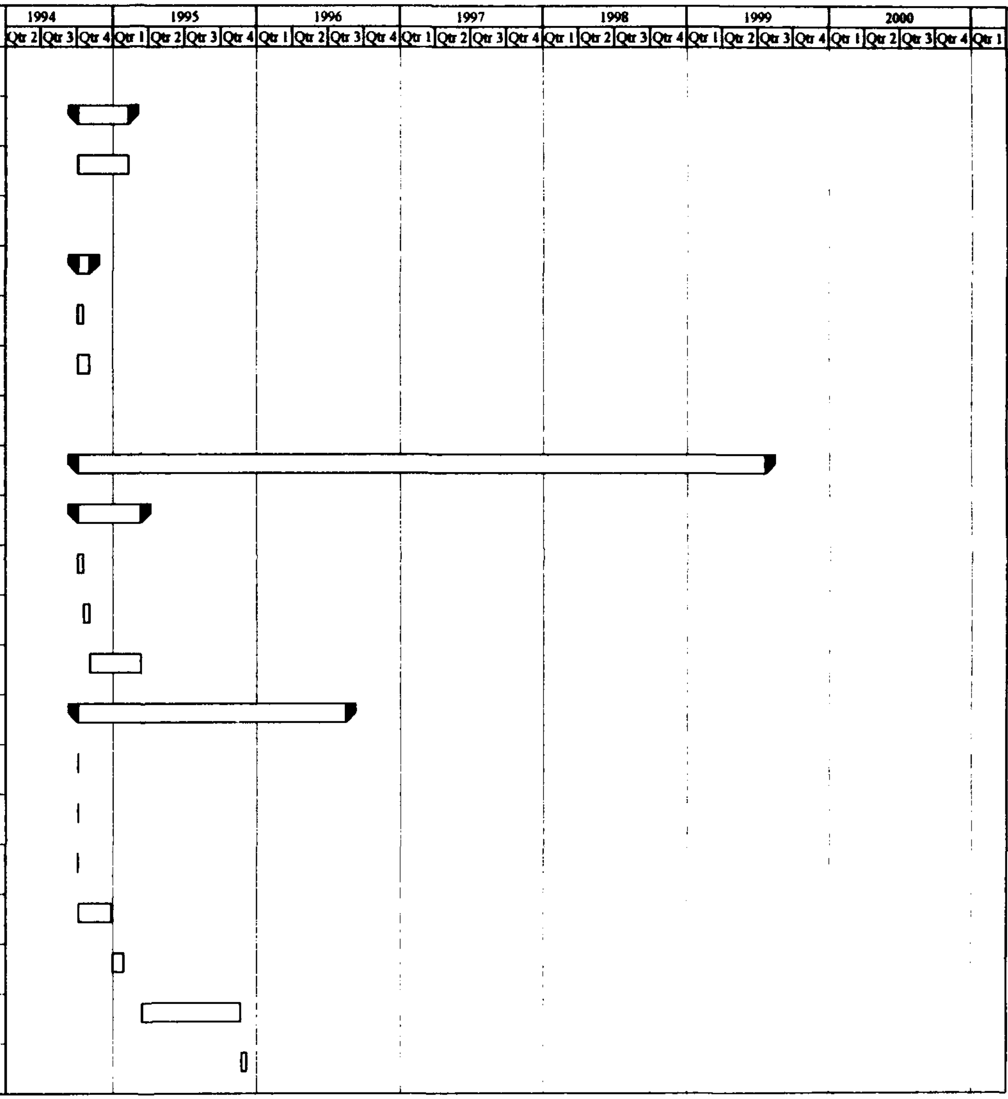
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
1	**Alternative 6 (MCL,LGAC, UTILITIES) Draft Final**	**1822d**	**4/1/94**	**3/26/01**	
2					
3	**Master Plan/Work Plan of Remedial Action**	**186d**	**4/1/94**	**12/17/94**	
4	**Develop Remedial Action Master**	**21d**	**4/1/94**	**5/1/94**	
5	Extraction System	30ed	4/1/94	5/1/94	
6	Treatment System	30ed	4/1/94	5/1/94	
7	End Use System	30ed	4/1/94	5/1/94	
8	Collection System	30ed	4/1/94	5/1/94	
9	Prepare DQOs	20d	4/1/94	4/28/94	
10	Prepare rationale	20d	4/1/94	4/28/94	
11	Prepare Health and Safety plan	20d	4/1/94	4/28/94	
12	Prepare QAPP	20d	4/1/94	4/28/94	
13	Prepare SAP	30ed	4/1/94	5/1/94	
14	Develop remedial action work plan	30ed	5/2/94	6/1/94	5,6,7,8,9,10,11,12,13
15	Submit RA Master Plan/Work Plan	1d	6/1/94	6/1/94	14
16	McClellan AFB review working	30ed	6/2/94	7/2/94	15
17	Prepare draft copy	30ed	7/4/94	8/3/94	16
18	McClellan AFB and agencies review	60ed	8/3/94	10/2/94	17
19	Prepare draft final	30ed	10/3/94	11/2/94	18
20	Agency review draft final	30ed	11/2/94	12/2/94	19
21	Prepare final Remedial Action	15ed	12/2/94	12/17/94	20



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 6

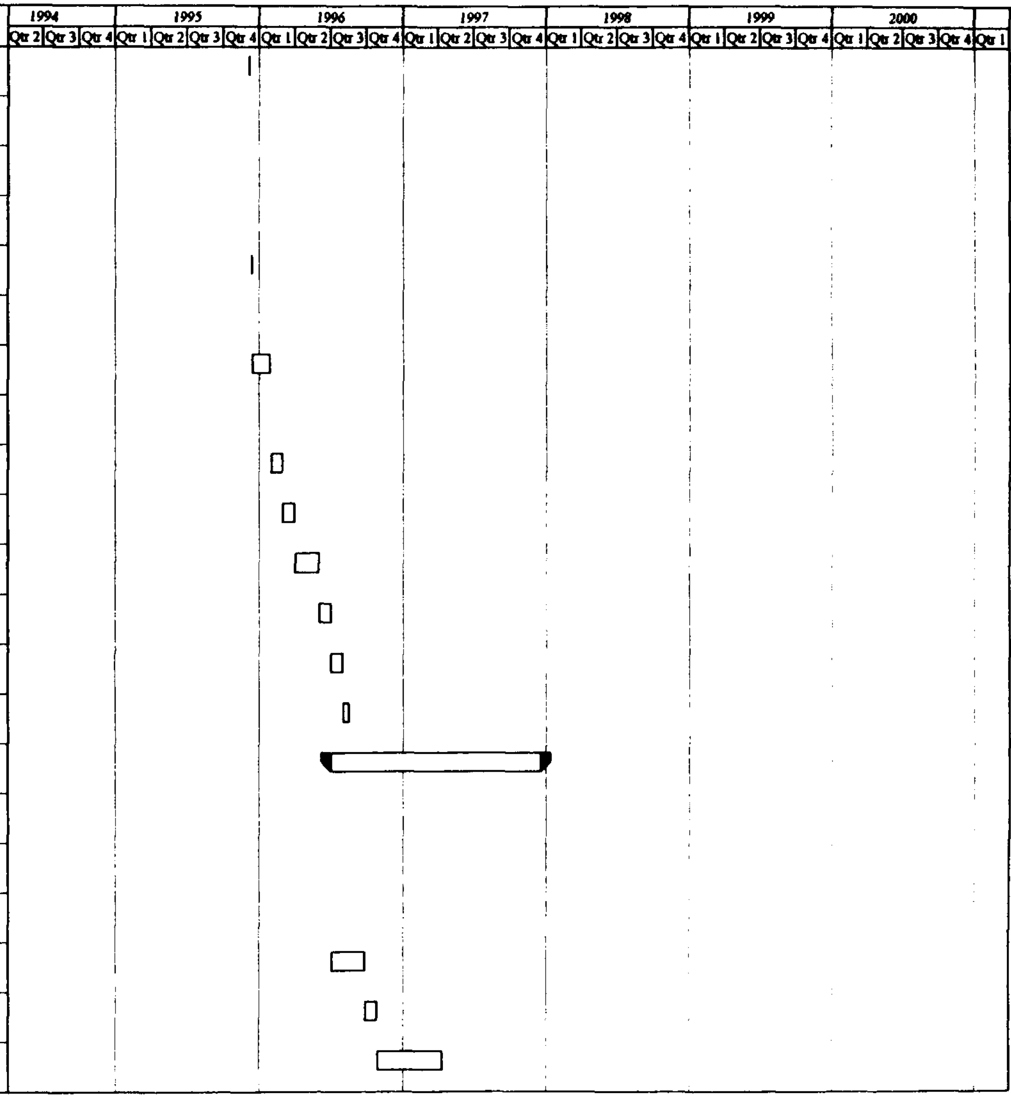
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
22					
23	**Utility Mapping**	**94d**	**10/3/94**	**2/9/95**	
24	Map Utilities (utilmap)	94d	10/3/94	2/9/95	18
25					
26	**On-base/Off-base production wells**	**22d**	**10/3/94**	**11/2/94**	
27	Prepare Base Well 18 abandonment	15ed	10/3/94	10/18/94	18
28	Prepare production well contingency	30ed	10/3/94	11/2/94	18
29					
30	**Extraction System**	**1251d**	**10/3/94**	**7/20/99**	
31	**Subcontractor procurement**	**116d**	**10/3/94**	**3/13/95**	
32	Specify system requirements	15ed	10/3/94	10/18/94	18
33	Identify performance	15ed	10/18/94	11/2/94	32
34	Procure BOAs w/ 3 subs for	94d	11/2/94	3/13/95	33
35	**Phase 1**	**488d**	**10/3/94**	**8/15/96**	
36	Off base monitoring	1d	10/3/94	10/3/94	18
37	Off base extraction	1d	10/3/94	10/3/94	18
38	Hot Spot extraction	1d	10/3/94	10/3/94	18
39	Final layout of wells	62d	10/4/94	12/28/94	36,37,38
40	Prepare for installation	22d	12/29/94	1/27/95	39
41	Installation/Int Data	180d	3/14/95	11/20/95	34,40
42	Abandon Base well 18	15ed	11/21/95	12/6/95	27,28,41



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 6

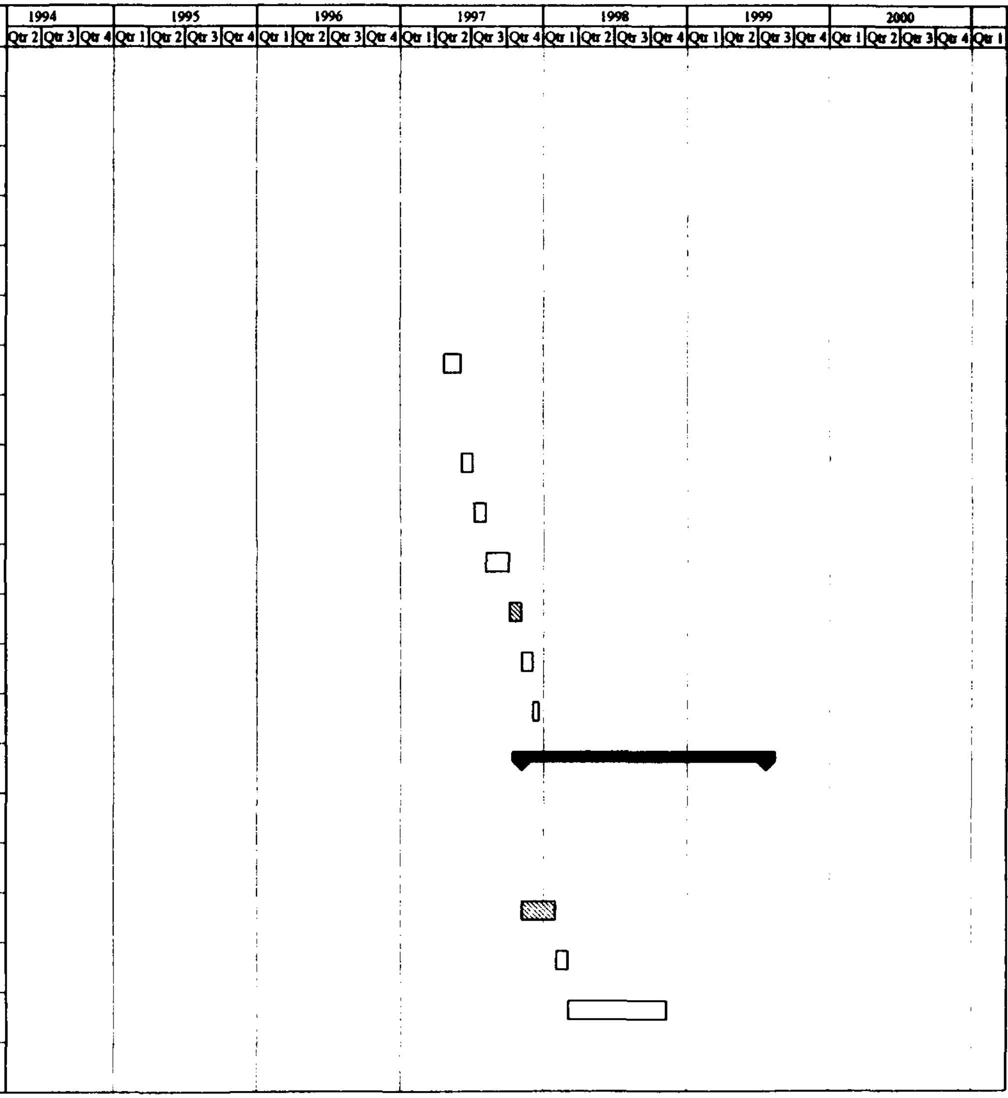
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
43	Reduce uncertainty in	1d	12/6/95	12/6/95	42
44	Reduce uncertainty in	1d	12/7/95	12/7/95	43
45	Reduce uncertainty of	1d	12/8/95	12/8/95	44
46	Reduce uncertainty in	1d	12/11/95	12/11/95	45
47	Reduce uncertainty	1d	12/12/95	12/12/95	46
48	Implement contingency	0d	12/12/95	12/12/95	47
49	Prepare Phase 1	45ed	12/13/95	1/27/96	48
50	Submit Phase 1	1d	1/29/96	1/29/96	49
51	McClellan AFB review	30ed	1/30/96	2/29/96	50
52	Prepare draft copy	30ed	2/29/96	3/30/96	51
53	McClellan AFB and	60ed	4/1/96	5/31/96	52
54	Prepare draft final	30ed	5/31/96	6/30/96	53
55	Agency review draft final	30ed	7/1/96	7/31/96	54
56	Prepare final Phase 1	15ed	7/31/96	8/15/96	55
57	**Phase 2**	**385d**	**7/1/96**	**12/20/97**	
58	Off base monitoring	1d	7/1/96	7/1/96	54
59	Off base extraction	1d	7/1/96	7/1/96	54
60	Hot Spot extraction	1d	7/1/96	7/1/96	54
61	Final layout of wells	62d	7/2/96	9/25/96	58,59,60
62	Prepare for installation	22d	9/26/96	10/25/96	61
63	Installation/Int Data	120d	10/28/96	4/11/97	62



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 6

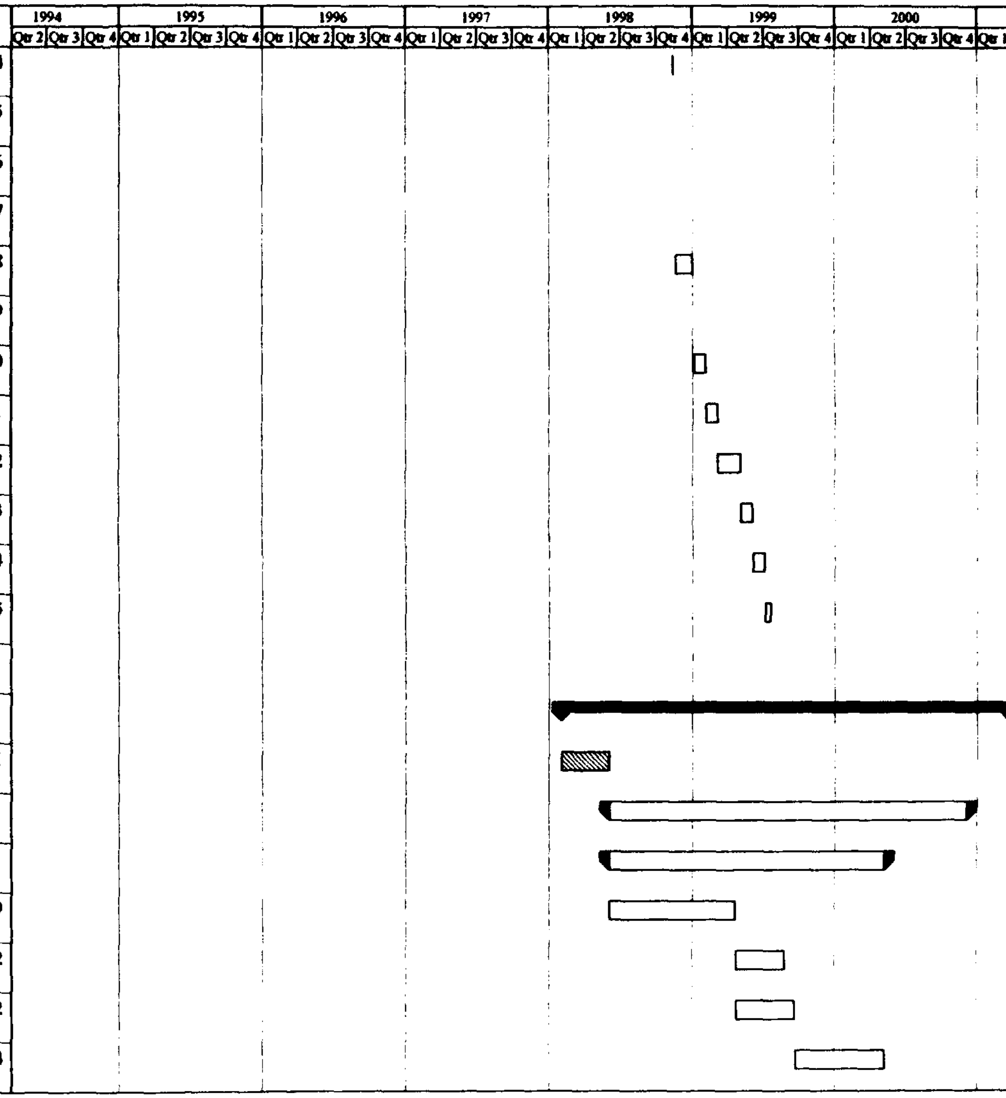
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
64	Resolve uncertainty in	1d	4/14/97	4/14/97	63
65	Further reduce uncertainty in	1d	4/15/97	4/15/97	64
66	Resolve uncertainty in	1d	4/16/97	4/16/97	65
67	Resolve uncertainty in	1d	4/17/97	4/17/97	66
68	Resolve uncertainty	1d	4/18/97	4/18/97	67
69	Implement contingency	0d	4/18/97	4/18/97	68
70	Prepare Phase 2	45ed	4/21/97	6/5/97	69
71	Submit Phase 2	1d	6/5/97	6/5/97	70
72	McClellan AFB review	30ed	6/6/97	7/6/97	71
73	Prepare draft copy	30ed	7/7/97	8/6/97	72
74	McClellan AFB and	60ed	8/6/97	10/5/97	73
75	Prepare draft final	30ed	10/6/97	11/5/97	74
76	Agency review draft final	30ed	11/5/97	12/5/97	75
77	Prepare final Phase 2	15ed	12/5/97	12/20/97	76
78	**Phase 3**	**444d**	**11/5/97**	**7/20/99**	
79	On base monitoring	1d	11/5/97	11/5/97	75
80	On base extraction	1d	11/5/97	11/5/97	75
81	Final layout of wells	62d	11/6/97	1/30/98	79,80
82	Prepare for installation	22d	2/2/98	3/3/98	81
83	Installation/Int Data	180d	3/4/98	11/10/98	82
84	Resolve uncertainty in	1d	11/11/98	11/11/98	83



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 6

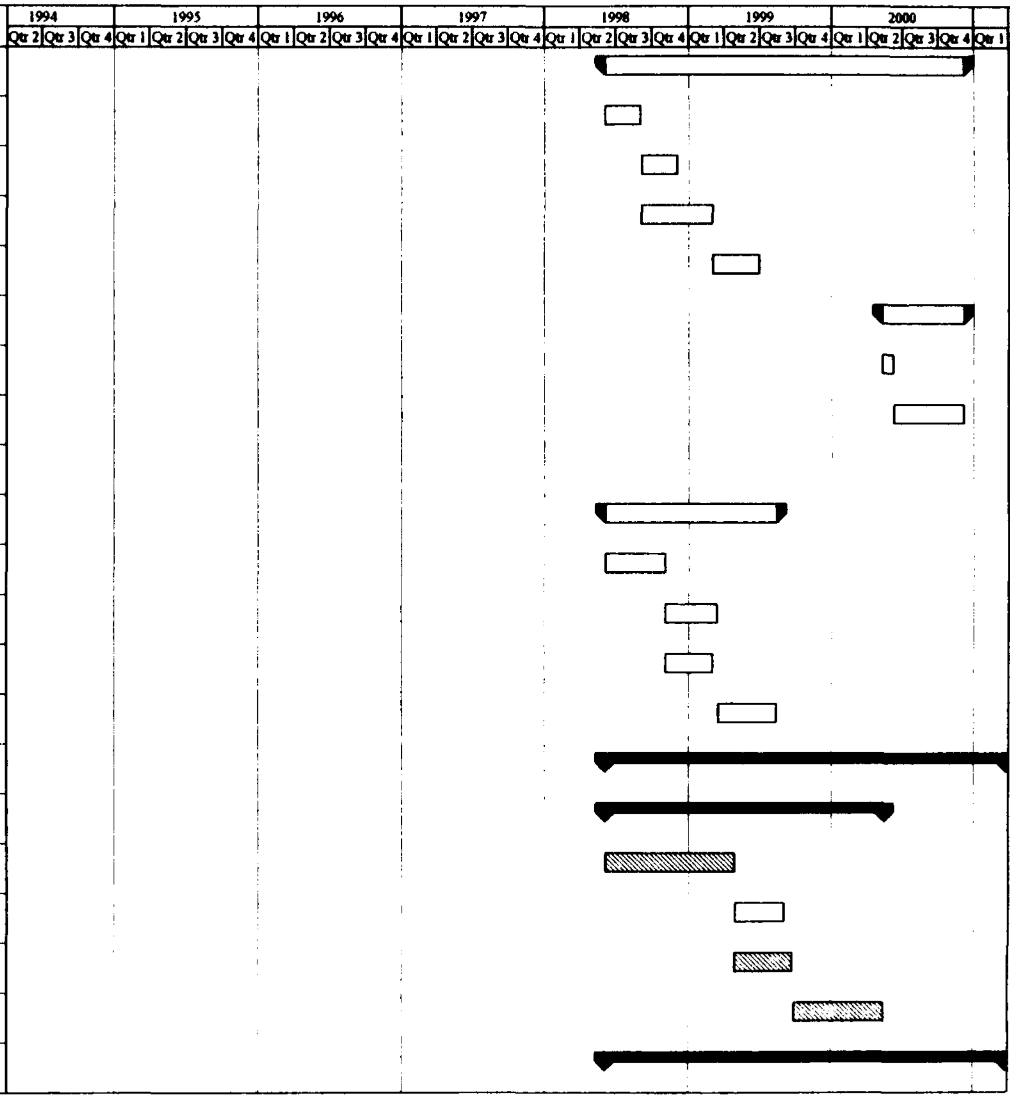
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
85	Resolve uncertainty in	1d	11/12/98	11/12/98	84
86	Resolve uncertainty in	1d	11/13/98	11/13/98	85
87	Resolve uncertainty in	1d	11/16/98	11/16/98	86
88	Implement contingency	0d	11/16/98	11/16/98	87
89	Prepare Phase 3 Report	45ed	11/17/98	1/1/99	88
90	Submit Phase 3 Report	1d	1/1/99	1/1/99	89
91	McClellan AFB review	30ed	1/4/99	2/3/99	90
92	Prepare draft copy	30ed	2/3/99	3/5/99	91
93	McClellan AFB and	60ed	3/5/99	5/4/99	92
94	Prepare draft final	30ed	5/4/99	6/3/99	93
95	Agency review draft final	30ed	6/3/99	7/3/99	94
96	Prepare final Phase 3	15ed	7/5/99	7/20/99	95
97					
98	Treatment/End Use/ Collection Systems	821d	2/2/98	3/26/01	
99	Procure turnkey contractor	88d	2/2/98	6/3/98	24,81
100	Western Area	656d	6/4/98	12/7/00	
101	Collection piping	504d	6/4/98	5/9/00	
102	Prelimin Design	231d	6/4/98	4/22/99	99
103	Final design	90d	4/23/99	8/26/99	102
104	Prepare for	108d	4/23/99	9/21/99	102
105	Construc	165d	9/22/99	5/9/00	88,103,104



