FINAL

THREE-TIERED
GROUNDWATER MONITORING NETWORK
OPTIMIZATION EVALUATION
FOR
MAIN BASE/SAC PLUME AREA
FORMER MATHER AIR FORCE BASE
SACRAMENTO COUNTY, CALIFORNIA

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PARSONS

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TABLE OF CONTENTS

Page

LIST OF ACRONYMS AND ABBREVIATIONS iv

SECTION 1 - INTRODUCTION 1-1

SECTION 2 - SITE BACKGROUND INFORMATION 2-1

2.1 Site Description 2-1
2.2 Geology and Hydrogeology 2-3
2.2.1 Geology 2-3
2.2.2 Hydrogeology 2-5
2.3 Nature and Extent of GROUNDWATER Contamination 2-7
2.4 Remedial System 2-10

SECTION 3 – LONG-TERM MONITORING PROGRAM AT THE MAIN BASE/SAC PLUME 3-1

3.1 Description of Monitoring Program 3-1
3.2 Summary of Analytical Data 3-11

SECTION 4 - QUALITATIVE MNO EVALUATION 4-1

4.1 Methodology for Qualitative Evaluation of Monitoring Network 4-2
4.2 Results of Qualitative MNO Evaluation 4-3
4.2.1 WT/A Zone Wells 4-12
4.2.2 Zone B Wells 4-14
4.2.3 Zone D Wells 4-15
4.2.4 Laboratory Analytical Program 4-16
4.2.5 LTM Program Flexibility 4-17

SECTION 5 - TEMPORAL STATISTICAL EVALUATION 5-1

5.1 Methodology for Temporal Trend Analysis of Contaminant Concentrations 5-1
5.2 Temporal Evaluation Results 5-5

TABLE OF CONTENTS (Continued)

Page

SECTION 6 - SPATIAL STATISTICAL EVALUATION 6-1

6.1 Geostatistical methods for evaluating Monitoring networks 6-1
6.2 Spatial Evaluation of Monitoring Network at the Main Base/SAC Area Plume 6-4
6.3 Spatial Statistical Evaluation Results 6-18
6.3.1 Kriging Ranking Results 6-18

SECTION 7 - SUMMARY OF THREE-TIERED MONITORING NETWORK EVALUATION 7-1

SECTION 8 - REFERENCES 8-1

LIST OF TABLES

No.	Title	Page
2.1	Hydrostraographic Unit Conductivity and Transmissivty Data	2-7
3.1	Current Monitoring Well Network	3-3
3.2	Main Base/SAC Area Monitoring Well Program Type and Monitoring Frequency Breakdown	3-11
3.3	Summary of Occurrence of Groundwater Contaminants of Concern in Monitoring Wells	3-12
4.1	Monitoring Network Optimization Decision Logic	4-3
4.2	Monitoring Frequency Decision Logic	4-4
4.3	Qualitative Evaluation of Groundwater Monitoring Network	4-5
5.1	Results of Temporal Trend Analysis of Groundwater Monitoring Results	5-8
6.1	Results of Geostatistical Evaluation Ranking of Select WT/A Zone Wells by Relative Value of Total COC Information	6-6
6.2	Results of Geostatistical Evaluation Ranking of Select B Zone Wells by Relative Value of Total COC Information	6-9
6.3	Results of Geostatistical Evaluation Ranking of Select Zone D Wells by Relative Value of Total COC Information	6-13
7.1	Summary of Evaluation of Current Groundwater Monitoring Program	7-3
7.2	Summary of Revised and Original Monitoring Programs	7-13

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

No	Title	Page
2.1	WT/A Zone Monitoring Well Network and COC Concentrations	2-9
3.1	B Zone Monitoring Well Network and COC Concentrations	3-9
3.2	D Zone Monitoring Well Network and COC Concentrations	3-10
5.1	PCE Concentrations Through Time at Well MAFB-313	5-2
5.2	Conceptual Representations of Temporal Trends and Temporal Variations in Concentrations	5-3
5.3	Conceptual Representation of Continued Monitoring at Location Where no Temporal Trend in Concentrations is present	5-6
5.4	Temporal Trend Decision Rationale Flow Chart	5-7
5.5	Mann-Kendall Trends for PCE in WT Zone Wells	5-18
5.6	Mann-Kendall Trends for PCE in B Zone Wells	5-19
5.7	Mann-Kendall Trends for PCE in D Zone Wells	5-20
6.1	Idealized Semvariogram Model	6-3
6.2	Results of Geostatistical Analysis Showing Relative Value of Information of Total COCs in WT/A Zone Wells	6-5
6.3	Results of Geostatistical Analysis Showing Relative Value of Information of Total COCs in B Zone Wells	6-8
6.4	Results of Geostatistical Analysis Showing Relative Value of Information of Total COCs in D Zone Wells	6-12
6.5	Impact of Missing Wells on Predicted Standard Error	6-17

LIST OF ACRONYMS AND ABBREVIATIONS

AC&W	Aircraft Control and Warning
AFB	Air Force Base
AFBCA	Air Force Base Conversion Agency
bgs	below ground surface
BRCA	Base Realignment and Closure Act
CAH	chlorinated aliphatic hydrocarbon
CDWR	California Department of Water Resources
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CCl_4	carbon tetrachloride
COC	contaminant of concern
DCA	dichloroethane
DCE	dichloroethene
ESRI	Environmental Systems Research Institute, Inc.
ETI	extraction, treatment, and injection
FFA	Federal Facility Agreement
ft/day	feet per day
ft^2/day	cubic feet per day
ft/ft	feet per foot
GIS	geographical information system
GWTP	groundwater treatment plant
IRP	Installation Restoration Program
IT Corp.	International Technology Corporation
LMT	Laguna-Mehrten transition
LTM	long-term monitoring
µg/L	microgram(s) per liter
MCL	maximum contaminant level
MNO	monitoring network optimization
MWH	Montgomery Watson Harza
NPL	National Priorities List
OU	operable unit
PCE	perchloroethene, a.k.a. tetrachloroethene
PQL	practical quantitation limit
RAO	remedial action objective
ROD	Record of Decision
SAC	Strategic Air Command
TCE	trichloroethene
TPH-g	gasoline-range total petroleum hydrocarbons
TPH-d	diesel-range total petroleum hydrocarbons
USAF	United Stated Air Force
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

SECTION 1

INTRODUCTION

Groundwater monitoring programs have two primary objectives (U.S. Environmental Protection Agency [USEPA], 1994; Gibbons, 1994):

1. Evaluate long-term temporal trends in contaminant concentrations at one or more points within or outside of the remediation zone, as a means of monitoring the performance of the remedial measure (*temporal objective*); and

2. Evaluate the extent to which contaminant migration is occurring, particularly if a potential exposure point for a susceptible receptor exists (*spatial objective*).

The relative success of any remediation system and its components (including the monitoring network) must be judged based on the degree to which it achieves the stated objectives of the system. Designing an effective groundwater monitoring program involves locating monitoring points and developing a site-specific strategy for groundwater sampling and analysis to obtain enough relevant information to satisfy the data quality objectives of the monitoring program at the least cost. The effectiveness of a monitoring network in achieving these two primary objectives can be evaluated quantitatively using statistical techniques. In addition, there may be other important considerations associated with a particular monitoring network that are most appropriately addressed through a qualitative assessment of the network. The qualitative evaluation may consider such factors as hydrostratigraphy, locations of potential receptor exposure points with respect to a dissolved contaminant plume, and the direction(s) and rate(s) of contaminant migration.

This report presents a description and evaluation of the groundwater monitoring program associated with the Main Base/Strategic Air Command (SAC) Industrial Area Plume at the former Mather Air Force Base (Mather) in Sacramento County, California. A 306-well monitoring network was evaluated to identify potential opportunities to streamline monitoring activities while still maintaining an effective monitoring program. A three-tiered approach, consisting of a qualitative evaluation, an evaluation of temporal trends in contaminant concentrations, and a statistical spatial analysis, was conducted to assess the degree to which the monitoring network addresses each of the two primary objectives of monitoring, and other important considerations such as regulatory concerns and specific site hydrogeologic conditions. The results of the three evaluations were combined and used to assess the optimal frequency of monitoring and the spatial distribution of the components of the monitoring network. The results of the analysis were then used to develop recommendations for optimizing the monitoring program at the Main Base/SAC Area Plume at Mather.

SECTION 2

SITE BACKGROUND INFORMATION

The location, operational history, geology, and hydrogeology of the Main Base/SAC Area Plume at Mather are briefly described in the following subsections.

2.1 SITE DESCRIPTION

Mather is a closed military installation located in Sacramento County, California, approximately 12 miles east of Sacramento. The installation is located south of US Highway 50 and north of California Highway 16, and covers an area of approximately 5,845 acres. Military activities on Mather AFB were terminated, and the Base was decommissioned on 30 September 1993, in accordance with the requirements of the Base Realignment and Closure Act (BRCA).

Various types of contaminants were introduced to soil and groundwater in the subsurface at Mather AFB during the course of routine Base operations that included fuel storage and delivery, fire-fighting training, equipment maintenance, waste disposal, and other industrial activities conducted throughout the operational history of the Base. Environmental investigation and restoration activities were initiated at Mather AFB in 1982, and continue to the present in conjunction with a facility-wide Installation Restoration Program (IRP). In July 1989, the United States Air Force (USAF), the USEPA (Region IX), and the State of California signed a Federal Facilitiy Agreement (FFA), in accordance with the requirements of Section (§) 120 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), to ensure that environmental effects associated with past and current operations are properly evaluated, and that appropriate restoration actions are taken to protect human health, welfare, and the environment. The FFA defines the roles and responsibilities of the signatory parties,

establishes enforceable deadlines for deliverables, and provides a vehicle for resolution of disputes. According to the terms of the FFA, the USAF, as the owner of the site, is the principal responsible party, and the lead agency responsible for conducting investigation and restoration activities.

The results of early investigations confirmed that volatile organic compounds (VOCs) and other organic contaminants were present in environmental media at several of the IRP sites; and as a consequence, Mather AFB was proposed for listing on the Superfund National Priorities List (NPL) in July 1989, and was placed on the NPL in November 1989. Several IRP sites were identified in the Final Superfund ROD as sources of contaminants in soil and groundwater, with the majority of sites located in the Main Base/SAC Area Industrial Area. The Main Base Plume is a widespread plume composed primarily of chlorinated solvent constituents dissolved in groundwater, which originates in the Main Base area and extends off-Base to the west. The SAC Industrial Plume also consists primarily of chlorinated solvent constituents dissolved in groundwater, originating near Site 57 and extending off-Base to the west and southwest. Three other groundwater plumes have been identified in areas south and/or east of the Main Base/SAC area: the Northeast Plume, the Site 7 Plume, and the Aircraft Control and Warning (AC&W) Plume.

The Main Base and the SAC plumes are the focus of this Monitoring Network Optimization (MNO) evaluation. For the purposes of investigation and restoration activities, these commingled plumes generally are regarded as a single plume, and are collectively referred to as the "Main Base/SAC Industrial Area Plume". The contaminants of concern (COCs) in the Main Base/SAC Industrial Area Plume include chloromethane, carbon tetrachloride (CCl_4), 1,2-dichloroethane (1,2-DCA), tetrachloroethene (PCE), trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), benzene, xylene isomers, total petroleum hydrocarbons measured as gasoline-range and diesel-range constituents (TPH-g and TPH-d, respectively), and lead.

The Main Base/SAC Industrial Area groundwater plume consists of several commingled plumes originating at Sites 18, 23C, and 57 that are present in groundwater in the upper part of the water-bearing unit, together with other plumes from sites such as 37, 39, and 59 that have commingled at greater depths in the saturated zone. The plume underlies the Main Base and SAC Industrial Area and extends off Base to the west [International Technology Corporation (IT Corp.), 1993 and 1994a). That part of the plume within the Main Base area is characterized by relatively higher concentrations of PCE and relatively lower concentrations of TCE and CCl_4, while that part of the plume originating within the SAC Industrial Area is characterized by relatively higher concentrations of TCE and relatively lower concentrations of PCE and *cis*-1,2-DCE. The axis of the Main Base/SAC Industrial Area plume is oriented east northeast to west southwest in general alignment with the direction of groundwater movement across Mather. The monitoring program for the Main Base/SAC Area Plume is fully described in Section 3.

2.2 GEOLOGY AND HYDROGEOLOGY

2.2.1 Geology

A sequence of sedimentary rock and unconsolidated sediments that dip and thicken to the west underlies the eastern flank of the Central Valley in the vicinity of Mather. These sediments were eroded and transported as a consequence of the tectonic uplift of the Sierra Nevada Range, which borders the eastern edge of the Central Valley. The sediments were deposited into the subsiding structural trough of the ancestral Central Valley. This sequence is reportedly approximately 1,000 feet thick beneath the central part of Mather, and consists of Late Cretaceous to Eocene marine and continental sedimentary rock overlain by late Tertiary to Quaternary unconsolidated alluvial and fluvial sediments (Harwood and Helley, 1987). The sequence overlies Jurassic-Cretaceous igneous and metamorphic basement rock. The geologic units of interest at Mather are (from oldest to youngest): the Mehrten Formation, the Laguna Formation, and the terrace gravels.

The Mehrten Formation, consisting primarily of andesitic sand and gravel, is the deepest and oldest unit (ranging from late Miocene to early Pliocene in age) (Shlemon, 1967a and 1967b) of interest at Mather. The Mehrten Formation dips westward (at an angle of 1 to 2 degrees), and thickens westward from 200 feet thick east of Mather, to 400 to 500 feet thick beneath the axis of the Central Valley (California Department of Water Resources [CDWR], 1964). Generally, the contact of the Mehrten Formation with the overlying Laguna Formation is not distinct, so that a "transition zone" between the two formations, ranging in thickness from 60 to 100 feet, is recognized in the general area of Mather. The sediments of this transition zone (known as the "Laguna-Mehrten Transition Zone") consist of a mixture of arkosic sands (similar to the Laguna Formation) and andesitic material (Mehrten Formation). Regionally, the Laguna Formation is a relatively fine-grained unit, consisting primarily of interbedded sand, silt, and clay. However, the Laguna Formation also contains channel deposits consisting of gravel of metamorphic provenance, with subordinate granitic silt and sand (Shlemon, 1967a).

In the vicinity of Mather, the Laguna Formation is informally subdivided into lower, middle, and upper units (IT Corp., 1994b). The lower unit of the Laguna Formation consists primarily of discontinuous sand and gravel channel-fill deposits, separated by relatively thick, fine-grained interbeds (silt and clay), and ranges in thickness from 100 to 245 feet. Beneath the northwestern part of Mather and farther west, the lower Laguna Formation contains an interval of superimposed channel-fill deposits (IT Corp., 1994a). The middle unit of the Laguna Formation consists of overbank deposits of silt, with some channel-fill deposits of silty sand, sand, and gravel, and ranges in thickness from 31 to 63 feet. In the western part of Mather, the middle unit is subdivided into two gravel strata separated by a layer of silt (IT Corp., 1994a). The upper unit of the Laguna Formation consists primarily of silt, with sporadic channel-fill deposits of silty sand and gravel. The upper unit ranges from 15 to 130 feet in thickness, and locally becomes thinner in the northeastern part of Mather.

Terrace Gravels of Quaternary and Recent age constitute the uppermost geologic unit at Mather. The terraces were formed during northwestward migration of the channel of

an ancestral American River. The Terrace Gravels are composed primarily of silty gravel, capped with silt and silty sand.

2.2.2 Hydrogeology

The geologic units in the subsurface at Mather were informally divided into hydrostratigraphic units to provide a framework for describing the local hydrogeology. The Terrace Gravels are above the groundwater table, and consequently are unsaturated across Mather. Hydrogeologic unit "A" of the upper Laguna Formation is the uppermost water-bearing unit at Mather. Unit "A" lies unconformably beneath the Terrace Gravels and consists primarily of silt, but also contains thin, discontinuous channel-fill deposits of silty sand and gravel. Much of unit "A" is above the groundwater table at Mather, and consequently is unsaturated; however, the lower part of unit "A" is saturated in the western part of Mather.

Hydrogeologic units "Bu" and "B" of the middle Laguna Formation consist of overbank deposits of silt and channel-fill deposits of silty sand, sand, and gravel; the relative proportions of coarse-grained and fine-grained materials in units "Bu" and "B" are variable, depending upon location. In the Main Base area and immediately west of Mather, units "Bu" and "B" consist primarily of sands and gravels. In this area, multiple superimposed and juxtaposed channels form thick, vertically uninterrupted sequences of coarse-grained material within units "Bu" and "B". As a consequence of their relatively high permeability, these channel deposits have the highest water production of any units within the Laguna Formation, and provide the primary pathways for the movement of groundwater beneath Mather.

Hydrogeologic Unit D of the lower Laguna Formation consist primarily of silt and clay; channel-fill deposits of silty sand and sand within Units C and D typically are separated by relatively thick deposits of silt and clay. Relatively continuous deposits of silt and clay, encountered in the hydrostratigraphic interval between the sands and gravels of Unit B and the sand of Unit D, are identified as Unit C. In areas where Unit C is relatively thick and continuous, it may function as an aquitard. Hydrogeologic Unit D

extends from the base of unit C to the top of the transition zone between the Laguna and Mehrten Formations; Unit D consists primarily of fine-grained overbank deposits (silt and clay), with sporadic coarse-grained channel deposits. In areas where channel deposits are not present within Unit D, Units C and D consist primarily of silt, and are not readily distinguished. The E Unit comprises the sands and gravels of Laguna-Mehrten transition (LMT) zone. The underlying Mehrten Formation sands are the producing zone for many of the off-Base water-supply wells. The hydrostratigraphic unit names used at Mather have evolved from a system with zones A through E to one with A through D and the Laguna-Mehrten Transition (LMT), but that the model still uses a Unit E for the lower part of the Laguna Formation.

Regionally, groundwater movement generally is to the southwest, from upland areas east of Mather toward the Sacramento River. Substantial groundwater pumping was initiated in the Sacramento region between 1890 and 1910, and has continued to the present (CDWR, 1974). Three groundwater cones of depression located northwest, southwest, and south of Mather have been created by the pumping of municipal and agricultural wells across the river basin. The southwest depression strongly influences the rate and direction of groundwater movement at Mather (IT Corp., 1996). Since 1890, groundwater pumping has caused the elevation of the groundwater potentiometric surface (water table) to decline by approximately 70 feet in the vicinity of Mather.

Groundwater at Mather is encountered at depths ranging from 52 to 150 feet below ground surface (bgs); the local configuration of the groundwater potentiometric surface is such that the hydraulic gradient is from northeast to southwest beneath Mather, at about 0.002 feet per foot (ft/ft). Groundwater is present under water-table (unconfined) conditions in hydrogeologic Units A and Bu, and under semi-confined conditions in deeper hydrogeologic units. The coarser sand and gravel deposits within Units Bu and B are fairly transmissive, apparently continuous, and abundant throughout the Main Base/SAC Area, and extend beyond Mather to the West. These coarser-grained intervals function as pathways for the preferential movement of groundwater and dissolved constituents. Horizontal hydraulic conductivity and transmissivity and vertical

conductivity data for Units A, Bu, B, and D were compiled from wells installed at Mather, and are presented in Table 2.1.

TABLE 2.1
HYDROSTRAOGRAPHIC UNIT CONDUCTIVITY AND TRANSMISSIVTY DATA
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC PLUME AREA
FORMER MATHER AFB, CALIFORNIA

Hydrostraigraphic Unit	Conductivity (ft/day)[a/]	Transmissivity (ft^2/day)[a/]	Vertical Conductivity (ft/day)
A	1 – 290 average 48	3 – 3,378 average 570	7.7×10^{-3} to 0.17 average 0.027
Bu	2 – 222 average 58	8 – 5,500 average 1,550	6.5×10^{-4} to 0.1 average 0.022
B	2 – 350 average 82	24 – 14,000 average 2,550	4.5×10^{-5} to 0.26 average 4.5×10^{-3}
D	1 – 182 average 29	70 – 8,000 average 1,596	0.011 to 1.5 average 0.12

a/ Montgomery Watson Harza [MWH], 2002a
b/ IT Corp., 1994b

Groundwater recharge to water-bearing zones underlying Mather occurs in upland areas to the east. Rainfall, streamflow from the American River, and applied irrigation in upland areas to the east percolate directly into permeable strata that crop out at the surface and are contiguous with similar strata underlying Mather. Rainfall and irrigation water occurring at Mather also provide recharge to the groundwater system. Potential additional sources of local recharge include the Morrison Creek drainage, Mather Lake, and settling ponds associated with nearby quarries (IT Corp., 1997). Changes in operation to the settling ponds could potentially impact monitoring wells on the southeast side of the site.

2.3 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

Contaminants have been introduced to soil and groundwater beneath the Main Base/SAC Area as a consequence of historical activities on Mather. Chlorinated VOCs are the primary contaminants in the subsurface, although the fuel hydrocarbons benzene and xylene isomers also have been detected (IT Corp., 1996).

Halogenated VOCs represent the only COCs that are systematically detected at Mather. TCE, PCE, and CCl_4 are the main contaminants in groundwater beneath the Main Base/SAC Industrial Area (MWH, 2002b). Smaller distributions of the other COCs such as TPH-g, *cis*-1,2-DCE, and 1,1-DCE also have been detected in groundwater samples from a few wells. These other COCs do not form large identifiable plumes because their occurance is localized. Prior to installation of the groundwater extraction wells at the site (Section 2.4), the highest concentrations of TCE, PCE, and 1,1-DCE were detected in samples collected from well MAFB-203, located near the oil-water separator at Building 7024 (IRP Site 66) and downgradient of a suspected source area (IRP site 57 concrete wash pads) (IT Corp., 1994a). The highest concentration of CCl_4 was detected at well MAFB-207, located west of Building 7022 (IT Corp.., 1994a) (Figure 2.1). The ROD-established plume cleanup levels for groundwater contaminants are based on the more stringent of the federal and State Maximum Contaminant Levels (MCLs) for drinking water and other values for contaminants for which primary MCLs don't exist. The plume cleanup levels for the COCs are 5 micrograms per liter (µg/L) for TCE and PCE and 0.5 µg/L for CCL_4 (AFBCA, 1996).

Several distinct "hot spots" (defined to be areas within which the concentrations of a particular contaminant in groundwater exceed the plume cleanup level for that constituent by a factor of 10 or more) are associated with particular source areas. For example, a CCl_4 "hot spot" in the vicinity of wells MAFB-207 and MAFB-246 appears to be associated with the IRP site 57 wash-pad source area west of Building 7022. The directions and rates of groundwater movement beneath the Main Base/SAC Area are such that contaminants originating at several source areas have commingled as dissolved contaminants have migrated advectively, both laterally and vertically, with moving groundwater.

Contaminants have moved in groundwater from source areas to downgradient locations beyond the western boundary of Mather, and have been detected in groundwater samples from several water-supply wells beyond Mather (e.g., the Juvenile Hall wells [JH-1 and JH-2] owned by Sacramento County). Contaminants also have

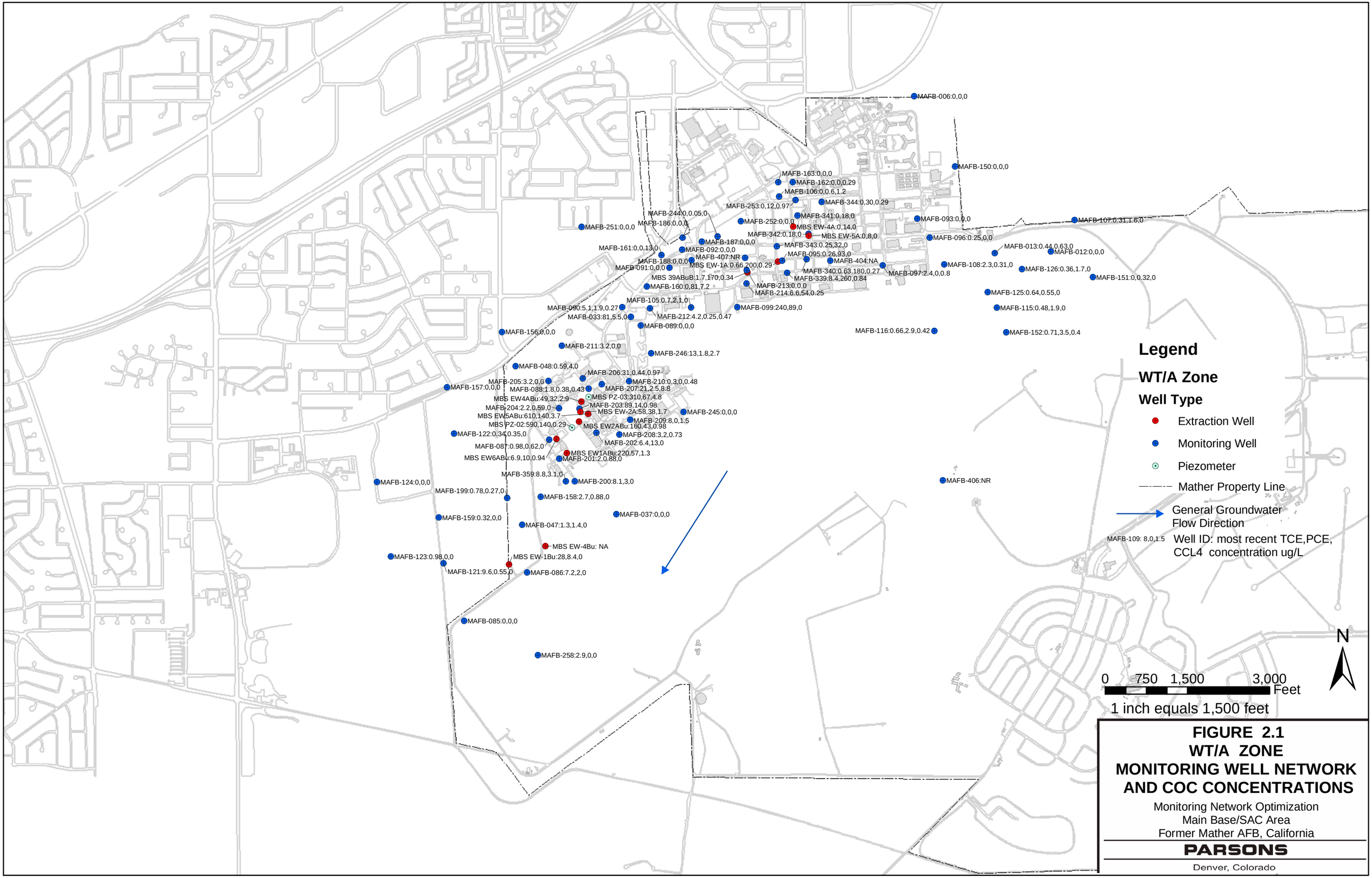

FIGURE 2.1
WT/A ZONE
MONITORING WELL NETWORK AND COC CONCENTRATIONS

Monitoring Network Optimization
Main Base/SAC Area
Former Mather AFB, California

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moved from the shallow saturated zone near the water table to deeper intervals of the groundwater system beneath and downgradient from source areas. Recent groundwater monitoring results (MWH, 2002b) indicate that the concentrations of TCE, PCE, and CCl_4 in groundwater generally are higher within the upper part of the groundwater system (Unit A) than in groundwater at greater depths (in the underlying Bu/B and D Units).