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 6

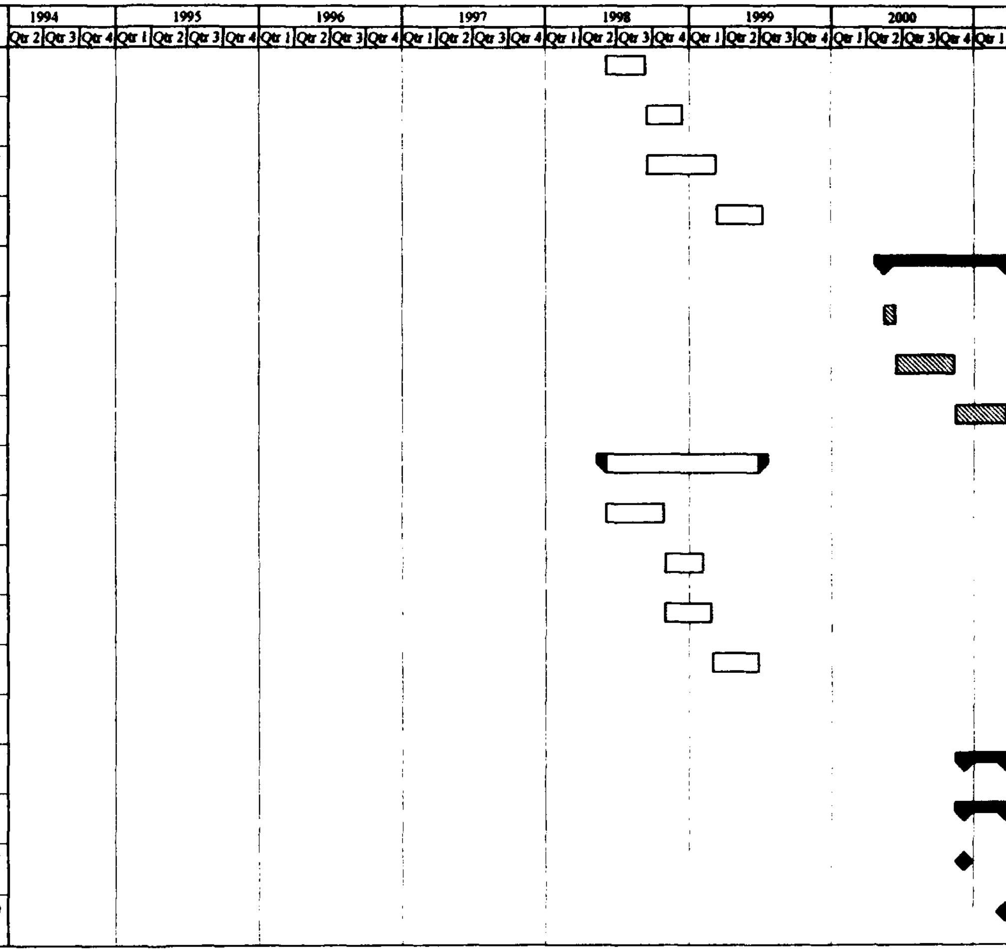
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
106	**Treatment plant**	**656d**	**6/4/98**	**12/7/00**	
107	Prelimin Design	64d	6/4/98	9/1/98	99
108	Final Design	66d	9/2/98	12/2/98	107
109	Prepare for	130d	9/2/98	3/2/99	107
110	Construc	86d	3/3/99	6/30/99	108,109
111	**Start-up**	**152d**	**5/10/00**	**12/7/00**	
112	Star	30ed	5/10/00	6/9/00	105,110
113	Pro con	130d	6/9/00	12/7/00	112
114	Cap con	0d	12/7/00	12/7/00	113
115	**End Use Piping**	**311d**	**6/4/98**	**8/12/99**	
116	Prelimin Design	108d	6/4/98	11/2/98	99
117	Final Design	95d	11/3/98	3/15/99	116
118	Prepare for	86d	11/3/98	3/2/99	116
119	Construc	108d	3/16/99	8/12/99	117,118
120	**Eastern Area**	**733d**	**6/4/98**	**3/26/01**	
121	**Collection piping**	**508d**	**6/4/98**	**5/15/00**	
122	Prelimin Design	234d	6/4/98	4/27/99	99
123	Final design	90d	4/28/99	8/31/99	122
124	Prepare for	108d	4/28/99	9/24/99	122
125	Construc	166d	9/27/99	5/15/00	88,123,124
126	**Treatment plant**	**733d**	**6/4/98**	**3/26/01**	



Date: 3/26/94 | **Critical** | **Milestone** | **Summary** | **Noncritical**

McClellan AFB GWOU RI/FS Alternative 6

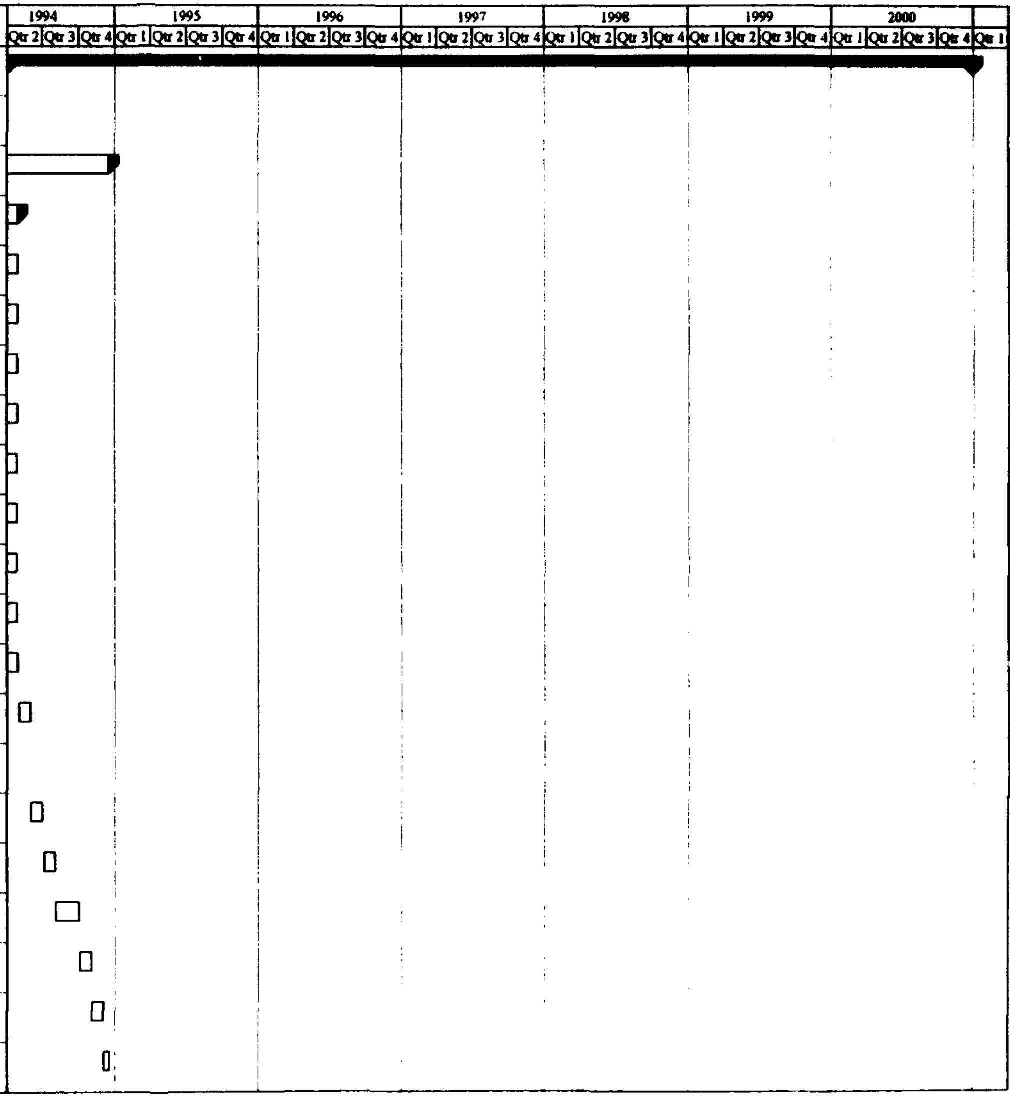
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
127	Prelimin Design	72d	6/4/98	9/11/98	99
128	Final Design	66d	9/14/98	12/14/98	127
129	Prepare for	128d	9/14/98	3/10/99	127
130	Construc (etreacon	87d	3/11/99	7/9/99	128,129
131	**Start-up**	**225d**	**5/16/00**	**3/26/01**	
132	Star	30ed	5/16/00	6/15/00	125,130
133	Pro con	107d	6/15/00	11/10/00	132
134	Cap con	96d	11/13/00	3/26/01	133
135	**End Use Piping**	**278d**	**6/4/98**	**6/28/99**	
136	Prelimin Design	106d	6/4/98	10/29/98	99
137	Final Design	70d	10/30/98	2/4/99	136
138	Prepare for	86d	10/30/98	2/26/99	136
139	Construc	86d	3/1/99	6/28/99	137,138
140					
141	**Operation of Remedial Action**	**77d**	**12/7/00**	**3/26/01**	
142	**Containment of Contaminated**	**77d**	**12/7/00**	**3/26/01**	
143	***West Base***	*0d*	*12/7/00*	*12/7/00*	*105,114*
144	***East Base***	*0d*	*3/26/01*	*3/26/01*	*125,134,139*



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 2

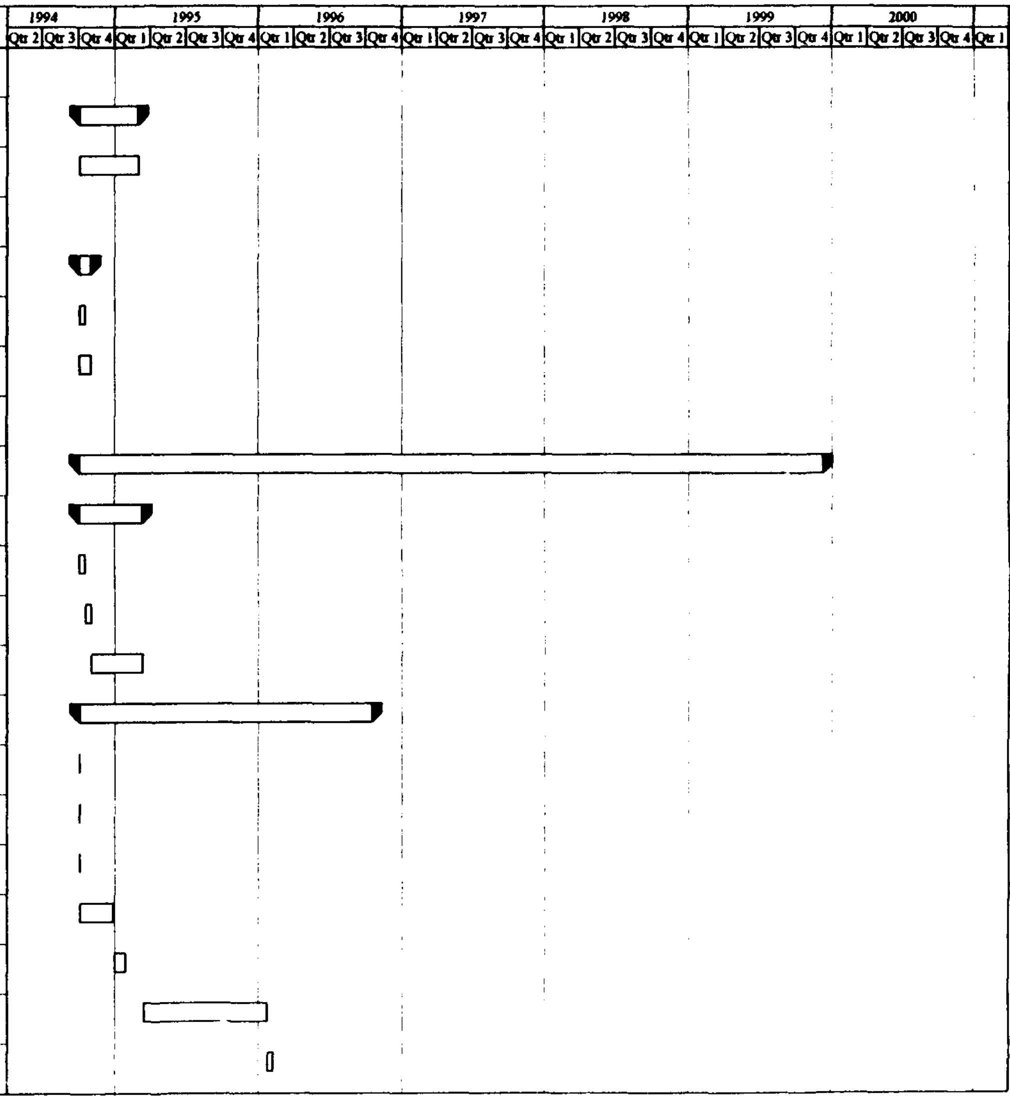
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
1	**Alternative 2 (CANCER RISK, AS/CATOX,**	**1761d**	**4/1/94**	**12/30/00**	
2					
3	**Master Plan/Work Plan of Remedial Action**	**186d**	**4/1/94**	**12/17/94**	
4	**Develop Remedial Action Master**	**21d**	**4/1/94**	**5/1/94**	
5	Extraction System	30ed	4/1/94	5/1/94	
6	Treatment System	30ed	4/1/94	5/1/94	
7	End Use System	30ed	4/1/94	5/1/94	
8	Collection System	30ed	4/1/94	5/1/94	
9	Prepare DQOs	20d	4/1/94	4/28/94	
10	Prepare rationale	20d	4/1/94	4/28/94	
11	Prepare Health and Safety plan	20d	4/1/94	4/28/94	
12	Prepare QAPP	20d	4/1/94	4/28/94	
13	Prepare SAP	30ed	4/1/94	5/1/94	
14	Develop remedial action work plan	30ed	5/2/94	6/1/94	5,6,7,8,9,10,11,12,13
15	Submit RA Master Plan/Work Plan	1d	6/1/94	6/1/94	14
16	McClellan AFB review working	30ed	6/2/94	7/2/94	15
17	Prepare draft copy	30ed	7/4/94	8/3/94	16
18	McClellan AFB and agencies review	60ed	8/3/94	10/2/94	17
19	Prepare draft final	30ed	10/3/94	11/2/94	18
20	Agency review draft final	30ed	11/2/94	12/2/94	19
21	Prepare final Remedial Action	15ed	12/2/94	12/17/94	20



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 2

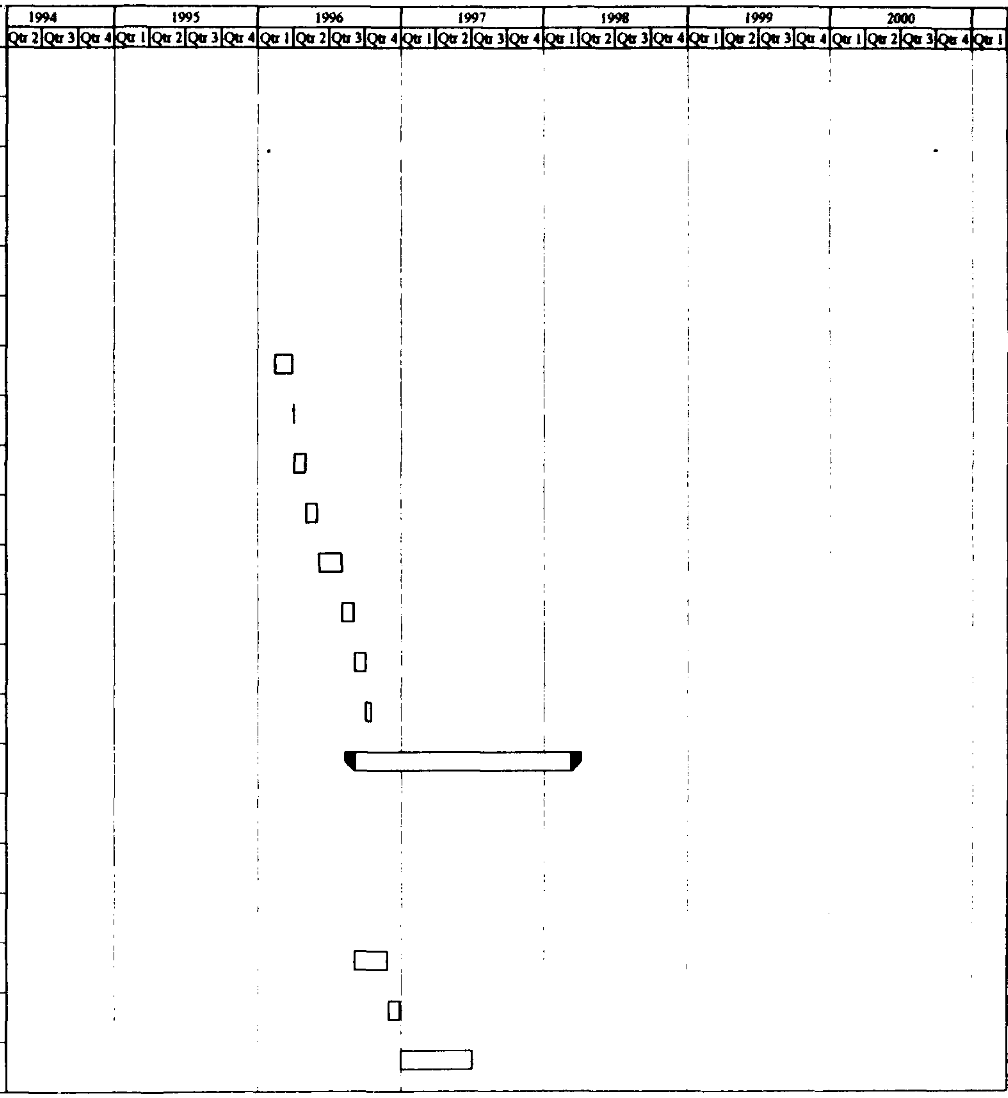
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
22					
23	**Utility Mapping**	**109d**	**10/3/94**	**3/2/95**	
24	Map Utilities (utilmap)	109d	10/3/94	3/2/95	18
25					
26	**On-base/Off-base production wells**	**22d**	**10/3/94**	**11/2/94**	
27	Prepare Base Well 18 abandonment	15ed	10/3/94	10/18/94	18
28	Prepare production well contingency	30ed	10/3/94	11/2/94	18
29					
30	**Extraction System**	**1353d**	**10/3/94**	**12/9/99**	
31	**Subcontractor procurement**	**116d**	**10/3/94**	**3/13/95**	
32	Specify system requirements	15ed	10/3/94	10/18/94	18
33	Identify performance	15ed	10/18/94	11/2/94	32
34	Procure BOAs w/ 3 subs for	94d	11/2/94	3/13/95	33
35	**Phase 1**	**533d**	**10/3/94**	**10/17/96**	
36	Off base monitoring	1d	10/3/94	10/3/94	18
37	Off base extraction	1d	10/3/94	10/3/94	18
38	Hot Spot extraction	1d	10/3/94	10/3/94	18
39	Final layout of wells	62d	10/4/94	12/28/94	36,37,38
40	Prepare for installation	22d	12/29/94	1/27/95	39
41	Installation/Int Data	225d	3/14/95	1/22/96	34,40
42	Abandon Base well 18	15ed	1/23/96	2/7/96	27,28,41



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 2

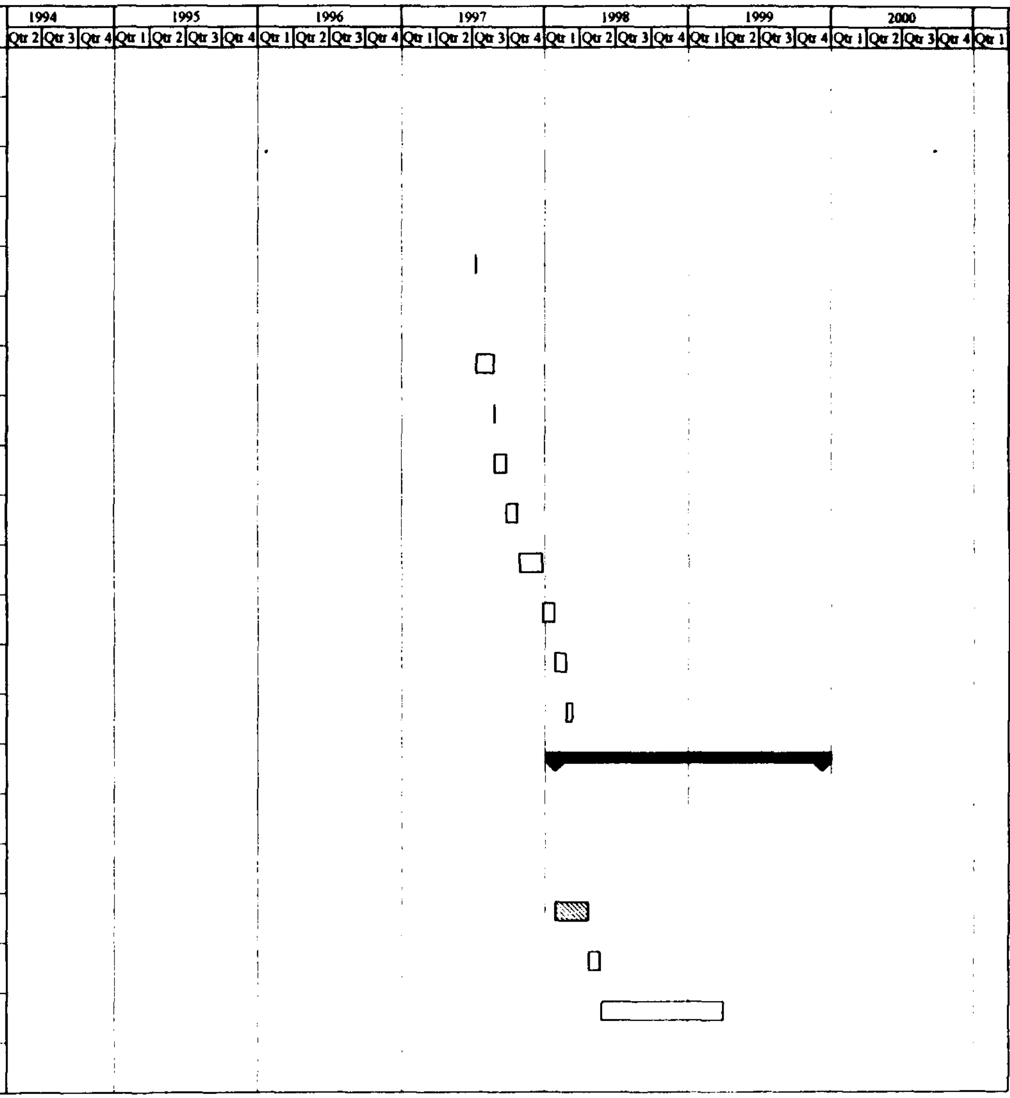
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
43	Reduce uncertainty in	1d	2/7/96	2/7/96	42
44	Reduce uncertainty in	1d	2/8/96	2/8/96	43
45	Reduce uncertainty of	1d	2/9/96	2/9/96	44
46	Reduce uncertainty in	1d	2/12/96	2/12/96	45
47	Reduce uncertainty	1d	2/13/96	2/13/96	46
48	Implement contingency	0d	2/13/96	2/13/96	47
49	Prepare Phase 1	45ed	2/14/96	3/30/96	48
50	Submit Phase 1	1d	4/1/96	4/1/96	49
51	McClellan AFB review	30ed	4/2/96	5/2/96	50
52	Prepare draft copy	30ed	5/2/96	6/1/96	51
53	McClellan AFB and	60ed	6/3/96	8/2/96	52
54	Prepare draft final	30ed	8/2/96	9/1/96	53
55	Agency review draft final	30ed	9/2/96	10/2/96	54
56	Prepare final Phase 1	15ed	10/2/96	10/17/96	55
57	**Phase 2**	**398d**	**9/2/96**	**3/12/98**	
58	Off base monitoring	1d	9/2/96	9/2/96	54
59	Off base extraction	1d	9/2/96	9/2/96	54
60	Hot Spot extraction	1d	9/2/96	9/2/96	54
61	Final layout of wells	62d	9/3/96	11/27/96	58,59,60
62	Prepare for installation	22d	11/28/96	12/27/96	61
63	Installation/Int Data	133d	12/30/96	7/2/97	62