2.4 REMEDIAL SYSTEM

In 1998, a groundwater extraction, treatment, and injection (ETI) system was constructed and became operational in the Main Base/SAC Area. Consistent with the selected ETI remedy specified in the ROD (AFBCA, 1996), groundwater remediation for the Main Base/SAC Industrial plume was implemented in phases:

- Wells installed during Phase I were intended primarily to remove CAH mass from groundwater "hot spots".
- The objective of Phase II groundwater remediation was to expand the hydraulic influence of the Phase I extraction system, and address "hot spots" of PCE and CCl_4 in off-Base locations.
- Additional contaminant mass removal from on-Base "hot spots" was addressed during Phase III.
- The primary goal of Phase IV (the current phase of expansion of the groundwater ETI system) is to control the majority of the Main Base/SAC Area Plume that extends beyond Mather boundary at concentrations greater than cleanup levels. Phase IV wells are intended to augment, but not necessarily duplicate, capture achieved by existing water-supply wells that have operating wellhead treatment systems.

Thirty three extraction wells have been installed in a phased manner, and two existing aquifer test wells have been incorporated into the system. As of January 2003, twenty

nine of these well are in service. The groundwater extraction wells are constructed of 6- or 8-inch-diameter, low-carbon steel, blank casing and 6- or 8-inch-diameter, stainless steel, wire-wrapped screen. Two 2-inch-diameter polyvinyl chloride sounding tubes were installed adjacent to each extraction well to gauge water levels.

Water from the extraction wells is pumped to a central groundwater treatment plant (GWTP), located adjacent to the fuel farm at Site 19. The maximum treatment capacity of the GWTP is 2,200 gallons per minute. Extracted groundwater is treated by passing it through one (or both) of two vertical counterflow air-stripping towers to remove VOCs. Air-stripper off-gas is vented to the atmosphere, and the treated groundwater is then filtered and pH adjusted. Treated groundwater is re-injected into deeper zones within the water-bearing unit through a series of four injection wells. Treatment system influents and effluents are sampled monthly.

SECTION 3

LONG-TERM MONITORING PROGRAM AT THE MAIN BASE/SAC PLUME

The 2002 groundwater monitoring program at the Main Base/SAC Area Plume at Mather was examined to identify potential opportunities for streamlining monitoring activities while still maintaining an effective monitoring program. The 2002 monitoring program at the Main Base/SAC Area Plume is reviewed in the following subsections.

3.1 DESCRIPTION OF MONITORING PROGRAM

The Mather groundwater monitoring program contains 559 wells, including injection and extraction wells, monitoring wells, bioventing wells, and pieziometers, and is segregated into six groups: Landfill Post-Closure and Northeast Plume Monitoring; AC&W, Site 7; Main Base/SAC Area Performance Monitoring; Off-Base Supply Well Monitoring; and Basewide Monitoring. The monitoring program examined in this 3-tiered MNO evaluation includes the 306 wells associated with the Main Base/SAC Area plume that are included in both the Main Base/SAC Area Performance Monitoring and Basewide Monitoring program. The objectives of the monitoring program at the Main Base/SAC Area of Mather (MWH, 2002b) are to:

- Monitor progress towards established cleanup levels by periodically evaluating the distribution, extent, and changes in concentrations of COCs in the subsurface;
- Assess the removal of COC mass from the subsurface by monitoring concentrations of COCs in extracted groundwater and the production rates of extraction wells;
- Monitor the hydraulic influence of the groundwater extraction system; and

- Assess the potential impacts resulting from contaminant migration to off-Base drinking-water wells.

This set of wells and their associated 2003 monitoring frequencies were identified from site plume maps, the comprehensive list of wells in Table 2-1 (MWH, 2002b) and subsequent review by MWH site hydrogeologist Dean Thomas (Thomas, 2003). Well information is listed in Table 3.1; the wells are grouped into the following three zones in accordance with the Draft Final *2002 Groundwater Monitoring Program Evaluation Report* (MWH, 2002b):

- WT/A Zone: Water-table wells, including Zone A and Zone A/B wells
- B Zone: B and Bu Zone wells
- D Zone: D, Dd and LMT Zone wells

The WT/A, B and D zone wells, and the most recent COC concentrations for each well, are displayed on Figures 2.1, 3.1, and 3.2, respectively. Monitoring wells, piezometers, and extraction wells were included in the MNO analysis. Table 3.2 provides a breakdown of the number and frequency of each type of well in each zone. Of the 306 wells:

- 86 are in zone WT/A, 120 are in zone B, and 100 are in Zone D
- 32 are extraction wells and 274 are monitoring wells or piezometers
- Based on recommended 2003 sampling, 99 are sampled annually, 70 semi-annually, and 101 quarterly. The MNO analysis also includes the 36 area wells that were not sampled in 2003, but could potentially be included in the monitoring program.

TABLE 3.1
CURRENT MONITORING WELL NETWORK
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl) [a/]	Hydrostrat-igraphic Unit	2003 Sampling Frequency	First Available Sampling Event[c/]	Well Type
WT/A Zone Wells					
MAFB-006	14.3 - -3.7	WT/B	Not Sampled	Jan-96	Monitoring
MAFB-033	6.88 - -13.12	WT/Bu	Semi-Annual	Apr-96	Monitoring
MAFB-037	12.24 - -7.76	WT/Bu	Annual	Apr-96	Monitoring
MAFB-047	0.93 - -19.07	WT/Bu	Annual	May-96	Monitoring
MAFB-048	4.26 - -15.74	WT	Annual	Feb-96	Monitoring
MAFB-085	2.78 - -12.22	WT	Semi-Annual	Feb-96	Monitoring
MAFB-086	8.28 - 4.78	WT	Quarterly	Apr-96	Monitoring
MAFB-087	4.67 - -10.33	WT	Quarterly	Apr-96	Monitoring
MAFB-088	5.45 - -9.55	WT	Semi-Annual	Apr-96	Monitoring
MAFB-089	9.88 - -5.12	WT	Annual	Apr-96	Monitoring
MAFB-090	3.39 - -11.61	WT/Bu	Semi-Annual	May-96	Monitoring
MAFB-091	7.09 - -7.91	WT	Not Sampled	Apr-96	Monitoring
MAFB-092	5.51 - -9.49	WT	Annual	May-96	Monitoring
MAFB-093	6.38 - -8.62	WT/B	Not Sampled	Jan-96	Monitoring
MAFB-095	10.04 - -4.96	WT	Quarterly	Apr-96	Monitoring
MAFB-096	5.93 - -9.07	WT/B	Annual	Feb-96	Monitoring
MAFB-097	1.03 - -13.97	WT/B	Annual	Jan-96	Monitoring
MAFB-099	7.71 - -7.29	WT	Annual	Apr-96	Monitoring
MAFB-105	7.47 - -7.53	WT	Annual	Apr-96	Monitoring
MAFB-106	11.94 - -3.06	WT	Semi-Annual	Apr-98	Monitoring
MAFB-121	0.17 - -14.83	WT	Annual	Feb-96	Monitoring
MAFB-122	2.42 - -12.58	WT	Semi-Annual	Jan-96	Monitoring
MAFB-123	-0.53 - -15.53	WT	Annual	Feb-96	Monitoring
MAFB-124	-0.34 - -15.34	WT	Annual	Feb-96	Monitoring
MAFB-150	8.5 - -6.5	WT/B	Not Sampled	Feb-96	Monitoring
MAFB-156	-2.05 - -17.05	WT	Not Sampled	Feb-96	Monitoring
MAFB-157	-5.56 - -20.56	WT	Not Sampled	Jan-96	Monitoring
MAFB-158	0.06 - -14.94	WT/Bu	Not Sampled	May-96	Monitoring
MAFB-159	0.73 - -14.27	WT	Semi-Annual	Feb-96	Monitoring
MAFB-160	7.35 - -7.65	WT	Annual	Apr-96	Monitoring
MAFB-161	6.4 - -8.6	WT	Not Sampled	Apr-96	Monitoring
MAFB-162	12.52 - -2.48	WT	Annual	May-96	Monitoring
MAFB-163	11.89 - -3.11	WT	Not Sampled	Apr-98	Monitoring
MAFB-186	9.14 - -5.86	WT	Not Sampled	Oct-97	Monitoring
MAFB-187	8.14 - -6.86	WT	Not Sampled	Apr-96	Monitoring
MAFB-188	6.64 - -8.36	WT	Not Sampled	Apr-96	Monitoring
MAFB-199	-3.9 - -18.9	WT/Bu	Annual	May-96	Monitoring
MAFB-200	-2.8 - -17.8	WT/Bu	Annual	Apr-96	Monitoring
MAFB-201	-1.0 - -16.0	WT/Bu	Quarterly	Apr-96	Monitoring
MAFB-202	-0.5 - -15.5	WT	Semi-Annual	Apr-96	Monitoring
MAFB-203	-1.0 - -16.0	WT	Quarterly	May-96	Monitoring
MAFB-204	0.3 - -14.7	WT	Semi-Annual	Apr-96	Monitoring
MAFB-205	-2.6 - -17.6	WT	Annual	Apr-96	Monitoring
MAFB-206	1.6 - -13.4	WT	Semi-Annual	Apr-96	Monitoring
MAFB-207	-0.4 - -15.4	WT	Semi-Annual	Apr-96	Monitoring
MAFB-208	0.4 - -14.6	WT	Quarterly	Apr-96	Monitoring
MAFB-209	1.7 - -13.3	WT	Annual	May-96	Monitoring
MAFB-210	0.2 - -14.8	WT	Not Sampled	Apr-96	Monitoring
MAFB-211	-1.3 - -16.3	WT	Semi-Annual	May-96	Monitoring
MAFB-212	3.4 - -11.6	WT	Annual	Apr-96	Monitoring
MAFB-213	5.5 - -4.5	WT	Quarterly	Apr-96	Monitoring
MAFB-214	5.1 - -9.9	WT	Semi-Annual	Apr-96	Monitoring
MAFB-244	4.0 - -11.0	WT	Not Sampled	Oct-97	Monitoring
MAFB-245	1.7 - -8.3	WT/Bu	Not Sampled	May-96	Monitoring
MAFB-246	-5.5 - -15.5	WT/Bu	Semi-Annual	May-96	Monitoring
MAFB-251	1.8 - -13.2	WT	Not Sampled	Jan-02	Monitoring
MAFB-252	9.7 - -5.3	WT	Annual	May-98	Monitoring
MAFB-253	13.6 - -1.4	WT	Annual	Apr-96	Monitoring

TABLE 3.1 (Continued)
CURRENT MONITORING WELL NETWORK
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl) [a/]	Hydrostrat-igraphic Unit	2003 Sampling Frequency	First Available Sampling Event[c/]	Well Type
MAFB-258	-18.5 - -33.5	WT/Bu	Annual	Apr-96	Monitoring
MAFB-275	8.4 - -6.6	WT/Bu	Annual	New Well	Monitoring
MAFB-339	11.15 - -8.85	WT/B	Quarterly	Jul-98	Monitoring
MAFB-340	11.16 - -8.84	WT/B	Semi-Annual	Jul-98	Monitoring
MAFB-341	8.74 - -11.26	WT/B	Quarterly	Jul-98	Monitoring
MAFB-342	9.7 - -10.3	WT/B	Quarterly	Jul-98	Monitoring
MAFB-343	12.32 - -7.68	WT/B	Semi-Annual	Jul-98	Monitoring
MAFB-344	11.65 - -8.35	WT/B	Semi-Annual	Jul-98	Monitoring
MAFB-359	2.93 - -37.07	WT/Bu	Annual	Feb-00	Monitoring
MAFB-404	-2.3 - 17.7	WT/B	Quarterly	Aug-02	Monitoring
MAFB-405	0 - -20	WT/B	Quarterly	Oct-02	Monitoring
MAFB-407	-5.0 - -15.0	WT/Bu	Quarterly	Aug-02	Monitoring
MBS EW-1A	11.58 - -38.42	WT	Quarterly	Aug-99	Extraction
MBS EW-2A	-1.43 - -41.43	WT	Quarterly	Sep-02	Extraction
MBS EW-4A	14.73 - -5.27	WT/B	Quarterly	Apr-98	Extraction
MBS EW-5A	4.37 - -30.63	WT/B	Quarterly	Aug-99	Extraction
MBS PZ-02	-9.56 - -29.56	WT	Quarterly	Apr-98	Piezometer
MBS PZ-03	2.63 - -17.37	WT	Quarterly	Apr-98	Piezometer
MBS 39ABuB	5.04 - -34.96	WT/B	Quarterly	Jul-99	Extraction
MBS EW1ABu	3.73 - -16.27	WT/Bu	Quarterly	New Well	Extraction
MBS EW-1Bu	10.11 - -29.89	WT/Bu	Quarterly	Jul-99	Extraction
MBS EW-12AB	4.28 - -35.72	WT/B	Quarterly	Aug-99	Extraction
MBS EW2ABu	-10.94 - -50.94	WT/Bu	Quarterly	Sep-02	Extraction
MBS EW3A	9.59 - -30.41	WT/Bu	Quarterly	Jul-99	Extraction
MBS EW4ABu	3.04 - -36.96	WT/Bu	Quarterly	Aug-99	Extraction
MBS EW-4Bu	-2.219 - -42.219	Bu	Quarterly	Aug-99	Extraction
MBS EW5ABu	-4.4 - -14.4	WT/Bu	Quarterly	Dec-98	Extraction
MBS EW6ABu	-3.4 - -13.4	WT	Quarterly	Dec-98	Extraction
B Zone Wells					
MAFB-073	-20.38 - -40.38	B	Not Sampled	Feb-96	Monitoring
MAFB-094	-1.1 - -16.1	B	Annual	Jan-96	Monitoring
MAFB-101	-35.32 - -50.32	B	Quarterly	Apr-96	Monitoring
MAFB-154	0.53 - -14.47	B	Not Sampled	Jan-96	Monitoring
MAFB-155	-0.8 - -15.8	B	Annual	Jan-96	Monitoring
MAFB-164	-56.87 - -71.87	B	Quarterly	Feb-96	Monitoring
MAFB-165	-50.16 - -65.16	B	Not Sampled	Feb-96	Monitoring
MAFB-166	-41.82 - -56.82	B	Not Sampled	Feb-96	Monitoring
MAFB-167	-41.01 - -56.01	B	Annual	May-96	Monitoring
MAFB-168	-27.22 - -42.22	Bu	Quarterly	Apr-96	Monitoring
MAFB-169	-46.68 - -61.68	B	Not Sampled	Apr-96	Monitoring
MAFB-170	-46.29 - -61.29	B	Quarterly	Apr-96	Monitoring
MAFB-171	-40.15 - -55.15	B	Annual	May-96	Monitoring
MAFB-172	-19.89 - -34.89	Bu	Semi-Annual	Feb-96	Monitoring
MAFB-173	-51.26 - -66.26	B	Annual	Feb-96	Monitoring
MAFB-174	-24.07 - -39.07	Bu	Annual	Feb-96	Monitoring
MAFB-175	-63.46 - -78.46	B	Annual	Jan-96	Monitoring
MAFB-176	-28.7 - -43.7	Bu	Annual	Feb-96	Monitoring
MAFB-177	-67.29 - -82.29	B	Quarterly	Feb-96	Monitoring
MAFB-215	-57.8 - -72.8	B	Annual	Apr-96	Monitoring
MAFB-216	-35.9 - -50.9	B	Quarterly	Apr-96	Monitoring
MAFB-217	-40.8 - -55.8	B	Annual	Apr-96	Monitoring
MAFB-218	-47.9 - -62.9	B	Semi-Annual	May-96	Monitoring
MAFB-219	-44.8 - -59.8	B	Not Sampled	Apr-96	Monitoring
MAFB-220	-47.6 - -62.6	B	Annual	Apr-96	Monitoring
MAFB-221	-23.9 - -33.9	Bu	Semi-Annual	Feb-96	Monitoring
MAFB-222	-42.1 - -57.1	B	Quarterly	May-96	Monitoring
MAFB-223	-42.4 - -57.4	B	Semi-Annual	Apr-96	Monitoring
MAFB-224	-47.3 - -62.3	B	Semi-Annual	Apr-96	Monitoring
MAFB-225	-36.4 - -51.4	B	Not Sampled	May-96	Monitoring

TABLE 3.1 (Continued)
CURRENT MONITORING WELL NETWORK
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl) [a/]	Hydrostrat-igraphic Unit	2003 Sampling Frequency	First Available Sampling Event[c/]	Well Type
MAFB-226	-41.2 - -56.2	B	Not Sampled	Apr-96	Monitoring
MAFB-227	-41.2 - -56.2	B	Annual	Apr-96	Monitoring
MAFB-228	-36.7 - -51.7	B	Quarterly	Apr-96	Monitoring
MAFB-229	-30.5 - -45.5	B	Quarterly	Apr-96	Monitoring
MAFB-230	-25.9 - -40.9	B	Annual	Apr-96	Monitoring
MAFB-231	-24.7 - -39.7	B	Semi-Annual	Apr-96	Monitoring
MAFB-232	-4.6 - -19.6	B	Annual	Feb-96	Monitoring
MAFB-233	-3.5 - -18.5	B	Not Sampled	Jan-96	Monitoring
MAFB-234	-19.6 - -34.6	B	Quarterly	Apr-96	Monitoring
MAFB-247	-37.8 - -52.8	B	Annual	Apr-96	Monitoring
MAFB-248	-29.4 - -44.4	B	Annual	May-96	Monitoring
MAFB-249	-23.8 - -38.8	B	Annual	Apr-96	Monitoring
MAFB-259	-32.0 - -37.0	Bu	Annual	Apr-96	Monitoring
MAFB-260	-31.9 - -41.9	Bu	Annual	Feb-96	Monitoring
MAFB-261	-36.0 - -51.0	Bu	Semi-Annual	Feb-96	Monitoring
MAFB-263	-34.6 - -44.6	Bu	Annual	Apr-96	Monitoring
MAFB-264	-11.1 - -26.1	Bu	Semi-Annual	Apr-96	Monitoring
MAFB-265	-38.8 - -53.8	B	Annual	May-96	Monitoring
MAFB-266	-62.6 - -77.6	B	Semi-Annual	Apr-96	Monitoring
MAFB-267	-78.7 - -93.7	B	Annual	Apr-96	Monitoring
MAFB-268	-76.9 - -91.9	B	Semi-Annual	Feb-96	Monitoring
MAFB-269	-81.0 - -96.0	B	Semi-Annual	Feb-96	Monitoring
MAFB-270	-95.5 - -110.5	B	Quarterly	Apr-96	Monitoring
MAFB-271	-78.8 - -93.8	B	Quarterly	Feb-96	Monitoring
MAFB-272	-67.1 - -82.1	B	Not Sampled	Apr-96	Monitoring
MAFB-273	-45.2 - -60.2	B	Not Sampled	Apr-96	Monitoring
MAFB-274	-30.5 - -45.5	B	Annual	Apr-96	Monitoring
MAFB-280	-17.1 - -27.1	B	Annual	Feb-96	Monitoring
MAFB-281	-9.7 - -24.7	B	Annual	Jan-96	Monitoring
MAFB-282	-13.5 - -28.5	B	Semi-Annual	Apr-96	Monitoring
MAFB-308	-28.44 - -43.44	B	Annual	Feb-96	Monitoring
MAFB-309	-75.36 - -90.36	B	Not Sampled	Feb-96	Monitoring
MAFB-310	-91.08 - -106.08	B	Annual	Feb-96	Monitoring
MAFB-311	-104.92 - -119.92	B	Quarterly	Feb-96	Monitoring
MAFB-312	-124.79 - -139.79	B	Quarterly	Feb-96	Monitoring
MAFB-313	-79.92 - -94.92	B	Quarterly	Feb-96	Monitoring
MAFB-322	-114.14 - -129.14	B	Quarterly	Feb-96	Monitoring
MAFB-323	-122.68 - -132.68	B	Quarterly	Feb-96	Monitoring
MAFB-324	-82.26 - -97.26	B	Quarterly	Feb-96	Monitoring
MAFB-325	-81.42 - -96.42	B	Annual	Feb-96	Monitoring
MAFB-330	-124.19 - -139.19	B	Quarterly	Feb-96	Monitoring
MAFB-331	-124.0 - -139.0	B	Quarterly	Feb-96	Monitoring
MAFB-346Bd	-122.11 - -132.11	B	Annual	Jan-99	Monitoring
MAFB-346Bs	-70.51 - -80.51	B	Semi-Annual	Jan-99	Monitoring
MAFB-348B	-101.45 - -111.45	B	Quarterly	Jan-99	Monitoring
MAFB-351Bd	-143.39 - -153.39	B	Semi-Annual	Jan-99	Monitoring
MAFB-351Bs	-66.89 - -76.89	B	Annual	Jan-99	Monitoring
MAFB-354B	-136.78 - -146.78	B	Quarterly	Jan-99	Monitoring
MAFB-355B	-133.4 - -143.4	B	Annual	Jan-99	Monitoring
MAFB-356B	-138.42 - -148.42	B	Semi-Annual	Jan-99	Monitoring
MAFB-358B	-37.4 - -47.4	B	Semi-Annual	Jan-00	Monitoring
MAFB-360	-63.75 - -73.75	B	Annual	Aug-99	Monitoring
MAFB-361	-47.65 - -57.65	B	Annual	Aug-99	Monitoring
MAFB-362	-56.66 - -66.66	B	Semi-Annual	Aug-99	Monitoring
MAFB-363	-59.16 - -69.16	B	Quarterly	Aug-99	Monitoring
MAFB-364B	-75.53 - -85.53	B	Annual	Jan-00	Monitoring
MAFB-365B	-82.5 - -92.5	B	Annual	Jan-00	Monitoring
MAFB-366B	-80.72 - -90.72	B	Annual	Jan-00	Monitoring
MAFB-368B	-102.87 - -112.87	B	Quarterly	Jan-00	Monitoring

TABLE 3.1 (Continued)
CURRENT MONITORING WELL NETWORK
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl) [a/]	Hydrostrat-igraphic Unit	2003 Sampling Frequency	First Available Sampling Event[c/]	Well Type
MAFB-378B	-32.52 - -42.52	B	Quarterly	Jun-01	Monitoring
MAFB-379B	-80.579 - -90.579	B	Annual	Jun-01	Monitoring
MAFB-380B	-98.299 - -108.299	B	Annual	Jun-01	Monitoring
MAFB-381B	-70 - -80	B	Quarterly	Feb-02	Monitoring
MAFB-382B	-85.87 - -100.87	B	Quarterly	Dec-01	Monitoring
MAFB-383B	-69.364 - -79.364	B	Quarterly	Jun-01	Monitoring
MAFB-384B	1.76 - -18.24	B	Semi-Annual	Jun-01	Monitoring
MAFB-385B	-109.678 - -119.678	B	Quarterly	Jun-01	Monitoring
MAFB-386B	-100.597 - -110.597	B	Annual	Jun-01	Monitoring
MAFB-387B	-119.749 - -139.749	B	Quarterly	Jun-01	Monitoring
MAFB-388B	-132.229 - -142.229	B	Quarterly	Jun-01	Monitoring
MBS EW-10B	-70.38 - -110.38	B	Quarterly	Sep-02	Extraction
MBS EW-11B	-81.95 - -121.95	B	Quarterly	Sep-02	Extraction
MBS EW-1B	-23.3 - -63.3	B	Quarterly	Apr-98	Extraction
MBS EW-2B	-54.33 - -79.33	B	Quarterly	Apr-98	Extraction
MBS EW-3B	-24.07 - -84.07	B	Quarterly	Jul-99	Extraction
MBS EW-3Bu	-20.89 - -35.89	Bu	Annual	Apr-98	Extraction
MBS EW-4B	-44.84 - -74.84	B	Quarterly	Aug-99	Extraction
MBS EW-5B	-65.72 - -95.72	B	Quarterly	Sep-99	Extraction
MBS EW-6B	-75.91 - -115.91	B	Quarterly	Aug-99	Extraction
MBS EW-7B	-47.703 - -87.703	B	Quarterly	Aug-01	Extraction
MBS EW-8B	-33.3 - -63.3	B	Quarterly	Aug-99	Extraction
MBS EW-9B	-45.42 - -85.42	B	Quarterly	Sep-02	Extraction
MBS PZ-11	-55.7 - -65.7	B	Annual	Nov-98	Piezometer
MBS PZ-37	-96.68 - 106.68	B	Semi-Annual	Dec-99	Piezometer
MBS PZ-38	-74.32 - -93.32	B	Semi-Annual	Jan-00	Piezometer
MBS PZ-39	-77.14 - -87.14	B	Semi-Annual	Jan-00	Piezometer
MBS PZ-42D	-130.0 - -105.63	B	Quarterly	Jan-00	Piezometer
MBS PZ-44	-23.37 - -33.37	B	Semi-Annual	Nov-99	Piezometer
MBS PZ-55B	-68.7 - -78.7	B	Annual	Aug-02	Piezometer
MBS PZ-55Bu	-26.7 - -36.7	Bu	Semi-Annual	Aug-02	Piezometer
D Zone Wells					
FFS MW15-6	-95.4 - -100.4	D	Semi-Annual	Feb-96	Monitoring
MAFB-060	-98.68 - -118.68	D	Annual	May-96	Monitoring
MAFB-061	-106.63 - -126.63	D	Semi-Annual	Feb-96	Monitoring
MAFB-062	-102.08 - -122.08	D	Annual	Feb-96	Monitoring
MAFB-063	-100.4 - -120.4	D1	Quarterly	Feb-96	Monitoring
MAFB-066	-154.52 - -174.52	Dd	Annual	Feb-96	Monitoring
MAFB-102	-107.45 - -122.45	D	Annual	Apr-96	Monitoring
MAFB-103	-97.64 - -112.64	D	Annual	Apr-96	Monitoring
MAFB-104	-122.33 - -137.33	D	Semi-Annual	Jan-96	Monitoring
MAFB-178	-97.16 - -112.16	D	Not Sampled	Jan-96	Monitoring
MAFB-180	-97.13 - -112.13	D	Quarterly	Feb-96	Monitoring
MAFB-181	-118.58 - -133.58	D	Quarterly	Jan-96	Monitoring
MAFB-235	-81.1 - -91.1	D	Annual	Apr-96	Monitoring
MAFB-239	-103.8 - -118.8	D	Annual	May-96	Monitoring
MAFB-240	-108.5 - -123.5	D	Semi-Annual	Feb-96	Monitoring
MAFB-241	-122.5 - -137.5	D	Not Sampled	Apr-96	Monitoring
MAFB-242	-91.0 - -106.0	D	Semi-Annual	May-96	Monitoring
MAFB-243	-135.6 - -145.6	D2	Not Sampled	Feb-96	Monitoring
MAFB-250	-101.4 - -116.4	D	Semi-Annual	Apr-96	Monitoring
MAFB-290	-127.8 - -137.8	D	Annual	Feb-96	Monitoring
MAFB-291	-98.7 - -113.7	D	Not Sampled	Apr-96	Monitoring
MAFB-292	-99.2 - -114.2	D	Not Sampled	Apr-96	Monitoring
MAFB-293	-165.6 - -180.6	D	Semi-Annual	Apr-96	Monitoring
MAFB-296	-96.8 - -106.8	D	Annual	Feb-96	Monitoring
MAFB-314	-93.37 - -108.37	D	Quarterly	Feb-96	Monitoring
MAFB-315	-129.39 - -139.39	D	Not Sampled	Feb-96	Monitoring
MAFB-316	-161.14 - -176.14	D	Not Sampled	Feb-96	Monitoring