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 2

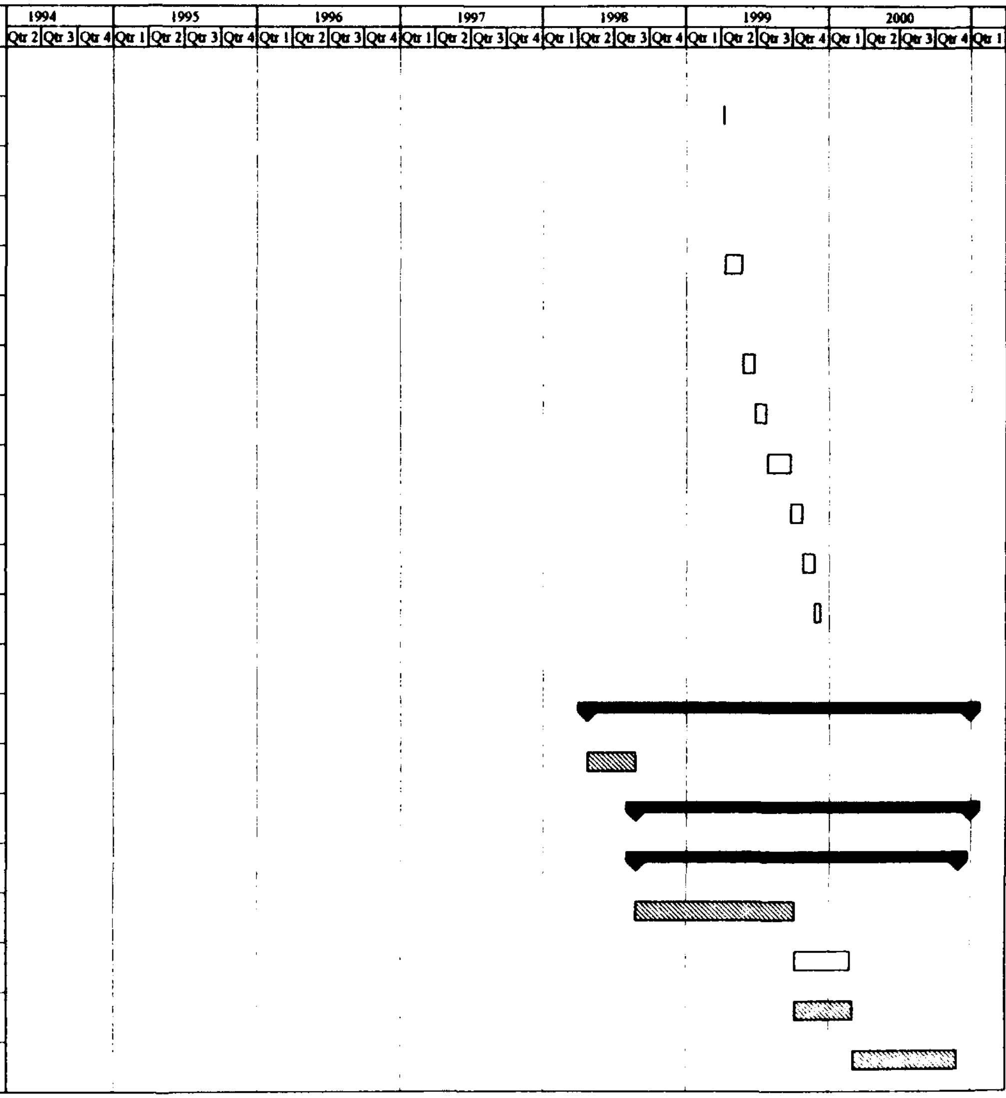
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
64	Resolve uncertainty in	1d	7/3/97	7/3/97	63
65	Further reduce uncertainty in	1d	7/4/97	7/4/97	64
66	Resolve uncertainty in	1d	7/7/97	7/7/97	65
67	Resolve uncertainty in	1d	7/8/97	7/8/97	66
68	Resolve uncertainty	1d	7/9/97	7/9/97	67
69	Implement contingency	0d	7/9/97	7/9/97	68
70	Prepare Phase 2	45ed	7/10/97	8/24/97	69
71	Submit Phase 2	1d	8/25/97	8/25/97	70
72	McClellan AFB review	30ed	8/26/97	9/25/97	71
73	Prepare draft copy	30ed	9/25/97	10/25/97	72
74	McClellan AFB and	60ed	10/27/97	12/26/97	73
75	Prepare draft final	30ed	12/26/97	1/25/98	74
76	Agency review draft final	30ed	1/26/98	2/25/98	75
77	Prepare final Phase 2	15ed	2/25/98	3/12/98	76
78	**Phase 3**	**488d**	**1/26/98**	**12/9/99**	
79	On base monitoring	1d	1/26/98	1/26/98	75
80	On base extraction	1d	1/26/98	1/26/98	75
81	Final layout of wells	62d	1/27/98	4/22/98	79,80
82	Prepare for installation	22d	4/23/98	5/22/98	81
83	Installation/Int Data	225d	5/25/98	4/2/99	82
84	Resolve uncertainty in	1d	4/5/99	4/5/99	83



Date: 3/26/94 — Critical — Milestone — Summary — Noncritical

McClellan AFB GWOU RI/FS Alternative 2

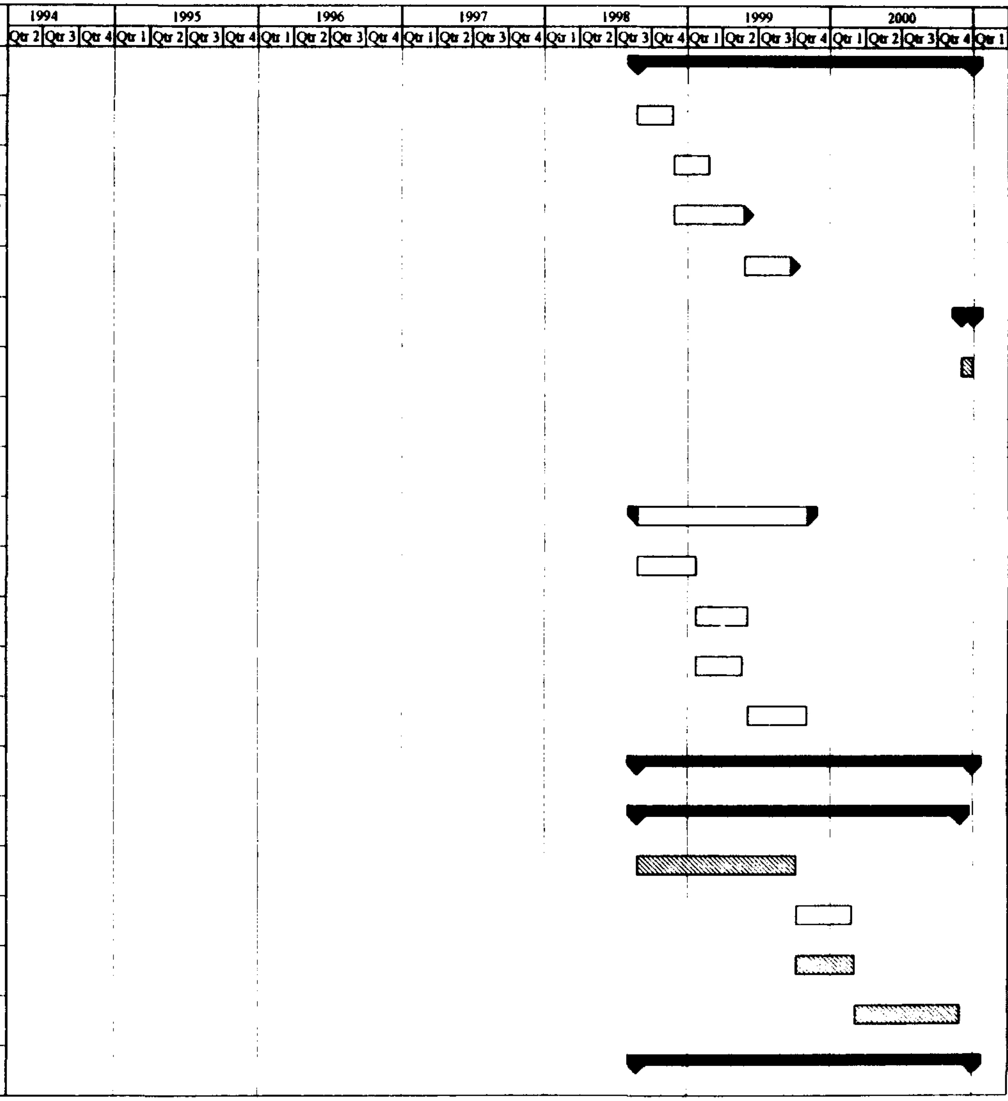
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
85	Resolve uncertainty in	1d	4/6/99	4/6/99	84
86	Resolve uncertainty in	1d	4/7/99	4/7/99	85
87	Resolve uncertainty in	1d	4/8/99	4/8/99	86
88	Implement contingency	0d	4/8/99	4/8/99	87
89	Prepare Phase 3 Report	45ed	4/9/99	5/24/99	88
90	Submit Phase 3 Report	1d	5/24/99	5/24/99	89
91	McClellan AFB review	30ed	5/25/99	6/24/99	90
92	Prepare draft copy	30ed	6/24/99	7/24/99	91
93	McClellan AFB and	60ed	7/26/99	9/24/99	92
94	Prepare draft final	30ed	9/24/99	10/24/99	93
95	Agency review draft final	30ed	10/25/99	11/24/99	94
96	Prepare final Phase 3	15ed	11/24/99	12/9/99	95
97					
98	**Treatment/End Use/ Collection Systems**	**702d**	**4/23/98**	**12/30/00**	
99	Procure turnkey contractor	88d	4/23/98	8/24/98	24,81
100	**Western Area**	**614d**	**8/25/98**	**12/30/00**	
101	**Collection piping**	**592d**	**8/25/98**	**11/29/00**	
102	Prelimin Design	290d	8/25/98	10/4/99	99
103	Final design	103d	10/5/99	2/24/00	102
104	Prepare for	108d	10/5/99	3/2/00	102
105	Construc	194d	3/3/00	11/29/00	88,103,104



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 2

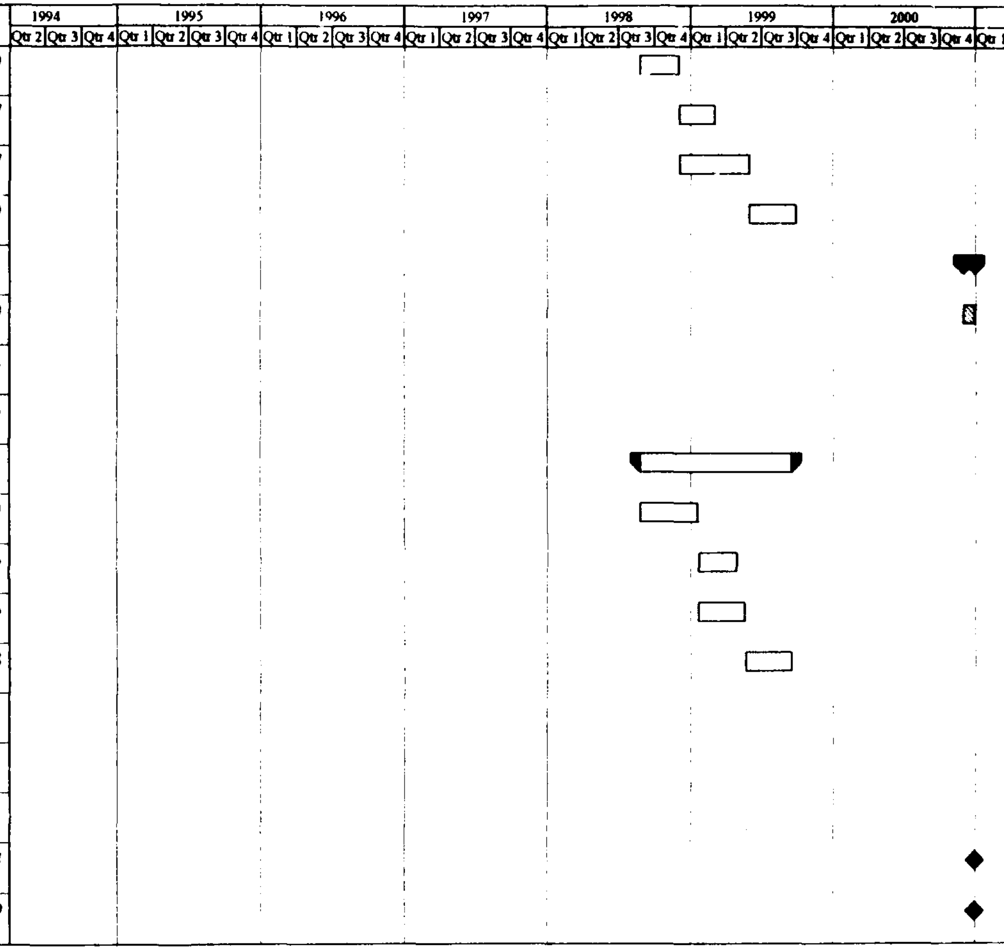
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
106	**Treatment plant**	**614d**	**8/25/98**	**12/30/00**	
107	Prelimin Design	67d	8/25/98	11/25/98	99
108	Final Design	66d	11/26/98	2/25/99	107
109	***Prepare for***	***130d***	***11/26/98***	***5/26/99***	***107***
110	***Constru***	***86d***	***5/27/99***	***9/23/99***	***108,109***
111	**Start-up**	**22d**	**11/30/00**	**12/30/00**	
112	Star	30ed	11/30/00	12/30/00	105,110
113	Pro con	0d	12/30/00	12/30/00	112
114	Cap con	0d	12/30/00	12/30/00	113
115	**End Use Piping**	**311d**	**8/25/98**	**11/2/99**	
116	Prelimin Design	108d	8/25/98	1/21/99	99
117	Final Design	95d	1/22/99	6/3/99	116
118	Prepare for	86d	1/22/99	5/21/99	116
119	Construc	108d	6/4/99	11/2/99	117,118
120	**Eastern Area**	**614d**	**8/25/98**	**12/30/00**	
121	**Collection piping**	**592d**	**8/25/98**	**11/29/00**	
122	Prelimin Design	290d	8/25/98	10/4/99	99
123	Final design	103d	10/5/99	2/24/00	122
124	Prepare for	108d	10/5/99	3/2/00	122
125	Construc	194d	3/3/00	11/29/00	88,123,124
126	**Treatment plant**	**614d**	**8/25/98**	**12/30/00**	



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 2

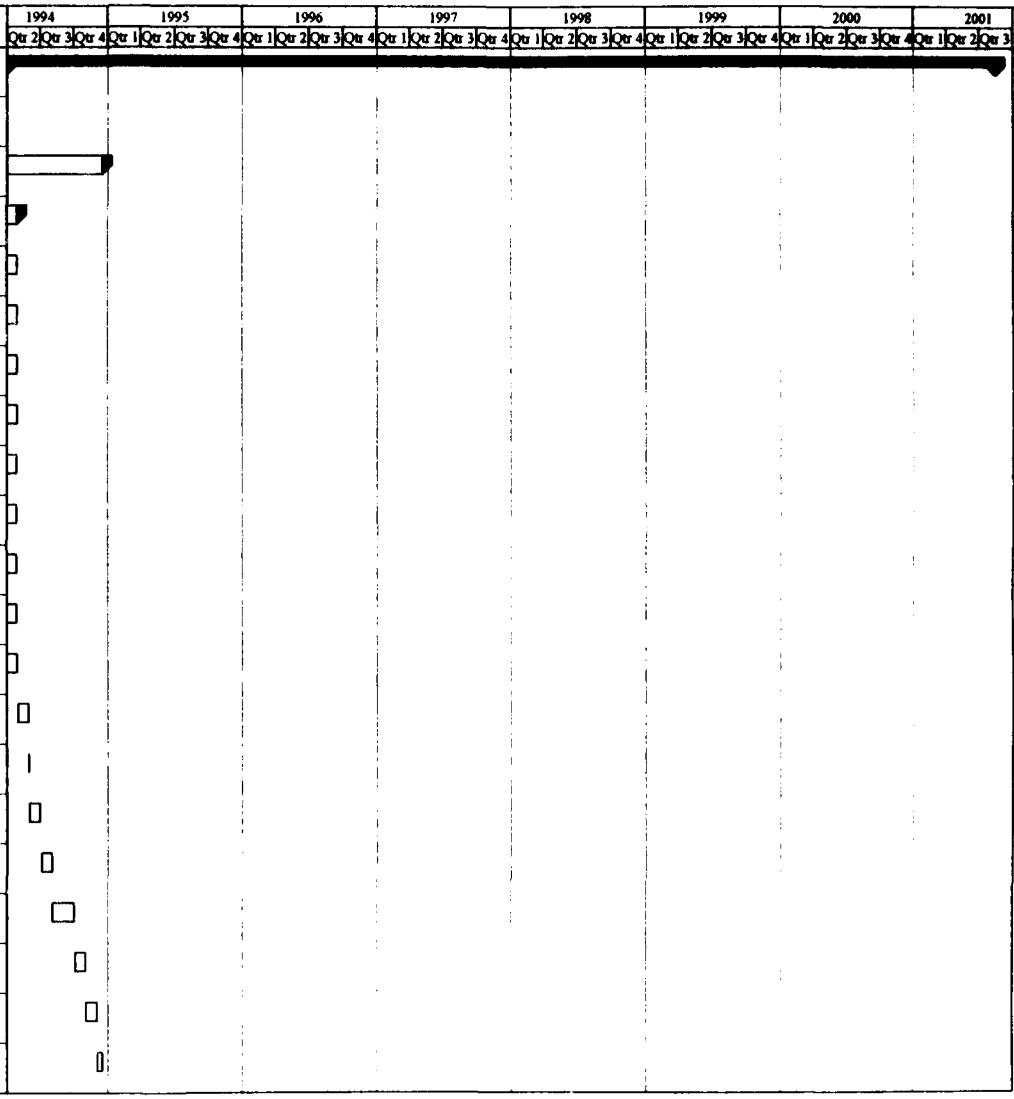
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
127	Prelimin Design	72d	8/25/98	12/2/98	99
128	Final Design	66d	12/3/98	3/4/99	127
129	Prepare for	128d	12/3/98	5/31/99	127
130	Construc (etreacon	87d	6/1/99	9/29/99	128,129
131	**Start-up**	**22d**	**11/30/00**	**12/30/00**	
132	Star	30ed	11/30/00	12/30/00	125,130
133	Pro con	0d	12/30/00	12/30/00	132
134	Cap con	0d	12/30/00	12/30/00	133
135	**End Use Piping**	**278d**	**8/25/98**	**9/16/99**	
136	Prelimin Design	106d	8/25/98	1/19/99	99
137	Final Design	70d	1/20/99	4/27/99	136
138	Prepare for	86d	1/20/99	5/19/99	136
139	Construc	86d	5/20/99	9/16/99	137,138
140					
141	**Operation of Remedial Action**	**0d**	**12/30/00**	**12/30/00**	
142	**Containment of Contaminated**	**0d**	**12/30/00**	**12/30/00**	
143	***West Base***	***0d***	***12/30/00***	***12/30/00***	***105,114***
144	***East Base***	***0d***	***12/30/00***	***12/30/00***	***125,134,139***



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 3

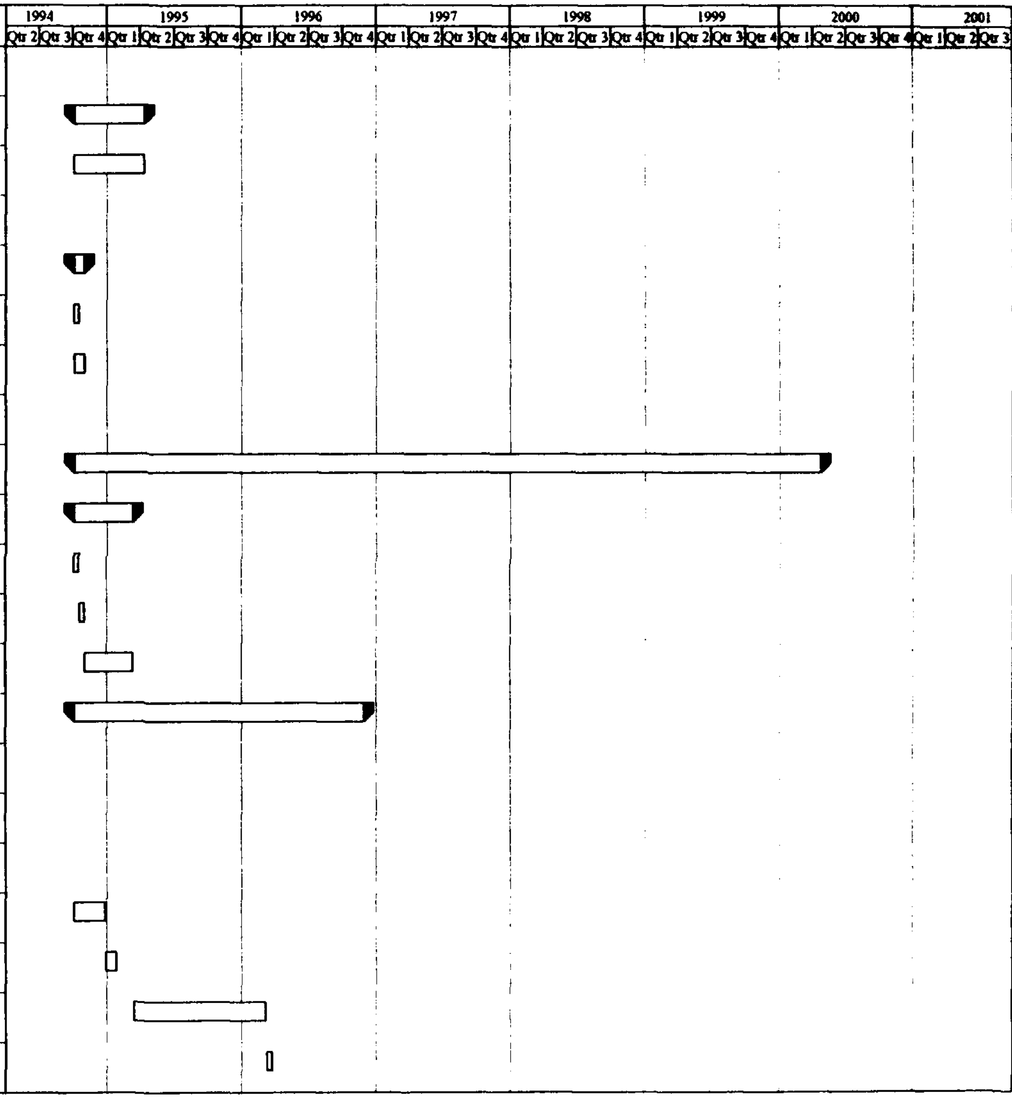
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
1	**Alternative 3 (BACKGROUND,**	**1923d**	**4/1/94**	**8/15/01**	
2					
3	**Master Plan/Work Plan of Remedial Action**	**186d**	**4/1/94**	**12/17/94**	
4	**Develop Remedial Action Master**	**21d**	**4/1/94**	**5/1/94**	
5	Extraction System	30ed	4/1/94	5/1/94	
6	Treatment System	30ed	4/1/94	5/1/94	
7	End Use System	30ed	4/1/94	5/1/94	
8	Collection System	30ed	4/1/94	5/1/94	
9	Prepare DQOs	20d	4/1/94	4/28/94	
10	Prepare rationale	20d	4/1/94	4/28/94	
11	Prepare Health and Safety plan	20d	4/1/94	4/28/94	
12	Prepare QAPP	20d	4/1/94	4/28/94	
13	Prepare SAP	30ed	4/1/94	5/1/94	
14	Develop remedial action work plan	30ed	5/2/94	6/1/94	5,6,7,8,9,10,11,12,13
15	Submit RA Master Plan/Work Plan	1d	6/1/94	6/1/94	14
16	McClellan AFB review working	30ed	6/2/94	7/2/94	15
17	Prepare draft copy	30ed	7/4/94	8/3/94	16
18	McClellan AFB and agencies review	60ed	8/3/94	10/2/94	17
19	Prepare draft final	30ed	10/3/94	11/2/94	18
20	Agency review draft final	30ed	11/2/94	12/2/94	19
21	Prepare final Remedial Action	15ed	12/2/94	12/17/94	20



Date: 3/26/94 — Critical — Milestone — Summary — Noncritical

McClellan AFB GWOU RI/FS Alternative 3

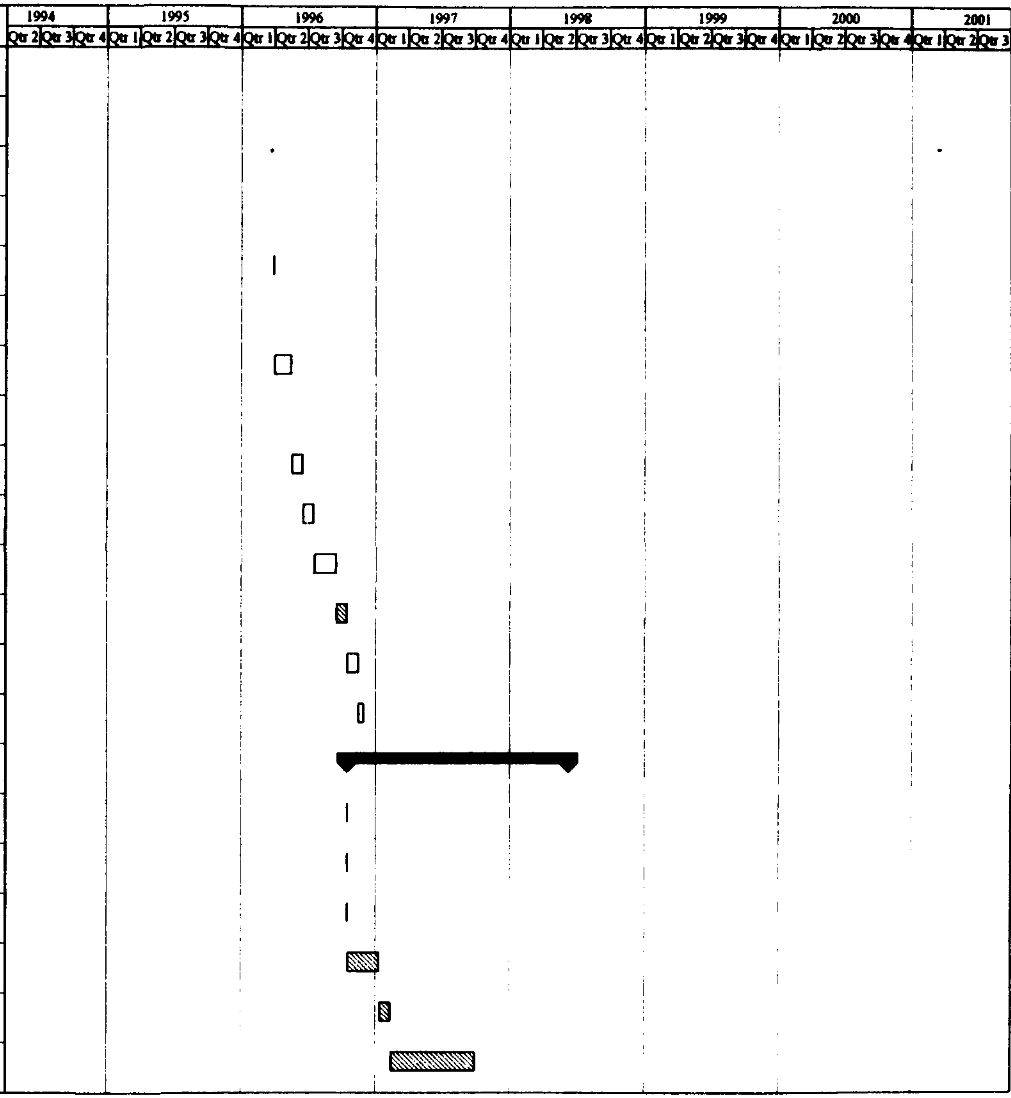
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
22					
23	**Utility Mapping**	**139d**	**10/3/94**	**4/13/95**	
24	Map Utilities (utilmap)	139d	10/3/94	4/13/95	18
25					
26	**On-base/Off-base production wells**	**22d**	**10/3/94**	**11/2/94**	
27	Prepare Base Well 18 abandonment	15ed	10/3/94	10/18/94	18
28	Prepare production well contingency	30ed	10/3/94	11/2/94	18
29					
30	**Extraction System**	**1450d**	**10/3/94**	**4/22/00**	
31	**Subcontractor procurement**	**116d**	**10/3/94**	**3/13/95**	
32	Specify system requirements	15ed	10/3/94	10/18/94	18
33	Identify performance	15ed	10/18/94	11/2/94	32
34	Procure BOAs w/ 3 subs for	94d	11/2/94	3/13/95	33
35	**Phase 1**	**565d**	**10/3/94**	**11/30/96**	
36	Off base monitoring	1d	10/3/94	10/3/94	18
37	Off base extraction	1d	10/3/94	10/3/94	18
38	Hot Spot extraction	1d	10/3/94	10/3/94	18
39	Final layout of wells	62d	10/4/94	12/28/94	36,37,38
40	Prepare for installation	22d	12/29/94	1/27/95	39
41	Installation/Int Data	258d	3/14/95	3/7/96	34,40
42	Abandon Base well 18	15ed	3/8/96	3/23/96	27,28,41



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 3

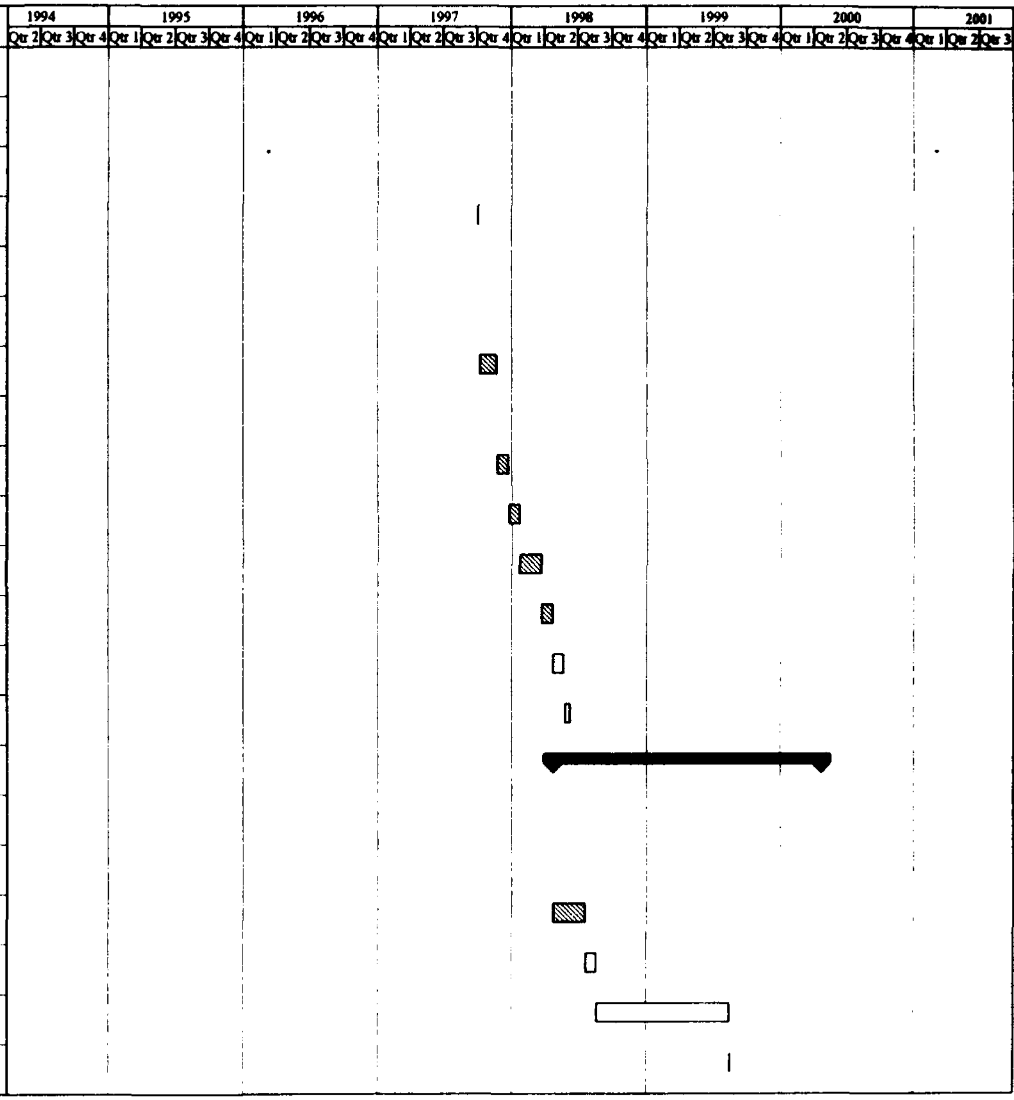
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
43	Reduce uncertainty in	1d	3/25/96	3/25/96	42
44	Reduce uncertainty in	1d	3/26/96	3/26/96	43
45	Reduce uncertainty of	1d	3/27/96	3/27/96	44
46	Reduce uncertainty in	1d	3/28/96	3/28/96	45
47	Reduce uncertainty	1d	3/29/96	3/29/96	46
48	Implement contingency	0d	3/29/96	3/29/96	47
49	Prepare Phase 1	45ed	4/1/96	5/16/96	48
50	Submit Phase 1	1d	5/16/96	5/16/96	49
51	McClellan AFB review	30ed	5/17/96	6/16/96	50
52	Prepare draft copy	30ed	6/17/96	7/17/96	51
53	McClellan AFB and	60ed	7/17/96	9/15/96	52
54	Prepare draft final	30ed	9/16/96	10/16/96	53
55	Agency review draft final	30ed	10/16/96	11/15/96	54
56	Prepare final Phase 1	15ed	11/15/96	11/30/96	55
57	**Phase 2**	**429d**	**10/16/96**	**6/9/98**	
58	Off base monitoring	1d	10/16/96	10/16/96	54
59	Off base extraction	1d	10/16/96	10/16/96	54
60	Hot Spot extraction	1d	10/16/96	10/16/96	54
61	Final layout of wells	62d	10/17/96	1/10/97	58,59,60
62	Prepare for installation	22d	1/13/97	2/11/97	61
63	Installation/Int Data	164d	2/12/97	9/29/97	62



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 3

ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
64	Resolve uncertainty in	1d	9/30/97	9/30/97	63
65	Further reduce uncertainty in	1d	10/1/97	10/1/97	64
66	Resolve uncertainty in	1d	10/2/97	10/2/97	65
67	Resolve uncertainty in	1d	10/3/97	10/3/97	66
68	Resolve uncertainty	1d	10/6/97	10/6/97	67
69	Implement contingency	0d	10/6/97	10/6/97	68
70	Prepare Phase 2	45ed	10/7/97	11/21/97	69
71	Submit Phase 2	1d	11/21/97	11/21/97	70
72	McClellan AFB review	30ed	11/24/97	12/24/97	71
73	Prepare draft copy	30ed	12/24/97	1/23/98	72
74	McClellan AFB and	60ed	1/23/98	3/24/98	73
75	Prepare draft final	30ed	3/24/98	4/23/98	74
76	Agency review draft final	30ed	4/23/98	5/23/98	75
77	Prepare final Phase 2	15ed	5/25/98	6/9/98	76
78	**Phase 3**	**522d**	**4/23/98**	**4/22/00**	
79	On base monitoring	1d	4/23/98	4/23/98	75
80	On base extraction	1d	4/23/98	4/23/98	75
81	Final layout of wells	62d	4/24/98	7/20/98	79,80
82	Prepare for installation	22d	7/21/98	8/19/98	81
83	Installation/Int Data	258d	8/20/98	8/16/99	82
84	Resolve uncertainty in	1d	8/17/99	8/17/99	83

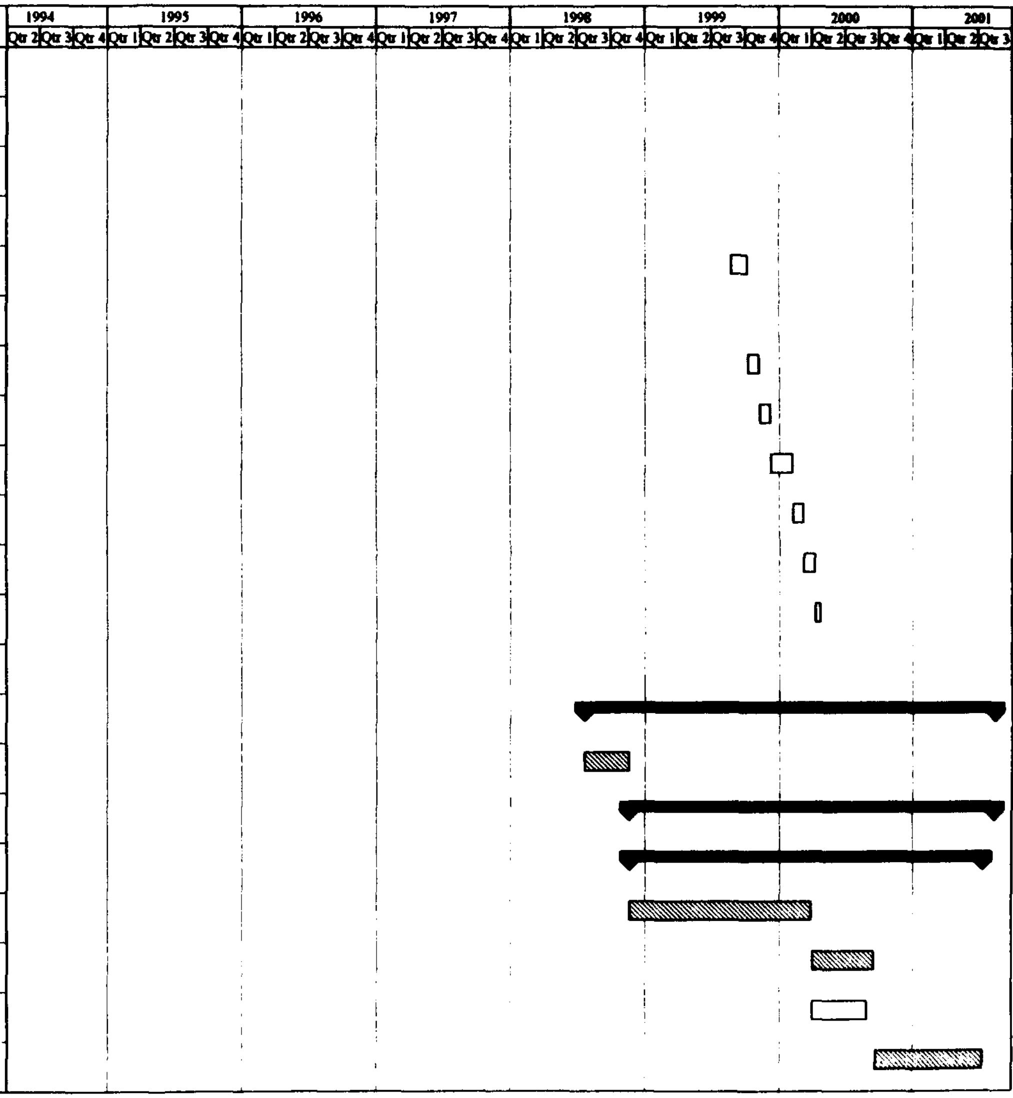


Date: 3/26/94

Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 3

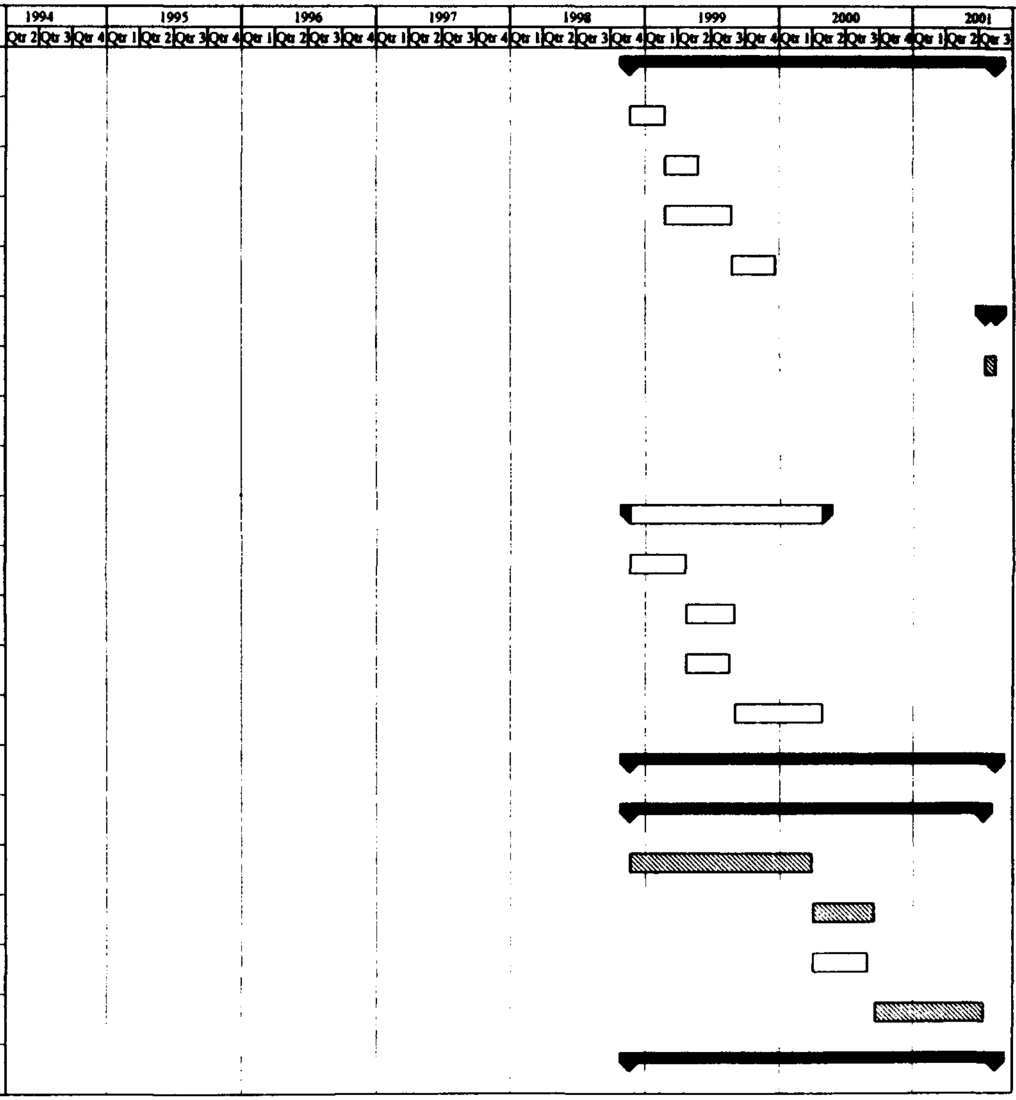
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
85	Resolve uncertainty in	1d	8/18/99	8/18/99	84
86	Resolve uncertainty in	1d	8/19/99	8/19/99	85
87	Resolve uncertainty in	1d	8/20/99	8/20/99	86
88	Implement contingency	0d	8/20/99	8/20/99	87
89	Prepare Phase 3 Report	45ed	8/23/99	10/7/99	88
90	Submit Phase 3 Report	1d	10/7/99	10/7/99	89
91	McClellan AFB review	30ed	10/8/99	11/7/99	90
92	Prepare draft copy	30ed	11/8/99	12/8/99	91
93	McClellan AFB and	60ed	12/8/99	2/6/00	92
94	Prepare draft final	30ed	2/7/00	3/8/00	93
95	Agency review draft final	30ed	3/8/00	4/7/00	94
96	Prepare final Phase 3	15ed	4/7/00	4/22/00	95
97					
98	**Treatment/End Use/ Collection Systems**	**801d**	**7/21/98**	**8/15/01**	
99	Procure turnkey contractor	88d	7/21/98	11/19/98	24,81
100	**Western Area**	**713d**	**11/20/98**	**8/15/01**	
101	**Collection piping**	**691d**	**11/20/98**	**7/13/01**	
102	Prelimin Design	354d	11/20/98	3/29/00	99
103	Final design	122d	3/30/00	9/15/00	102
104	Prepare for	108d	3/30/00	8/28/00	102
105	Construc	215d	9/18/00	7/13/01	88,103,104



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 3

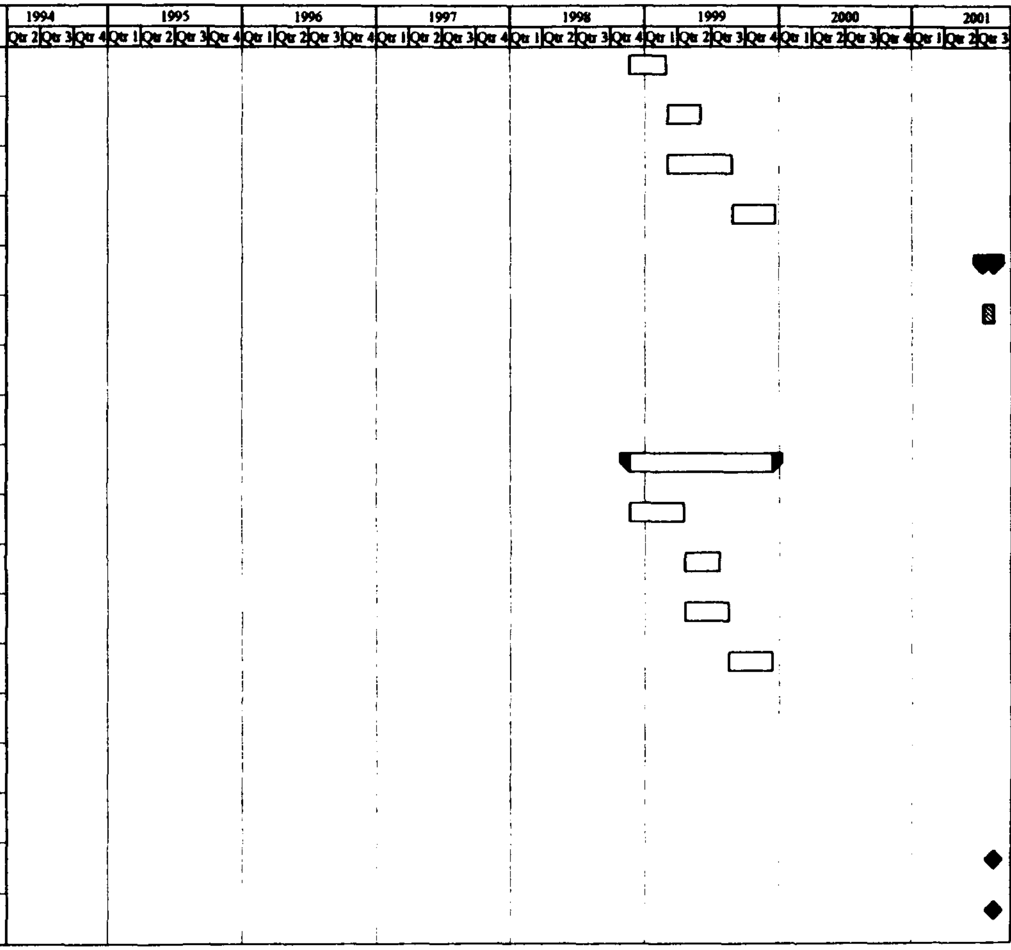
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
106	**Treatment plant**	**713d**	**11/20/98**	**8/15/01**	
107	Prelimin Design	68d	11/20/98	2/23/99	99
108	Final Design	66d	2/24/99	5/26/99	107
109	Prepare for	130d	2/24/99	8/24/99	107
110	Construc	86d	8/25/99	12/22/99	108,109
111	**Start-up**	**22d**	**7/16/01**	**8/15/01**	
112	Star	30ed	7/16/01	8/15/01	105,110
113	Pro con	0d	8/15/01	8/15/01	112
114	Cap con	0d	8/15/01	8/15/01	113
115	**End Use Piping**	**375d**	**11/20/98**	**4/27/00**	
116	Prelimin Design	108d	11/20/98	4/20/99	99
117	Final Design	95d	4/21/99	8/31/99	116
118	Prepare for	86d	4/21/99	8/18/99	116
119	Construc	172d	9/1/99	4/27/00	117,118
120	**Eastern Area**	**713d**	**11/20/98**	**8/15/01**	
121	**Collection piping**	**691d**	**11/20/98**	**7/13/01**	
122	Prelimin Design	354d	11/20/98	3/29/00	99
123	Final design	122d	3/30/00	9/15/00	122
124	Prepare for	108d	3/30/00	8/28/00	122
125	Construc	215d	9/18/00	7/13/01	88,123,124
126	**Treatment plant**	**713d**	**11/20/98**	**8/15/01**	