TABLE 3.1 (Continued)
CURRENT MONITORING WELL NETWORK
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl) [a/]	Hydrostrat-igraphic Unit	2003 Sampling Frequency	First Available Sampling Event[c/]	Well Type
MAFB-317	-175.88 - -185.88	D	Quarterly	Feb-96	Monitoring
MAFB-318	-174.57 - -184.57	D	Quarterly	Feb-96	Monitoring
MAFB-319	-134.55 - -149.55	D	Quarterly	Feb-96	Monitoring
MAFB-320	-123.25 - -138.25	D	Quarterly	Feb-96	Monitoring
MAFB-321	-174.65 - -184.65	Dd	Quarterly	Feb-96	Monitoring
MAFB-326	-170.09 - -185.09	D	Quarterly	Feb-96	Monitoring
MAFB-327	-184.02 - -199.02	D	Semi-Annual	Feb-96	Monitoring
MAFB-328	-124.72 - -134.72	D	Quarterly	Feb-96	Monitoring
MAFB-329	-126.36 - -136.36	D	Not Sampled	Feb-96	Monitoring
MAFB-332	-145.3 - -155.3	D	Semi-Annual	Feb-96	Monitoring
MAFB-336	-200.13 - -210.13	D	Semi-Annual	May-98	Monitoring
MAFB-337	-279.99 - -289.99	Dd	Quarterly	May-98	Monitoring
MAFB-338	-245.0 - -255.0	Dd	Quarterly	May-98	Monitoring
MAFB-345	-315.14 - -325.14	Dd	Annual	Jan-99	Monitoring
MAFB-346D	-177.11 - -187.11	D	Annual	Jan-99	Monitoring
MAFB-347	-422.27 - -432.27	LMT	Semi-Annual	Jan-99	Monitoring
MAFB-348Dd	-245.45 - -255.45	Dd	Annual	Jan-99	Monitoring
MAFB-348Ds	-171.45 - -181.45	D	Semi-Annual	Jan-99	Monitoring
MAFB-349	-365.43 - -375.43	LMT	Semi-Annual	Feb-99	Monitoring
MAFB-350	-371.06 - -381.06	LMT	Annual	Jan-99	Monitoring
MAFB-351D	-191.39 - -201.39	D	Semi-Annual	Jan-99	Monitoring
MAFB-352D	-228.33 - -238.33	Dd	Annual	Jan-99	Monitoring
MAFB-352LM	-382.33 - -392.33	LMT	Annual	Jan-99	Monitoring
MAFB-353	-361.67 - -371.67	LMT	Annual	Jan-99	Monitoring
MAFB-354D	-221.78 - -231.78	D	Semi-Annual	Jan-99	Monitoring
MAFB-355D	-228.7 - -238.7	D	Annual	Jan-99	Monitoring
MAFB-356Dd	-284.42 - -294.42	Dd	Annual	Jan-99	Monitoring
MAFB-356Ds	-232.42 - -242.42	D	Annual	Jan-99	Monitoring
MAFB-357D	-80.57 - -90.57	D1	Annual	Jan-00	Monitoring
MAFB-357Dd	-170.57 - -180.57	Dd	Semi-Annual	Jan-00	Monitoring
MAFB-357Ds	-120.57 - -130.57	D2	Annual	Jan-00	Monitoring
MAFB-358D	-82.4 - -92.4	D	Semi-Annual	Jan-00	Monitoring
MAFB-364D	-118.53 - -128.53	D	Semi-Annual	Jan-00	Monitoring
MAFB-365D	-127.5 - -137.5	D	Annual	Jan-00	Monitoring
MAFB-366D	-110.72 - -120.72	D	Quarterly	Jan-00	Monitoring
MAFB-367	-145.08 - -155.08	D	Semi-Annual	Aug-99	Monitoring
MAFB-368D	-172.87 - -182.87	D	Quarterly	Jan-00	Monitoring
MAFB-369	-138.28 - -148.28	D	Quarterly	Sep-99	Monitoring
MAFB-374	-83.676 - -93.676	D	Annual	May-01	Monitoring
MAFB-375	-102.386 - -112.386	D	Semi-Annual	May-01	Monitoring
MAFB-376	-123.826 - -133.826	D	Semi-Annual	Jun-01	Monitoring
MAFB-377	-114.9 - -124.9	D	Quarterly	May-02	Monitoring
MAFB-378D	-88.52 - -98.52	D	Quarterly	Jun-01	Monitoring
MAFB-379D	-140.579 - -150.579	D	Semi-Annual	Jun-01	Monitoring
MAFB-380D	-141.799 - -151.799	D	Semi-Annual	Jun-01	Monitoring
MAFB-381D	-165 - -175	D	Quarterly	Feb-02	Monitoring
MAFB-382D	-175.87 - -185.87	D	Quarterly	Dec-01	Monitoring
MAFB-383D	-134.364 - -144.364	D	Semi-Annual	Jun-01	Monitoring
MAFB-384D	-77.24 - -87.24	D	Annual	Jun-01	Monitoring
MAFB-385D	-159.678 - -169.678	D	Quarterly	Jun-01	Monitoring
MAFB-386D	-180.597 - -190.597	D	Annual	Jun-01	Monitoring
MAFB-387Dd	-259.749 - -269.749	D	Quarterly	Jun-01	Monitoring
MAFB-387Ds	-214.749 - -224.749	D	Semi-Annual	Jun-01	Monitoring
MAFB-388Dd	-267.229 - -277.229	D	Semi-Annual	Jun-01	Monitoring
MAFB-388Ds	-222.229 - -232.229	D	Semi-Annual	Jun-01	Monitoring
MAFB-397	-154.0 - -164.0	Dd	Quarterly	Aug-02	Monitoring
MBS EW-1D	unknown	D	Quarterly	Apr-98	Extraction
MBS EW-2D	-105.11 - -145.11	D	Quarterly	Apr-98	Extraction
MBS EW-3D	-85.204 - -125.204	D	Quarterly	Aug-01	Extraction

TABLE 3.1 (Continued)
CURRENT MONITORING WELL NETWORK
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl) [a/]	Hydrostrat-igraphic Unit	2003 Sampling Frequency	First Available Sampling Event[c/]	Well Type
MBS EW-4D	-78.72 - -103.72	D	Quarterly	Sep-02	Extraction
MBS EW-5D	-107.17 - -142.17	D	Quarterly	Sep-02	Extraction
MBS EW-6D	-156.07 - -181.07	D	Quarterly	Sep-02	Extraction
MBS PZ-12	-295.2 - -305.2	LMT	Annual	Dec-98	Piezometer
MBS PZ-13	-166.0 - -176.0	Dd	Semi-Annual	Dec-98	Piezometer
MBS PZ-14	-286.4 - -301.4	LMT	Annual	Dec-98	Piezometer
MBS PZ-15	-290.8 - -300.8	LMT	Annual	Dec-98	Piezometer
MBS PZ-49D	-285.71 - -295.71	LMT	Annual	Feb-00	Piezometer
MBS PZ-50D	-298.52 - -308.52	LMT	Semi-Annual	Jan-00	Piezometer
MBS PZ-51	-93.638 - -103.638	D	Annual	Aug-01	Piezometer
MBS PZ-52	-90.435 - -100.435	D	Annual	Aug-01	Piezometer
MBS PZ-53	-101.765 - -116.765	D	Annual	Aug-01	Piezometer
MBS PZ-54	-95.625 - -105.625	D	Annual	Aug-01	Piezometer
MBS PZ-58	-99.23 - -109.23	D	Semi-Annual	Aug-02	Piezometer

[a/] ftbmsl = feet below mean sea level
[b/] 2003 Sampling frequency based on 2002 Groundwater Monitoring Program Evaluation Report (MWH, 2002b).

MAFB-280:0,0, 0
MAFB-073:0,0, 0
MAFB-154:0,0, 0
MAFB-281:0,0, 0
MAFB-155:2,0, 0
MAFB-233:0,0, 0
MAFB-378B:0,0, 0
MAFB-384B:0,6.5, 0
MAFB-273:0,0, 0
MAFB-309:0,0, 0
MAFB-230:0,0, 0
MAFB-094:21,0, 0
MAFB-358B:0,14, 0
MAFB-272:0,0, 0
MAFB-274:0,4.5, 0
MAFB-234:0,48, 0
MAFB-325:0,0, 0
MAFB-308:0,3, 0
MAFB-231:2.2,45, 0
MAFB-232:2.5,0, 0.72
MAFB-282:3.8,0, 0
MBS PZ-11:0,2.6, 0
MAFB-228:0.26,37, 0.43
MAFB-379B:0,12, 0.61
MAFB-229:2,170, 0.7
MAFB-310:0,0, 0
MBS EW-3B:16,37, 1.2
MAFB-101:0.57,19, 0.65
MAFB-324:0,0.35, 0
MBS EW-2B:17,95, 0.86
MAFB-271:0,0.66, 0
MBS EW-1B:3.5,42, 2.1
MAFB-366B:0,13, 0.53
MAFB-222:32,73, 13
MAFB-322:0,0, 0
MAFB-385B:0,0, 0
MAFB-264:46,3.8, 4.1
MAFB-265:42,5.6, 4
MAFB-249:9.7,1.5, 1.3
MAFB-380B:0,1.5, 0.37
MAFB-164:0,23, 0.97
MAFB-221:0.4,0, 0
MAFB-227:59,8, 4.4
MBS EW-8B:0.8,1, 0.28
MAFB-223:46,19, 2.7
MBS PZ-39:0,15, 0.63
MAFB-220:22,52, 11
MAFB-224:23,0.85, 5.3
MAFB-226:14,0.7, 4.2
MBS PZ-42D:0,31,2.3
MAFB-363:2.2,34, 1
MAFB-169:21,1.1, 4.7
MBS EW-5B:0,24, 1.9
MAFB-348B:0,0.98, 0.58
MBS EW-7B:2.1,28, 1
MBS PZ-38:0,22, 1.9
MAFB-219:17.8,8, 1.6
MAFB-218:14,33, 2
MAFB-248:8.6,0.27, 3.1
MBS EW-6B:0,18, 2.1
MAFB-313:0,11, 1.4
MAFB-362:2,9.8, 0.3
MAFB-225:6.9,0.062, 1.1
MAFB-311:0,0, 0
MBS PZ-37:0,36, 3.9
MAFB-165:3.5,21, 0.72
MAFB-217:20,0, 2.8
MAFB-270:0,2.8, 3.8
MAFB-175:2.9,45, 2.3
MAFB-360:4.1,6, 0.85
MAFB-170:7,12, 1.8
MAFB-166:6,2.4, 1.1
MAFB-365B:2.1,35, 1.3
MAFB-216:21,6.7, 2.4
MBS PZ-44:10,4, 0
MAFB-368B:0,8.1, 3.3
MBS EW-10B:
MAFB-177:1.5,18, 3.7
MAFB-361:3.1,2, 0.65
MAFB-215:40,7.3, 2
MBS EW-11B: NA
MAFB-263:0,0, 2.9
MAFB-364B:5.7,21, 2
MAFB-171:2.2,0.89, 0
MAFB-351Bd:0,0, 0
MAFB-351Bs:0,0, 0
MAFB-247:5.3,0, 1.3
MAFB-174:2.3,0, 0
MAFB-323:0,0, 0
MAFB-381B:0,1.1, 1.6
MAFB-167:65,18, 1.7
MAFB-355B:0,0, 0
MBS PZ-55Bu: NA
MBS EW-4B:1.9,30, 1.3
MAFB-269:1.2,1.7, 2.1
MAFB-261:0,0.52, 0.62
MBS PZ-55B: NA
MAFB-176:6.1,0, 0
MAFB-173:2.9,0, 0.59
MAFB-168:52,15, 0.85
MAFB-346Bd:0,0, 0
MAFB-312:0,0, 2.1
MAFB-346Bs:0,1.8, 2.4
MAFB-266:13,3.1, 1.2
MAFB-331:0,0, 1.3
MBS EW-9B:NA
MAFB-388B:0,0, 0.41
MAFB-354B:0,0, 0
MAFB-172:0.93,0.35, 0
MAFB-330:0,0, 0.92
MAFB-387B:0,0, 0
MBS EW-3Bu:0.28,0, 0
MAFB-268:2.5,0, 0.55
MAFB-260:0,0, 0
MAFB-382B:0,0, 0
MAFB-383B:17,2.2, 0
MAFB-356B:0,0, 0
MAFB-386B:0,0, 0
MAFB-259:0,0, 0
MAFB-267:0,0, 0

Legend

B Zone

Well Type

- Extraction Well
- Monitoring Well
- Piezometer
- Mather Property Line
- General Groundwater Flow Direction
- MAFB-109: 8,0,1.5 — Well ID: most recent TCE,PCE, CCL4 concentration ug/L

N

0 750 1,500 3,000 Feet

1 inch equals 1,500 feet

FIGURE 3.1
B ZONE
MONITORING WELL NETWORK AND COC CONCENTRATIONS

Monitoring Network Optimization
Main Base/SAC Area
Former Mather AFB, California

PARSONS
Denver, Colorado

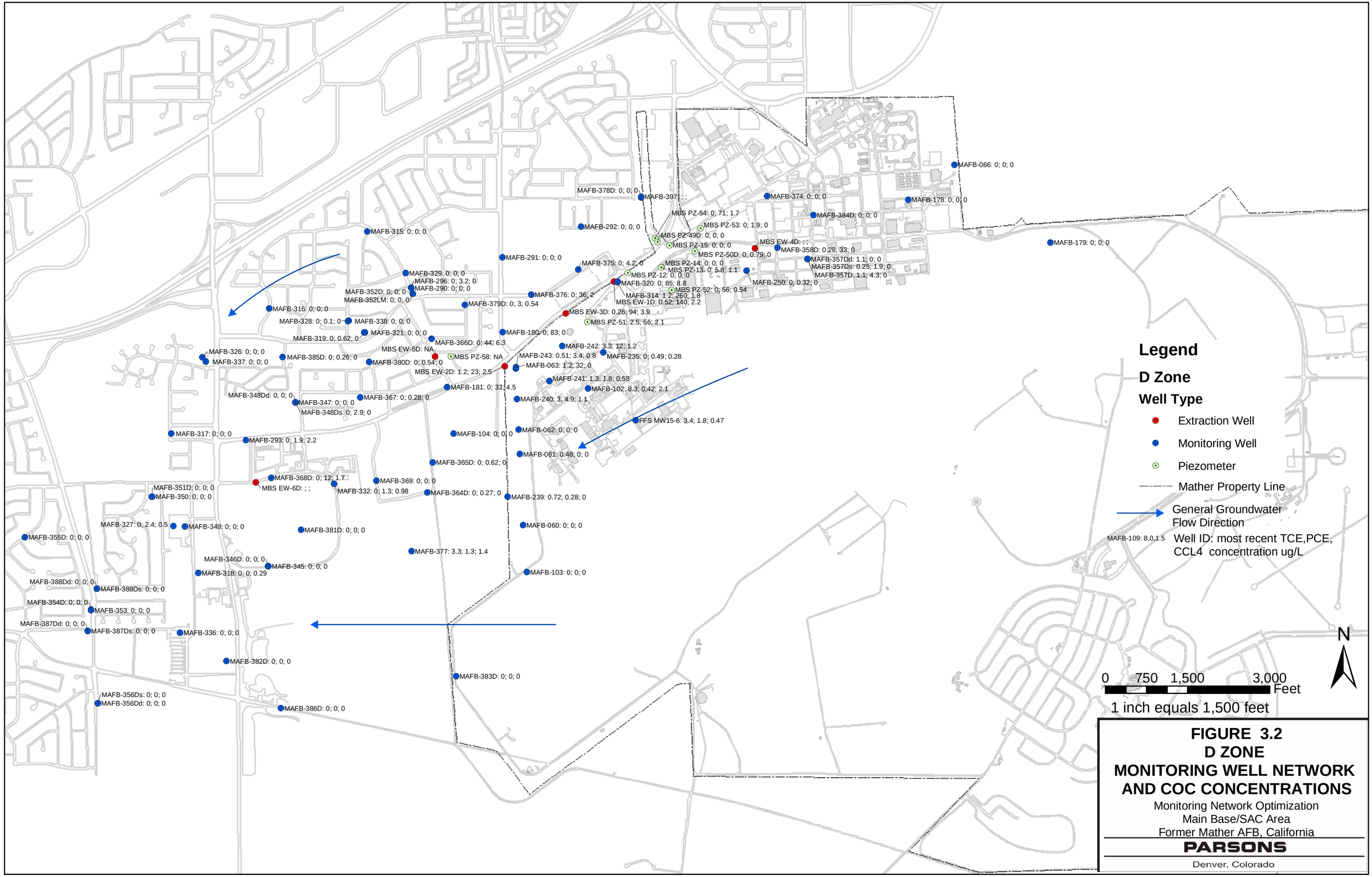


FIGURE 3.2
D ZONE
MONITORING WELL NETWORK AND COC CONCENTRATIONS

Monitoring Network Optimization
Main Base/SAC Area
Former Mather AFB, California

PARSONS
Denver, Colorado

TABLE 3.2
MAIN BASE/SAC AREA MONITORING WELL PROGRAM TYPE AND MONITORING FREQUENCY BREAKDOWN
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AFB, CALIFORNIA

Zone	Type of Well	Monitoring Frequency				Total Wells
		Not Sampled	Annual	Semi-Annual	Quarterly	
WT/A	Groundwater Extraction Wells	0	0	0	14	14
WT/A	Monitoring Wells/Piezometers	16	24	17	15	72
B	Groundwater Extraction Wells	0	1	0	11	12
B	Monitoring Wells/Piezometers	12	41	23	32	108
D	Groundwater Extraction Wells	0	0	0	6	6
D	Monitoring Wells/Piezometers	8	33	30	23	94
Total Wells		36	99	70	101	**306**

3.2 SUMMARY OF ANALYTICAL DATA

In general, the Mather Main Base/SAC Area groundwater plume is well-characterized both laterally and vertically. The groundwater monitoring program for this plume was evaluated using results for sampling events performed from January 1996 through November 2002. Analytical data was available for 304 of the 306 wells analyzed; wells MAFB-275 and MBS EW-3A are new wells and did not have analytical results for the data obtained for the analysis (through 11/02). The database was processed to remove duplicate data by retaining the maximum result for each duplicate sample pair. As discussed in Section 2.3, the COCs identified for the Main Base/SAC Area plume include halogenated VOCs; these are the only COCs that are systematically detected at Mather. Table 3.3 presents a summary of the occurrence of COCs in groundwater based on the data collected from the Main Base/SAC Area wells for all of the wells combined and by zone. Table 3.3 confirms that TCE, PCE, and CCl_4 are the main contaminants in groundwater beneath the Main Base/SAC Industrial Area based on their widespread and relatively high concentrations.

Overall (i.e., in all of the zones combined), PCE has been detected in approximately 59 percent of the total groundwater samples over time, and has exceeded its MCL of

TABLE 3.3
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN IN MONITORING WELLS
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Parameter	Total Samples[a/]	Percentage of Detects	Range of Detects (µg/L)[b/]	Cleanup Standards (µg/L)[b/]	Percentage of Cleanup Standard Exceedances	Number of Wells with Results	Number of Wells with Detections	Number of Wells with Cleanup Standard Exceedances
All Wells								
Benzene	1213	2.1%	0.26-5	1	0.2%	228	11	3
Carbon Tetrachloride	**3484**	**44.8%**	**0.072-27**	**0.5**	**38.3%**	**304**	**178**	**160**
chloromethane	3484	0.8%	0.25-2.2	3	0.0%	304	24	0
1,2-dichloroethane	3487	2.1%	0.047-12	0.5	0.9%	304	37	14
1,1-dichloroethene	3484	11.0%	0.057-860	6	3.4%	304	58	12
1,2-cis-dichloroethene	3484	16.9%	0.053-15	6	0.7%	304	97	11
Lead	243	18.5%	1.1-58.7	15	3.3%	76	22	3
Tetrachloroethene	**3484**	**58.9%**	**0.05-3120**	**5**	**37.1%**	**304**	**231**	**130**
total diesel-range petroleum hydrocarbons	183	6.0%	10-1190	100	4.4%	76	11	8
total gasoline-range petroleum hydrocarbons	383	28.5%	10-5600	50	24.5%	98	36	28
Trichloroethene	**3484**	**44.6%**	**0.12-13000**	**5**	**22.7%**	**304**	**169**	**93**
Xylenes	830	1.0%	0.5-3.8	17	0.0%	153	7	0
Zone WT/A								
Benzene	248	6.9%	0.26-5	1	0.8%	52	7	2
Carbon Tetrachloride	925	39.1%	0.072-27	0.5	27.7%	84	45	37
chloromethane	925	0.4%	0.27-0.46	3	0.0%	84	4	0
1,2-dichloroethane	926	4.6%	0.08-12	0.5	3.0%	84	16	11
1,1-dichloroethene	925	28.3%	0.057-860	6	12.9%	84	29	12
1,2-cis-dichloroethene	925	29.0%	0.07-15	6	2.6%	84	37	11
Lead	95	26.3%	1.3-58.7	15	8.4%	33	12	3
Tetrachloroethene	925	69.3%	0.05-3120	5	47.4%	84	66	46
total diesel-range petroleum hydrocarbons	60	8.3%	10-320	100	3.3%	32	5	2
total gasoline-range petroleum hydrocarbons	123	45.5%	33-5600	50	43.9%	43	21	20
Trichloroethene	925	67.6%	0.13-13000	5	39.5%	84	63	39
Xylenes	174	1.1%	0.52-2	17	0.0%	39	2	0

TABLE 3.3 (Continued)
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN IN MONITORING WELLS
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Parameter	Total Samples[a/]	Percentage of Detects	Range of Detects (µg/L)[b/]	Cleanup Standards (µg/L)[b/]	Percentage of Cleanup Standard Exceedances	Number of Wells with Results	Number of Wells with Detections	Number of Wells with Cleanup Standard Exceedances
Zone B/Bu								
Benzene	481	1.7%	0.26-2.9	1	0.2%	90	3	1
Carbon Tetrachloride	1513	55.3%	0.078-15	0.5	50.4%	120	88	83
chloromethane	1513	1.0%	0.27-1.9	3	0.0%	120	11	0
1,2-dichloroethane	1515	2.0%	0.047-0.99	0.5	0.2%	120	21	3
1,1-dichloroethene	1513	7.9%	0.058-1.9	6	0.0%	120	28	0
1,2-cis-dichloroethene	1513	20.2%	0.053-3.8	6	0.0%	120	53	0
Lead	89	14.6%	1.2-13.3	15	0.0%	26	6	0
Tetrachloroethene	1513	60.9%	0.056-640	5	39.9%	120	94	57
total diesel-range petroleum hydrocarbons	80	6.3%	150-1190	100	6.3%	29	5	5
total gasoline-range petroleum hydrocarbons	144	9.7%	20-80	50	4.2%	38	9	5
Trichloroethene	1513	48.0%	0.14-94	5	26.8%	120	75	49
Xylenes	313	1.6%	0.5-3.8	17	0.0%	56	4	0
Zone D								
Benzene	484	0.2%	0.65-0.65	1	0.0%	86	1	0
Carbon Tetrachloride	1046	34.8%	0.1-14	0.5	30.1%	100	45	40
chloromethane	1046	0.9%	0.25-2.2	3	0.0%	100	9	0
1,2-dichloroethane	1046	0.0%	-	0.5	0.0%	100	0	0
1,1-dichloroethene	1046	0.1%	0.4-0.4	6	0.0%	100	1	0
1,2-cis-dichloroethene	1046	1.5%	0.11-0.72	6	0.0%	100	7	0
Lead	59	11.9%	1.1-8	15	0.0%	17	4	0
Tetrachloroethene	1046	46.9%	0.058-520	5	24.0%	100	71	27
total diesel-range petroleum hydrocarbons	43	2.3%	240-240	100	2.3%	15	1	1
total gasoline-range petroleum hydrocarbons	116	33.6%	10-250	50	29.3%	17	6	3
Trichloroethene	1046	19.5%	0.12-10	5	2.1%	100	31	5
Xylenes	343	0.3%	0.58-0.58	17	0.0%	58	1	0

[a/] Includes sampling results from January 1996 to November 2002.

[b/] µg/L = micrograms per liter.

5 μg/L in approximately 37 percent of the samples. PCE has been detected in 231 of the 304 (76 percent) wells/piezometers with analytical results in the Main Base/SAC Area plume, and has exceeded the MCL at 130 (43 percent) of these wells. TCE has been detected in 45 percent of the total groundwater samples over time, and has exceeded its MCL of 5 μg/L in 23 percent of the samples. TCE has been detected in 169 of the 304 (56 percent) wells with analytical results in the Main Base/SAC plume area, and has exceeded its MCL at 93 (31 percent) of these wells. CCl_4 has been detected in approximately 45 percent of the total groundwater samples over time, and has exceeded its MCL of 0.5 μg/L in approximately 38 percent of the samples. CCl_4 has been detected in 178 of the 304 (59%) wells with analytical results in the Main Base/SAC plume area, and has exceeded its MCL at 160 (53%) of these wells. The analytical results for these three COCs constituted the primary data used to conduct the qualitative and temporal components of the three-tiered MNO evaluation due to the magnitude and spatial extent of their concentrations in groundwater compared to other detected compounds. The sum of the concentrations for the three primary COCs was used as the "indicator" chemical in the spatial evaluation.

SECTION 4

QUALITATIVE MNO EVALUATION

An effective groundwater monitoring program will provide information regarding contaminant plume migration and changes in chemical concentrations through time at appropriate locations, enabling decision-makers to assess whether that contaminants are threatening potential receptors, and that remediation is occurring at rates sufficient to achieve remedial action objectives (RAOs) within a reasonable time frame. The design of the monitoring program should therefore include consideration of existing receptor exposure pathways, as well as exposure pathways arising from potential future use of the groundwater.

Performance monitoring wells located within and downgradient from a plume provide a means of evaluating the effectiveness of a groundwater remedy relative to performance criteria. Long-term monitoring (LTM) of these wells also provides information about migration of the plume and temporal trends in chemical concentrations. Groundwater monitoring wells located downgradient from the leading edge of a plume (i.e., sentry wells) are used to evaluate possible changes in the extent of the plume and, if warranted, to trigger a contingency response action if contaminants are detected.

Primary factors to consider when developing a groundwater monitoring program include at a minimum:

- Aquifer heterogeneity,
- Types of contaminants,
- Distance to potential receptor exposure points,

- Groundwater seepage velocity and flow direction(s),
- Potential surface-water impacts,
- The effects of the remediation system, and
- Other sources of discharge from or recharge to the aquifer (i.e., pumping wells)

These factors will influence the locations and spacing of monitoring points and the sampling frequency. Typically, the greater the seepage velocity and the shorter the distance to receptor exposure points, the more frequently groundwater sampling should be conducted.

One of the most important purposes of LTM is to confirm that the contaminant plume is behaving as predicted. Graphical and statistical tests can be used to evaluate plume stability. If a groundwater remediation system or strategy is effective, then over the long term, groundwater-monitoring data should demonstrate a clear and meaningful decreasing trend in concentrations at appropriate monitoring points. The current groundwater monitoring program at Mather was evaluated to identify potential opportunities for streamlining monitoring activities while still maintaining an effective performance and compliance monitoring program.

4.1 METHODOLOGY FOR QUALITATIVE EVALUATION OF MONITORING NETWORK

The MNO evaluation included 306 wells located in the Main Base/SAC Plume area of Mather. These wells, their screened intervals, and the 2002 monitoring frequencies are listed in Table 3.1, and their locations are depicted on Figures 3.1 to 3.3. As shown in the table, the MNO evaluation included groundwater monitoring wells, piezometers, and extraction wells.

Multiple factors were considered in developing recommendations for continuation or cessation of groundwater monitoring at each well. In some cases, a recommendation was made to continue monitoring a particular well, but at a reduced frequency. A

recommendation to discontinue monitoring at a particular well based on the information reviewed does not necessarily constitute a recommendation to physically abandon the well. A change in site conditions might warrant resumption of monitoring at some time in the future at wells that are not currently recommended for continued sampling. Typical factors considered in developing recommendations to retain a well in, or remove a well from, a LTM program are summarized in Table 4.1. Typical factors considered in developing recommendations for monitoring frequency are summarized in Table 4.2.