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

McClellan AFB GWOU RI/FS Alternative 3

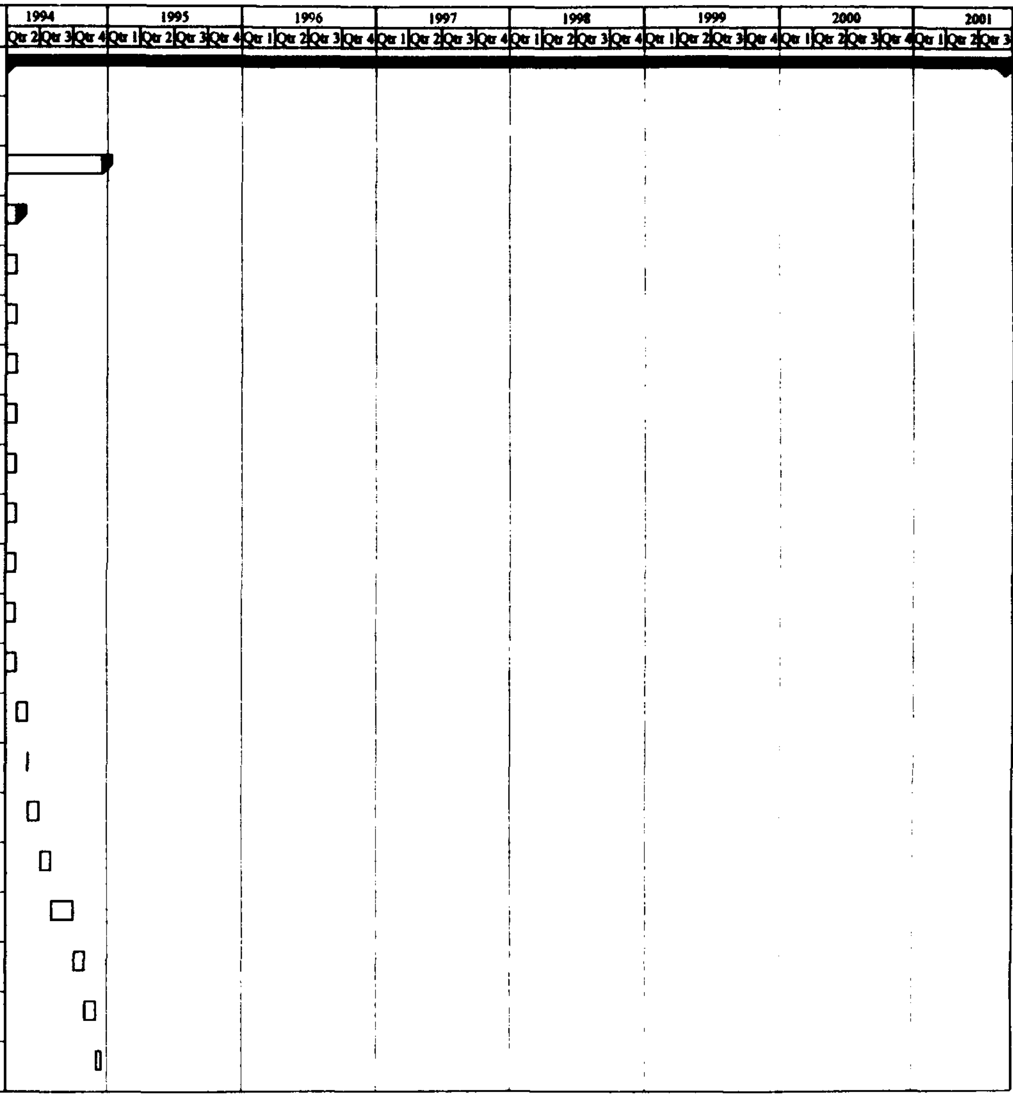
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
127	Prelimin Design	72d	11/20/98	3/1/99	99
128	Final Design	66d	3/2/99	6/1/99	127
129	Prepare for	128d	3/2/99	8/26/99	127
130	Construc (streacon	86d	8/27/99	12/24/99	128,129
131	**Start-up**	**22d**	**7/16/01**	**8/15/01**	
132	Star	30ed	7/16/01	8/15/01	125,130
133	Pro con	0d	8/15/01	8/15/01	132
134	Cap con	0d	8/15/01	8/15/01	133
135	**End Use Piping**	**278d**	**11/20/98**	**12/14/99**	
136	Prelimin Design	106d	11/20/98	4/16/99	99
137	Final Design	70d	4/19/99	7/23/99	136
138	Prepare for	86d	4/19/99	8/16/99	136
139	Construc	86d	8/17/99	12/14/99	137,138
140					
141	**Operation of Remedial Action**	**0d**	**8/15/01**	**8/15/01**	
142	**Containment of Contaminated**	**0d**	**8/15/01**	**8/15/01**	
143	***West Base***	***0d***	***8/15/01***	***8/15/01***	***105,114***
144	***East Base***	***0d***	***8/15/01***	***8/15/01***	***125,134,139***



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

Alternatives 1, 4, 5, and 6 With Implementation of Contingency Plans

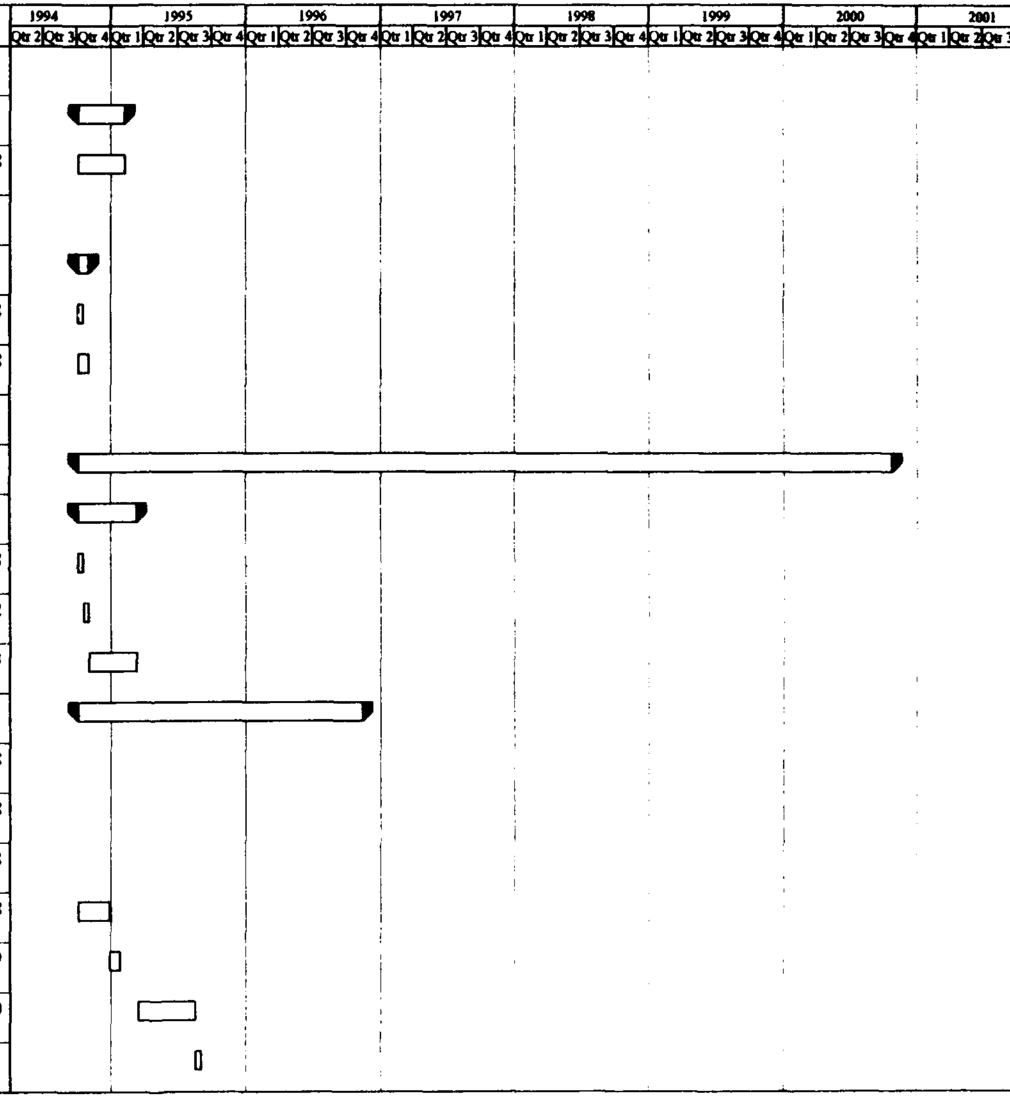
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
1	Alternative 1 (MCL, AS/CATOX, UTILITIES)	1943d	4/1/94	9/11/01	
2					
3	Master Plan/Work Plan of Remedial Action	186d	4/1/94	12/17/94	
4	Develop Remedial Action Master	21d	4/1/94	5/1/94	
5	Extraction System	30ed	4/1/94	5/1/94	
6	Treatment System	30ed	4/1/94	5/1/94	
7	End Use System	30ed	4/1/94	5/1/94	
8	Collection System	30ed	4/1/94	5/1/94	
9	Prepare DQOs	20d	4/1/94	4/28/94	
10	Prepare rationale	20d	4/1/94	4/28/94	
11	Prepare Health and Safety plan	20d	4/1/94	4/28/94	
12	Prepare QAPP	20d	4/1/94	4/28/94	
13	Prepare SAP	30ed	4/1/94	5/1/94	
14	Develop remedial action work plan	30ed	5/2/94	6/1/94	5,6,7,8,9,10,11,12,13
15	Submit RA Master Plan/Work Plan	1d	6/1/94	6/1/94	14
16	McClellan AFB review working	30ed	6/2/94	7/2/94	15
17	Prepare draft copy	30ed	7/4/94	8/3/94	16
18	McClellan AFB and agencies review	60ed	8/3/94	10/2/94	17
19	Prepare draft final	30ed	10/3/94	11/2/94	18
20	Agency review draft final	30ed	11/2/94	12/2/94	19
21	Prepare final Remedial Action	15ed	12/2/94	12/17/94	20



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

Alternatives 1, 4, 5, and 6 With Implementation of Contingency Plans

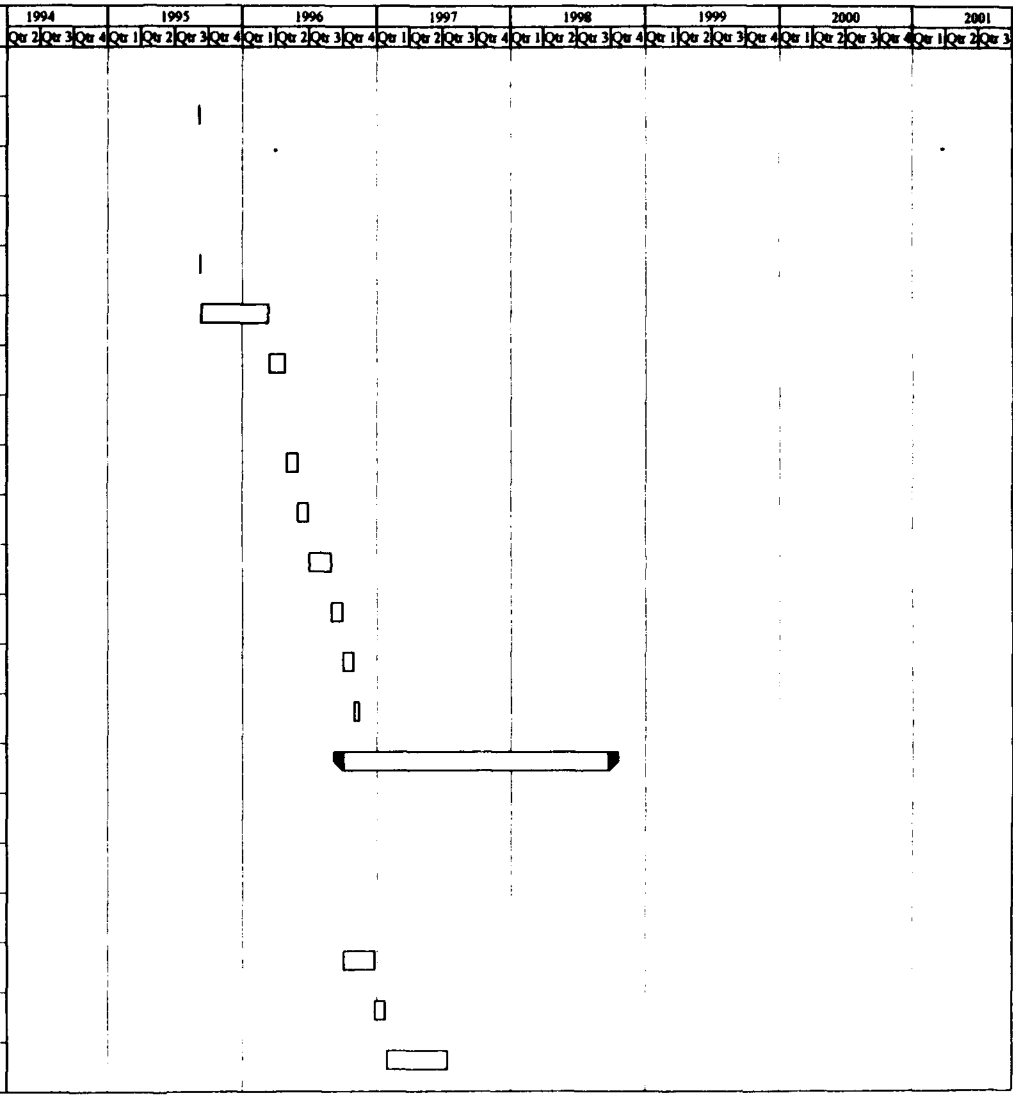
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
22					
23	**Utility Mapping**	**94d**	**10/3/94**	**2/9/95**	
24	Map Utilities (utilmap)	94d	10/3/94	2/9/95	18
25					
26	**On-base/Off-base production wells**	**22d**	**10/3/94**	**11/2/94**	
27	Prepare Base Well 18 abandonment	15ed	10/3/94	10/18/94	18
28	Prepare production well contingency	30ed	10/3/94	11/2/94	18
29					
30	**Extraction System**	**1581d**	**10/3/94**	**10/24/00**	
31	**Subcontractor procurement**	**116d**	**10/3/94**	**3/13/95**	
32	Specify system requirements	15ed	10/3/94	10/18/94	18
33	Identify performance	15ed	10/18/94	11/2/94	32
34	Procure BOAs w/ 3 subs for	94d	11/2/94	3/13/95	33
35	**Task Order 1**	**553d**	**10/3/94**	**11/14/96**	
36	Off base monitoring	1d	10/3/94	10/3/94	18
37	Off base extraction	1d	10/3/94	10/3/94	18
38	Hot Spot extraction	1d	10/3/94	10/3/94	18
39	Prepare final layout of wells	62d	10/4/94	12/28/94	36,37,38
40	Prepare for installation	22d	12/29/94	1/27/95	39
41	Install wells/Interpret	113d	3/14/95	8/17/95	34,40
42	Abandon Base well 18	15ed	8/18/95	9/2/95	27,28,41



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

Alternatives 1, 4, 5, and 6 With Implementation of Contingency Plans

ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
43	Reduce uncertainty in	1d	9/4/95	9/4/95	42
44	Reduce uncertainty in	1d	9/5/95	9/5/95	43
45	Reduce uncertainty of	1d	9/6/95	9/6/95	44
46	Reduce uncertainty in	1d	9/7/95	9/7/95	45
47	Reduce uncertainty	1d	9/8/95	9/8/95	46
48	Implement contingency	132d	9/11/95	3/12/96	47
49	Prepare Phase 1	45ed	3/13/96	4/27/96	48
50	Submit Phase 1	1d	4/29/96	4/29/96	49
51	McClellan AFB review	30ed	4/30/96	5/30/96	50
52	Prepare draft copy	30ed	5/30/96	6/29/96	51
53	McClellan AFB and	60ed	7/1/96	8/30/96	52
54	Prepare draft final	30ed	8/30/96	9/29/96	53
55	Agency review draft final	30ed	9/30/96	10/30/96	54
56	Prepare final Phase I	15ed	10/30/96	11/14/96	55
57	**Task Order 2**	**518d**	**9/30/96**	**9/24/98**	
58	Off base monitoring	1d	9/30/96	9/30/96	54
59	Off base extraction	1d	9/30/96	9/30/96	54
60	Hot Spot extraction	1d	9/30/96	9/30/96	54
61	Prepare final layout of wells	62d	10/1/96	12/25/96	58,59,60
62	Prepare for installation	22d	12/26/96	1/24/97	61
63	Install wells/Interpret	120d	1/27/97	7/11/97	62

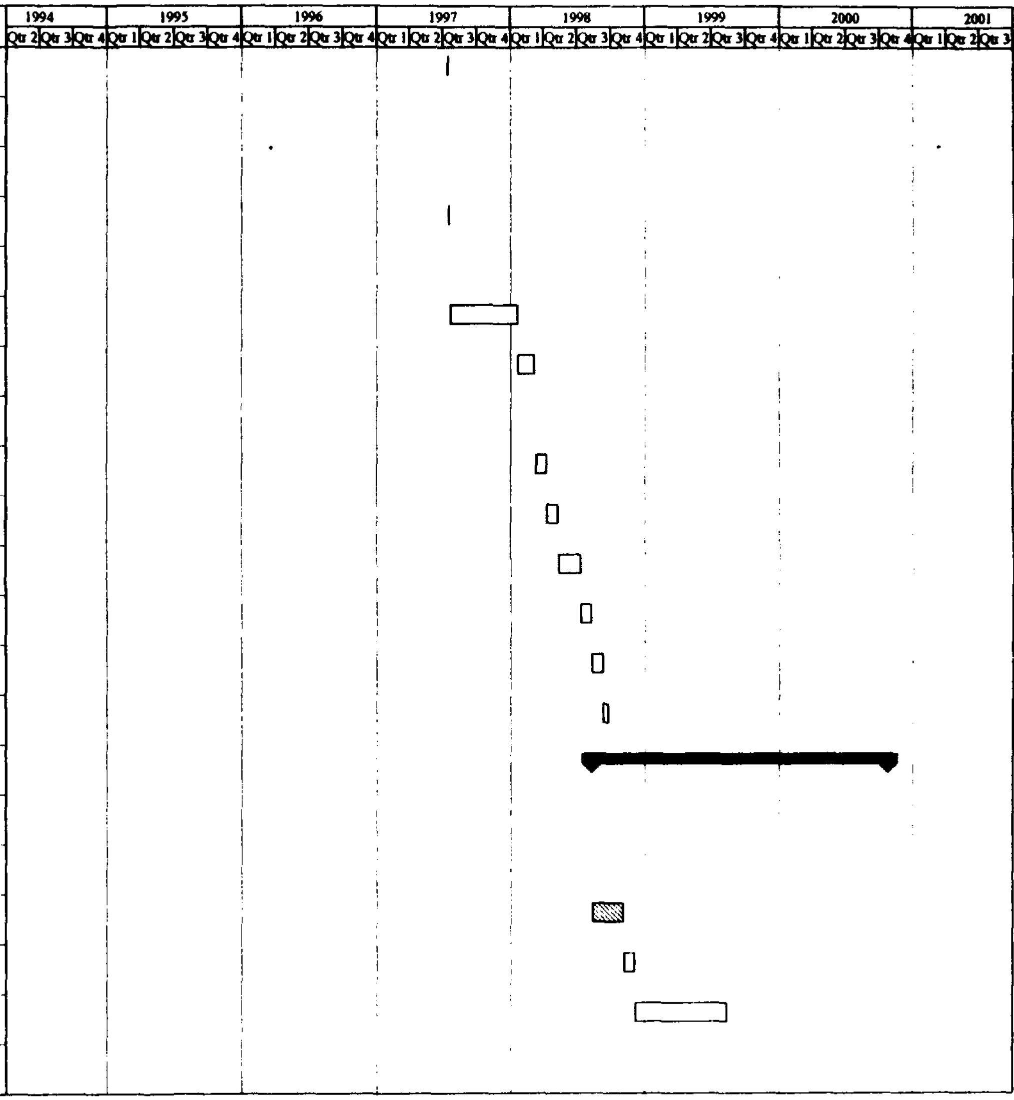


Date: 3/26/94

Critical | Milestone | Summary | Noncritical

Alternatives 1, 4, 5, and 6 With Implementation of Contingency Plans

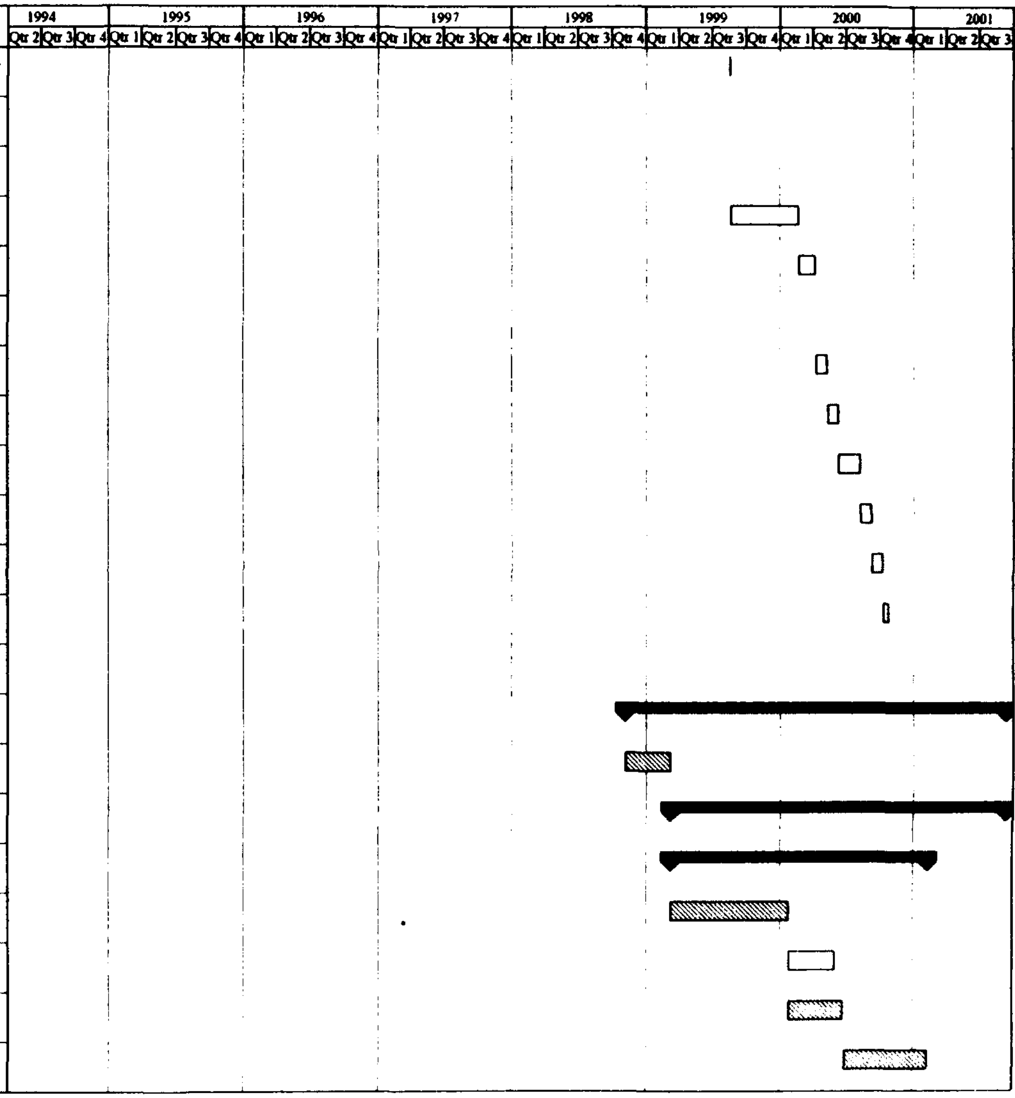
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
64	Resolve uncertainty in	1d	7/14/97	7/14/97	63
65	Further reduce uncertainty in	1d	7/15/97	7/15/97	64
66	Resolve uncertainty in	1d	7/16/97	7/16/97	65
67	Resolve uncertainty in	1d	7/17/97	7/17/97	66
68	Resolve uncertainty	1d	7/18/97	7/18/97	67
69	Implement contingency	132d	7/21/97	1/20/98	68
70	Prepare Phase 2	45ed	1/21/98	3/7/98	69
71	Submit Phase 2	1d	3/9/98	3/9/98	70
72	McClellan AFB review	30ed	3/10/98	4/9/98	71
73	Prepare draft copy	30ed	4/9/98	5/9/98	72
74	McClellan AFB and	60ed	5/11/98	7/10/98	73
75	Prepare draft final	30ed	7/10/98	8/9/98	74
76	Agency review draft final	30ed	8/10/98	9/9/98	75
77	Prepare final Phase 2	15ed	9/9/98	9/24/98	76
78	**Task Order 3**	**576d**	**8/10/98**	**10/24/00**	
79	On base monitoring	1d	8/10/98	8/10/98	75
80	On base extraction	1d	8/10/98	8/10/98	75
81	Prepare final layout of wells	62d	8/11/98	11/4/98	79,80
82	Prepare for installation	22d	11/5/98	12/4/98	81
83	Install/Interpre Data	180d	12/7/98	8/13/99	82
84	Resolve uncertainty in	1d	8/16/99	8/16/99	83