TABLE 4.1
MONITORING NETWORK OPTIMIZATION DECISION LOGIC
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AFB, CALIFORNIA

Reasons for Retaining a Well in Monitoring Network	Reasons for Removing a Well From Monitoring Network
Well is needed to further characterize the site or monitor changes in contaminant concentrations through time	Well provides spatially redundant information with a neighboring well (e.g., same constituents, and/or short distance between wells)
Well is important for defining the lateral or vertical extent of contaminants.	Well has been dry for more than 2 years[a/]
Well is needed to monitor water quality at compliance point or receptor exposure point (e.g., water supply well)	Contaminant concentrations are consistently below laboratory detection limits or cleanup goals
Well is important for defining background water quality	Well is completed in same water-bearing zone as nearby well(s)

a/ Periodic water-level monitoring should be performed in dry wells to confirm that the upper boundary of the saturated zone remains below the well screen. If the well becomes re-wetted, then its inclusion in the monitoring program should be evaluated. A well that has been dry for more than two years should be replaced with a new well screened at a deeper interval if groundwater monitoring at that location is deemed to be required.

4.2 RESULTS OF QUALITATIVE MNO EVALUATION

The results of the qualitative evaluation of wells in the Main Base/SAC Area Plume at Mather are described in this subsection. The evaluation included the 306 monitoring wells, piezometers and extraction wells listed in Table 3.1. The evaluation grouped the wells into three zones (zones WT/A, B, and D) based on the hydrostratigraphic unit within which the well screen is located, as discussed in Section 3.1. The qualitative

MNO evaluation considered only analytical results for the primary COCs (PCE, TCE and CCl_4) for groundwater monitoring events conducted during the past five years (1998 through 2002).

TABLE 4.2
MONITORING FREQUENCY DECISION LOGIC
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AFB, CALIFORNIA

Reasons for Increasing Sampling Frequency	Reasons for Decreasing Sampling Frequency
Groundwater velocity is high	Groundwater velocity is low
Change in contaminant concentration would significantly alter a decision or course of action	Change in contaminant concentration would not significantly alter a decision or course of action
Well is necessary to monitor source area or operating remedial system	Well is distal from source area and remedial system
Cannot predict if concentrations will change significantly over time	Concentrations are not expected to change significantly over time, or contaminant levels have been below groundwater cleanup objectives for some prescribed period of time

Table 4.3 includes recommendations for retaining or removing each well and the sampling frequency, and the rationale for the recommendations. Wells that met one of the criteria listed below were retained for quarterly sampling, consistent with the 2002 monitoring frequency:

1. Wells within 1,000 feet of a water-supply well.

2. Wells included as part of the Off-Base Supply Well Monitoring Program.

3. Downgradient edge-of-plume wells.

4. Wells with less than four quarters of data.

TABLE 4.3

QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl)[a/]	2003 Sampling Frequency[b/]	Qualitative Analysis			Rationale
			Exclude	Retain	Monitoring Frequency Recommendation	
WT/A Zone Wells						
MAFB-006	14.3 - -3.7	Not Sampled	√		--	Upgradient well, no historical COC detections.
MAFB-033	6.88 - -13.12	Semi-Annual		√	Semi-annual	Monitors TCE hot spot.
MAFB-037	12.24 - -7.76	Annual		√	Annual	Monitors water quality near southeastern plume boundary.
MAFB-047	0.93 - -19.07	Annual		√	Annual	Monitors water quality downgradient of hot spots.
MAFB-048	4.26 - -15.74	Annual		√	Annual	Monitors water quality near western plume boundary.
MAFB-085	2.78 - -12.22	Semi-Annual		√	Semi-annual	Montiors water quality downgradient.
MAFB-086	8.28 - 4.78	Quarterly		√	Semi-annual	Monitors water quality downgradient of extraction wells.
MAFB-087	4.67 - -10.33	Quarterly		√	Semi-annual	Defines extent of hot spot[c/], monitors water near MBS EW6ABu. Reduce frequency due to COCs consistently under MCLs.
MAFB-088	5.45 - -9.55	Semi-Annual	√		--	Redundant with well MAFB-206, which has higher TCE concentration.
MAFB-089	9.88 - -5.12	Annual		√	Annual	Defines extent of plume.
MAFB-090	3.39 - -11.61	Semi-Annual		√	Semi-annual	Monitors potential increase in TCE above MCL.
MAFB-091	7.09 - -7.91	Not Sampled	√		--	Spatially redundant. MAFB-092 is sampled annually. COCs not detected historically.
MAFB-092	5.51 - -9.49	Annual		√	Annual	Defines plume extent to west.
MAFB-093	6.38 - -8.62	Not Sampled	√		--	Available in reserve for future sampling if MB-3 becomes operational.
MAFB-095	10.04 - -4.96	Quarterly		√	Quarterly	Monitors hot spot and effects of extraction system near MBS EW 1A (declining PCE concentrations).
MAFB-096	5.93 - -9.07	Annual		√	Annual	Reduce sampling frequency due to COCs consistently under MCLs. Hydraulically upgradient of plume.
MAFB-097	1.03 - -13.97	Annual		√	Annual	Monitors groundwater quality within upgradient portion of the plume.
MAFB-099	7.71 - -7.29	Annual		√	Quarterly	Increase frequency due to order of magnitude increase in PCE/TCE concentrations.
MAFB-105	7.47 - -7.53	Annual		√	Annual	Monitorings increasing concentrations in upgradient well MAFB-099,
MAFB-106	11.94 - -3.06	Semi-Annual		√	Annual	Monitors groundwater at upgradient plume boundary. Reduce frequency due to low COCs.
MAFB-121	0.17 - -14.83	Annual		√	Semi-annual	Monitors downgradient portion of Main Base/SAC plume.
MAFB-122	2.42 - -12.58	Semi-Annual		√	Semi-annual	Defines plume boundary to the west.
MAFB-123	-0.53 - -15.53	Annual		√	Annual	Monitors groundwater quality within downgradient portion of plume.
MAFB-124	-0.34 - -15.34	Annual	√		--	No COC detections during last 5 sampling events. 2,000 feet from western plume boundary.
MAFB-150	8.5 - -6.5	Not Sampled	√		--	Retain for future sampling if MB-4 becomes operational.
MAFB-156	-2.05 - -17.05	Not Sampled	√		--	Cross gradient of plume boundary.--EPA comment
MAFB-157	-5.56 - -20.56	Not Sampled	√		--	MAFB-048 and MAFB-122 monitor western extent of plume.
MAFB-158	0.06 - -14.94	Not Sampled	√		--	Spatially redundant to MAFB-047.
MAFB-159	0.73 - -14.27	Semi-Annual		√	Annual	Defines plume boundary to the west. Decrease frequency due to COCs consistently under MCLs.
MAFB-160	7.35 - -7.65	Annual		√	Annual	Monitor COC concentrations near west plume boundary.
MAFB-161	6.4 - -8.6	Not Sampled	√		--	Spatially redundant to MAFB-092.
MAFB-162	12.52 - -2.48	Annual		√	Biennial	ND in monitoring history; defines extent of PCE and CCL_4 upgradient of plume boundary; reduce sampling to biennial.
MAFB-163	11.89 - -3.11	Not Sampled	√		--	Spatially redundant to MAFB-162.
MAFB-186	9.14 - -5.86	Not Sampled	√		--	Spatially redundant to MAFB-092. Last sampled for TPH/BTEX prior to 1997; sample once for TPH & BTEX in 2004.
MAFB-187	8.14 - -6.86	Not Sampled	√		--	Spatially redundant to MAFB-092. Only one TPH/BTEX sample since 1996; sample once for TPH & BTEX in 2004.
MAFB-188	6.64 - -8.36	Not Sampled	√		--	Spatially redundant to MAFB-092. Only one TPH/BTEX sample since 1997; sample once for TPH & BTEX in 2004
MAFB-199	-3.9 - -18.9	Annual		√	Biennial	Similar results to MAFB-047. Reduce to biennial sampling.
MAFB-200	-2.8 - -17.8	Annual	√		--	Spatially redundant to MAFB-359.
MAFB-201	-1.0 - -16.0	Quarterly		√	Semi-annual	Reduce sampling frequency due to COCs consistently under MCLs. Evaluates water quality downgradient of hot spot.
MAFB-202	-0.5 - -15.5	Semi-Annual		√	Semi-annual	Defines eastern extent of hot spot.
MAFB-203	-1.0 - -16.0	Quarterly		√	Quarterly	Evaluate effectiveness of extraction wells.
MAFB-204	0.3 - -14.7	Semi-Annual		√	Annual	Reduce sampling frequency due to stable COC concentrations consistently under MCLs.
MAFB-205	-2.6 - -17.6	Annual	√		--	Does not provide useful data in evaluating plume extent or remedial effectiveness.
MAFB-206	1.6 - -13.4	Semi-Annual		√	Semi-annual	Defines extent of hot spots and water quality near MBS EW4ABu.
MAFB-207	-0.4 - -15.4	Semi-Annual		√	Semi-annual	Recent increase in PCE.
MAFB-208	0.4 - -14.6	Quarterly	√		--	Spatially redundant to MAFB-209. Does not provide useful data in evaluating plume extent or remedial effectiveness.
MAFB-209	1.7 - -13.3	Annual		√	Annual	Defines eastern extent of hot spot.

TABLE 4.3 (Continued)
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl)[a/]	2003 Sampling Frequency[b/]	Qualitative Analysis			Rationale
			Exclude	Retain	Monitoring Frequency Recommendation	
MAFB-210	0.2 - -14.8	Not Sampled		√	Biennial	Defines eastern extent of hot spot.
MAFB-211	-1.3 - -16.3	Semi-Annual		√	Annual	Reduce sampling frequency due to COC concentrations under MCLs.
MAFB-212	3.4 - -11.6	Annual		√	Annual	Defines extent of hot spot.
MAFB-213	5.5 - -4.5	Quarterly		√	Quarterly	Monitors PCE hot spot and effectiveness of extraction wells.
MAFB-214	5.1 - -9.9	Semi-Annual		√	Semi-annual	Downgradient of PCE hot spot/extraction system.
MAFB-244	4.0 - -11.0	Not Sampled	√		--	Spatially redundant to MAFB-252.
MAFB-245	1.7 - -8.3	Not Sampled		√	Annual	Defines eastern plume boundary.
MAFB-246	-5.5 - -15.5	Semi-Annual		√	Semi-annual	Monitors hot spot.
MAFB-251	1.8 - -13.2	Not Sampled	√		--	No historical COC detections. Does not provide useful data for evaluating plume extent or remediation system
MAFB-252	9.7 - -5.3	Annual		√	Annual	Defines eastern extent of plume.
MAFB-253	13.6 - -1.4	Annual		√	Annual	Monitor water quality within upgradient portion of plume
MAFB-258	-18.5 - -33.5	Annual		√	Annual	Monitors downgradient extent of plume
MAFB-275	8.4 - -6.6	Annual		√	Quarterly	Less than 4 rounds of analytical data.
MAFB-339	11.15 - -8.85	Quarterly		√	Quarterly	Monitors plume hot spot.
MAFB-340	11.16 - -8.84	Semi-Annual		√	Semi-annual	Monitors PCE hot spot.
MAFB-341	8.74 - -11.26	Quarterly		√	Quarterly	Upgradient of hot spot, monitor declining COC concentrations
MAFB-342	9.7 - -10.3	Quarterly		√	Quarterly	Evaluate declining COC concentrations adjacent to MBS EW-5A.
MAFB-343	12.32 - -7.68	Semi-Annual		√	Semi-annual	Evaluates water quality near extraction system at PCE hot spot.
MAFB-344	11.65 - -8.35	Semi-Annual		√	Semi-annual	Monitors upgradient portion of plume.
MAFB-359	2.93 - -37.07	Annual		√	Annual	Evaluates water quality downgradient of hot spot.
MAFB-404	-2.3 - 17.7	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MAFB-405	0 - -20	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MAFB-407	-5.0 - -15.0	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS 39ABuB	11.58 - -38.42	Quarterly		√	Quarterly	Calculation of mass removal rates from plume core, evaluates remedial progress.
MBS EW-12AB	-1.43 - -41.43	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS EW-1A	14.73 - -5.27	Quarterly		√	Quarterly	Calculation of mass removal rates from plume core, evaluates remedial progress.
MBS EW1ABu	4.37 - -30.63	Quarterly		√	Quarterly	Calculation of mass removal rates from plume core, evaluates remedial progress.
MBS EW-1Bu	-9.56 - -29.56	Quarterly		√	Quarterly	Downgradient of hot spots. Calculation of mass removal rates.
MBS EW-2A	2.63 - -17.37	Quarterly		√	Quarterly	Calculation of mass removal rates from plume core, evaluates remedial progress.
MBS EW2ABu	5.04 - -34.96	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-3A	3.73 - -16.27	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS EW-4A	10.11 - -29.89	Quarterly		√	Quarterly	Calculation of mass removal rates.
MBS EW4ABu	4.28 - -35.72	Quarterly		√	Quarterly	Calculation of mass removal rates, track increasing CCL_4 concentrations.
MBS EW-4Bu	-10.94 - -50.94	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS EW-5A	9.59 - -30.41	Quarterly		√	Semi-annual	Reduce frequency due to low COCs.
MBS EW5ABu	3.04 - -36.96	Quarterly		√	Quarterly	Calculation of mass removal rates from hot spot, evaluates remedial progress.
MBS EW6ABu	-2.219 - -42.219	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS PZ-02	-4.4 - -14.4	Quarterly		√	Quarterly	Monitoring increasing COC concentrations in hot spot area near extraction wells.
MBS PZ-03	-3.4 - -13.4	Quarterly		√	Quarterly	Monitoring COC concentrations in hot spot area near extraction wells.
B Zone Wells						
MAFB-073	-20.38 - -40.38	Not Sampled	√		--	Available in reserve for future sampling if MB-4 becomes operational.
MAFB-094	-1.1 - -16.1	Annual		√	Annual	Monitors water quality upgradient of plume boundary.
MAFB-101	-35.32 - -50.32	Quarterly		√	Quarterly	Monitors water quality near MAFB EW-3B.
MAFB-154	0.53 - -14.47	Not Sampled	√		--	Available in reserve for future sampling if MB-3 becomes operational.
MAFB-155	-0.8 - -15.8	Annual		√	Annual	Monitors water quality upgradient of plume boundary.
MAFB-164	-56.87 - -71.87	Quarterly		√	Quarterly	Monitors COC concentrations near MBS EW-1B, -7Bm and -8b.
MAFB-165	-50.16 - -65.16	Not Sampled	√		--	Spatially redundant to MAFB -170
MAFB-166	-41.82 - -56.82	Not Sampled	√		--	MAFB-216 provides less important information than MAFB-216 and MAFB-361.

TABLE 4.3 (Continued)
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl)[a/]	2003 Sampling Frequency[b/]	Qualitative Analysis			Rationale
			Exclude	Retain	Monitoring Frequency Recommendation	
MAFB-167	-41.01 - -56.01	Annual		√	Annual	Monitors hot spot.
MAFB-168	-27.22 - -42.22	Quarterly		√	Quarterly	Monitors COCs above MCLs.
MAFB-169	-46.68 - -61.68	Not Sampled	√		--	Spatially redundant to MAFB-224
MAFB-170	-46.29 - -61.29	Quarterly		√	Quarterly	Monitors water quality near MBS EW6ABu
MAFB-171	-40.15 - -55.15	Annual		√	Annual	Defines northern extent of TCE hot spot.
MAFB-172	-19.89 - -34.89	Semi-Annual		√	Annual	Reduce frequency due to COCs consistently under MCLs. Monitors water quality near MBS EW 3Bu.
MAFB-173	-51.26 - -66.26	Annual		√	Annual	Reduce frequency due to concentrations consistently under MCLs.
MAFB-174	-24.07 - -39.07	Annual		√	Annual	Location is important to relationship of MB and SAC plumes. Reduce sampling to biennial.
MAFB-175	-63.46 - -78.46	Annual		√	Annual	Monitors water quality downgradient of extraction system.
MAFB-176	-28.7 - -43.7	Annual		√	Annual	Monitor plume near downgradient extent.
MAFB-177	-67.29 - -82.29	Quarterly		√	Annual	Monitors water qualty near MBS EW-10B.
MAFB-215	-57.8 - -72.8	Annual		√	Annual	Monitors jump in TCE concentration >MCLs.
MAFB-216	-35.9 - -50.9	Quarterly		√	Quarterly	Monitors downgradient extect of elevated TCE concetrations.
MAFB-217	-40.8 - -55.8	Annual		√	Annual	Defines eastern extent of TCE hot spot.
MAFB-218	-47.9 - -62.9	Semi-Annual		√	Semi-annual	Monitors water quality/remedial effectiveness near MBS EW4ABu
MAFB-219	-44.8 - -59.8	Not Sampled	√		--	Spatially redundant to MAFB-218
MAFB-220	-47.6 - -62.6	Annual		√	Semi-annual	Increased sampling frequency to monitor potential increase in COC concentrations.
MAFB-221	-23.9 - -33.9	Semi-Annual		√	Annual	Reduce sampling frequency due to COC concentrations consistently under MCLs.
MAFB-222	-42.1 - -57.1	Quarterly		√	Quarterly	Monitors hot spots.
MAFB-223	-42.4 - -57.4	Semi-Annual		√	Semi-annual	Defines eastern extent of hot spot.
MAFB-224	-47.3 - -62.3	Semi-Annual		√	Semi-annual	Mointors remediation within plume.
MAFB-225	-36.4 - -51.4	Not Sampled	√		--	Spatially redundant to MAFB-217.
MAFB-226	-41.2 - -56.2	Not Sampled	√		--	Spatially redundant to MAFB-224.
MAFB-227	-41.2 - -56.2	Annual		√	Annual	Monitors plume hot spots.
MAFB-228	-36.7 - -51.7	Quarterly		√	Quarterly	Defines western extent of hot spot.
MAFB-229	-30.5 - -45.5	Quarterly		√	Quarterly	Monitors plume hot spot.
MAFB-230	-25.9 - -40.9	Annual		√	Annual	Defines western plume boundary.
MAFB-231	-24.7 - -39.7	Semi-Annual		√	Semi-annual	Monitors plume hot spot.
MAFB-232	-4.6 - -19.6	Annual		√	Annual	Monitors water quality upgradient of plume boundary.
MAFB-233	-3.5 - -18.5	Not Sampled	√		--	Available in reserve for future sampling if MB-4 becomes operational.
MAFB-234	-19.6 - -34.6	Quarterly		√	Quarterly	Monitors water quality adjacent to extraction well MBS 39 ABuB.
MAFB-247	-37.8 - -52.8	Annual		√	Annual	Monitors eastern plume boundary.
MAFB-248	-29.4 - -44.4	Annual		√	Annual	Monitors hot spot.
MAFB-249	-23.8 - -38.8	Annual		√	Annual	Defines eastern extent of hot spot.
MAFB-259	-32.0 - -37.0	Annual		√	Annual	Monitors water quality downgradient of plume boundary.
MAFB-260	-31.9 - -41.9	Annual		√	Biennial	COCs ND historically. MAFB-268 monitors water quality at deeper screened interval with COC detections. Reduce mointoring frequency.
MAFB-261	-36.0 - -51.0	Semi-Annual		√	Semi-annual	Monitors CCl4 near MCL in downgradient portion of the plume.
MAFB-263	-34.6 - -44.6	Annual		√	Annual	Monitors water quality near MAFB EW-10B.
MAFB-264	-11.1 - -26.1	Semi-Annual		√	Semi-annual	Monitors hot spots.
MAFB-265	-38.8 - -53.8	Annual		√	Annual	Defines eastern extent of hot spot.
MAFB-266	-62.6 - -77.6	Semi-Annual		√	Annual	Monitors water quality near MBS EW-9B.
MAFB-267	-78.7 - -93.7	Annual		√	Annual	Monitors water quality downgradient of plume boundary.
MAFB-268	-76.9 - -91.9	Semi-Annual		√	Semi-annual	Monitors plume water quality near downgradient boundary.
MAFB-269	-81.0 - -96.0	Semi-Annual		√	Semi-annual	Monitors elevated CCl4 elevations.
MAFB-270	-95.5 - -110.5	Quarterly		√	Quarterly	Monitors elevated CCl4 concentrations.
MAFB-271	-78.8 - -93.8	Quarterly		√	Quarterly	Included in Off-Base Supply Well Monitoring Program.
MAFB-272	-67.1 - -82.1	Not Sampled	√		--	Upgradient of plume. No COCs detected historically.
MAFB-273	-45.2 - -60.2	Not Sampled	√		--	Upgradient of plume. No COCs detected historically.

TABLE 4.3 (Continued)
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl)[a/]	2003 Sampling Frequency[b/]	Qualitative Analysis			Rationale
			Exclude	Retain	Monitoring Frequency Recommendation	
MAFB-274	-30.5 - -45.5	Annual		√	Annual	Defines western extent of hot spot
MAFB-280	-17.1 - -27.1	Annual	√		--	Retain for future sampling if MB-3 becomes operational.
MAFB-281	-9.7 - -24.7	Annual		√	Biennial	Defines extent of PCE plume from Site 23 and detection in MAFB-155
MAFB-282	-13.5 - -28.5	Semi-Annual		√	Semi-annual	Monitors water quality near upgradient plume boundary.
MAFB-308	-28.44 - -43.44	Annual		√	Annual	Define extent of hot spot, monitors water quality near MAFB property line.
MAFB-309	-75.36 - -90.36	Not Sampled		√	Annual	Potentially upgradient of water supply well Mars
MAFB-310	-91.08 - -106.08	Annual		√	Annual	Potentially upgradient of water supply well Oaken Bucket.
MAFB-311	-104.92 - -119.92	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-312	-124.79 - -139.79	Quarterly		√	Quarterly	Monitors water quality within downgradient portion of plume.
MAFB-313	-79.92 - -94.92	Quarterly		√	Quarterly	Monitors water quality near MBS EW-6B.
MAFB-322	-114.14 - -129.14	Quarterly		√	Quarterly	Included in Off-Base Supply Well Monitoring Program.
MAFB-323	-122.68 - -132.68	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-324	-82.26 - -97.26	Quarterly		√	Quarterly	Included in Off-Base Supply Well Monitoring Program. If Mars well is taken off line, MAFB-324 should be sampled annually.
MAFB-325	-81.42 - -96.42	Annual		√	Annual	Potentially upgradient of water supply well Mars.
MAFB-330	-124.19 - -139.19	Quarterly		√	Quarterly	Monitors water quality within downgradient portion of plume.
MAFB-331	-124.0 - -139.0	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-346Bd	-122.11 - -132.11	Annual		√	Biennial	COCs ND historically. Retain at lower frequency to monitor potential vertical migration from Well MAFB-346Bs.
MAFB-346Bs	-70.51 - -80.51	Semi-Annual		√	Annual	Reduce frequency due COCs consistently under MCLs.
MAFB-348B	-101.45 - -111.45	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-351Bd	-143.39 - -153.39	Semi-Annual		√	Annual	COCs ND historically. Reduce monitoring frequency.
MAFB-351Bs	-66.89 - -76.89	Annual		√	Annual	Monitors water quality downgradient of plume boundary.
MAFB-354B	-136.78 - -146.78	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-355B	-133.4 - -143.4	Annual		√	Biennial	COCs ND historically. Biennial samplng until plume capture is documented; MAFB-351 wells serve primary monitoring of plume extent.
MAFB-356B	-138.42 - -148.42	Semi-Annual		√	Biennial	COCs ND historically. Upgradient wells MAFB-312, -330 are monitored quarterly, sentry well.
MAFB-358B	-37.4 - -47.4	Semi-Annual		√	Semi-annual	Monitors water quality within former hot spot area.
MAFB-360	-63.75 - -73.75	Annual		√	Annual	Monitors water quality downgradient of MBS EW- 7B
MAFB-361	-47.65 - -57.65	Annual		√	Annual	Defines plume extent.
MAFB-362	-56.66 - -66.66	Semi-Annual		√	Semi-annual	Defines extent of hot spots.
MAFB-363	-59.16 - -69.16	Quarterly		√	Quarterly	Defines downgradient extent of hot spots.
MAFB-364B	-75.53 - -85.53	Annual	√		--	Lower PCE results than nearby well MAFB-365B. Well not critical to decisions.
MAFB-365B	-82.5 - -92.5	Annual		√	Annual	Monitors water quality downgradient of extraction system .
MAFB-366B	-80.72 - -90.72	Annual		√	Annual	Measures remediation within plume.
MAFB-368B	-102.87 - -112.87	Quarterly		√	Quarterly	Monitors CCl4 and PCE concentrations >MCLs.
MAFB-378B	-32.52 - -42.52	Quarterly		√	Quarterly	Within 1000' of Nut Plains water supply well.
MAFB-379B	-80.579 - -90.579	Annual		√	Semi-annual	Defines western extent of plume
MAFB-380B	-98.299 - -108.299	Annual	√		--	Spatially redundant to MAFB-324, MAFB-385B, MAFB-348B.
MAFB-381B	-70 - -80	Quarterly		√	Semi-annual	Detected PCE and CCl4 at less than 2.5 ug/L. Reduce monitoring frequency.
MAFB-382B	-85.87 - -100.87	Quarterly		√	Semi-annual	COCs ND for 5 sampling rounds. Reduce monitoring frequency.
MAFB-383B	-69.364 - -79.364	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-384B	1.76 - -18.24	Semi-Annual		√	Semi-annual	Monitors water quality near upgradient plume boundary.
MAFB-385B	-109.678 - -119.678	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-386B	-100.597 - -110.597	Annual		√	Annual	Monitors water quality downgradient of plume boundary.
MAFB-387B	-119.749 - -139.749	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-388B	-132.229 - -142.229	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MBS EW-10B	-70.38 - -110.38	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS EW-11B	-81.95 - -121.95	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS EW-1B	-23.3 - -63.3	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-2B	-54.33 - -79.33	Quarterly		√	Quarterly	Calculation of mass removal rates from plume hot spot, evaluates remedial progress.

TABLE 4.3 (Continued)
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl)[a/]	2003 Sampling Frequency[b/]	Qualitative Analysis			Rationale
			Exclude	Retain	Monitoring Frequency Recommendation	
MBS EW-3B	-24.07 - -84.07	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-3Bu	-20.89 - -35.89	Annual		√	Annual	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-4B	-44.84 - -74.84	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-5B	-65.72 - -95.72	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-6B	-75.91 - -115.91	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-7B	-47.703 - -87.703	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-8B	-33.3 - -63.3	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-9B	-45.42 - -85.42	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS PZ-11	-55.7 - -65.7	Annual		√	Annual	Defines western extent of hot spot.
MBS PZ-37	-96.68 - 106.68	Semi-Annual		√	Semi-annual	Monitors water quality downgradient of MBS EW- 6B.
MBS PZ-38	-74.32 - -93.32	Semi-Annual		√	Semi-annual	Monitors water quality downgradient of MBS EW- 5B.
MBS PZ-39	-77.14 - -87.14	Semi-Annual		√	Semi-annual	Monitors performance of MBS EW-5B and other Unit B extraction wells
MBS PZ-42D	-130.0 - -105.63	Quarterly		√	Quarterly	Monitors elevated CCl4 and PCE concentrations.
MBS PZ-44	-23.37 - -33.37	Semi-Annual		√	Semi-annual	PCE and TCE near MCLs within the plume.
MBS PZ-55B	-68.7 - -78.7	Annual		√	Annual	Less than 4 rounds of analytical data; primarily for potentiometric data.
MBS PZ-55Bu	-26.7 - -36.7	Semi-Annual		√	Semi-Annual	Less than 4 rounds of analytical data; primarily for potentiometric data.
D Zone Wells						
FFS MW15-6	-95.4 - -100.4	Semi-Annual		√	Semi-annual	Monitors eastern extent of plume
MAFB-060	-98.68 - -118.68	Annual		√	Annual	Underlies B zone hot spot.
MAFB-061	-106.63 - -126.63	Semi-Annual		√	Annual	Reduce sampling frequency due to COC consistently under MCLs.
MAFB-062	-102.08 - -122.08	Annual	√		--	Spatially redundant to MAFB-061.
MAFB-063	-100.4 - -120.4	Quarterly		√	Quarterly	Monitors water quality near MBS EW-2D.
MAFB-066	-154.52 - -174.52	Annual		√	Biennial	Increase sampling frequency if MB-4 becomes operational.
MAFB-102	-107.45 - -122.45	Annual		√	Biennial	Monitors D zone down gradient of Site 18 source. Consistent TCE and CTCL concentrations. Reduce monitoring.
MAFB-103	-97.64 - -112.64	Annual		√	Annual	Monitors potential impacts from Zone B.
MAFB-104	-122.33 - -137.33	Semi-Annual		√	Annual	Reduce sampling frequency due COCs consistently under the MCL. Monitors groundwater downgradient of extraction system.
MAFB-178	-97.16 - -112.16	Not Sampled	√		--	Available in reserve for future sampling if MB-3 or MB-4 become operational.
MAFB-180	-97.13 - -112.13	Quarterly		√	Quarterly	Monitor plume hot spot.
MAFB-181	-118.58 - -133.58	Quarterly		√	Quarterly	Monitors elevated CCl4 and PCE concentrations.
MAFB-235	-81.1 - -91.1	Annual		√	Annual	Monitors D zone down gradient of Site 18 source. Consistent TCE and CTCL concentrations. Reduce monitoring.
MAFB-239	-103.8 - -118.8	Annual		√	Annual	Monitors potential impacts from Zone B.
MAFB-240	-108.5 - -123.5	Semi-Annual		√	Semi-annual	Monitors CCl4 above MCLs.
MAFB-241	-122.5 - -137.5	Not Sampled	√		--	Spatially redundant to MAFB-063
MAFB-242	-91.0 - -106.0	Semi-Annual		√	Semi-annual	Monitors edge of hot spot.
MAFB-243	-135.6 - -145.6	Not Sampled	√		--	Spatially redundant to MAFB-063
MAFB-250	-101.4 - -116.4	Semi-Annual		√	Annual	Five consecutive quarters with no detections starting in 4Q93; retain annual.
MAFB-290	-127.8 - -137.8	Annual		√	Annual	Monitor plume boundary.
MAFB-291	-98.7 - -113.7	Not Sampled	√		--	Historical COCs non-detect. Upgradient of plume. MAFB-290 defines plume extent.
MAFB-292	-99.2 - -114.2	Not Sampled	√		--	Historical COCs non-detect. Upgradient of plume. MAFB-378D defines plume extent.
MAFB-293	-165.6 - -180.6	Semi-Annual		√	Semi-annual	Measures CCl4 values >MCLs downgradient.
MAFB-296	-96.8 - -106.8	Annual		√	Annual	Monitor plume boundary.
MAFB-314	-93.37 - -108.37	Quarterly		√	Quarterly	Monitor water quality at MAFB property line.
MAFB-315	-129.39 - -139.39	Not Sampled	√		--	COCs historically ND. Cross-gradient from plume. Other wells define extent of plume to west.
MAFB-316	-161.14 - -176.14	Not Sampled	√		--	COCs historically ND. Cross-gradient from plume. Other wells define extent of plume to west.
MAFB-317	-175.88 - -185.88	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-318	-174.57 - -184.57	Quarterly		√	Semi-annual	Reduce sampling frequency due to COCs consistently below MCLs.
MAFB-319	-134.55 - -149.55	Quarterly		√	Quarterly	Included in Off-Base Supply Well Monitoring Program.
MAFB-320	-123.25 - -138.25	Quarterly		√	Quarterly	Monitors performance of MBS EW-1D

TABLE 4.3 (Continued)
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl)[a/]	2003 Sampling Frequency[b/]	Qualitative Analysis			Rationale
			Exclude	Retain	Monitoring Frequency Recommendation	
MAFB-321	-174.65 - -184.65	Quarterly		√	Quarterly	Included in Off-Base Supply Well Monitoring Program.
MAFB-326	-170.09 - -185.09	Quarterly		√	Quarterly	Included in Off-Base Supply Well Monitoring Program.
MAFB-327	-184.02 - -199.02	Semi-Annual		√	Semi-annual	Included in Off-Base Supply Well Monitoring Program.
MAFB-328	-124.72 - -134.72	Quarterly		√	Quarterly	Included in Off-Base Supply Well Monitoring Program.
MAFB-329	-126.36 - -136.36	Not Sampled	√		--	Spatially redundant to MAFB-290
MAFB-332	-145.3 - -155.3	Semi-Annual		√	Semi-annual	Monitors plume extent.
MAFB-336	-200.13 - -210.13	Semi-Annual		√	Semi-annual	<1,000 feet from Juvenile Hall water-supply well.
MAFB-337	-279.99 - -289.99	Quarterly		√	Quarterly	Included in Off-Base Supply Well Monitoring Program.
MAFB-338	-245.0 - -255.0	Quarterly		√	Quarterly	Included in Off-Base Supply Well Monitoring Program.
MAFB-345	-315.14 - -325.14	Annual		√	Annual	Monitor potential impacts form Zone B.
MAFB-346D	-177.11 - -187.11	Annual		√	Annual	Monitor potential impacts form Zone B.
MAFB-347	-422.27 - -432.27	Semi-Annual		√	Annual	Reduce sampling frequency. COCs ND for last 4 events.
MAFB-348Dd	-245.45 - -255.45	Annual		√	Annual	Monitor downgradient portion of plume
MAFB-348Ds	-171.45 - -181.45	Semi-Annual		√	Semi-annual	Reduce sampling frequency due to low concentrations within plume.
MAFB-349	-365.43 - -375.43	Semi-Annual		√	Semi-annual	<1,000 feet of Moonbeam water-supply wells.
MAFB-350	-371.06 - -381.06	Annual		√	Annual	Monitor water quality downgradient of plume
MAFB-351D	-191.39 - -201.39	Semi-Annual		√	Semi-Annual	Provides downgradient sentry information.
MAFB-352D	-228.33 - -238.33	Annual	√		--	COCs non-detect for two years. Does not provide useful data in plume definition.
MAFB-352LM	-382.33 - -392.33	Annual	√		--	COCs non-detect for two years. Does not provide useful data in plume definition.
MAFB-353	-361.67 - -371.67	Annual		√	Biennial	No COCs detected historically. Sentry well for LMT zone.
MAFB-354D	-221.78 - -231.78	Semi-Annual		√	Semi-Annual	No COCs detected historically. Monitor until plume capture is documented.
MAFB-355D	-228.7 - -238.7	Annual	√		--	No COCs detected historically. Other wells monitor downgradient extent of plume.
MAFB-356Dd	-284.42 - -294.42	Annual		√	Biennial	No COCs detected historically. Recommend biennial until plume capture is documented.
MAFB-356Ds	-232.42 - -242.42	Annual		√	Biennial	No COCs detected historically. Recommend biennial until plume capture is documented.
MAFB-357D	-80.57 - -90.57	Annual		√	Annual	Monitors upgradient portion of plume.
MAFB-357Dd	-170.57 - -180.57	Semi-Annual		√	Annual	Monitors upgradient portion of plume.
MAFB-357Ds	-120.57 - -130.57	Annual		√	Annual	Monitors upgradient portion of plume.
MAFB-358D	-82.4 - -92.4	Semi-Annual		√	Annual	Monitors concentrations near Site 23 source area.
MAFB-364D	-118.53 - -128.53	Semi-Annual		√	Annual	Reduce frequency due to COCs consistently below MCLs.
MAFB-365D	-127.5 - -137.5	Annual	√		--	Spatially redundant to MAFB-364D
MAFB-366D	-110.72 - -120.72	Quarterly		√	Quarterly	Monitor downgradient extent of hot spot.
MAFB-367	-145.08 - -155.08	Semi-Annual		√	Annual	Reduce frequency due to COC concentrations consistently below MCLs. Monitor water quality near MAFB EW-6D.
MAFB-368D	-172.87 - -182.87	Quarterly		√	Quarterly	Monitor water quality near new extraction well MAFB EW-6D.
MAFB-369	-138.28 - -148.28	Quarterly		√	Annual	Reduce frequency due to COC concentrations consistently below MCLs.
MAFB-374	-83.676 - -93.676	Annual		√	Biennial	COCs not detected historically. Well is upgradient from Site 23C. Reduce frequency.
MAFB-375	-102.386 - -112.386	Semi-Annual		√	Semi-annual	Defines extent of hot spot.
MAFB-376	-123.826 - -133.826	Semi-Annual		√	Semi-annual	Defines extent of hot spot
MAFB-377	-114.9 - -124.9	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MAFB-378D	-88.52 - -98.52	Quarterly		√	Quarterly	Within 1,000 feet of Nut Plains water-supply wells.
MAFB-379D	-140.579 - -150.579	Semi-Annual		√	Semi-Annual	Defines extent of hot spot.
MAFB-380D	-141.799 - -151.799	Semi-Annual		√	Semi-Annual	Monitors performance of MBS EW-5D.
MAFB-381D	-165 - -175	Quarterly		√	Semi-annual	Reduce frequency due to non-detected COCs.
MAFB-382D	-175.87 - -185.87	Quarterly		√	Semi-annual	Reduce frequency due to non-detected COCs.
MAFB-383D	-134.364 - -144.364	Semi-Annual		√	Semi-Annual	Monitor potential impacts from Zone B.
MAFB-384D	-77.24 - -87.24	Annual		√	Semi-Annual	Monitor water quality upgradient of plume
MAFB-385D	-159.678 - -169.678	Quarterly		√	Quarterly	Downgradient edge-of-plume well.
MAFB-386D	-180.597 - -190.597	Annual		√	Quarterly	Monitor potential impacts from Zone B and for escape from Granite well's seasonal capture.
MAFB-387Dd	-259.749 - -269.749	Quarterly		√	Semi-annual	Monitors for vertical migration. ND for last 5 sampling rounds. Reduce sampling frequency.

TABLE 4.3 (Continued)
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screened Interval (fb msl)[a/]	2003 Sampling Frequency[b/]	Qualitative Analysis			Rationale
			Exclude	Retain	Monitoring Frequency Recommendation	
MAFB-387Ds	-214.749 - -224.749	Semi-Annual		√	Semi-annual	COCs not detected during last 4 monitoring events.
MAFB-388Dd	-267.229 - -277.229	Semi-Annual		√	Annual	Sentry well downgradient. ND for last 6 sampling rounds.
MAFB-388Ds	-222.229 - -232.229	Semi-Annual		√	Semi-Annual	Sentry well downgradient. ND for last 6 sampling rounds.
MAFB-397	-154.0 - -164.0	Quarterly		√	Quarterly	Less than 4 rounds of analytical data. Within 1,000 feet of Nut Plains water-supply well.
MBS EW-1D	unknown	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-2D	-105.11 - -145.11	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.
MBS EW-3D	-85.204 - -125.204	Quarterly		√	Quarterly	Calculation of mass removal rates, evaluates remedial progress.(>4 rounds of data)
MBS EW-4D	-78.72 - -103.72	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS EW-5D	-107.17 - -142.17	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS EW-6D	-156.07 - -181.07	Quarterly		√	Quarterly	Less than 4 rounds of analytical data.
MBS PZ-12	-295.2 - -305.2	Annual		√	Annual	Monitors hot spot.
MBS PZ-13	-166.0 - -176.0	Semi-Annual		√	Semi-annual	Monitors elevated CCl4 within plume.
MBS PZ-14	-286.4 - -301.4	Annual		√	Annual	Monitors hot spot.
MBS PZ-15	-290.8 - -300.8	Annual		√	Annual	Monitors hot spot.
MBS PZ-49D	-285.71 - -295.71	Annual		√	Annual	Monitors hot spot.
MBS PZ-50D	-298.52 - -308.52	Semi-Annual		√	Annual	Reduce frequency due to COC concentrations ND or <<MCL.
MBS PZ-51	-93.638 - -103.638	Annual		√	Annual	Less than 4 rounds of analytical data; primarily for potentiometric data.
MBS PZ-52	-90.435 - -100.435	Annual		√	Annual	Less than 4 rounds of analytical data; primarily for potentiometric data.
MBS PZ-53	-101.765 - -116.765	Annual		√	Annual	Less than 4 rounds of analytical data; primarily for potentiometric data.
MBS PZ-54	-95.625 - -105.625	Annual		√	Annual	Less than 4 rounds of analytical data; primarily for potentiometric data.
MBS PZ-58	-99.23 - -109.23	Semi-Annual		√	Semi-Annual	Less than 4 rounds of analytical data; primarily for potentiometric data.

[a/] ftbmsl = feet below mean sea level
[b/] 2003 Sampling frequency based on 2002 Groundwater Monitoring Program Evaluation Report (MWH, 2002b).
[c/] Hot spots are defined as contaminant concentrations greater than the cleanup level by a factor of 10 or more (MWH, 2002b).

Wells meeting one of these criteria were retained for quarterly sampling to evaluate potential exposures to receptors (Criteria 1, 2, and 3) or to collect a minimum of four quarters of data at a well location prior to modifying the sampling frequency (Criteria 4). An exception to the first criteria applies to monitoring wells located within 1,000 feet of water-supply wells that are not currently operated on a continual basis (standby wells), as these wells do not provide direct exposure pathways. Quarterly monitoring for wells within 1,000 feet of standby water supply wells was not recommended as long as the associated water supply well remains non-operational. If a well is used at all for providing drinking water (unless only during fire flow) during the interval between monitoring events, the exception should not be taken with the criterion.

Other wells were evaluated based on factors such as location with respect to other wells screened in the same hydrostratigraphic unit, groundwater flow direction, potential receptors, temporal trends in COC concentrations, use of the well to evaluate performance of the ETI system, and location with respect to the plume. Temporal trends in COC concentrations were reviewed to determine if a change in monitoring frequency was warranted by qualitatively evaluating the ***last four rounds of data*** for a particular well; the temporal statistical evaluation of contaminant concentrations trends over the entire history of monitoring events is discussed in Section 5.

4.2.1 WT/A Zone Wells

A total of 86 monitoring, extraction wells and piezometers screened in the WT/A Zone were considered during the MNO process for the Main Base/SAC Area Plume at Mather. The recommendations and accompanying rationale for wells in the WT/A Zone are summarized in the following paragraphs.

Nineteen wells are recommended from exclusion from the LTM program. The remaining 67 wells and piezometers are recommended to be retained in the LTM plan.

Water-supply wells MB-3 and MB-4 are both standby wells used only in the event of an emergency, and two monitoring wells (MAFB-093 and MAFB-150) located within

1,000 feet of these standby water-supply wells should be sampled quarterly in the event the supply wells become operational. These wells are upgradient of the plumes and have had negligible concentrations of COC historically, so do not add value to the monitoring program.

Three WT/A zone monitoring wells (MAFB-404, MAFB-405, and MAFB-407) and three extraction wells (MBS EW-12AB, MBS EW-3B, and MBS EW-4Bu) were retained for quarterly sampling because less than 4 rounds of groundwater samples have been collected at these wells. The sampling frequency at these wells should be evaluated after 4 rounds of data have been collected.

As indicated in Table 4.3, several of the water table wells were recommended for exclusion from the LTM plan due to spatial redundancy with other wells. Some of these wells were likely installed to obtain initial plume characterization data; however, continued monitoring of each of these wells is not necessary to evaluate the plume extent or to monitor COC concentrations near extraction wells. For example, recommendations are made to exclude wells MAFB-091 and MAFB-161 from the LTM program due to spatial redundancy with well MAFB-092. These wells are all located near the northwestern plume boundary, have similar screened intervals, and similar historical COC concentrations. Similarly, well MAFB-200 is recommended for removal because it is redundant with well MAFB-359.

Less-frequent monitoring is also recommended for some WT/A Zone monitoring wells (e.g., MAFB-087, MAFB-096). The recommendation to reduce the monitoring frequency is generally based on the fact that COC concentrations have consistently been well below MCLs, and a reduced sampling frequency should still provide sufficient data to monitor COC concentrations at these locations.

If annual monitoring at wells with stable COC concentrations does not indicate significant temporal variations in contaminant concentrations, the monitoring frequency at some wells could eventually be reduced to biennial (i.e., every other year). However, annual monitoring of wells near the downgradient plume boundary should be continued

(at a minimum) to evaluate plume stability and the potential for impacts to downgradient receptors.

All of the fourteen WT/A Zone extraction wells were recommended for continued sampling to facilitate periodic calculation of contaminant mass-removal rates and assessment of remedial progress and system optimization needs. Well MBS EW-5A is recommended for reduction to semi-annual monitoring because of its proximity to MBS EW-4A and consistently low COC concentrations. All other extraction wells are recommended for continued quarterly monitoring.

4.2.2 Zone B Wells

A total of 120 wells and piezometers screened in Zone B were considered during the MNO evaluation for the Main Base/SAC Area Plume at Mather. Fourteen of these wells and piezometers are recommended for exclusion from the LTM program, and the remaining 106 wells and piezometers are recommended for retention.

Water-supply wells MB-3 and MB-4 are both standby wells used only in the event of an emergency. Seven monitoring wells located within 1,000 feet of these water-supply wells should be held in reserve for quarterly monitoring in the event the supply wells become operational. Nine edge-of-plume wells (MAFB-311, MAFB-323, MAFB-331, MAFB-348B, MAFB-354B, MAFB-383B, MAFB-384B, MAFB-387B, and MAFB-388B) and three wells (MAFB-271, MAFB-322, and MAFB-324) included in the Off-Base Supply Well Monitoring Program were also retained for quarterly monitoring.

Wells were generally recommended for exclusion from the LTM program due to spatial redundancy with another well and/or historical COC concentrations below detection limits in a non-critical area. Wells that do not appear to contribute meaningful data regarding plume extent, hot spot extent, or remedial effectiveness also were recommended for removal. For example, well MAFB-364B was recommended for exclusion from the monitoring program because it is nearby to well MAFB-365B, but has lower PCE concentrations, and was not considered critical to decisions.

Less frequent monitoring is recommended for wells COC concentrations consistently under MCLs (e.g., well MAFB-172 and MAFB-221) because the reduced sampling frequency will provide sufficient data for plume evaluation. More frequent (semi-annual) monitoring is recommended for one well (MAFB-220) due to potential increasing trends in COC concentrations.

Twelve Zone B Extraction Wells were included in the MNO evaluation. These 12 wells were recommended for retention in the LTM program, including three extraction wells retained for quarterly sampling because less that 4 rounds of groundwater samples have been collected. The remaining wells were also recommended for quarterly monitoring to measure mass removal rates and progress toward rememediation.

4.2.3 Zone D Wells

A total of 100 monitoring wells and piezometers screened in Zone D were considered during the MNO process for the Main Base/SAC Area Plume at Mather. Thirteen monitoring wells are recommended for exclusion from the LTM program. The remaining 87 wells and piezometers were recommended for retention in the LTM plan.

Water-supply wells MB-3 and MB-4 are both standby wells used only in the event of an emergency, and the two monitoring wells (MAFB-066 and MAFB-178) located within 1,000 feet of the water-supply wells should be sampled quarterly in the event the supply wells become operational. However, while the water-supply wells are non-operational, the sampling frequency for MAFB-066 could be reduced to biennial to evaluate water quality upgradient of the plume boundary, and MAFB-178 can remain unsampled.

Two Zone D wells (, MAFB-377, and MAFB-397) were retained for quarterly sampling because less than four rounds of groundwater samples have been collected at these wells. The sampling frequency at these wells should be evaluated after four rounds of data have been collected. MAFB-250 had five consecutive quarters with no detections starting in the fourth quarter of 1993, and should be retained for annual sampling. The seven wells included in the Off-Base Supply Well Monitoring Program (MAFB-319,

MAFB-321, MAFB-326, MAFB-327, MAFB-328, MAFB-337 and MAFB-338) and two edge-of-plume wells (MAFB-385D and MAFB-317) were also retained for quarterly sampling. As of 2002, wells MAFB-381D, MAFB-382D, MAFB-387Dd were sampled quarterly due to the limited amount of data available for these wells; Parsons recommends reducing the sampling frequency for these wells due to the fact that COC concentrations are either stable or not detected. Wells were recommended for removal from the LTM program due to such factors as spatial redundancy with other wells, historical COC concentrations below detection limits, and/or location of the well with respect to the plume. For example, well MAFB-062 was recommended for removal because it is redundant with well MAFB-061, and MAFB-365D was recommended for removal because it is redundant with MAFB-364D.A reduced sampling frequency is typically recommended for Zone D wells that exhibit COC concentrations that have consistently been below MCLs, such as MAFB-104 and MAFB-318.

Six Zone D extraction wells were included in the MNO evaluation. The extraction wells were all recommended for retention in the LTM program, including three extraction wells with less that 4 rounds of analytical data collected. All of the extraction wells are recommended for continues quarterly sampling.

4.2.4 Laboratory Analytical Program

For wells in the Mather Program, groundwater samples currently are analyzed using EPA Method 8260B (MWH, 2002). Exceptions to this include the private utility or county owned drinking-water-supply wells and associated monitoring wells. The water-supply wells and their nearest monitoring wells are analyzed using EPA Method 524.2 (with trace-level detection limits) to allow CCl_4 concentrations to be quantified at levels below the MCL for this compound (0.5 µg/L). EPA Method 8260B provides a practical quantitation limit (PQL) for CCL_4 of 0.5 µg/L, whereas EPA Method 524.2 provides a PQL for CCl_4 of 0.2 µg/L. If laboratory analysis using Method 524.2 consistently detects CCl_4 at a concentration above 0.5 µg/L, Method 8260 is then used for analysis of subsequent samples. This conservative, dual-method approach is appropriate for

monitoring potential impacts to drinking-water-supply wells, and no changes are recommended.

4.2.5 LTM Program Flexibility

The LTM program recommendations summarized in Table 4.3 are based on available data regarding current (and expected future) site conditions. Changing site conditions (e.g., lengthy malfunction or significant adjustment of the groundwater extraction system) could affect plume behavior. Therefore, the LTM program should be reviewed if hydraulic conditions change significantly, and revised as necessary to adequately track changes in plume magnitude and extent over time. Modification to the usage of the municipal and agricultural wells located northwest, southwest and south of Mather could result in significant changes to the groundwater flow direction currently observed at and near Mather.

SECTION 5

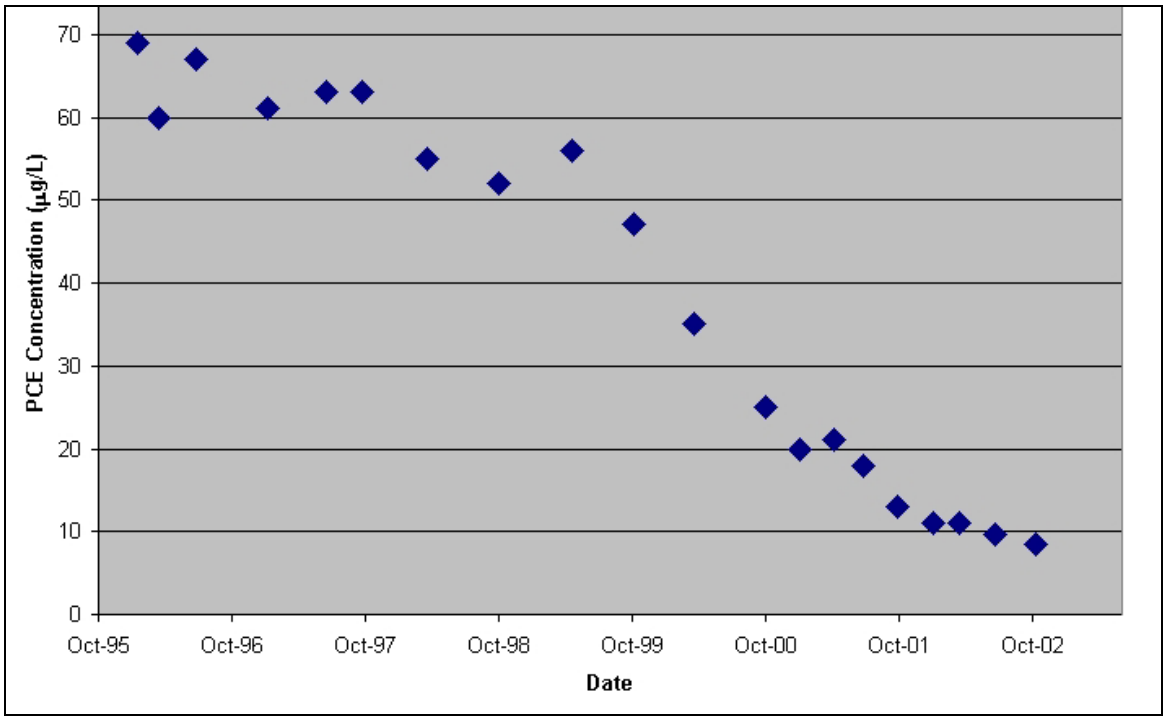
TEMPORAL STATISTICAL EVALUATION

Chemical concentrations measured at different points in time (temporal data) can be examined graphically or using statistical tests, to evaluate dissolved-contaminant plume stability. If removal of chemical mass is occurring in the subsurface as a consequence of attenuation processes or operation of a remediation system, mass removal will be apparent as a decrease in chemical concentrations through time at a particular sampling location, as a decrease in chemical concentrations with increasing distance from chemical source areas, and/or as a change in the suite of chemicals detected through time or with increasing migration distance.

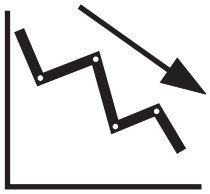
5.1 METHODOLOGY FOR TEMPORAL TREND ANALYSIS OF CONTAMINANT CONCENTRATIONS

Temporal chemical-concentration data can be evaluated for trends by plotting contaminant concentrations through time for individual monitoring wells (Figure 5.1), or by plotting contaminant concentrations versus downgradient distance from the contaminant source for several wells along the groundwater flowpath, over several monitoring events. Plotting temporal concentration data is recommended for any analysis of plume stability (Wiedemeier and Haas, 2000); however, visual identification of trends in plotted data may be a subjective process, particularly if (as is likely) the concentration data do not exhibit a uniform trend, but are variable through time (Figure 5.2).