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

Alternatives 1, 4, 5, and 6 With Implementation of Contingency Plans

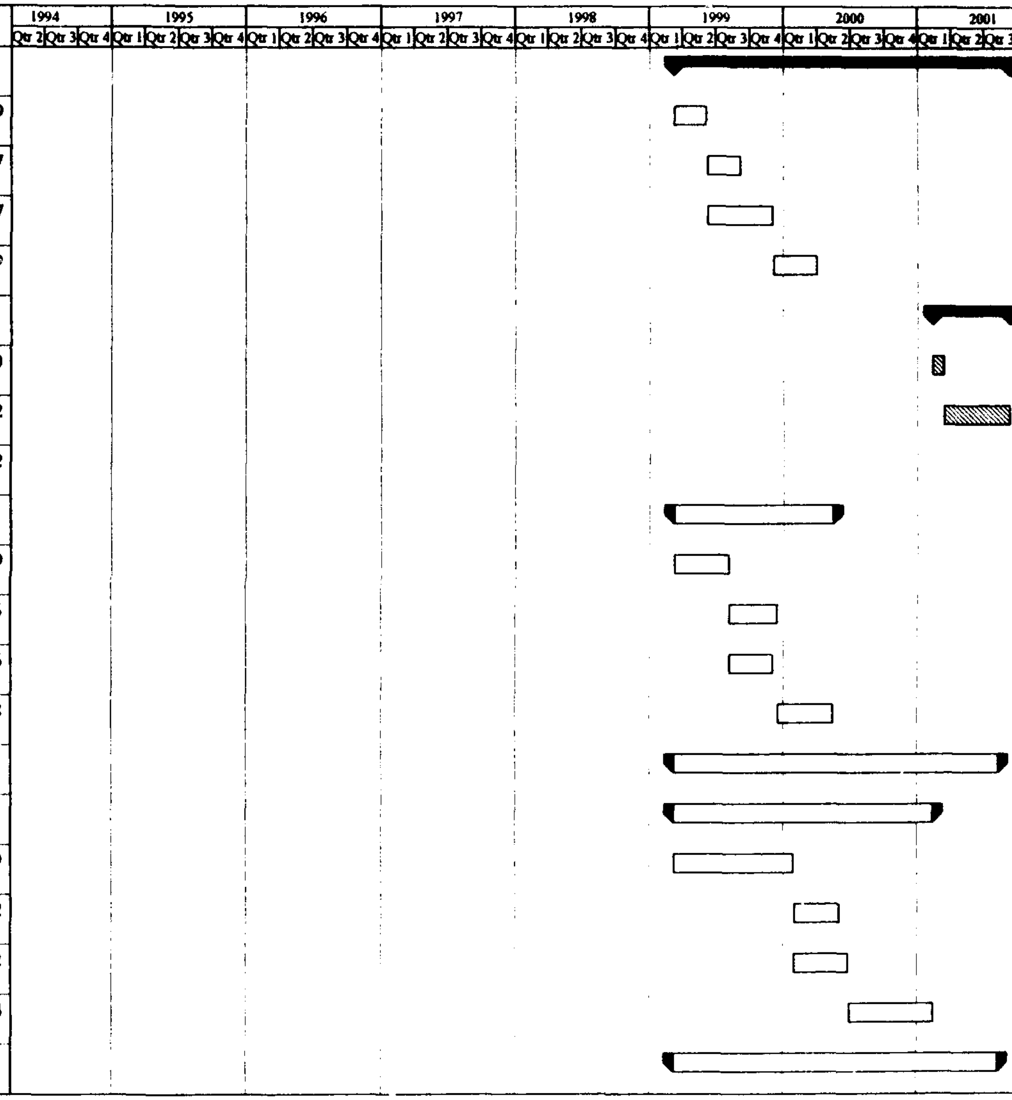
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
85	Resolve uncertainty in	1d	8/17/99	8/17/99	84
86	Resolve uncertainty in	1d	8/18/99	8/18/99	85
87	Resolve uncertainty in	1d	8/19/99	8/19/99	86
88	Implement contingency	132d	8/20/99	2/21/00	87
89	Prepare Phase 3 Report	45ed	2/22/00	4/7/00	88
90	Submit Phase 3 Report	1d	4/7/00	4/7/00	89
91	McClellan AFB review	30ed	4/10/00	5/10/00	90
92	Prepare draft copy	30ed	5/10/00	6/9/00	91
93	McClellan AFB and	60ed	6/9/00	8/8/00	92
94	Prepare draft final	30ed	8/8/00	9/7/00	93
95	Agency review draft final	30ed	9/7/00	10/7/00	94
96	Prepare final Phase 3	15ed	10/9/00	10/24/00	95
97					
98	**Treatment/End Use/ Collection Systems**	**744d**	**11/5/98**	**9/11/01**	
99	Procure turnkey contractor	88d	11/5/98	3/8/99	24,81
100	**Western Area**	**656d**	**3/9/99**	**9/11/01**	
101	**Collection piping**	**504d**	**3/9/99**	**2/9/01**	
102	Prepare prelimina	231d	3/9/99	1/25/00	99
103	Prepare final	90d	1/26/00	5/30/00	102
104	Prepare for	108d	1/26/00	6/23/00	102
105	Construc piping	165d	6/26/00	2/9/01	88,103,104



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

Alternatives 1, 4, 5, and 6 With Implementation of Contingency Plans

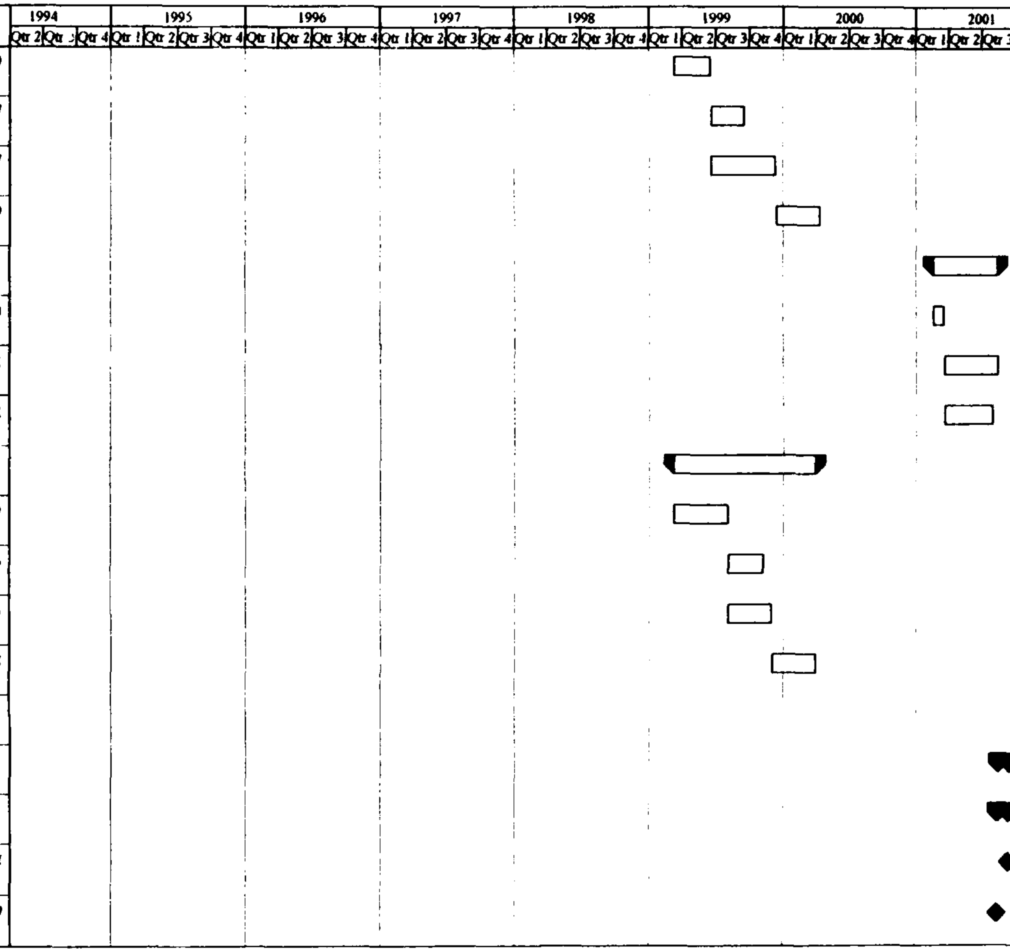
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
106	**Treatment plant**	**656d**	**3/9/99**	**9/11/01**	
107	Prepare prelimina	64d	3/9/99	6/4/99	99
108	Prepare final	66d	6/7/99	9/6/99	107
109	Prepare for	130d	6/7/99	12/3/99	107
110	Construc treatment	86d	12/6/99	4/3/00	108,109
111	**Start-up**	**152d**	**2/12/01**	**9/11/01**	
112	Co Star	30ed	2/12/01	3/14/01	105,110
113	Imp pro	130d	3/14/01	9/11/01	112
114	Imp cap	0d	3/14/01	3/14/01	112
115	**End Use Piping**	**311d**	**3/9/99**	**5/16/00**	
116	Prepare prelimina	108d	3/9/99	8/5/99	99
117	Prepare final	95d	8/6/99	12/16/99	116
118	Prepare for	86d	8/6/99	12/3/99	116
119	Construc end use	108d	12/17/99	5/16/00	117,118
120	**Eastern Area**	**636d**	**3/9/99**	**8/14/01**	
121	**Collection piping**	**508d**	**3/9/99**	**2/15/01**	
122	Prepare prelimina	234d	3/9/99	1/28/00	99
123	Prepare final	90d	1/31/00	6/2/00	122
124	Prepare for	108d	1/31/00	6/28/00	122
125	Construc collectio	166d	6/29/00	2/15/01	88,123,124
126	**Treatment plant**	**636d**	**3/9/99**	**8/14/01**	



Date: 3/26/94 **Critical** **Milestone** ◆ **Summary** **Noncritical**

Alternatives 1, 4, 5, and 6 With Implementation of Contingency Plans

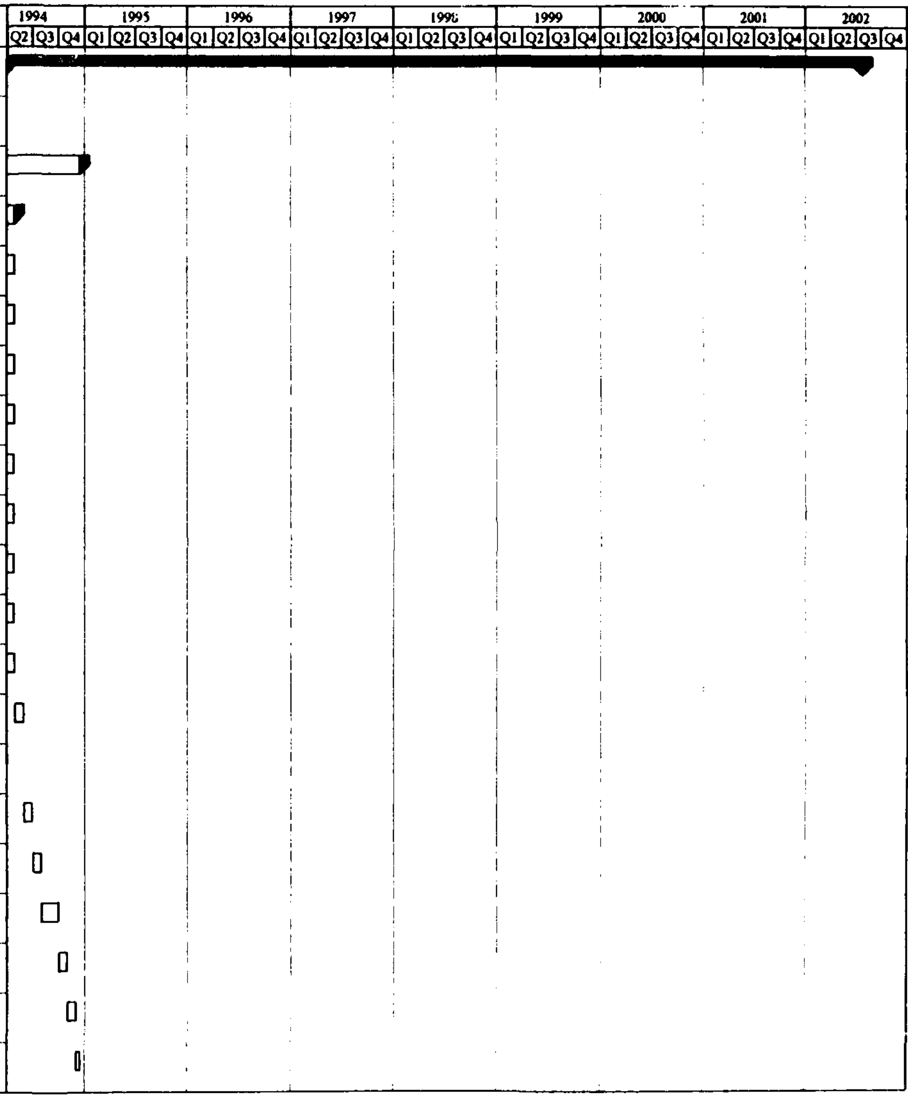
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
127	Prepare prelimina	72d	3/9/99	6/16/99	99
128	Prepare final	66d	6/17/99	9/16/99	127
129	Prepare for	128d	6/17/99	12/13/99	127
130	Construc treatment	87d	12/14/99	4/12/00	128,129
131	**Start-up**	**128d**	**2/16/01**	**8/14/01**	
132	Co Star	30ed	2/16/01	3/18/01	125,130
133	Imp pro	107d	3/19/01	8/14/01	132
134	Imp cap	96d	3/19/01	7/30/01	132
135	**End Use Piping**	**278d**	**3/9/99**	**3/30/00**	
136	Prepare prelimina	106d	3/9/99	8/3/99	99
137	Prepare final	70d	8/4/99	11/9/99	136
138	Prepare for	86d	8/4/99	12/1/99	136
139	Construc end use	86d	12/2/99	3/30/00	137,138
140					
141	**Operation of Remedial Action**	**20d**	**8/14/01**	**9/11/01**	
142	**Containment of Contaminated**	**20d**	**8/14/01**	**9/11/01**	
143	***West Base***	***0d***	***9/11/01***	***9/11/01***	***105,113,114***
144	***East Base***	***0d***	***8/14/01***	***8/14/01***	***125,133,134,139***



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

Alternative 2 With Implementation of Contingency Plans

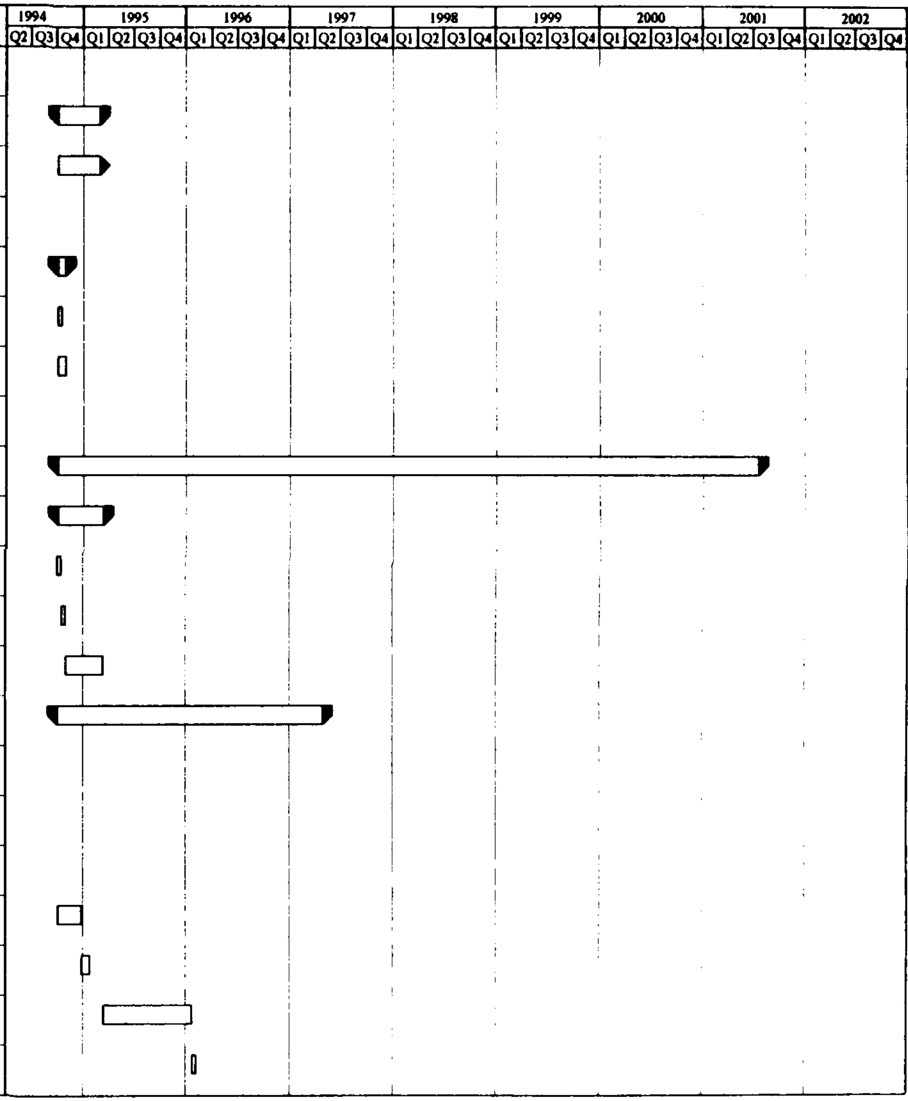
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
1	**Alternative 2 (CANCER RISK, AS/CATOX, UTILITIES) Draft final**	**2171d**	**4/1/94**	**7/26/02**	
2					
3	**Master Plan/Work Plan of Remedial Action**	**186d**	**4/1/94**	**12/17/94**	
4	**Develop Remedial Action Master Plan**	**21d**	**4/1/94**	**5/1/94**	
5	Extraction System	30ed	4/1/94	5/1/94	
6	Treatment System	30ed	4/1/94	5/1/94	
7	End Use System	30ed	4/1/94	5/1/94	
8	Collection System	30ed	4/1/94	5/1/94	
9	Prepare DQOs	20d	4/1/94	4/28/94	
10	Prepare rationale	20d	4/1/94	4/28/94	
11	Prepare Health and Safety plan	20d	4/1/94	4/28/94	
12	Prepare QAPP	20d	4/1/94	4/28/94	
13	Prepare SAP	30ed	4/1/94	5/1/94	
14	Develop remedial action work plan	30ed	5/2/94	6/1/94	5,6,7,8,9,10,11,12,13
15	Submit RA Master Plan/Work Plan Working Copy	1d	6/1/94	6/1/94	14
16	McClellan AFB review working copy	30ed	6/2/94	7/2/94	15
17	Prepare draft copy	30ed	7/4/94	8/3/94	16
18	McClellan AFB and agencies review draft document	60ed	8/3/94	10/2/94	17
19	Prepare draft final	30ed	10/3/94	11/2/94	18
20	Agency review draft final	30ed	11/2/94	12/2/94	19
21	Prepare final Remedial Action Master Plan and Work Plan	15ed	12/2/94	12/17/94	20



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

Alternative 2 With Implementation of Contingency Plans

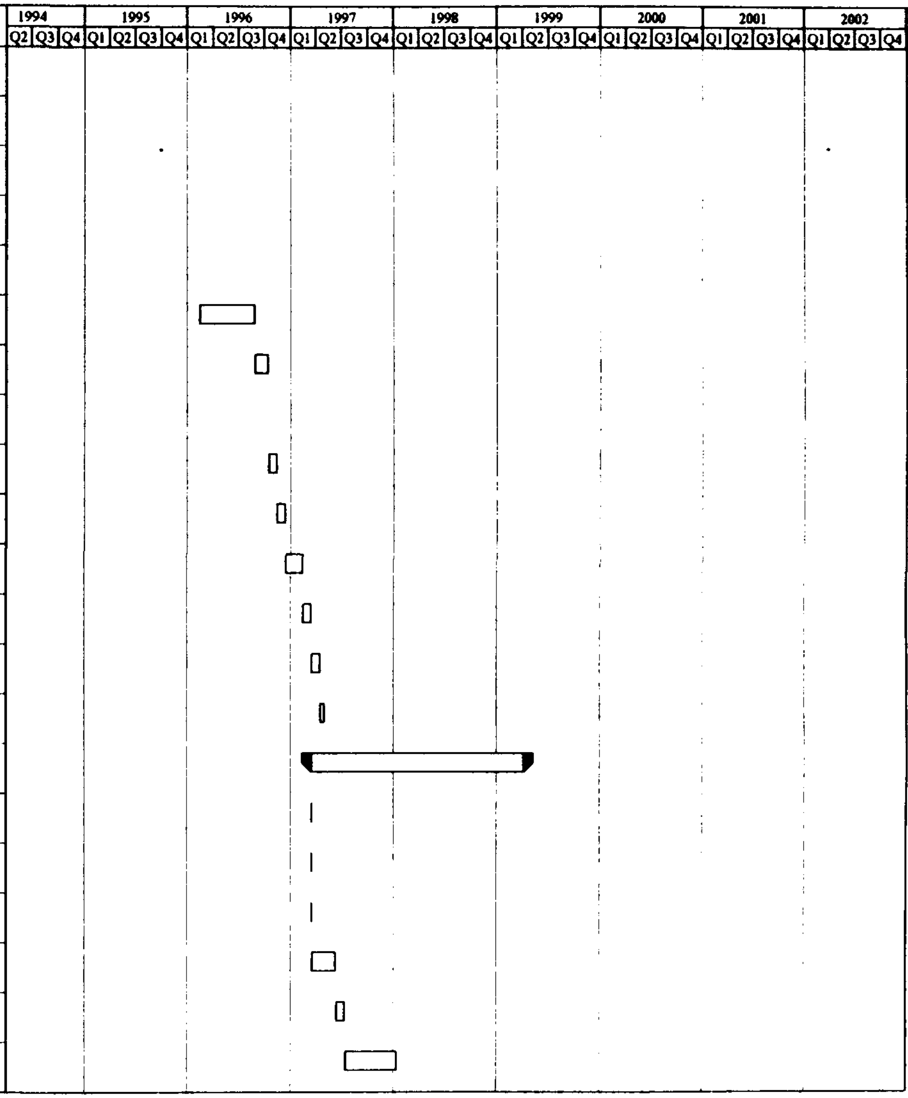
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
22					
23	**Utility Mapping**	**109d**	**10/3/94**	**3/2/95**	
24	***Map utilities (utilmap)***	***109d***	***10/3/94***	***3/2/95***	***18***
25					
26	**On-base/Off-base production wells**	**22d**	**10/3/94**	**11/2/94**	
27	Prepare Base Well 18 abandonment program	15ed	10/3/94	10/18/94	18
28	Prepare production well contingency plans	30ed	10/3/94	11/2/94	18
29					
30	**Extraction System**	**1773d**	**10/3/94**	**7/19/01**	
31	**Subcontractor procurement**	**116d**	**10/3/94**	**3/13/95**	
32	Specify system requirements	15ed	10/3/94	10/18/94	18
33	Identify performance criteria	15ed	10/18/94	11/2/94	32
34	Procure BOAs w/ 3 subs for Basewide EW/MW	94d	11/2/94	3/13/95	33
35	**Task Order 1**	**673d**	**10/3/94**	**5/1/97**	
36	Off base monitoring wells(19)	1d	10/3/94	10/3/94	18
37	Off base extraction wells(8) w/ well head treatment	1d	10/3/94	10/3/94	18
38	Hot Spot extraction wells(15)	1d	10/3/94	10/3/94	18
39	Final layout of wells (wellfides)	62d	10/4/94	12/28/94	36,37,38
40	Prepare for installation (wellprep)	22d	12/29/94	1/27/95	39
41	Installation/Interpret Data (wellins1)	225d	3/14/95	1/22/96	34,40
42	Abandon Base well 18	15ed	1/23/96	2/7/96	27,28,41



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

Alternative 2 With Implementation of Contingency Plans

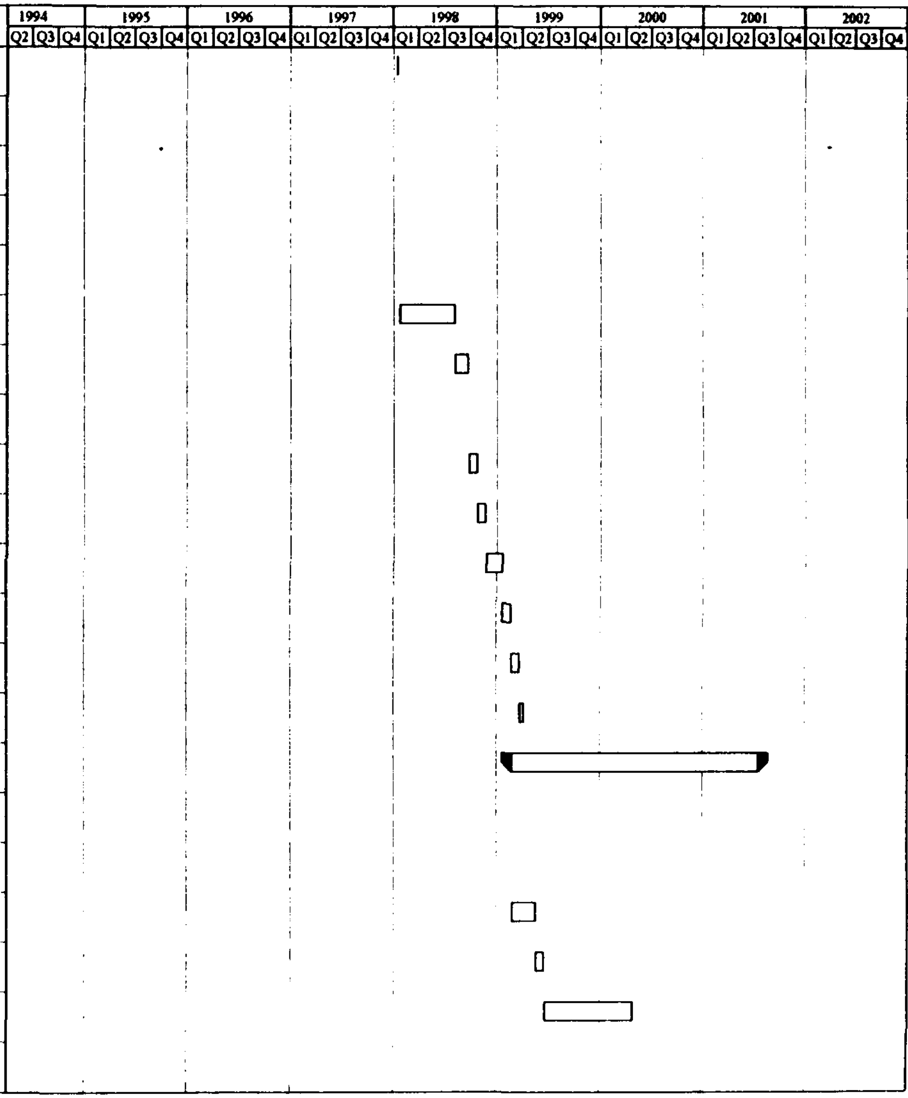
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
43	Reduce uncertainty in extent of contamination off base/hot	1d	2/7/96	2/7/96	42
44	Reduce uncertainty in off-base/hot spot flows to	1d	2/8/96	2/8/96	43
45	Reduce uncertainty of location and number of wells	1d	2/9/96	2/9/96	44
46	Reduce uncertainty in aquifer response	1d	2/12/96	2/12/96	45
47	Reduce uncertainty concerning potential	1d	2/13/96	2/13/96	46
48	Implement contingency plan (if necessary)/revise model	140d	2/14/96	8/27/96	47
49	Prepare Phase 1 Report/Phase 2 Plan	45ed	8/28/96	10/12/96	48
50	Submit Phase 1 Report/Phase 2 Plan Working Copy	1d	10/14/96	10/14/96	49
51	McClellan AFB review working copy	30ed	10/15/96	11/14/96	50
52	Prepare draft copy	30ed	11/14/96	12/14/96	51
53	McClellan AFB and agencies review draft document	60ed	12/16/96	2/14/97	52
54	Prepare draft final	30ed	2/14/97	3/16/97	53
55	Agency review draft final	30ed	3/17/97	4/16/97	54
56	Prepare final Phase 1 Report/Phase 2 Plan	15ed	4/16/97	5/1/97	55
57	**Task Order 2**	**538d**	**3/17/97**	**4/8/99**	
58	Off base monitoring wells(10)	1d	3/17/97	3/17/97	54
59	Off base extraction wells(22) w/ well head treatment	1d	3/17/97	3/17/97	54
60	Hot Spot extraction wells(14)	1d	3/17/97	3/17/97	54
61	Final layout of wells (wellfides)	62d	3/18/97	6/11/97	58,59,60
62	Prepare for installation (wellprep)	22d	6/12/97	7/11/97	61
63	Installation/Interpret Data (wellins1)	133d	7/14/97	1/14/98	62



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

Alternative 2 With Implementation of Contingency Plans

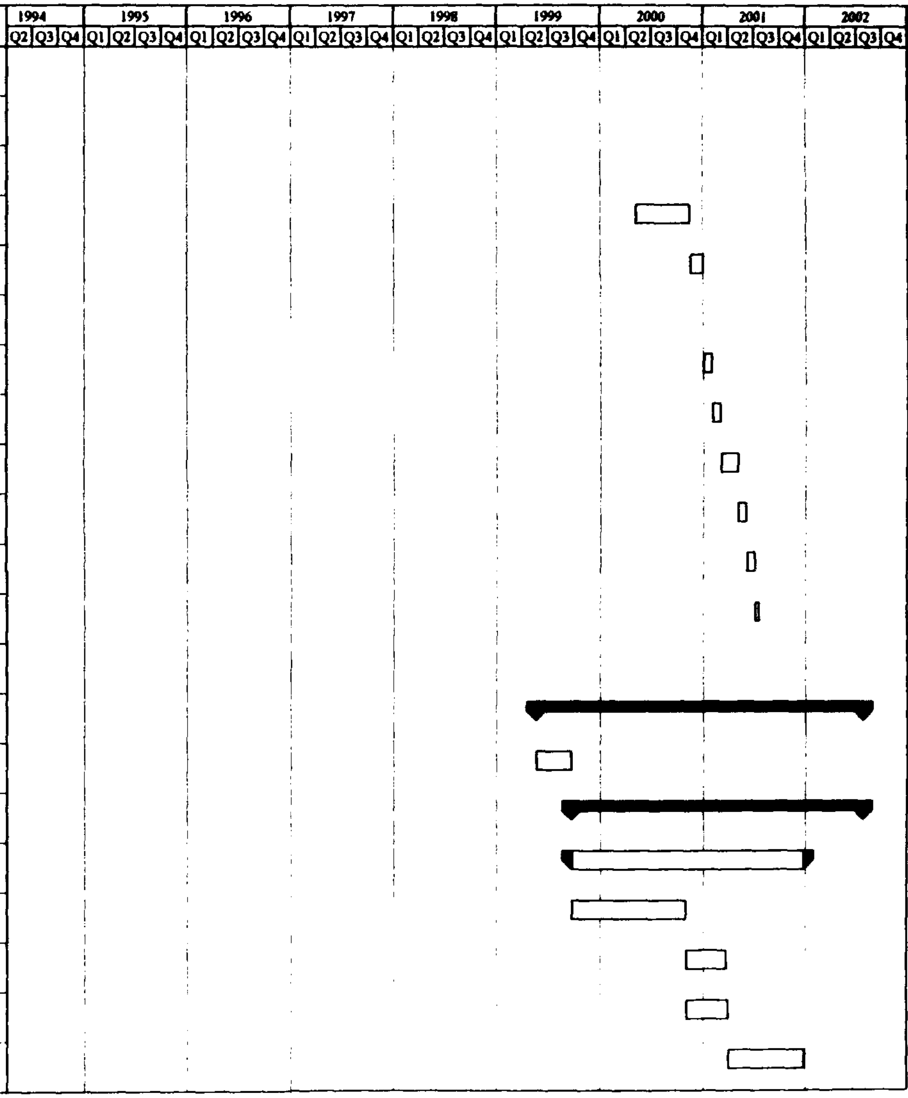
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
64	Resolve uncertainty in extent of contamination off base/hot	1d	1/15/98	1/15/98	63
65	Further reduce uncertainty in aquifer response	1d	1/16/98	1/16/98	64
66	Resolve uncertainty in location and number of	1d	1/19/98	1/19/98	65
67	Resolve uncertainty in off-base/hot spot flows to	1d	1/20/98	1/20/98	66
68	Resolve uncertainty concerning potential	1d	1/21/98	1/21/98	67
69	Implement contingency plan (if necessary)/revise model	140d	1/22/98	8/5/98	68
70	Prepare Phase 2 Report/Phase 3 Plan	45ed	8/6/98	9/20/98	69
71	Submit Phase 2 Report/Phase 3 Plan Working Copy	1d	9/21/98	9/21/98	70
72	McClellan AFB review working copy	30ed	9/22/98	10/22/98	71
73	Prepare draft copy	30ed	10/22/98	11/21/98	72
74	McClellan AFB and agencies review draft document	60ed	11/23/98	1/22/99	73
75	Prepare draft final	30ed	1/22/99	2/21/99	74
76	Agency review draft final	30ed	2/22/99	3/24/99	75
77	Prepare final Phase 2 Report/Phase 3 Plan	15ed	3/24/99	4/8/99	76
78	**Task Order 3**	**628d**	**2/22/99**	**7/19/01**	
79	On base monitoring wells(68)	1d	2/22/99	2/22/99	75
80	On base extraction wells(94)	1d	2/22/99	2/22/99	75
81	Final layout of wells (wellfides)	62d	2/23/99	5/19/99	79,80
82	Prepare for installation (wellprep)	22d	5/20/99	6/18/99	81
83	Installation/Interpret Data (wellins3)	225d	6/21/99	4/28/00	82
84	Resolve uncertainty in extent of contamination off base/hot	1d	5/1/00	5/1/00	83



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

Alternative 2 With Implementation of Contingency Plans

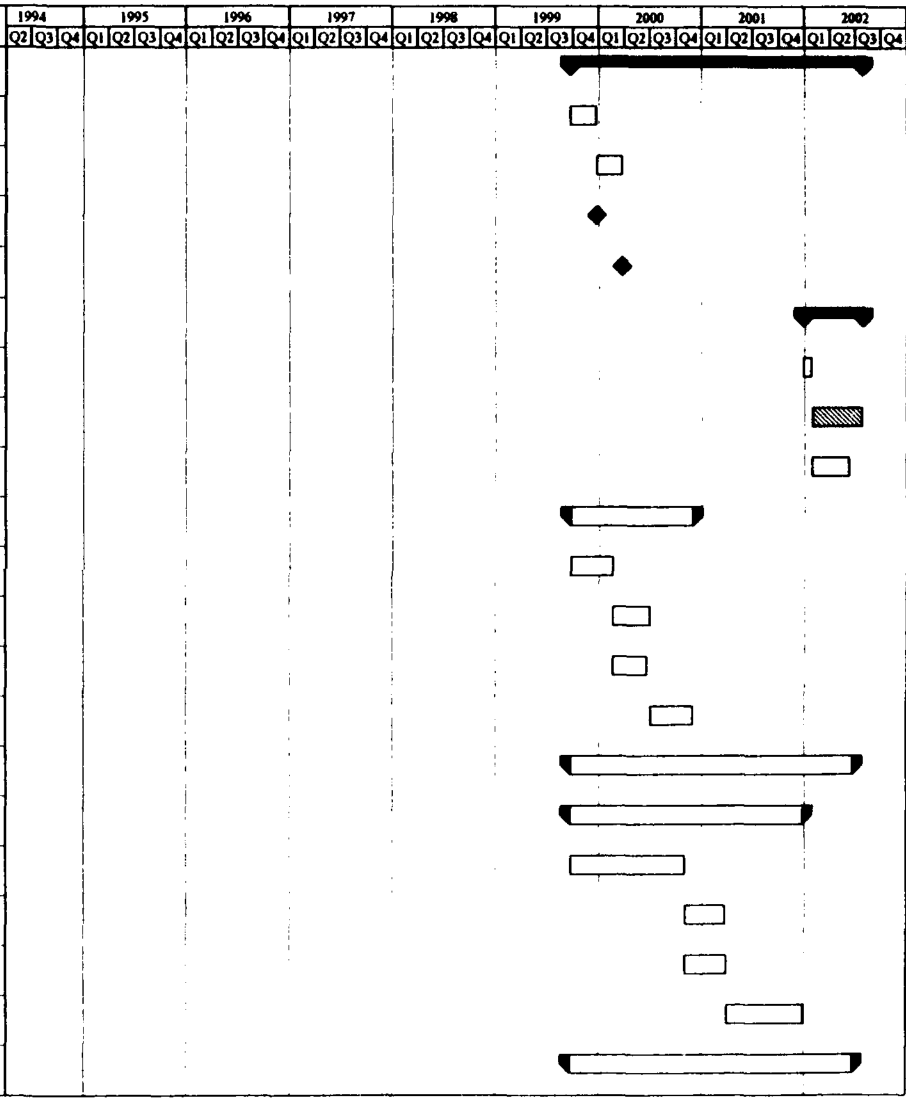
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
85	Resolve uncertainty in aquifer response	1d	5/2/00	5/2/00	84
86	Resolve uncertainty in location and number of	1d	5/3/00	5/3/00	85
87	Resolve uncertainty in on base flow to treatment plants	1d	5/4/00	5/4/00	86
88	Implement contingency plan (if necessary)/revise model	140d	5/5/00	11/16/00	87
89	Prepare Phase 3 Report	45ed	11/17/00	1/1/01	88
90	Submit Phase 3 Report Working Copy	1d	1/1/01	1/1/01	89
91	McClellan AFB review working copy	30ed	1/2/01	2/1/01	90
92	Prepare draft copy	30ed	2/1/01	3/3/01	91
93	McClellan AFB and agencies review draft document	60ed	3/5/01	5/4/01	92
94	Prepare draft final	30ed	5/4/01	6/3/01	93
95	Agency review draft final	30ed	6/4/01	7/4/01	94
96	Prepare final Phase 3 Report	15ed	7/4/01	7/19/01	95
97					
98	**Treatment/End Use/ Collection Systems**	**832d**	**5/20/99**	**7/26/02**	
99	Procure turnkey contractor (contproc)	88d	5/20/99	9/20/99	24,81
100	**Western Area**	**744d**	**9/21/99**	**7/26/02**	
101	**Collection piping**	**592d**	**9/21/99**	**12/26/01**	
102	Preliminary Design (wcolde60)	290d	9/21/99	10/30/00	99
103	Final design (wcolde95)	103d	10/31/00	3/22/01	102
104	Prepare for construction (wcolprep)	108d	10/31/00	3/29/01	102
105	Construction (wcollcon)	194d	3/30/01	12/26/01	88,103,104



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

Alternative 2 With Implementation of Contingency Plans

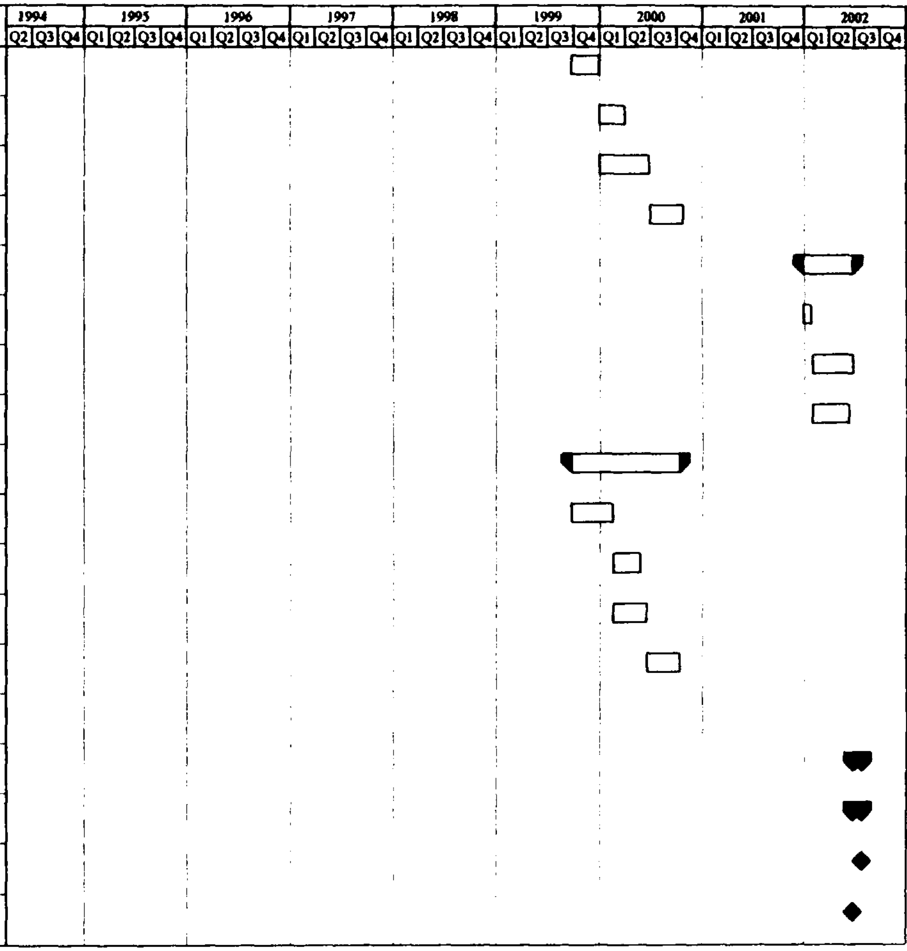
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
106	**Treatment plant**	**744d**	**9/21/99**	**7/26/02**	
107	Preliminary Design (wtrea60)	67d	9/21/99	12/22/99	99
108	Final Design (wtrea95)	66d	12/23/99	3/23/00	107
109	***Prepare for Construction***	***0d***	***12/22/99***	***12/22/99***	***107***
110	***Construction (wtreacon)***	***0d***	***3/23/00***	***3/23/00***	***108,109***
111	**Start-up/Shakedown**	**152d**	**12/27/01**	**7/26/02**	
112	Start-up/Shakedo	30ed	12/27/01	1/26/02	105,110
113	Process contingency plan	130d	1/28/02	7/26/02	112
114	Capacity contingency plan	96d	1/28/02	6/10/02	112
115	**End Use Piping**	**311d**	**9/21/99**	**11/28/00**	
116	Preliminary Design (wendu60)	108d	9/21/99	2/17/00	99
117	Final Design (wendu95)	95d	2/18/00	6/29/00	116
118	Prepare for construction (wendupre)	86d	2/18/00	6/16/00	116
119	Construction (wendcons)	108d	6/30/00	11/28/00	117,118
120	**Eastern Area**	**720d**	**9/21/99**	**6/24/02**	
121	**Collection piping**	**592d**	**9/21/99**	**12/26/01**	
122	Preliminary Design (ecolde60)	290d	9/21/99	10/30/00	99
123	Final design (ecolde95)	103d	10/31/00	3/22/01	122
124	Prepare for construction (ecolprep)	108d	10/31/00	3/29/01	122
125	Construction (ecollcon)	194d	3/30/01	12/26/01	88,123,124
126	**Treatment plant**	**720d**	**9/21/99**	**6/24/02**	



Date: 3/26/94 Critical Milestone Summary Noncritical

Alternative 2 With Implementation of Contingency Plans

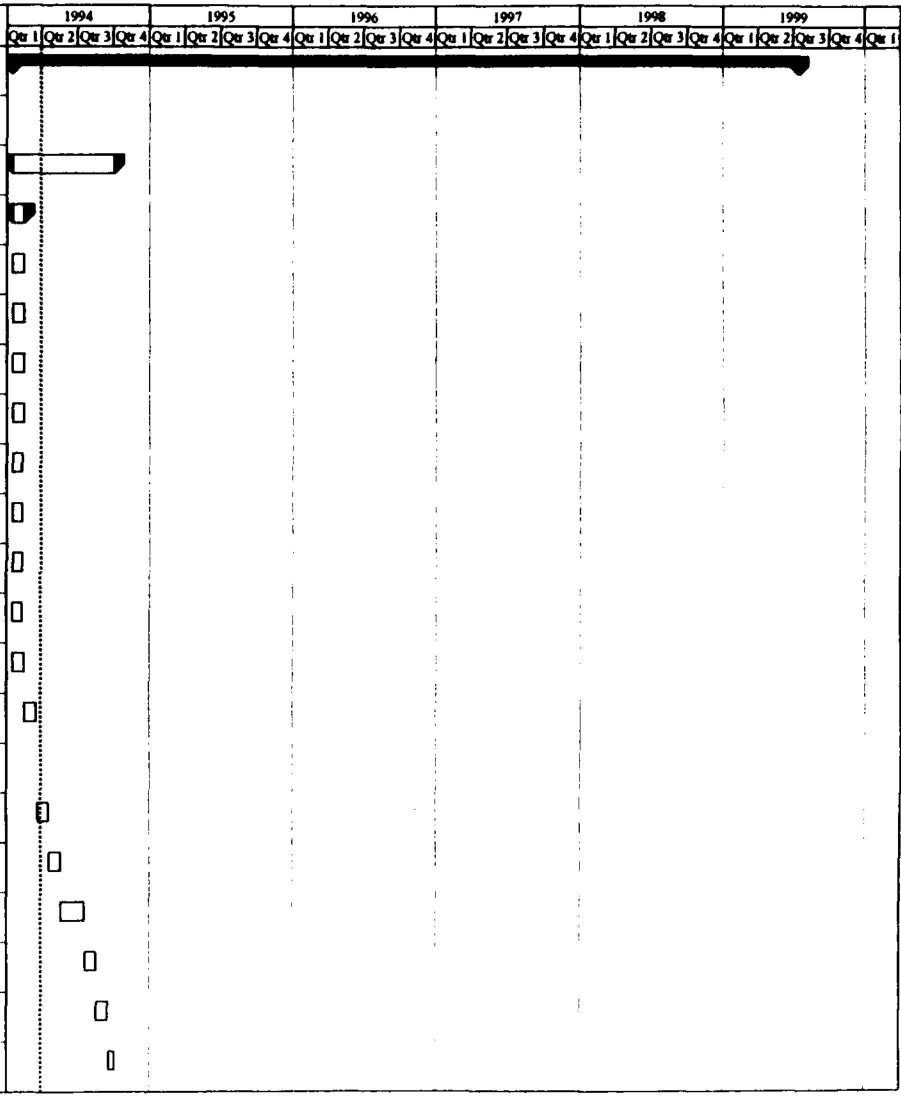
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
127	Preliminary Design (etrea60)	72d	9/21/99	12/29/99	99
128	Final Design (etrea95)	66d	12/30/99	3/30/00	127
129	Prepare for Construction	128d	12/30/99	6/26/00	127
130	Construction (etreacon)	87d	6/27/00	10/25/00	128,129
131	**Start-up/Shakedown**	**128d**	**12/27/01**	**6/24/02**	
132	Start-up/Shakedo	30ed	12/27/01	1/26/02	125,130
133	Process contingency plan	106d	1/28/02	6/24/02	132
134	Capacity contingency plan	96d	1/28/02	6/10/02	132
135	**End Use Piping**	**278d**	**9/21/99**	**10/12/00**	
136	Preliminary Design (eendu60)	106d	9/21/99	2/15/00	99
137	Final Design (eendu95)	70d	2/16/00	5/23/00	136
138	Prepare for construction (eendupre)	86d	2/16/00	6/14/00	136
139	Construction (eendcons)	86d	6/15/00	10/12/00	137,138
140					
141	**Operation of Remedial Action**	**24d**	**6/24/02**	**7/26/02**	
142	**Containment of Contaminated Target Volume**	**24d**	**6/24/02**	**7/26/02**	
143	***West Base***	***0d***	***7/26/02***	***7/26/02***	***105,113,114***
144	***East Base***	***0d***	***6/24/02***	***6/24/02***	***125,133,134,139***