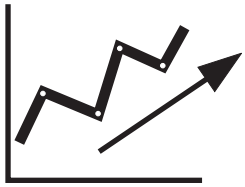
FIGURE 5.1
PCE CONCENTRATIONS THROUGH TIME
AT WELL MAFB-313
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AFB, CALIFORNIA



The possibility of arriving at incorrect conclusions regarding plume stability on the basis of visual examination of temporal concentration data can be reduced by examining temporal trends in chemical concentrations using various statistical procedures, including regression analyses and the Mann-Kendall test for trends. The Mann-Kendall nonparametric test (Gibbons, 1994) is well-suited for evaluation of environmental data because the sample size can be small (as few as four data points), no assumptions are made regarding the underlying statistical distribution of the data, and the test can be adapted to account for seasonal variations in the data. The Mann-Kendall test statistic can be calculated at a specified level of confidence to evaluate whether a statistically significant temporal trend is exhibited by contaminant concentrations detected through time in samples from an individual well. A negative slope (indicating decreasing

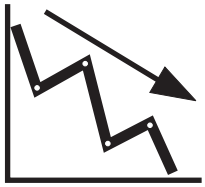


Decreasing Trend

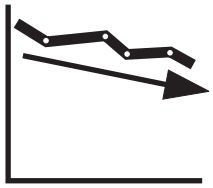


Increasing Trend

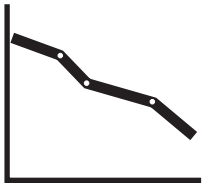
No Trend



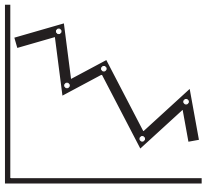
Confidence Factor
HIGH



Confidence Factor
LOW



Variation
LOW



Variation
HIGH

FIGURE 5.2

CONCEPTUAL REPRESENTATION OF TEMPORAL TRENDS AND TEMPORAL VARIATIONS IN CONCENTRATIONS

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contaminant concentrations through time) or a positive slope (increasing concentrations through time) provides statistical confirmation of temporal trends that may have been identified visually from plotted data (Figure 5.2). In this analysis, a 95% confidence level is used to define a statistically significant trend.

The relative value of information obtained from periodic monitoring at a particular monitoring well can be evaluated by considering the location of the well with respect to the dissolved contaminant plume and potential receptor exposure points, and the presence or absence of temporal trends in contaminant concentrations in samples collected from the well. The degree to which the amount and quality of information that can be obtained at a particular monitoring point serve the two primary (i.e., temporal and spatial) objectives of monitoring must be considered in this evaluation. For example, the continued non-detection of a target contaminant in groundwater at a particular monitoring location provides no information about temporal trends in contaminant concentrations at that location, or about the extent to which contaminant migration is occurring, unless the monitoring location lies along a groundwater flowpath between a contaminant source and a potential receptor exposure point (e.g., downgradient of a known contaminant plume). Therefore, a monitoring well having a history of contaminant concentrations below detection limits may be providing little or no useful information, depending on its location.

A trend of increasing contaminant concentrations in groundwater at a location between a contaminant source and a potential receptor exposure point may represent information critical in evaluating whether contaminants are migrating to the exposure point, thereby completing an exposure pathway. Identification of a trend of decreasing contaminant concentrations at the same location may be useful in evaluating decreases in the areal extent of dissolved contaminants, but does not represent information that is critical to the protection of a potential receptor. Similarly, a trend of decreasing contaminant concentrations in groundwater near a contaminant source may represent important information regarding the progress of remediation near, and downgradient from the source.. By contrast, the absence of a statistically significant (as defined by the Mann-

Kendall test with a 95% confidence level) temporal trend in contaminant concentrations at a particular location within or downgradient from a plume indicates that virtually no additional information can be obtained by frequent monitoring of groundwater at that location, in that the results of continued monitoring through time are likely to fall within the historic range of concentrations that have already been detected (Figure 5.3). Continued monitoring at locations where no temporal trend in contaminant concentrations is present serves merely to confirm the results of previous monitoring activities at that location.

The temporal trends and relative location of wells can be weighed to determine if a well should be retained, excluded, or continue in the program with reduced sampling. Figure 5.4 presents a flowchart demonstrating the methodology for utilizing trend results to draw these conclusions.

5.2 TEMPORAL EVALUATION RESULTS

The analytical data for groundwater samples collected from the 306 wells in the Mather Main Base/SAC Area Plume LTM program from January 1996 through November 2002 were examined for temporal trends using the Mann-Kendall test. The objective of the evaluation was to identify those wells having increasing or decreasing concentration trends for each COC, and to consider the quality of information represented by the existence or absence of concentration trends in terms of the location of each monitoring point. Increasing or decreasing trends are those identified as with positive or negative slopes, respectively, by the Mann-Kendall trend analysis with a confidence level of 95%.

Summary results of Mann-Kendall temporal trend analyses for COCs in groundwater samples from wells in the Main Base/SAC Area Plume are presented in Table 5.1. Trends for three COCs were evaluated to assess the value of temporal information for each well. As implemented, the algorithm used to evaluate concentration trends assigned a value of "ND" (not detected) to those wells with sampling results that were consistently below analytical detection limits through time, rather than assigning a surrogate value

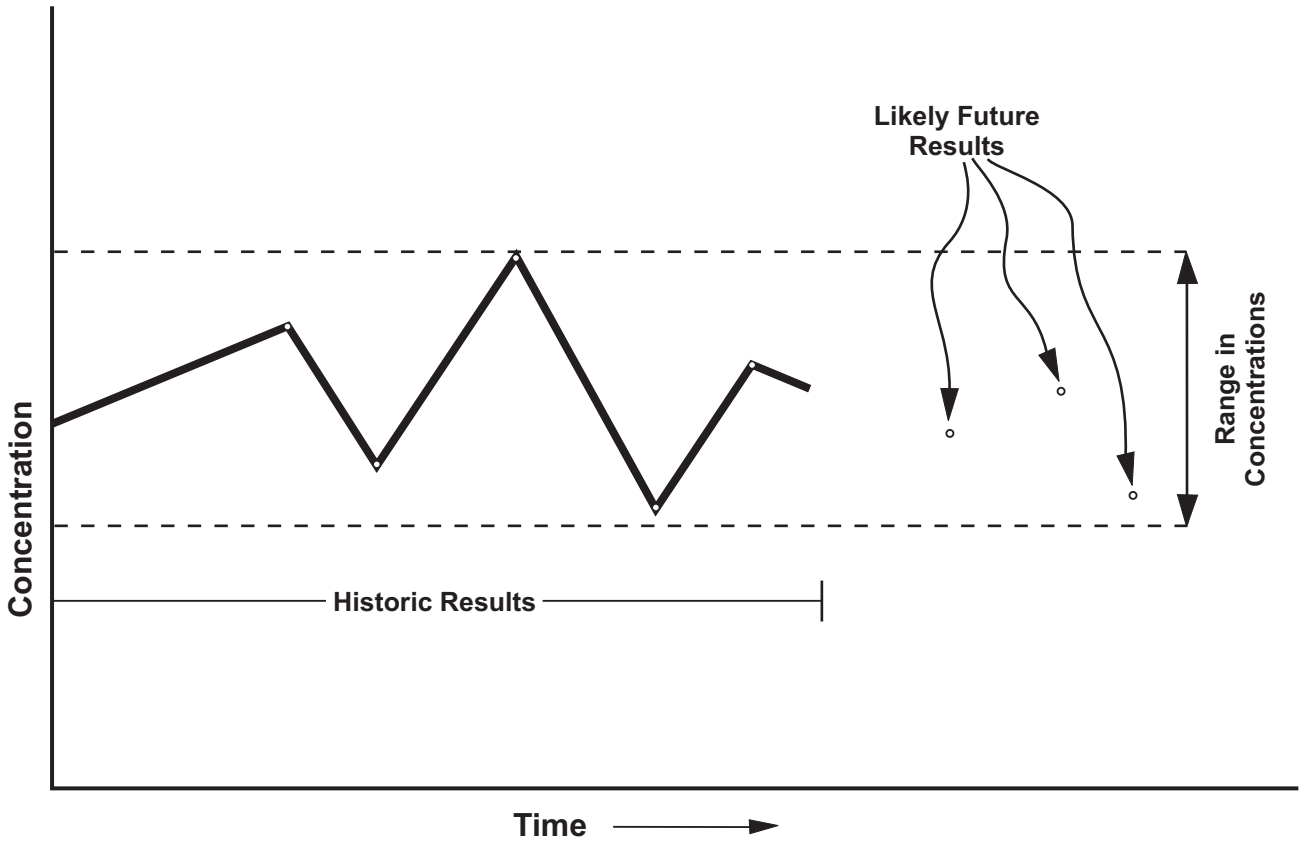

FIGURE 5.3
CONCEPTUAL REPRESENTATION OF CONTINUED MONITORING AT LOCATION WHERE NO TEMPORAL TREND IN CONCENTRATIONS IS PRESENT

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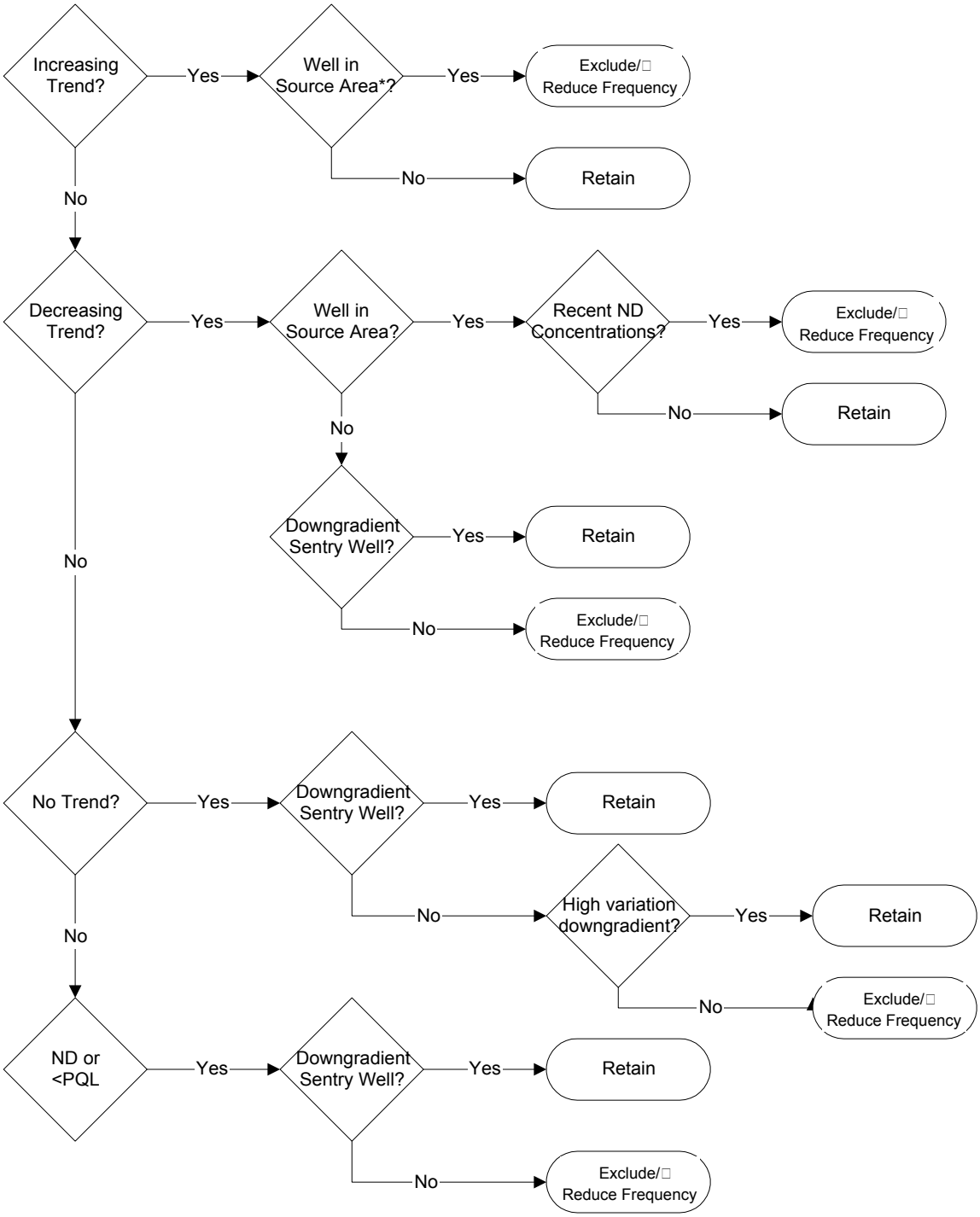

FIGURE 5.4
TEMPORAL TREND DECISION RATIONALE FLOW CHART

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PARSONS
Denver, Colorado

*If increasing trend occurs in a source area that is □ undergoing remediation, the well sould be retained.

TABLE 5.1

RESULTS OF TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS

MONITORING NETWORK OPTIMIZATION

MAIN BASE/SAC AREA

FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	CCL_4	PCE	TCE	Exclude/ Reduce Frequency	Retain	Rationale
WT/A Zone Wells						
MAFB-006	ND	ND	ND	√		No COCs[a/] detected in monitoring history (1/96-10/99) upgradient.
MAFB-033	No Trend	Decreasing	No Trend	√		Decreasing PCE < MCL; no-trend downgradient of source area.
MAFB-037	ND	ND	No Trend	√		ND or no-trend cross-gradient (TCE <2µg/L).
MAFB-047	ND	Decreasing	Decreasing	√		Decreasing trends in plume downgradient. COCs <MCLs[b/], limited temporal information.
MAFB-048	ND	No Trend	Increasing		√	TCE <1µg/L; increasing cross-gradient.
MAFB-085	ND	<PQL	ND		√	Downgradient senty well.
MAFB-086	ND	Decreasing	Decreasing	√		Decreasing downgradient.
MAFB-087	ND	No Trend	No Trend	√		ND or no trend << MCL within plume; limited temporal information.
MAFB-088	No Trend	No Trend	No Trend	√		No trend in plume; limited temporal information.
MAFB-089	No Trend	ND	No Trend	√		No trend/ND in plume; limited temporal information.
MAFB-090	<PQL	No Trend	Decreasing	√		Decreasing/no trend downgradient of source area.
MAFB-091	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-092	ND	ND	ND	√		ND cross-gradient of plume.
MAFB-093	ND	ND	<PQL	√		All COCs ND or <PQL in monitoring history (1/96-10/00) upgradient.
MAFB-095	No Trend	Decreasing	<PQL		√	Decreasing PCE in source area.
MAFB-096	No Trend	<PQL	<PQL	√		All COCs <1 µg/L in monitoring history upgradient.
MAFB-097	Increasing	ND	Increasing		√	Increasing concentrations (<1mg/L CCl4, <3mg/L TCE) upgradient
MAFB-099	ND	Increasing	No Trend		√	Increasing concentration downgradient of source area.
MAFB-105	ND	No Trend	No Trend	√		ND/no-trend in plume; limited temporal information.
MAFB-106	No Trend	Decreasing	ND	√		PCE <1mg/L since 10/00; limited temporal information.
MAFB-121	ND	Increasing	Decreasing		√	Increasing PCE concentrations (<1 µg/L) downgradient
MAFB-122	ND	Increasing	No Trend		√	Increasing PCE concentrations (<1 mg/L) downgradient
MAFB-123	ND	ND	Increasing		√	Increasing TCE concentration (<2mg/L) downgradient.
MAFB-124	<PQL	ND	ND	√		ND or <PQL downgradient; Far west of plume boundary.
MAFB-150	ND	ND	No Trend	√		No CCL_4, PCE detected in monitoring history (1-96-4/01) upgradient. One detect of TCE in 7/98, all other ND.
MAFB-156	ND	No Trend	ND	√		ND or no trend cross-gradient (PCE ND since 5/99)
MAFB-157	No Trend	No Trend	ND	√		ND or no trend cross-gradient (one detect of CCl4 and PCE in 1/99)
MAFB-158	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-159	ND	ND	Increasing	√		TCE <0.4mg/L since 10/97; PCE and CCL_4 ND in monitoring history cross-gradient.
MAFB-160	Decreasing	Increasing	ND		√	Decreasing CCL_4 >MCL.
MAFB-161	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-162	No Trend	ND	ND	√		ND or no trend upgradient.
MAFB-163	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-186	<4meas	<4meas	<4meas	Not Analyzed*		

TABLE 5.1 (Continued)

RESULTS OF TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS

MONITORING NETWORK OPTIMIZATION

MAIN BASE/SAC AREA

FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	CCL_4	PCE	TCE	Exclude/ Reduce Frequency	Retain	Rationale
MAFB-187	ND	Decreasing	No Trend	√		COCs ND since 10/97; limited temporal information.
MAFB-188	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-199	ND	No Trend	No Trend	√		ND or no-trend downgradient.
MAFB-200	ND	Decreasing	Decreasing	√		Decreasing in downgradient portion of plume.
MAFB-201	ND	Decreasing	Decreasing		√	Decreasing in source area.
MAFB-202	<PQL	No Trend	No Trend	√		No trend or <PQL in plume area; limited temporal information
MAFB-203	Increasing	Decreasing	Decreasing		√	Decreasing in source area.
MAFB-204	ND	No Trend	Increasing		√	TCE <3µg/L; increasing on outer edge of source area
MAFB-205	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-206	No Trend	No Trend	Increasing		√	Increasing TCE trend upgradient of source area.
MAFB-207	No Trend	No Trend	Decreasing		√	Jump in TCE in 10/02; decreasing TCE near source area.
MAFB-208	No Trend	No Trend	No Trend	√		No trend in plume; limited temporal information.
MAFB-209	Increasing	<PQL	No Trend		√	Increasing CCl_4 > MCL.
MAFB-210	No Trend	<PQL	<PQL	√		No trend and <PQL in plume; limited temporal information.
MAFB-211	Decreasing	Decreasing	Decreasing	√		Decreasing trend down/cross gradient of source area. All COCs <MCLs, limited future temporal information.
MAFB-212	Decreasing	No Trend	No Trend		√	Decreasing CCl_4 near MCL.
MAFB-213	ND	No Trend	Increasing		√	Increasing TCE trend. All COCs ND in most recent sampling round (7/01).
MAFB-214	<PQL	No Trend	No Trend	√		<PQL/no trend in plume; limited temporal information.
MAFB-244	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-245	ND	No Trend	ND	√		ND or no trend cross gradient; one detect of PCE <1µg/l in 10/99.
MAFB-246	Increasing	Decreasing	No Trend		√	CCl_4 increasing trend >MCL.
MAFB-251	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-252	ND	ND	ND	√		ND cross-gradient of plume.
MAFB-253	No Trend	Decreasing	ND		√	Decreasing PCE in plume.
MAFB-258	ND	ND	Increasing		√	Increasing concentration of TCE (<3 µg/L) downgradient.
MAFB-275	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-339	No Trend	Increasing	No Trend		√	Increasing concentrations of PCE >> MCL.
MAFB-340	Increasing	Increasing	No Trend		√	Increasing downgradient of extraction well.
MAFB-341	Decreasing	Decreasing	Decreasing		√	Decreasing in source area.
MAFB-342	Decreasing	Decreasing	No Trend		√	Decreasing in source area.
MAFB-343	No Trend	No Trend	No Trend	√		No trend in source area.
MAFB-344	Decreasing	Decreasing	ND		√	Decreasing in up-gradient plume.
MAFB-359	ND	No Trend	No Trend	√		No trend or ND within downgradient portion of plume; limited temporal information.
MAFB-404	<4meas	<4meas	<4meas	Not Analyzed		
MAFB-405	<4meas	<4meas	<4meas	Not Analyzed		
MAFB-407	<4meas	<4meas	<4meas	Not Analyzed		

TABLE 5.1 (Continued)

RESULTS OF TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS

MONITORING NETWORK OPTIMIZATION

MAIN BASE/SAC AREA

FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	CCL_4	PCE	TCE	Exclude/ Reduce Frequency	Retain	Rationale
MBS 39ABuB	Decreasing	No Trend	Decreasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW-12AB	<4meas	<4meas	<4meas	Not Analyzed		
MBS EW-1A	No Trend	Decreasing	Increasing		√	Decreasing extraction well measures PCE remediation and mass removal
MBS EW1ABu	Increasing	No Trend	No Trend		√	Increasing or no-trend in remediation area.
MBS EW-1Bu	<PQL	Decreasing	Decreasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW-2A	Increasing	Decreasing	Decreasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW2ABu	No Trend	Decreasing	No Trend		√	Decreasing extraction well measures remediation and mass removal
MBS EW-3A	<4meas	<4meas	<4meas	Not Analyzed		No analytical data.
MBS EW-4A	Decreasing	Decreasing	Decreasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW4ABu	Increasing	Decreasing	Decreasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW-4Bu	<4meas	<4meas	<4meas	Not Analyzed		
MBS EW-5A	<PQL	Decreasing	<PQL		√	Decreasing extraction well measures PCE remediation and mass removal
MBS EW5ABu	Increasing	Decreasing	Decreasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW6ABu	Increasing	Increasing	No Trend		√	Increasing or no-trend in remediation area.
MBS PZ-02	<PQL	Increasing	Increasing		√	Increasing downgradient of extraction well; PCE and TCE concentrations >> MCLs.
MBS PZ-03	Increasing	No Trend	No Trend		√	Increasing in remediation area.
B Zone Wells						
MAFB-073	ND	ND	ND	√		No COCs detected in monitoring history (4/96-4/01) upgradient.
MAFB-094	<PQL	ND	Increasing		√	Increasing TCE upgradient.
MAFB-101	No Trend	Decreasing	No Trend		√	Decreasing trend near extraction well measures remedy.
MAFB-154	ND	Increasing	Increasing	√		One detect of TCE and PCE in 10/00, all others ND.
MAFB-155	ND	ND	Decreasing		√	Decreasing TCE upgradient.
MAFB-164	Decreasing	Decreasing	Decreasing		√	Decreasing concentrations >MCLs in plume.
MAFB-165	Decreasing	Increasing	Decreasing		√	Increasing PCE within plume.
MAFB-166	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-167	Increasing	Increasing	No Trend		√	Increasing PCE and CCl_4 > MCL downgradient.
MAFB-168	Increasing	No Trend	Decreasing		√	Decreasing trend near extraction well measures remedy.
MAFB-169	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-170	Increasing	Increasing	Increasing		√	Increasing COCs within plume.
MAFB-171	Decreasing	Decreasing	Decreasing	√		Decreasing concentrations <MCL; limited temporal information.
MAFB-172	ND	Decreasing	Decreasing	√		Decreasing COCs < MCLs, limited temporal information.
MAFB-173	Increasing	Decreasing	Decreasing		√	Increasing CCl4 slightly greater than MCL.
MAFB-174	No Trend	<PQL	Decreasing	√		Decreasing TCE <MCL; limited temporal information.
MAFB-175	No Trend	Increasing	Decreasing		√	Increasing PCE within plume.
MAFB-176	No Trend	<PQL	Increasing		√	TCE (slightly greater than MCL) increasing in plume.
MAFB-177	Increasing	Increasing	No Trend		√	Increasing concentrations near extraction well.
MAFB-215	No Trend	No Trend	Increasing		√	Increasing trend of TCE within plume.

TABLE 5.1 (Continued)

RESULTS OF TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS

MONITORING NETWORK OPTIMIZATION

MAIN BASE/SAC AREA

FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	CCL_4	PCE	TCE	Exclude/ Reduce Frequency	Retain	Rationale
MAFB-216	Decreasing	Increasing	Increasing		√	Increasing TCE and PCE within plume.
MAFB-217	No Trend	<PQL	No Trend	√		No trend or <PQL in plume area; limited temporal information
MAFB-218	Decreasing	Increasing	Decreasing		√	Increasing PCE within plume.
MAFB-219	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-220	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-221	ND	ND	<PQL	√		ND or <PQL; co-located well (MAFB-164) with measured concentrations.
MAFB-222	Increasing	Decreasing	Increasing		√	Increasing CCl4 and TCE downgradient of extraction well.
MAFB-223	No Trend	Increasing	Increasing		√	Increasing concentrations >MCLs within plume.
MAFB-224	No Trend	Increasing	No Trend		√	Increasing PCE (<1µg/L) within plume.
MAFB-225	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-226	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-227	Increasing	No Trend	Increasing		√	Increasing concentrations within plume
MAFB-228	No Trend	Decreasing	No Trend		√	Decreasing PCE in source area.
MAFB-229	No Trend	Decreasing	Increasing		√	Decreasing PCE in source area.
MAFB-230	<PQL	No Trend	ND	√		PCE <2mg/L; cross-gradient.
MAFB-231	No Trend	Decreasing	Increasing		√	Increasing TCE trend upgradient of source area.
MAFB-232	Decreasing	No Trend	Increasing		√	Decreasing CCl4 > MCL.
MAFB-233	ND	ND	ND	√		No COCs detected in monitoring history (1/96-2/01) upgradient.
MAFB-234	No Trend	Decreasing	No Trend		√	Decreasing PCE in plume.
MAFB-247	No Trend	ND	Increasing		√	Increasing TCE on outside of plume.
MAFB-248	No Trend	Increasing	No Trend		√	CCl_4 >MCL; increasing PCE (<1mg/L) on outside of plume.
MAFB-249	No Trend	Increasing	No Trend		√	Increasing PCE (<2µg/L) on outside of plume.
MAFB-259	ND	ND	ND	√		No COCs detected in monitoring history.
MAFB-260	ND	ND	ND	√		Non detect in well monitoring history (2/96-5/02). Co-located deeper well (MAFB-268) with detections.
MAFB-261	Decreasing	Decreasing	No Trend		√	Decreasing trends <MCLs in downgradient portion of plume.
MAFB-263	Increasing	No Trend	ND		√	Increasing CCl4 > MCL in downgradient portion of plume.
MAFB-264	Increasing	Decreasing	Increasing		√	Increasing concentrations in plume.
MAFB-265	No Trend	Decreasing	No Trend	√		No trend or decreasing downgradient of source area.
MAFB-266	No Trend	No Trend	No Trend	√		No trend; limited temporal information.
MAFB-267	ND	ND	ND		√	Non detect in well monitoring history downgradient; sentry well (shallower than 269)
MAFB-268	Increasing	No Trend	Decreasing		√	Increasing CCl4 > MCL.
MAFB-269	No Trend	Increasing	Increasing		√	Increasing TCE and PCE (both <2µg/l)
MAFB-270	No Trend	Increasing	ND		√	Increasing PCE (<3µg/L) in downgradient portion of plume.
MAFB-271	Decreasing	Decreasing	No Trend	√		Decreasing trends <MCLs; limited continued temporal information.
MAFB-272	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-273	<4meas	<4meas	<4meas	Not Analyzed*		

TABLE 5.1 (Continued)

RESULTS OF TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS

MONITORING NETWORK OPTIMIZATION

MAIN BASE/SAC AREA

FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	CCL_4	PCE	TCE	Exclude/ Reduce Frequency	Retain	Rationale
MAFB-274	No Trend	Decreasing	No Trend	√		Decreasing PCE < MCL; limited continued temporal information.
MAFB-280	ND	ND	ND	√		No COCs detected in monitoring history (2/96-5/02) upgradient.
MAFB-281	ND	ND	<PQL	√		ND or < PQL upgradient.
MAFB-282	ND	No Trend	No Trend	√		ND or no-trend; limited temporal information.
MAFB-308	No Trend	Decreasing	ND	√		Decreasing PCE <MCL, limited continued temporal information.
MAFB-309	ND	ND	ND	√		No COCs detected in monitoring history (2/96-5/99) cross-gradient.
MAFB-310	ND	ND	ND	√		No COCs detected in monitoring history (2/96-4/02) cross-gradient.
MAFB-311	<PQL	ND	ND	√		No COCs or <PQL detected in monitoring history (2/96-7/01) cross-gradient.
MAFB-312	Increasing	Increasing	ND		√	Increasing trends on downgradient edge of plume.
MAFB-313	Decreasing	Decreasing	ND		√	Decreasing CCl4 and PCE near extraction well.
MAFB-322	ND	ND	ND	√		No COCs detected in monitoring history (2/96-10/02) cross-gradient.
MAFB-323	<PQL	<PQL	ND		√	<PQL or ND downgradient; sentry well.
MAFB-324	ND	Increasing	ND		√	PCE < 1µg/L; slight increasing trend cross-gradient.
MAFB-325	ND	ND	ND	√		No COCs detected in monitoring history (2/96-4/02) cross-gradient.
MAFB-330	Increasing	<PQL	<PQL		√	Increasing CCl4 > MCL downgradient.
MAFB-331	Increasing	ND	ND		√	Increasing CCl4 > MCL downgradient.
MAFB-346Bd	ND	ND	ND		√	COCs not detected in monitoring history. Assess vertical migration from well MAFB-346Bs.
MAFB-346Bs	Decreasing	Increasing	ND		√	Increasing PCE (<2mg/L) downgradient.
MAFB-348B	Decreasing	Decreasing	No Trend		√	Decreasing trends within plume; CCl4 > MCLs.
MAFB-351Bd	ND	ND	ND	√		ND in well monitoring history, co-located MAFB-351Bs is sentry well.
MAFB-351Bs	ND	ND	ND		√	ND downgradient; sentry well.
MAFB-354B	ND	ND	ND	√		Nearby MAFB-387B is downgradient sentry well.
MAFB-355B	ND	ND	ND	√		COCs not detected in monitoring history. Distant from plume.
MAFB-356B	ND	ND	ND		√	ND downgradient; sentry well.
MAFB-358B	<PQL	Decreasing	Decreasing		√	Decreasing concentrations upgradient
MAFB-360	No Trend	No Trend	No Trend	√		No temporal trends within plume.
MAFB-361	No Trend	No Trend	No Trend	√		No temporal trends within plume.
MAFB-362	No Trend	No Trend	No Trend	√		No temporal trends within plume.
MAFB-363	Increasing	No Trend	No Trend		√	Increasing CCl4 > MCL.
MAFB-364B	No Trend	No Trend	Decreasing	√		Decreasing concentrations of TCE < MCL; limited temporal information.
MAFB-365B	No Trend	No Trend	Decreasing		√	Decreasing TCE close to MCL.
MAFB-366B	Decreasing	Decreasing	No Trend		√	Decreasing PCE and CCl4 in plume.
MAFB-368B	Decreasing	Increasing	ND		√	Increasing PCE in downgradient portion of plume.
MAFB-378B	ND	<PQL	ND	√		<PQL or ND cross-gradient.
MAFB-379B	No Trend	Decreasing	ND		√	Decreasing PCE in plume.
MAFB-380B	Decreasing	Decreasing	ND	√		Decreasing trends ND or <MCL; limited continued temporal information.
MAFB-381B	No Trend	Increasing	ND		√	Increasing PCE (<2mg/L) in downgradient portion of plume.