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

Alternative 3 With Implementation of Contingency Plans

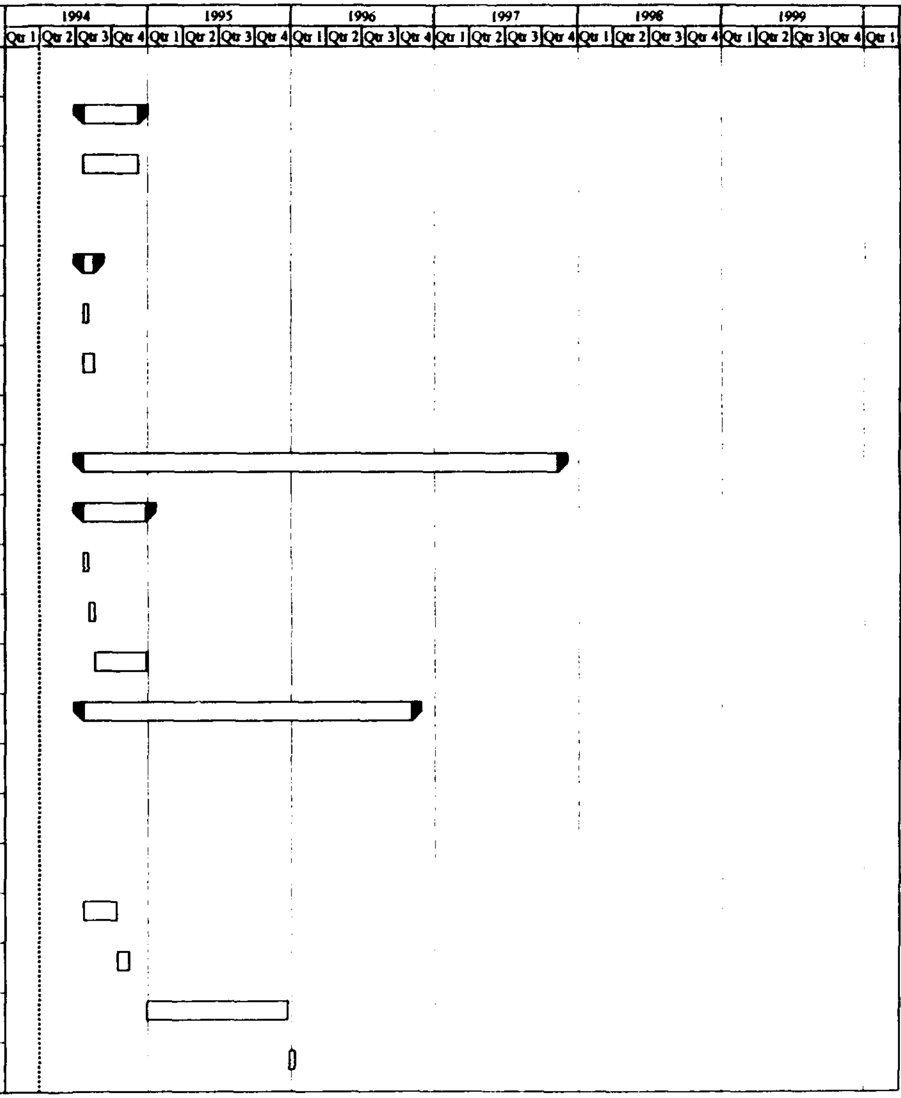
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
1	**Alternative 3 (BACKGROUND, AS/CATOX, UTILITIES)**	**1433d**	**1/17/94**	**7/15/99**	
2					
3	**Master Plan/Work Plan of Remedial Action**	**186d**	**1/17/94**	**10/4/94**	
4	**Develop Remedial Action Master Plan**	**22d**	**1/17/94**	**2/16/94**	
5	Extraction System	30ed	1/17/94	2/16/94	
6	Treatment System	30ed	1/17/94	2/16/94	
7	End Use System	30ed	1/17/94	2/16/94	
8	Collection System	30ed	1/17/94	2/16/94	
9	Prepare DQOs	20d	1/17/94	2/11/94	
10	Prepare rationale	20d	1/17/94	2/11/94	
11	Prepare Health and Safety plan	20d	1/17/94	2/11/94	
12	Prepare QAPP	20d	1/17/94	2/11/94	
13	Prepare SAP	30ed	1/17/94	2/16/94	
14	Develop remedial action work plan	30ed	2/16/94	3/18/94	5,6,7,8,9,10,11,12,13
15	Submit RA Master Plan/Work Plan Working Copy	1d	3/18/94	3/18/94	14
16	McClellan AFB review working copy	30ed	3/21/94	4/20/94	15
17	Prepare draft copy	30ed	4/20/94	5/20/94	16
18	McClellan AFB and agencies review draft document	60ed	5/20/94	7/19/94	17
19	Prepare draft final	30ed	7/19/94	8/18/94	18
20	Agency review draft final	30ed	8/18/94	9/17/94	19
21	Prepare final Remedial Action Master Plan and Work Plan	15ed	9/19/94	10/4/94	20



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

Alternative 3 With Implementation of Contingency Plans

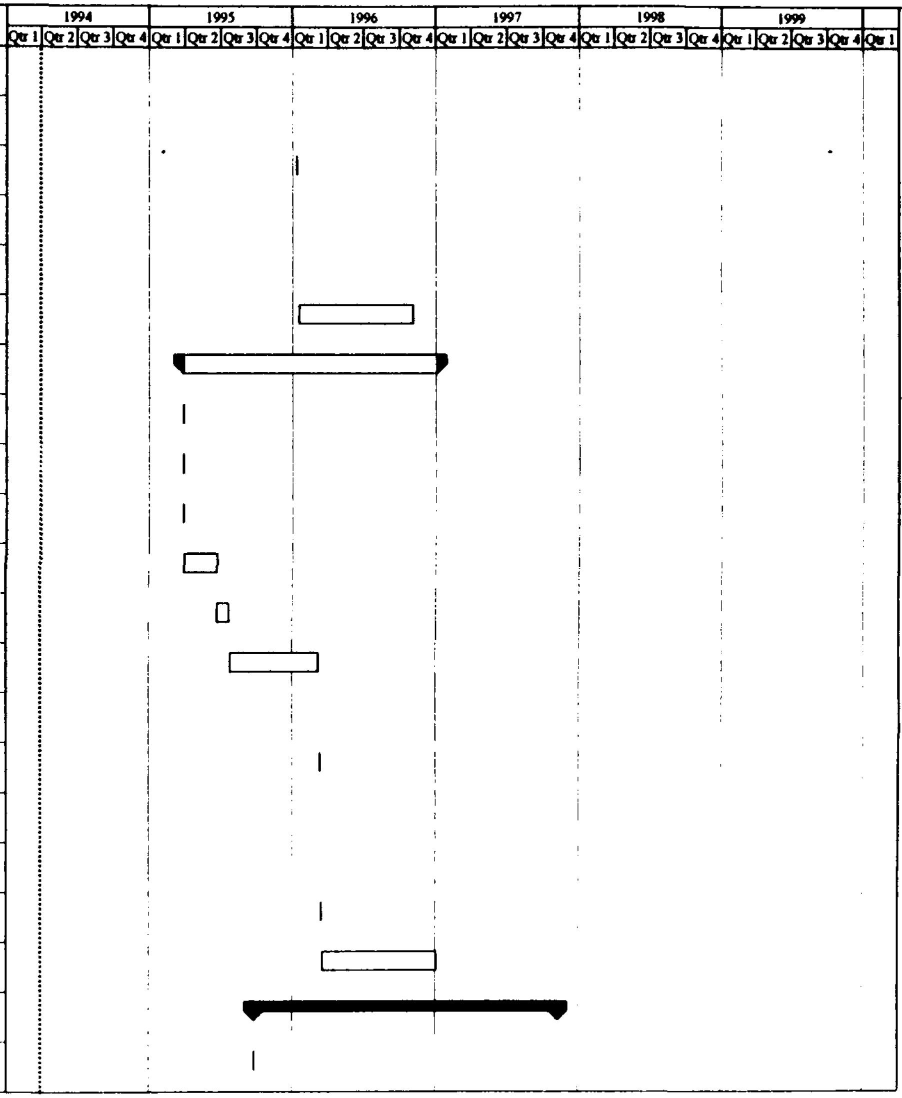
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
22					
23	**Utility Mapping**	**102d**	**7/19/94**	**12/7/94**	
24	Map utilities (utilmap)	102d	7/19/94	12/7/94	18
25					
26	**On-base/Off-base production wells**	**22d**	**7/19/94**	**8/18/94**	
27	Prepare Base Well 18 abandonment program	15ed	7/19/94	8/3/94	18
28	Prepare production well contingency plans	30ed	7/19/94	8/18/94	18
29					
30	**Extraction System**	**864d**	**7/19/94**	**11/10/97**	
31	**Subcontractor procurement**	**116d**	**7/19/94**	**12/27/94**	
32	Specify system requirements	15ed	7/19/94	8/3/94	18
33	Identify performance criteria	15ed	8/3/94	8/18/94	32
34	Procure BOAs w/ 3 subs for Basewide EW/MW	94d	8/18/94	12/27/94	33
35	**Task Order 1**	**599d**	**7/19/94**	**11/4/96**	
36	Off base monitoring wells(28)	1d	7/19/94	7/19/94	18
37	Off base extraction wells(22) w/ well head treatment	1d	7/19/94	7/19/94	18
38	Hot Spot extraction wells(15)	1d	7/19/94	7/19/94	18
39	Final layout of wells (wellfides)	62d	7/20/94	10/13/94	36,37,38
40	Prepare for installation (wellprep)	22d	10/14/94	11/14/94	39
41	Installation/Interpret Data (wellins1)	258d	12/28/94	12/22/95	34,40
42	Abandon Base well 18	15ed	12/25/95	1/9/96	27,28,41



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical

Alternative 3 With Implementation of Contingency Plans

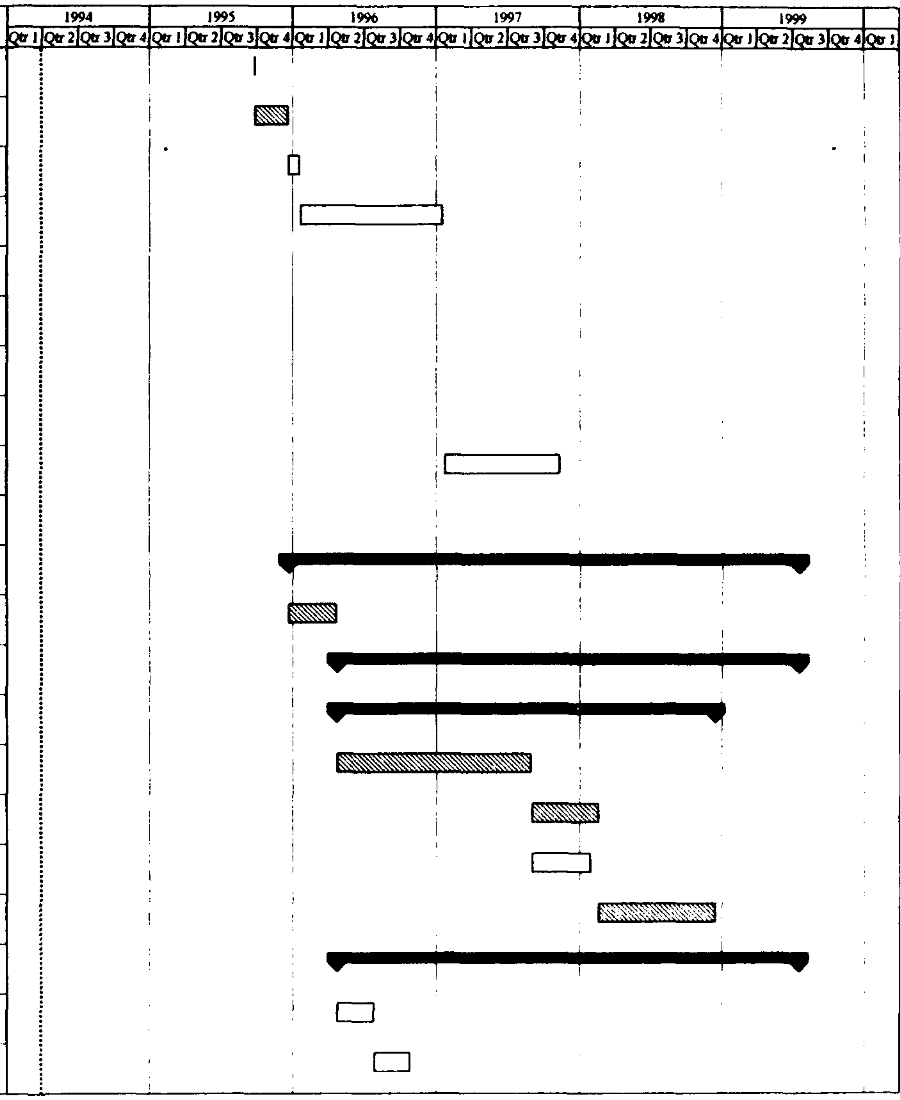
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
43	Reduce uncertainty in extent of contamination off base/hot	1d	1/9/96	1/9/96	42
44	Reduce uncertainty in off-base/hot spot flows to	1d	1/10/96	1/10/96	43
45	Reduce uncertainty of location and number of wells	1d	1/11/96	1/11/96	44
46	Reduce uncertainty in aquifer response	1d	1/12/96	1/12/96	45
47	Reduce uncertainty concerning potential	1d	1/15/96	1/15/96	46
48	Implement contingency plan (if necessary)/revise model	209d	1/16/96	11/4/96	47
49	**Task Order 2**	**463d**	**3/28/95**	**1/3/97**	
50	Off base monitoring wells(14)	1d	3/28/95	3/28/95	41SS+90ed
51	Off base extraction wells(43) w/ well head treatment	1d	3/28/95	3/28/95	41SS+90ed
52	Hot Spot extraction wells(14)	1d	3/28/95	3/28/95	41SS+90ed
53	Final layout of wells (wellfides)	62d	3/29/95	6/22/95	50,51,52
54	Prepare for installation (wellprep)	22d	6/23/95	7/24/95	53
55	Installation/Interpret Data (wellins1)	164d	7/25/95	3/8/96	54
56	Resolve uncertainty in extent of contamination off base/hot	1d	3/11/96	3/11/96	55
57	Further reduce uncertainty in aquifer response	1d	3/12/96	3/12/96	56
58	Resolve uncertainty in location and number of	1d	3/13/96	3/13/96	57
59	Resolve uncertainty in off-base/hot spot flows to	1d	3/14/96	3/14/96	58
60	Resolve uncertainty concerning potential	1d	3/15/96	3/15/96	59
61	Implement contingency plan (if necessary)/revise model	209d	3/18/96	1/3/97	60
62	**Task Order 3**	**555d**	**9/25/95**	**11/10/97**	
63	On base monitoring wells(72)	1d	9/25/95	9/25/95	55SS+60ed



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

Alternative 3 With Implementation of Contingency Plans

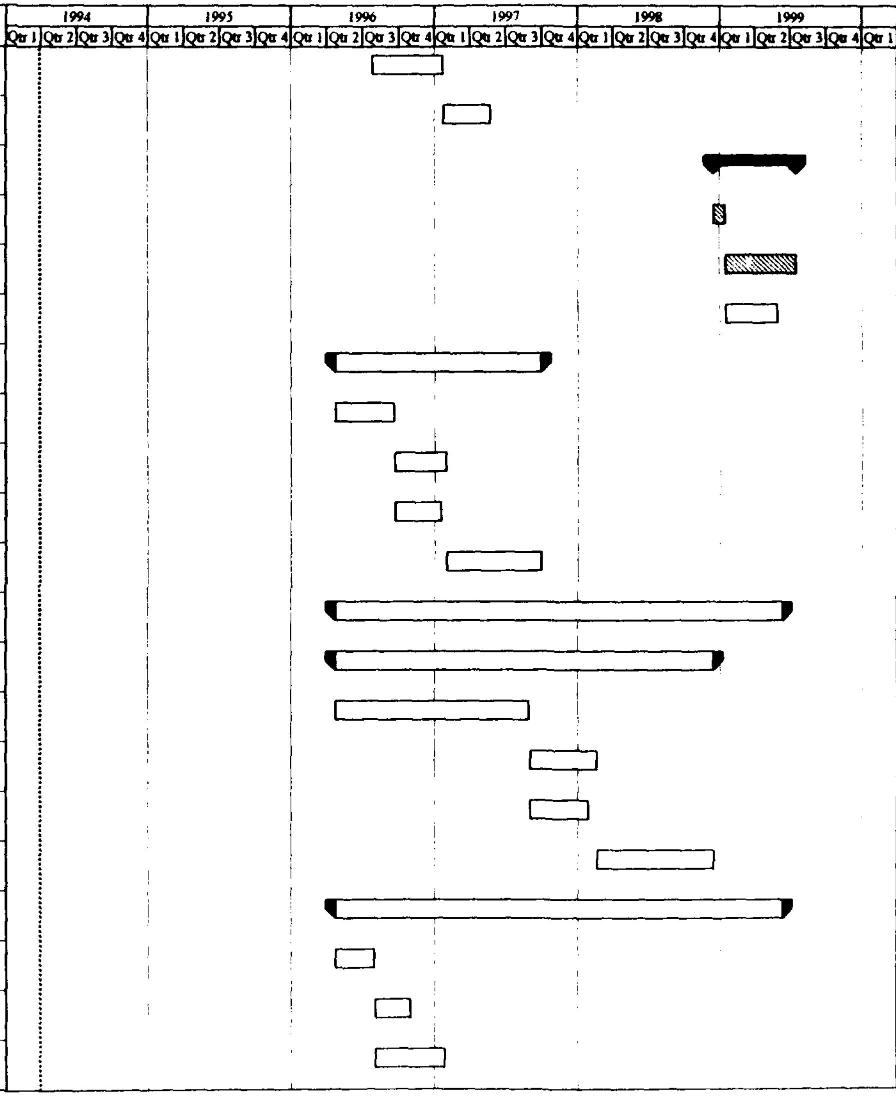
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
64	On base extraction wells(111)	1d	9/25/95	9/25/95	55SS+60ed
65	Final layout of wells (wellfides)	62d	9/25/95	12/19/95	55SS+60ed
66	Prepare for installation (wellprep)	22d	12/20/95	1/18/96	63,64,65
67	Installation/Interpret Data (wellins3)	258d	1/19/96	1/15/97	66
68	Resolve uncertainty in extent of contamination off base/hot	1d	1/16/97	1/16/97	67
69	Resolve uncertainty in aquifer response	1d	1/17/97	1/17/97	68
70	Resolve uncertainty in location and number of	1d	1/20/97	1/20/97	69
71	Resolve uncertainty in on base flow to treatment plants	1d	1/21/97	1/21/97	70
72	Implement contingency plan (if necessary)/revise model	209d	1/22/97	11/10/97	71
73					
74	**Treatment/End Use/ Collection Systems**	**931d**	**12/20/95**	**7/15/99**	
75	Procure turnkey contractor (contproc)	88d	12/20/95	4/19/96	24,65
76	**Western Area**	**843d**	**4/22/96**	**7/15/99**	
77	**Collection piping**	**691d**	**4/22/96**	**12/15/98**	
78	Preliminary Design (wcolde60)	354d	4/22/96	8/29/97	75
79	Final design (wcolde95)	122d	9/1/97	2/17/98	78
80	Prepare for construction (wcolprep)	108d	9/1/97	1/28/98	78
81	Construction (wcollcon)	215d	2/18/98	12/15/98	72,79,80
82	**Treatment plant**	**843d**	**4/22/96**	**7/15/99**	
83	Preliminary Design (wtrea60)	68d	4/22/96	7/25/96	75
84	Final Design (wtrea95)	66d	7/26/96	10/25/96	83



Date: 3/26/94 | Critical | Milestone | Summary | Noncritical

Alternative 3 With Implementation of Contingency Plans

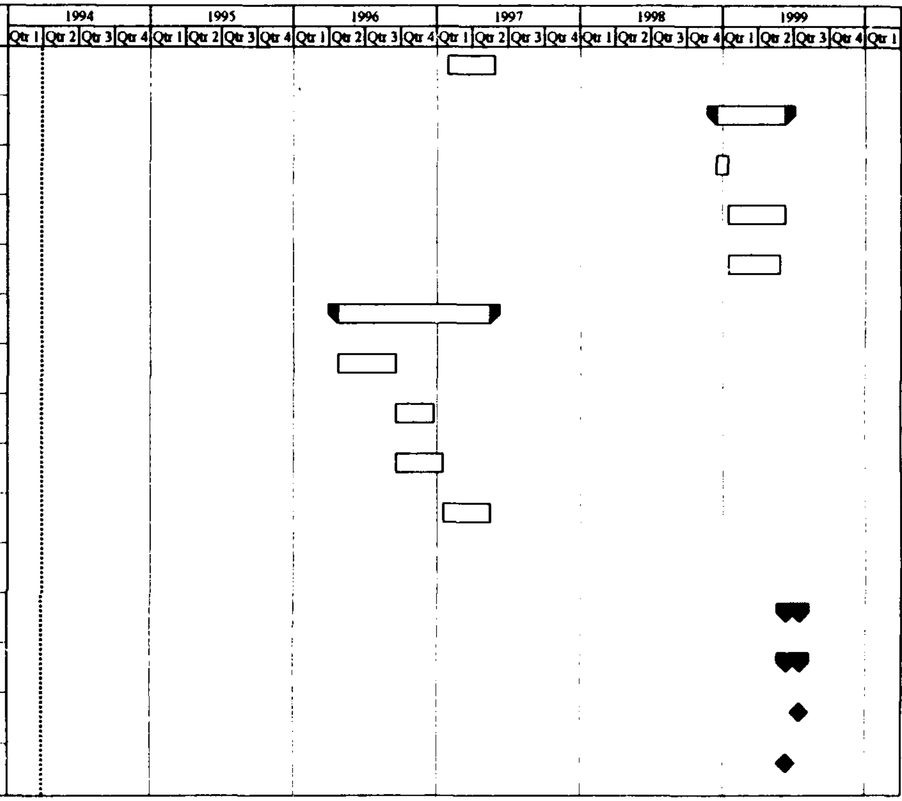
ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
85	Prepare for Construction	130d	7/26/96	1/23/97	83
86	Construction (wtreacon)	86d	1/24/97	5/23/97	84,85
87	**Start-up/Shakedown**	**152d**	**12/16/98**	**7/15/99**	
88	Start-up/Shakedo	30ed	12/16/98	1/15/99	81,86
89	Process contingency plan	130d	1/15/99	7/15/99	88
90	Capacity contingency plan	96d	1/15/99	5/28/99	88
91	**End Use Piping**	**375d**	**4/22/96**	**9/29/97**	
92	Preliminary Design (wendu60)	108d	4/22/96	9/19/96	75
93	Final Design (wendu95)	95d	9/20/96	1/30/97	92
94	Prepare for construction (wendupre)	86d	9/20/96	1/17/97	92
95	Construction (wendcons)	172d	1/31/97	9/29/97	93,94
96	**Eastern Area**	**819d**	**4/22/96**	**6/11/99**	
97	**Collection piping**	**691d**	**4/22/96**	**12/15/98**	
98	Preliminary Design (ecolde60)	354d	4/22/96	8/29/97	75
99	Final design (ecolde95)	122d	9/1/97	2/17/98	98
100	Prepare for construction (ecolprep)	108d	9/1/97	1/28/98	98
101	Construction (ecollcon)	215d	2/18/98	12/15/98	72,99,100
102	**Treatment plant**	**819d**	**4/22/96**	**6/11/99**	
103	Preliminary Design (etrea60)	72d	4/22/96	7/31/96	75
104	Final Design (etrea95)	66d	8/1/96	10/31/96	103
105	Prepare for Construction	128d	8/1/96	1/27/97	103



Date: 3/26/94 | **Critical** | **Milestone** ◆ | **Summary** | **Noncritical**

Alternative 3 With Implementation of Contingency Plans

ID	Name	Duration	Sched. Start	Sched. Finish	Predecessors
106	Construction (etreacon)	86d	1/28/97	5/27/97	104,105
107	**Start-up/Shakedown**	**128d**	**12/16/98**	**6/11/99**	
108	Start-up/Shakedo	30ed	12/16/98	1/15/99	101,106
109	Process contingency plan	106d	1/15/99	6/11/99	108
110	Capacity contingency plan	96d	1/15/99	5/28/99	108
111	**End Use Piping**	**278d**	**4/22/96**	**5/15/97**	
112	Preliminary Design (eendu60)	106d	4/22/96	9/17/96	75
113	Final Design (eendu95)	70d	9/18/96	12/24/96	112
114	Prepare for construction (eendupre)	86d	9/18/96	1/15/97	112
115	Construction (eendcons)	86d	1/16/97	5/15/97	113,114
116					
117	**Operation of Remedial Action**	**24d**	**6/11/99**	**7/15/99**	
118	**Containment of Contaminated Target Volume**	**24d**	**6/11/99**	**7/15/99**	
119	***West Base***	***0d***	***7/15/99***	***7/15/99***	***81,89,90***
120	***East Base***	***0d***	***6/11/99***	***6/11/99***	***101,109,110,115***



Date: 3/26/94 | Critical | Milestone ◆ | Summary | Noncritical