TABLE 5.1 (Continued)

RESULTS OF TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS

MONITORING NETWORK OPTIMIZATION

MAIN BASE/SAC AREA

FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	CCL_4	PCE	TCE	Exclude/ Reduce Frequency	Retain	Rationale
MAFB-382B	ND	ND	ND		√	ND downgradient; sentry well.
MAFB-383B	ND	No Trend	Increasing		√	Increasing TCE downgradient.
MAFB-384B	ND	No Trend	ND	√		ND/ no-trend at up-gradient portion of plume; limited temporal information.
MAFB-385B	ND	Decreasing	ND	√		PCE <1µg/L; limited temporal information cross-gradient.
MAFB-386B	ND	<PQL	ND		√	ND or <PQL; downgradient sentry well.
MAFB-387B	No Trend	No Trend	ND		√	Recent ND; downgradient sentry well.
MAFB-388B	No Trend	<PQL	ND	√		Nearby MAFB-387B is downgradient sentry well.
MBS EW-10B	<4meas	<4meas	<4meas	Not Analyzed		
MBS EW-11B	<4meas	<4meas	<4meas	Not Analyzed		
MBS EW-1B	No Trend	Decreasing	Decreasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW-2B	Increasing	Decreasing	No Trend		√	Decreasing extraction well measures remediation and mass removal
MBS EW-3B	Increasing	Decreasing	Increasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW-3Bu	No Trend	No Trend	No Trend	√		No trend; limited temporal information.
MBS EW-4B	No Trend	Decreasing	Decreasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW-5B	No Trend	Decreasing	<PQL		√	Decreasing extraction well measures remediation and mass removal
MBS EW-6B	No Trend	Decreasing	<PQL		√	Decreasing extraction well measures remediation and mass removal
MBS EW-7B	No Trend	No Trend	Decreasing		√	Decreasing extraction well measures remediation and mass removal
MBS EW-8B	Decreasing	Decreasing	ND		√	Decreasing extraction well measures remediation and mass removal
MBS EW-9B	<4meas	<4meas	<4meas	Not Analyzed		
MBS PZ-11	ND	Decreasing	ND	√		Decreasing PCE < MCL; limited continued temporal information.
MBS PZ-37	No Trend	Decreasing	<PQL	√		Decreasing PCE downgradient of extraction well.
MBS PZ-38	Decreasing	Decreasing	ND		√	Decreasing concentrations >MCL in plume.
MBS PZ-39	No Trend	No Trend	No Trend	√		No trend; limited temporal information.
MBS PZ-42D	Decreasing	Decreasing	ND		√	Decreasing trends within plume; CCl_4, PCE >MCL.
MBS PZ-44	Decreasing	Decreasing	Decreasing		√	Decreasing trends within plume; CCl_4 ND; PCE <MCL; TCE close to MCL.
MBS PZ-55B	<4meas	<4meas	<4meas	Not Analyzed		
MBS PZ-55Bu	<4meas	<4meas	<4meas	Not Analyzed		
D Zone Wells						
FFS MW15-6	No Trend	No Trend	No Trend	√		No trend; limited temporal information.
MAFB-060	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-061	ND	<PQL	Increasing		√	increasing TCE (<1µg/l) on outside of plume.
MAFB-062	ND	ND	ND	√		ND in monitoring history within plume.
MAFB-063	Decreasing	Decreasing	Decreasing		√	Decreasing concentrations within plume.
MAFB-066	ND	ND	ND	√		No COCs detected in monitoring history (2/96-4/02) upgradient.
MAFB-102	No Trend	Increasing	No Trend		√	Increasing PCE (<1µg/L) within plume.
MAFB-103	ND	ND	ND		√	ND in monitoring history; sentry well vertically downgradient from Unit B plume.
MAFB-104	<PQL	Increasing	No Trend		√	Increasing PCE (<1µg/L) within plume.

TABLE 5.1 (Continued)

RESULTS OF TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS

MONITORING NETWORK OPTIMIZATION

MAIN BASE/SAC AREA

FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	CCL_4	PCE	TCE	Exclude/ Reduce Frequency	Retain	Rationale
MAFB-178	ND	ND	ND	√		No COCs detected in monitoring history (1/96-2/01) upgradient.
MAFB-180	Increasing	Increasing	<PQL		√	Increasing CCl4 and PCE >MCLs downgradient of extraction well.
MAFB-181	Increasing	Increasing	ND		√	Increasing concentrations >MCLs within plume.
MAFB-235	<PQL	Increasing	ND		√	Increasing PCE (<1µg/L) within plume.
MAFB-239	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-240	No Trend	Decreasing	No Trend	√		Decreasing PCE < MCL; limited continued temporal information.
MAFB-241	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-242	No Trend	Increasing	Increasing		√	Increasing concentrations within plume.
MAFB-243	No Trend	No Trend	No Trend	√		No trend; limited temporal information.
MAFB-250	<4meas	<4meas	<4meas	Not Analyzed*		
MAFB-290	ND	<PQL	ND	√		PCE ND since 11/98; co-located well with (MAFB-296) concentrations.
MAFB-291	<4meas	<4meas	<4meas	Not Analyzed		
MAFB-292	<4meas	<4meas	<4meas	Not Analyzed		
MAFB-293	Decreasing	Decreasing	ND	√		Decreasing in downgradient portion of plume.
MAFB-296	Decreasing	Decreasing	ND		√	Decreasing concentrations within plume.
MAFB-314	Increasing	No Trend	Increasing	√		Increasing concentrations in source area.
MAFB-315	ND	ND	ND	√		ND in monitoring history cross-gradient.
MAFB-316	ND	ND	ND	√		ND in monitoring history cross-gradient.
MAFB-317	ND	Decreasing	ND	√		PCE ND since 10/97; cross-gradient of plume.
MAFB-318	Increasing	ND	ND		√	Increasing CCl_4 in downgradient portion of plume.
MAFB-319	Decreasing	Decreasing	Decreasing	√		Decreasing COCs < MCLs, edge of plume definition.
MAFB-320	Increasing	Increasing	<PQL		√	Increasing concentrations in remediation area.
MAFB-321	ND	ND	ND	√		ND in monitoring history.
MAFB-326	<PQL	ND	ND	√		<PQL or ND in monitoring history cross-gradient.
MAFB-327	Increasing	Increasing	ND		√	Increasing concentrations downgradient of plume.
MAFB-328	ND	<PQL	ND	√		ND or <PQL within plume.
MAFB-329	ND	<PQL	ND	√		ND or <PQL cross-gradient.
MAFB-332	Increasing	Increasing	ND		√	Increasing concentration in downgradient portion of plume.
MAFB-336	ND	ND	ND		√	ND in monitoring history; vertical sentry well.
MAFB-337	ND	ND	ND	√		ND in monitoring history cross-gradient.
MAFB-338	ND	ND	ND	√		ND in monitoring history. Co-located well (MAFB-328) <PQL/ND vertically upgradient.
MAFB-345	ND	ND	ND	√		ND in monitoring history; shallower co-located well (MAFB-346D) ND.
MAFB-346D	ND	ND	ND		√	Sentry well vertically downgradient from Unit B plume.
MAFB-347	ND	<PQL	ND	√		ND or <PQL in monitoring history.
MAFB-348Dd	No Trend	No Trend	ND	√		CCl4 and PCE ND since 5/01; limited temporal information.
MAFB-348Ds	Decreasing	No Trend	ND		√	Decreasing CCl4 close to MCL within plume.
MAFB-349	ND	ND	ND	√		ND in monitoring history.

TABLE 5.1 (Continued)

RESULTS OF TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS

MONITORING NETWORK OPTIMIZATION

MAIN BASE/SAC AREA

FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	CCL_4	PCE	TCE	Exclude/ Reduce Frequency	Retain	Rationale
MAFB-350	ND	ND	ND	√		ND in monitoring history downgradient of plume; shallower well (MAFB-351D) ND.
MAFB-351D	ND	ND	ND		√	ND in monitoring history downgradient of plume; sentry well.
MAFB-352D	ND	No Trend	ND	√		No trend or ND in plume; limited temporal information.
MAFB-352LM	No Trend	No Trend	ND	√		One detect of CCl4 and PCE in 1/99, all others ND within plume.
MAFB-353	ND	ND	ND		√	ND in monitoring history; sentry well for LMT.
MAFB-354D	ND	ND	ND	√		ND in monitoring history; downgradient wells serve as sentry wells.
MAFB-355D	ND	ND	ND	√		ND in monitoring history; distant from plume.
MAFB-356Dd	ND	ND	ND	√		ND in monitoring history, shallower well has historical ND.
MAFB-356Ds	ND	ND	ND	√		ND in monitoring history, shallower well has historical ND.
MAFB-357D	ND	No Trend	No Trend	√		ND or no trend on upgradient edge of plume; limited temporal information.
MAFB-357Dd	ND	No Trend	No Trend		√	ND or no trend on upgradient edge of plume; senty well for verticle plume extent.
MAFB-357Ds	ND	Increasing	<PQL		√	Increasing PCE on edge of plume.
MAFB-358D	ND	No Trend	No Trend	√		ND or no-trend upgradient; limited temporal information.
MAFB-364D	<PQL	No Trend	No Trend		√	Sentry well vertically downgradient from Unit B plume.
MAFB-365D	ND	Decreasing	Decreasing	√		Decreasing TCE and PCE (<2mg/L) in downgradient portion of plume.
MAFB-366D	No Trend	No Trend	ND	√		No trend or ND within plume; limited temporal information.
MAFB-367	Decreasing	No Trend	ND	√		One CCl4 detect in 8/99, all other ND; limited continued temporal information.
MAFB-368D	Decreasing	No Trend	ND	√		Decreasing CCl4 in downgradient portion of plume.
MAFB-369	ND	Decreasing	ND	√		Decreasing PCE <1mg/L in downgradient portion of plume; limited temporal information
MAFB-374	ND	ND	ND	√		No COCs detected in monitoring history (5/01-10/02) upgradient.
MAFB-375	No Trend	Decreasing	ND		√	Decreasing PCE (close to MCL) within plume
MAFB-376	Decreasing	Increasing	ND		√	Increasing PCE within plume.
MAFB-377	<4meas	<4meas	<4meas	Not Analyzed		
MAFB-378D	ND	<PQL	ND	√		ND or <PQL upgradient from plume.
MAFB-379D	No Trend	No Trend	ND	√		No trend or ND; limited temporal information.
MAFB-380D	Decreasing	Decreasing	ND	√		Decreasing CCl4 ND, PCE <1mg/L; limited continued temporal information.
MAFB-381D	ND	ND	ND		√	Sentry well vertically downgradient from Unit B plume.
MAFB-382D	ND	ND	ND		√	Sentry well vertically downgradient from Unit B plume.
MAFB-383D	ND	No Trend	Decreasing		√	Sentry well vertically downgradient from Unit B plume.
MAFB-384D	ND	Decreasing	ND	√		Decreasing PCE < 1µg/L upgradient; limited continued temporal information.
MAFB-385D	No Trend	No Trend	ND	√		No trend or ND within plume; limited temporal information.
MAFB-386D	ND	No Trend	ND		√	Sentry well vertically downgradient from Unit B plume.
MAFB-387Dd	ND	No Trend	ND		√	One detect (<1mg/L) of PCE in 6/01, all other ND, vertical sentry well.
MAFB-387Ds	ND	No Trend	ND	√		One detect (<1mg/L) of PCE in 6/01, all other ND, shallower well serves as sentry well.
MAFB-388Dd	ND	<PQL	ND		√	ND or <PQL in monitoring history, downgradient sentry wells.
MAFB-388Ds	ND	<PQL	ND		√	ND or <PQL in monitoring history, downgradient sentry wells.
MAFB-397	<4meas	<4meas	<4meas	Not Analyzed		

TABLE 5.1 (Continued)

RESULTS OF TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS

MONITORING NETWORK OPTIMIZATION

MAIN BASE/SAC AREA

FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	CCL_4	PCE	TCE	Exclude/ Reduce Frequency	Retain	Rationale
MBS EW-1D	No Trend	Decreasing	No Trend		√	Decreasing extraction well measures remediation and mass removal
MBS EW-2D	No Trend	Increasing	Increasing		√	Increasing extractin well measures remeditation and mass removal.
MBS EW-3D	Decreasing	No Trend	No Trend		√	Decreasing extraction well measures remediation and mass removal
MBS EW-4D	<4meas	<4meas	<4meas	Not Analyzed		
MBS EW-5D	<4meas	<4meas	<4meas	Not Analyzed		
MBS EW-6D	<4meas	<4meas	<4meas	Not Analyzed		
MBS PZ-12	ND	Decreasing	No Trend	√		PCE ND since 12/98; limited continued temporal information.
MBS PZ-13	Increasing	No Trend	Decreasing		√	Increasing CCl4 within plume.
MBS PZ-14	Decreasing	Decreasing	ND	√		CCl4 ND since 12/98; PCE ND since 7/00; limited continued temporal information.
MBS PZ-15	ND	No Trend	ND	√		ND or no trend in upgradient portion of plume; limited temporal information.
MBS PZ-49D	ND	<PQL	ND	√		ND or <PQL in upgradient portion of plume.
MBS PZ-50D	ND	No Trend	ND	√		ND or no trend in upgradient portion of plume; limited temporal information.
MBS PZ-51	<4meas	<4meas	<4meas	Not Analyzed		
MBS PZ-52	<4meas	<4meas	<4meas	Not Analyzed		
MBS PZ-53	<4meas	<4meas	<4meas	Not Analyzed		
MBS PZ-54	<4meas	<4meas	<4meas	Not Analyzed		
MBS PZ-58	<4meas	<4meas	<4meas	Not Analyzed		

ND	= Constituent has not been detected during history of monitoring at inidcated well.
No Trend	= No statistically significant temporal trend in concentrations.
Increasing	= Statistically significant increasing trend in concentrations (95% confidence level).
Decreasing	= Statistically significant decreasing trend in concentrations (95% confidence level).
<PQL	= Concentrations consistently below practical quantitation limit.
<4meas	= Fewer than 4 analytical results; Mann-Kendall trend not analyzed.

[a/] COC = Contaminant of Concern

[b/] MCL = maximum contaminant level

corresponding to the detection limit – a procedure that could generate potentially misleading and anomalous "trends" in concentrations. In addition, a value of "<PQL" was assigned to those constituents for which no values were measured above the PQL. For example, PCE results for groundwater samples from well MAFB-085 include one trace detection of 0.36 μg/L on 10/26/01 and 15 measurements in which PCE was not detected. In the absence of the "<PQL" classification category, the results of trend analysis would indicate an increasing trend for PCE in these samples, which is primarily an artifact of the analytical procedures, and could generate false conclusions regarding concentration trends. The color-coding of the Table 5.1 entries denotes the presence/absence of temporal trends, and allows those monitoring points having nondetectable concentrations, decreasing or increasing concentrations, or no discernible trend in concentrations to be readily identified. The 45 wells that had fewer than four analytical results for each of the COCs could not be analyzed using the Mann-Kendall trend analysis, and have a "<4meas" designation. Figures 5.5 through 5.7 display the Mann-Kendall results for PCE thematically by well for zones WT/A, B, and D, respectively.

The basis for the decision to exclude, reduce sampling or retain a well in the monitoring program based on the value of its temporal information is described in the "Rationale" column of Table 5.1, and a flow chart of the decision logic applied to the temporal trend analysis results is presented in Figure 5-4. In general, monitoring wells at which detected chemical concentrations display no discernible statistically significant temporal trends (i.e., they were not classified by the Mann-Kendall analysis as increasing or decreasing) (e.g., MAFB-088, MAFB-208, MAFB-343, MAFB-360) represent points generating the least amount of useful information, and typically can be recommended for exclusion or reduced monitoring. Monitoring wells that are not considered "sentry" wells at which concentrations of COCs consistently have been non-detected or <PQL through time (e.g., MAFB-006, MAFB-092, MAFB-073, MAFB-309, MAFB-062) also may provide relatively little information. Additionally, wells located downgradient of the source area that have either decreasing concentrations or a recent history of

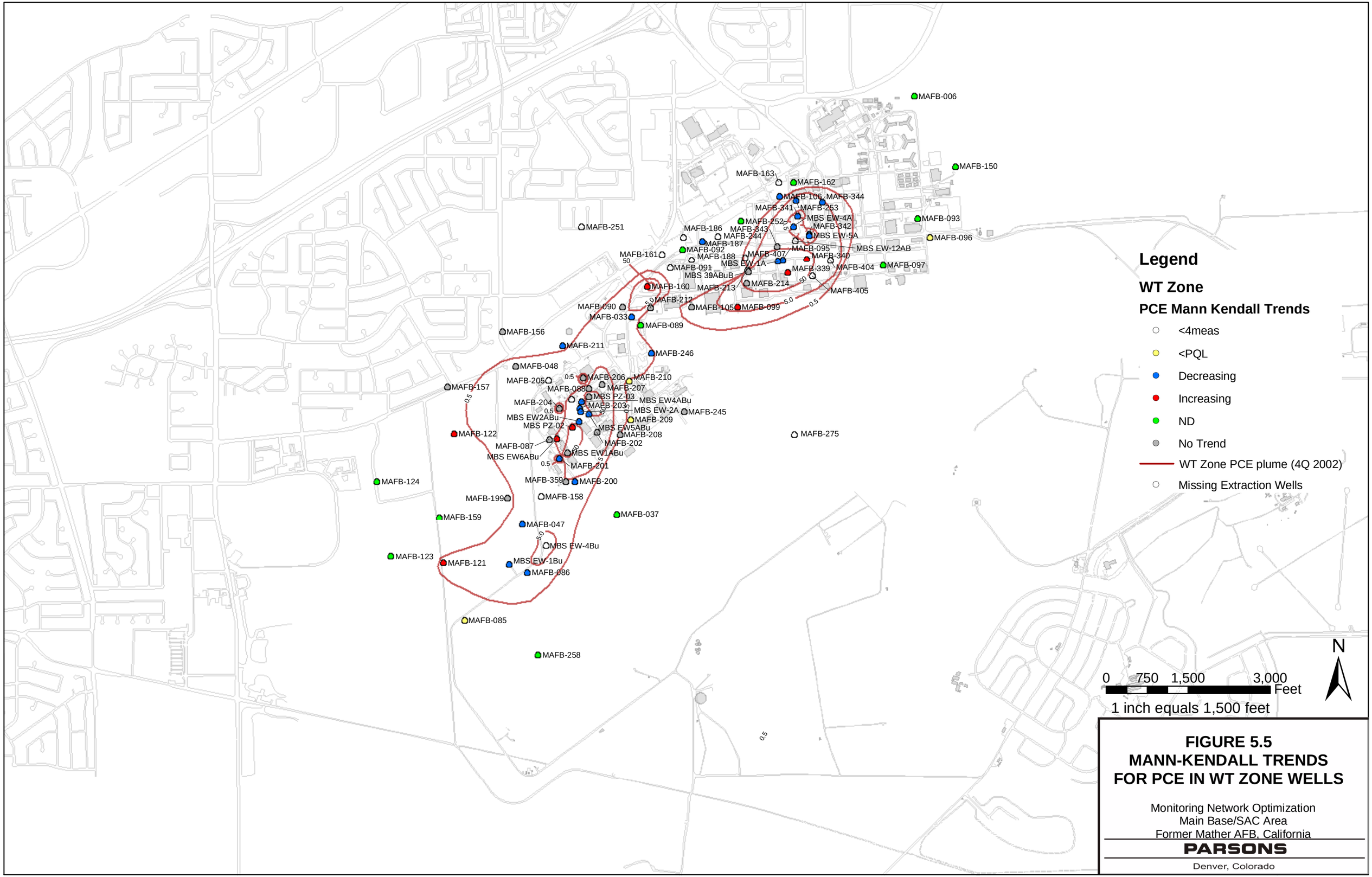


FIGURE 5.5
MANN-KENDALL TRENDS
FOR PCE IN WT ZONE WELLS

Monitoring Network Optimization
Main Base/SAC Area
Former Mather AFB, California

PARSONS
Denver, Colorado

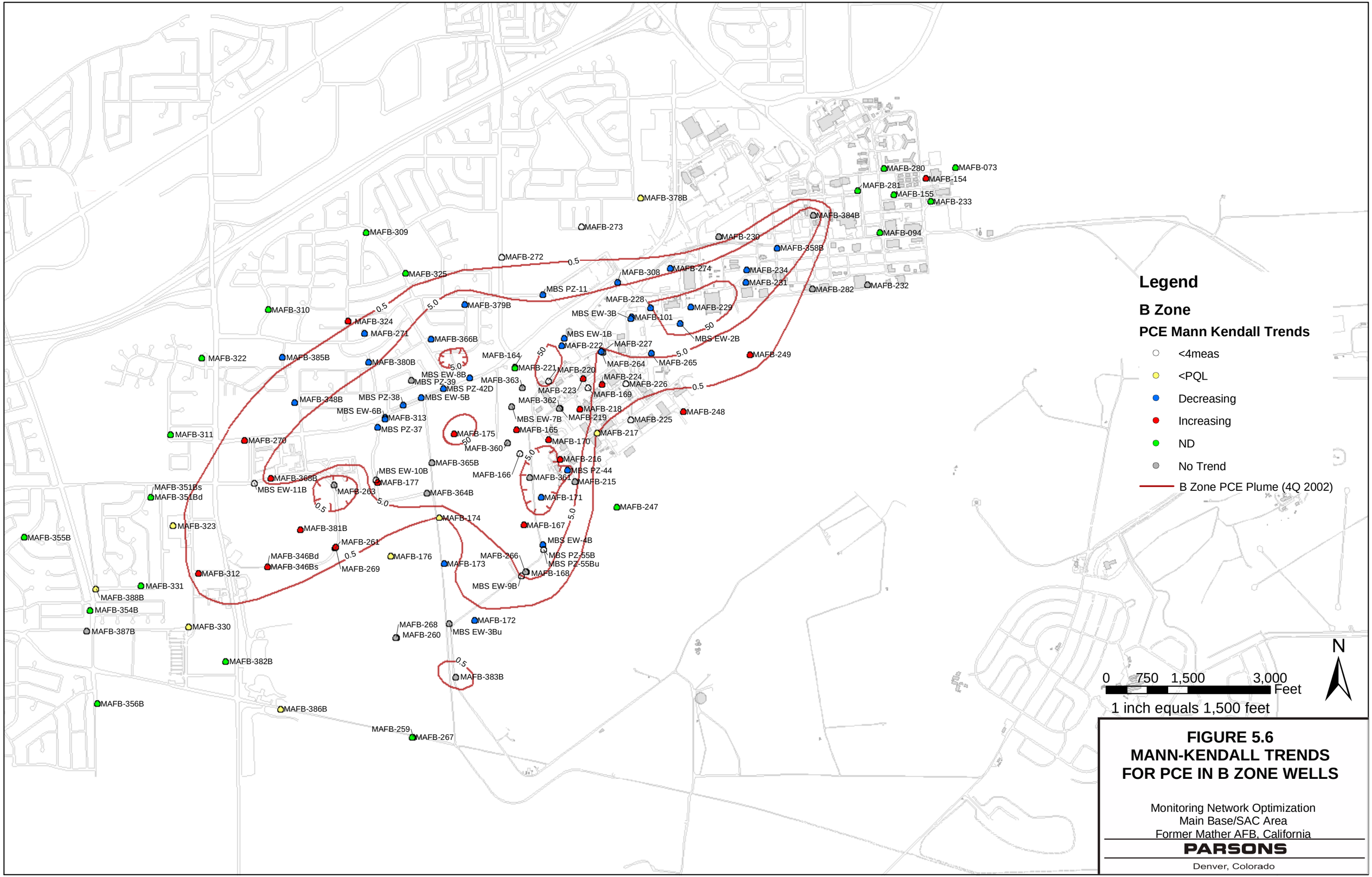


FIGURE 5.6
MANN-KENDALL TRENDS
FOR PCE IN B ZONE WELLS

Monitoring Network Optimization
Main Base/SAC Area
Former Mather AFB, California

PARSONS
Denver, Colorado

MAFB-066
MAFB-178
MAFB-374
MAFB-378D
MAFB-397
MAFB-384D
MAFB-292
MBS PZ-54
MBS PZ-53
MAFB-315
MBS PZ-49D
MBS PZ-15
MBS EW-4D
MAFB-291
MBS PZ-50D
MAFB-388D
MAFB-357Dd
MAFB-357Ds
MAFB-375
MBS PZ-12
MBS PZ-14
MBS PZ-13
MAFB-250
MAFB-329
MAFB-296
MAFB-290
MAFB-352LM
MBS EW-1D
MAFB-320
MAFB-314
MAFB-376
MAFB-316
MAFB-379D
MBS PZ-52
MAFB-328
MAFB-352D
MBS EW-3D
MAFB-338
MAFB-321
MAFB-319
MBS PZ-51
MAFB-360D
MAFB-180
MAFB-326
MAFB-337
MBS EW-5D
MBS PZ-58
MAFB-242
MAFB-235
MAFB-385D
MAFB-380D
MBS EW-2D
MAFB-243
MAFB-063
MAFB-241
MAFB-181
MAFB-102
MAFB-348Dd
MAFB-240
MAFB-367
MAFB-347
FFS MW15-6
MAFB-317
MAFB-348Ds
MAFB-104
MAFB-062
MAFB-293
MAFB-061
MAFB-365D
MAFB-368D
MAFB-369
MAFB-351D
MAFB-350
MBS EW-6D
MAFB-364D
MAFB-239
MAFB-332
MAFB-327
MAFB-349
MAFB-381D
MAFB-060
MAFB-355D
MAFB-377
MAFB-346D
MAFB-345
MAFB-103
MAFB-318
MAFB-388Dd
MAFB-388Ds
MAFB-354D
MAFB-353
MAFB-387Dd
MAFB-387Ds
MAFB-336
MAFB-382D
MAFB-383D
MAFB-356Ds
MAFB-356Dd
MAFB-386D

0.5
5.0
50

Legend

D Zone

PCE Mann Kendall Trends

- <4meas
- <PQL
- Decreasing
- Increasing
- ND
- No Trend
- D Zone PCE plume (4Q 2002)

N

0 750 1,500 3,000 Feet

1 inch equals 1,500 feet

FIGURE 5.7
MANN-KENDALL TRENDS FOR PCE IN D ZONE WELLS

Monitoring Network Optimization
Main Base/SAC Area
Former Mather AFB, California

PARSONS

Denver, Colorado

concencentrations below MCLs (e.g., MAFB-047, MAFB-187, MAFB-271, MAFB-380D, MBS PZ-14) will provide limited valuable temporal information in the future and are recommended for exclusion or reduced sampling. Conversely, monitoring wells (e.g., MAFB-201, MAFB-203, MAFB-341, MAFB-101, MAFB-164) that exhibit decreasing temporal trends near an extraction well or in a source area with recent concentrations above MCLs are valuable and should be retained because they provide information on the effectiveness of the remediation system. Additionally, downgradient wells with increasing COC concentration trends (e.g., wells MAFB-099, MAFB-340, MBS PZ-02, MAFB-167, MAFB-327) provide valuable information about potential migration of contaminants, and should be retained. Recommendations in wells that had different Mann-Kendall trend results for different COCs were based on the most conservative analysis. For example, well MAFB-099 has no detects for CCl_4, no temporal trend in TCE concentration, and an increasing trend in PCE concentration. The decision to retain the well is based on the increasing PCE trend. .

Table 5.1 summarizes recommendations to retain 140 and remove 121 of the 261 wells (excluding the 45 wells with fewer than four measurements) analyzed to optimize the monitoring program for the Main Base/SAC Area Plume. The recommendations provided in Table 5.1 are based on the evaluation of ***temporal statistical results only***, and must be used in conjunction with the results of the qualitative and spatial evaluations to generate final recommendations regarding retention of monitoring points in the LTM program, and the frequency of monitoring at particular locations in the Main Base/SAC Area Plume.

SECTION 6

SPATIAL STATISTICAL EVALUATION

Spatial statistical techniques also can be applied to the design and evaluation of groundwater monitoring programs to assess the quality of information generated during monitoring, and to evaluate monitoring networks. *Geostatistics*, or the Theory of Regionalized Variables (Clark, 1987; Rock, 1988; American Society of Civil Engineers Task Committee on Geostatistical Techniques in Hydrology, 1990a and 1990b), is concerned with variables having values dependent on location, and which are continuous in space, but which vary in a manner too complex for simple mathematical description. Geostatistics is based on the premise that the differences in values of a spatial variable depend only on the distances between sampling locations, and the relative orientations of sampling locations--that is, the values of a variable (e.g., chemical concentration) measured at two locations that are spatially "close together" will be more similar than values of that variable measured at two locations that are "far apart".

6.1 GEOSTATISTICAL METHODS FOR EVALUATING MONITORING NETWORKS

Ideally, application of geostatistical methods to the results of the groundwater monitoring program at the Main Base/SAC Area Plume could be used to estimate COC concentrations at every point within the dissolved contaminant plume, and also could be used to generate estimates of the “error,” or uncertainty, associated with each estimated concentration value. Thus, the monitoring program could be optimized by using available information to identify those areas having the greatest uncertainty associated with the estimated plume extent and configuration. Conversely, sampling points could be successively eliminated from simulations, and the resulting uncertainty examined, to evaluate if significant loss of information (represented by increasing error or uncertainty

in estimated chemical concentrations) occurs as the number of sampling locations is reduced. Repeated application of geostatistical estimating techniques, using tentatively identified sampling locations, then could be used to generate a sampling program that would provide an acceptable level of uncertainty regarding the distribution of COCs with the minimum possible number of samples collected. Furthermore, application of geostatistical methods can provide unbiased representations of the distribution of COCs at different locations in the subsurface, enabling the extent of COCs to be evaluated more precisely.

Fundamental to geostatistics is the concept of semivariance [$\gamma(h)$], which is a measure of the spatial dependence between sample variables (e.g., chemical concentrations) in a specified direction. Semivariance is defined for a constant spacing between samples (h) by:

$$\gamma(h) = \frac{1}{2n} \sum [g(x) - g(x + h)]^2 \qquad \textit{Equation 6-1}$$

Where:

$\gamma(h)$ = semivariance calculated for all samples at a distance h from each other;

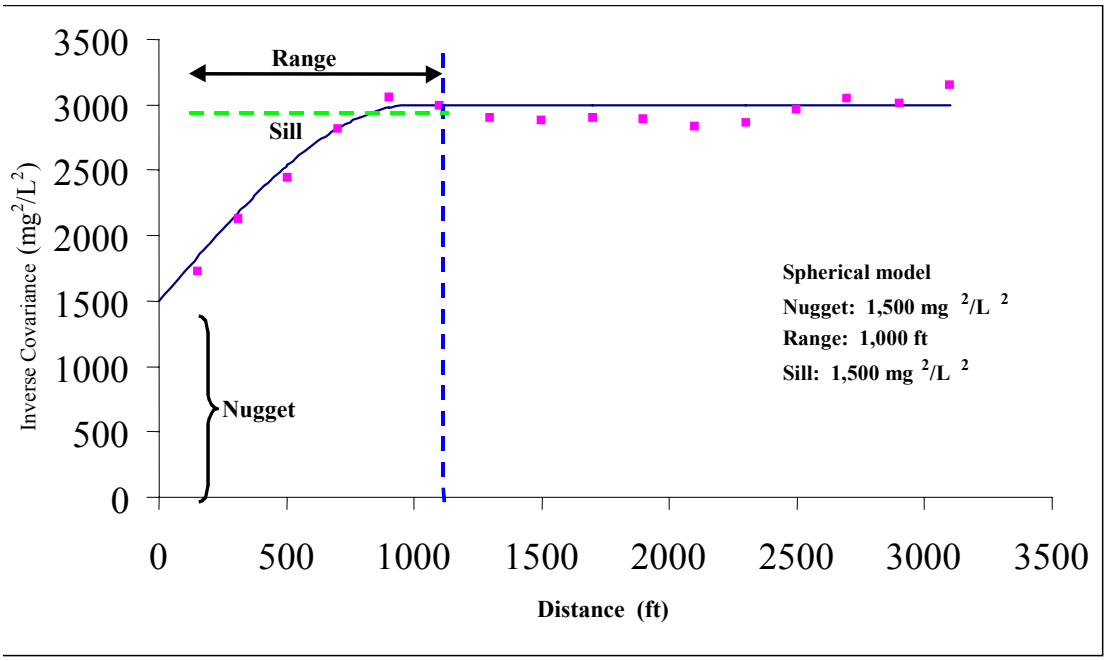
$g(x)$ = value of the variable in sample at location x;

$g(x + h)$ = value of the variable in sample at a distance h from sample at location x; and

n = number of samples in which the variable has been determined.

Semivariograms (plots of $\gamma(h)$ versus h) are a means of depicting graphically the range of distances over which, and the degree to which, sample values at a given point are related to sample values at adjacent, or nearby, points, and conversely, indicate how close together sample points must be for a value determined at one point to be useful in predicting unknown values at other points. For $h = 0$, for example, a sample is being

FIGURE 6.1
IDEALIZED SEMVARIOGRAM MODEL
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AFB, CALIFORNIA



compared with itself, so normally $\gamma(0) = 0$ (the semivariance at a spacing of zero, is zero), except where a so-called nugget effect is present (Figure 6.1), which implies that sample values are highly variable at distances less than the sampling interval. Analytical variability and sampling error can contribute to the nugget. As the distance between samples increases, sample values become less and less closely related, and the semivariance, therefore, increases, until a "sill" is eventually reached, where $\gamma(h)$ equals the overall variance (i.e., the variance around the average value). The sill is reached at a sample spacing called the "range of influence," beyond which sample values are not related. Only values between points at spacings less than the range of influence can be predicted; but within that distance, the semivariogram provides the proper weightings, which apply to sample values separated by different distances.

When a semivariogram is calculated for a variable over an area (e.g., concentrations of PCE in the Main Base/SAC Area groundwater plume), an irregular spread of points across the semivariogram plot is the usual result (Rock, 1988). One of the most subjective tasks of geostatistical analysis is to identify a continuous, theoretical semivariogram model that most closely follows the real data. Fitting a theoretical model to calculated semivariance points is accomplished by trial-and-error, rather than by a formal statistical procedure (Davis, 1986; Clark, 1987; Rock, 1988). If a "good" model fit results, then $\gamma(h)$ (the semivariance) can be confidently estimated for any value of h, and not only at the sampled points.

6.2 SPATIAL EVALUATION OF MONITORING NETWORK AT THE MAIN BASE/SAC AREA PLUME

The sum of PCE, TCE, and CCL_4 concentrations was used as the indicator chemical for the spatial evaluation of the groundwater monitoring network at the Main Base/SAC area because the sum of the COCs encompasses the largest spatial distribution of measurements that exceeded groundwater MCLs. The kriging evaluation examines a two-dimensional spatial “snapshot” of the data. Therefore, the most recent (2002) validated analytical data available at the start of this MNO evaluation were used in the kriging evaluation, and different kriging analyses were conducted for each of the three zones. Wells that were not sampled in 2002, or that are screened at a significantly different depth than the other wells in their Zone (e.g., wells in the LMT unit [see Table 3.1]) were not included in the geostatistical evaluation. Additionally, data from extraction wells are not appropriate for use in a kriging analysis because they represent COC concentrations averaged over the area within the well’s capture zone, and thus are not point-specific, nor temporally discrete; therefore, extraction wells were not included in the evaluation.

Fifty-five of the 72 monitoring wells and piezometers in the WT/A zone were included in the kriging evaluation. The 17 WT/A zone wells excluded from the spatial analysis were not sampled in 2002 and thus could not be included as part of the spatial snapshot. The 55 WT/A wells analyzed are shown on Figure 6.2 and listed in Table 6.1.

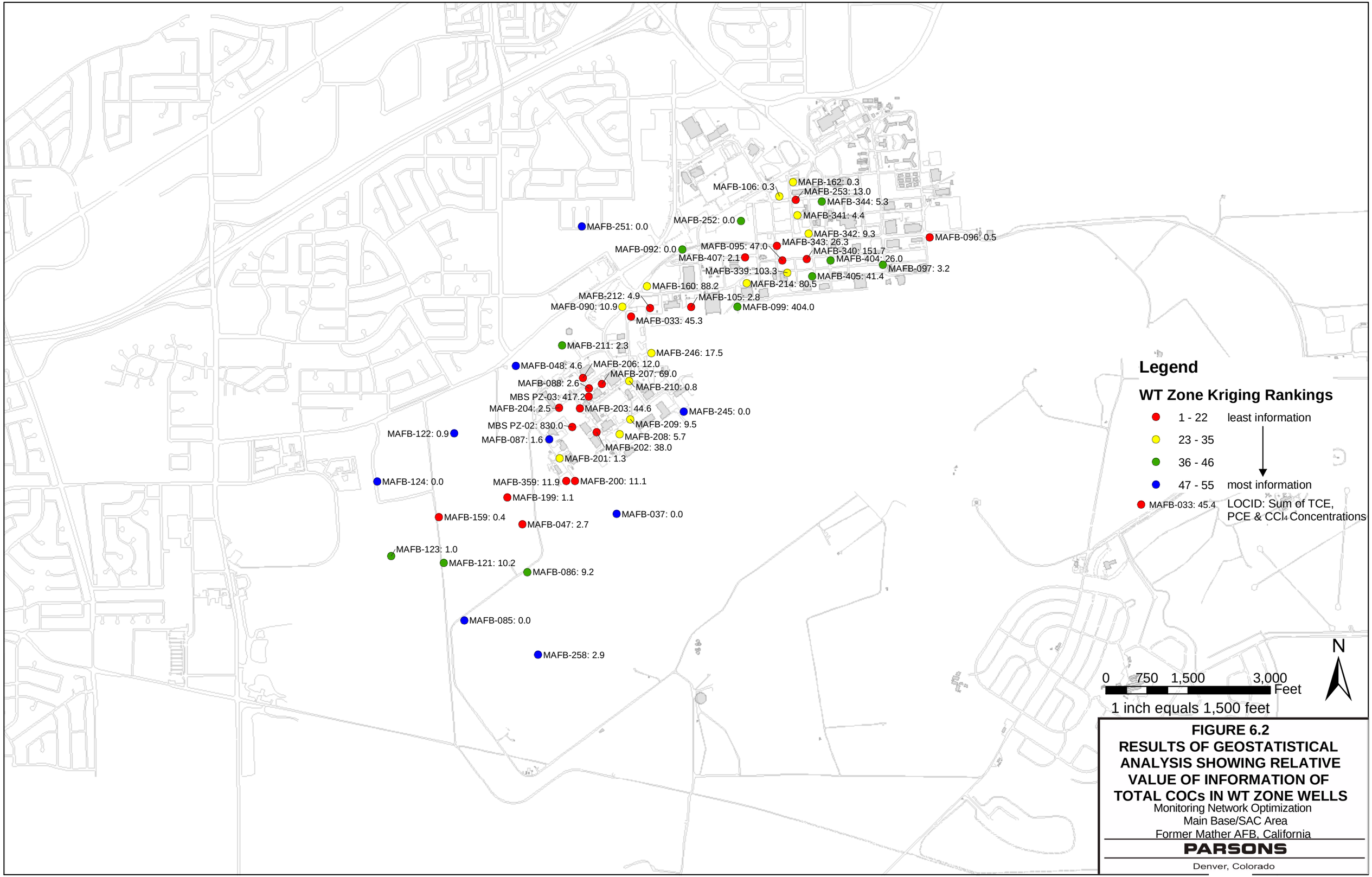


FIGURE 6.2
RESULTS OF GEOSTATISTICAL ANALYSIS SHOWING RELATIVE VALUE OF INFORMATION OF TOTAL COCs IN WT ZONE WELLS
Monitoring Network Optimization
Main Base/SAC Area
Former Mather AFB, California
PARSONS
Denver, Colorado

TABLE 6.1
RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF SELECT WT/A ZONE WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID [a/]	Kriging Test Statistic[b/]	Kriging Ranking [c/]	Exclude	Retain
MAFB-096	0.98347	1	√	
MAFB-159	0.99983	2	√	
MAFB-047	0.99985	3	√	
MAFB-199	0.99988	4	√	
MAFB-212	0.99996	5	√	
MAFB-033	0.99997	8[c/]	√	
MAFB-095	0.99997	8	√	
MAFB-204	0.99997	8	√	
MAFB-206	0.99997	8	√	
MAFB-359	0.99997	8	√	
MAFB-088	0.99999	12.5	√	
MAFB-200	0.99999	12.5	√	
MAFB-340	0.99999	12.5	√	
MAFB-407	0.99999	12.5	√	
MAFB-105	1.00000	18.5	√	
MAFB-202	1.00000	18.5	√	
MAFB-203	1.00000	18.5	√	
MAFB-207	1.00000	18.5	√	
MAFB-253	1.00000	18.5	√	
MAFB-343	1.00000	18.5	√	
MBS PZ-02	1.00000	18.5	√	
MBS PZ-03	1.00000	18.5	√	
MAFB-210	1.00001	23	--[d/]	--
MAFB-201	1.00002	24	--	--
MAFB-214	1.00002	25	--	--
MAFB-246	1.00002	26	--	--
MAFB-341	1.00002	27	--	--
MAFB-339	1.00010	28	--	--
MAFB-208	1.00011	29.5	--	--
MAFB-209	1.00011	29.5	--	--
MAFB-342	1.00019	31	--	--
MAFB-106	1.00020	32	--	--
MAFB-090	1.00034	33	--	--
MAFB-162	1.00038	34	--	--
MAFB-160	1.00043	35	--	--
MAFB-404	1.00056	36	--	--
MAFB-344	1.00072	37	--	--
MAFB-252	1.00085	38	--	--
MAFB-099	1.00100	39	--	--
MAFB-405	1.00124	40	--	--
MAFB-211	1.00170	41	--	--
MAFB-121	1.00242	42	--	--
MAFB-086	1.00301	43	--	--
MAFB-092	1.00304	44	--	--
MAFB-123	1.00336	45	--	--
MAFB-097	1.00481	46	--	--
MAFB-122	1.00554	47		√
MAFB-124	1.00670	48		√
MAFB-048	1.00687	49		√
MAFB-245	1.01012	50		√
MAFB-085	1.01038	51		√
MAFB-087	1.01130	52		√
MAFB-037	1.01295	53		√
MAFB-258	1.01463	54		√
MAFB-251	1.02460	55		√

[a/] WT zone wells not sampled in 2002 were excluded from the analysis.
[b/] ratio of the median "missing well" predicted standard error to median "base case" error
[c/] 1= least relative amount of information; 55= most relative amount of information.
[d/] Tie values receive the median ranking of the set.
[e/] Well in the "intermediate" range and received no recommendation exclusion or retention (see Section 6.3).

Of the 108 monitoring wells and piezometers in the B zone, 89 were included in the kriging evaluation. Twelve of the B zone wells not included in the spatial analysis because they were not sampled in 2002. The other seven B zone wells excluded from the analysis were co-located with other wells in the same zone; because Kriging predicts concentrations over a two-dimensional surface, including data from multiple co-located wells screened at different depths is not appropriate. The co-located wells excluded from analysis either have lower COC concentrations, or, in the case where both wells have no detected COC concentrations, are screened deeper than their counterparts. The wells included in the B zone kriging analysis are shown on Figure 6.3 and listed in Table 6.2.

Sixty-one of the 94 wells and piezometers in the D zone were included in the kriging evaluation. Seven wells were excluded because they were not sampled in 2002. Well MAFB-290 was excluded because it is co-located and redundant with well MAFB-296. The remaining 21 wells were not included because they are in the "Dd", "D2", or "LMT hydrostratigraphic unit (Table 3.1) and/or screened at a depth greater than 300 feet bgs, so were not considered to be part of the same two-dimensional surface as the D zone wells included in the analysis. The wells included in the D zone kriging analysis are shown on Figure 6.4 and listed in Table 6.3.

The commercially available geostatistical software package Geostatistical Analyst™ (an extension to the ArcView® geographic information system [GIS] software package) (Environmental Systems Research Institute, Inc. [ESRI], 2001) was used to develop a semivariogram model depicting the spatial variation in the sum of PCE, TCE and CCl_4 (Total COC) concentrations in groundwater for the selected wells in the WT/A, B and D zones.

As semivariogram models were calculated for Total COCs (Equation 6-1), considerable scatter of the data was apparent during fitting of the models. Several data transformations (including a log transformation) were attempted to obtain a representative semivariogram model. Ultimately, the concentration data were transformed to "rank statistics," in which, for example, the 55 wells in the WT/A zone

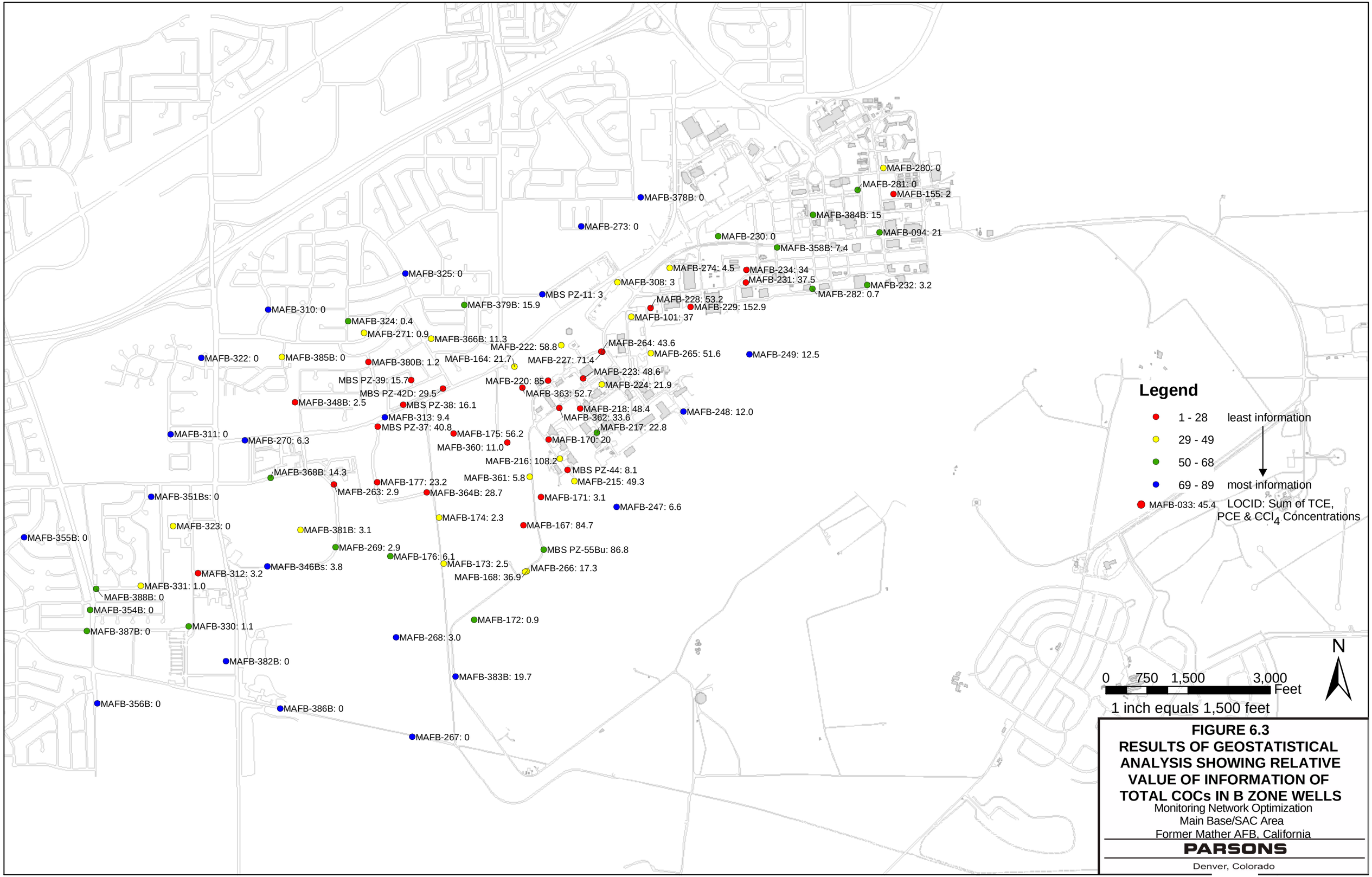


FIGURE 6.3
RESULTS OF GEOSTATISTICAL ANALYSIS SHOWING RELATIVE VALUE OF INFORMATION OF TOTAL COCs IN B ZONE WELLS
Monitoring Network Optimization
Main Base/SAC Area
Former Mather AFB, California
PARSONS
Denver, Colorado

TABLE 6.2

RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF SELECT B ZONE WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION

MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID [a/]	Kriging Test Statistic[b/]	Kriging Ranking [c/]	Exclude	Retain
MAFB-155	0.99729	1	√	
MAFB-167	0.99995	2.5[c/]	√	
MAFB-171	0.99995	2.5	√	
MAFB-234	0.99996	4	√	
MAFB-380B	0.99997	5	√	
MAFB-227	0.99998	6.5	√	
MAFB-264	0.99998	6.5	√	
MAFB-229	0.99999	9.5	√	
MAFB-231	0.99999	9.5	√	
MBS PZ-39	0.99999	9.5	√	
MBS PZ-44	0.99999	9.5	√	
MAFB-170	1.00000	19.5	√	
MAFB-175	1.00000	19.5	√	
MAFB-177	1.00000	19.5	√	
MAFB-218	1.00000	19.5	√	
MAFB-220	1.00000	19.5	√	
MAFB-223	1.00000	19.5	√	
MAFB-228	1.00000	19.5	√	
MAFB-263	1.00000	19.5	√	
MAFB-312	1.00000	19.5	√	
MAFB-348B	1.00000	19.5	√	
MAFB-360	1.00000	19.5	√	
MAFB-362	1.00000	19.5	√	
MAFB-363	1.00000	19.5	√	
MAFB-364B	1.00000	19.5	√	
MBS PZ-37	1.00000	19.5	√	
MBS PZ-38	1.00000	19.5	√	
MBS PZ-42D	1.00000	19.5	√	
MAFB-101	1.00001	29.5	--[d/]	--
MAFB-173	1.00001	29.5	--	--
MAFB-164	1.00002	31.5	--	--
MAFB-224	1.00002	31.5	--	--
MAFB-222	1.00003	33.5	--	--
MAFB-361	1.00003	33.5	--	--
MAFB-174	1.00004	35.5	--	--
MAFB-308	1.00004	35.5	--	--

TABLE 6.2 (Continued)

RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF SELECT B ZONE WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION

MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID [a/]	Kriging Test Statistic[b/]	Kriging Ranking [c/]	Exclude	Retain
MAFB-265	1.00005	37	--	--
MAFB-366B	1.00007	38	--	--
MAFB-216	1.00010	39	--	--
MAFB-215	1.00010	40	--	--
MAFB-271	1.00012	41	--	--
MAFB-385B	1.00015	42	--	--
MAFB-381B	1.00018	43	--	--
MAFB-331	1.00020	44	--	--
MAFB-274	1.00021	45	--	--
MAFB-280	1.00025	46	--	--
MAFB-266	1.00028	47	--	--
MAFB-168	1.00033	48	--	--
MAFB-323	1.00036	49	--	--
MAFB-358B	1.00043	50	--	--
MAFB-217	1.00049	51	--	--
MAFB-094	1.00055	52	--	--
MAFB-368B	1.00064	53	--	--
MAFB-281	1.00069	54	--	--
MAFB-354B	1.00097	55	--	--
MBS PZ-55Bu	1.00097	56	--	--
MAFB-324	1.00171	57	--	--
MAFB-384B	1.00226	58	--	--
MAFB-176	1.00247	59	--	--
MAFB-269	1.00274	60	--	--
MAFB-387B	1.00293	61	--	--
MAFB-282	1.00327	62	--	--
MAFB-172	1.00345	63	--	--
MAFB-388B	1.00350	64	--	--
MAFB-230	1.00388	65	--	--
MAFB-330	1.00442	66	--	--
MAFB-232	1.00452	67	--	--
MAFB-379B	1.00468	68	--	--
MAFB-351Bs	1.00519	69		√
MAFB-346Bs	1.00522	70		√
MBS PZ-11	1.00523	71		√
MAFB-310	1.00689	72		√
MAFB-247	1.00743	73		√

TABLE 6.2 (Continued)

RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF SELECT B ZONE WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION

MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID [a/]	Kriging Test Statistic[b/]	Kriging Ranking [c/]	Exclude	Retain
MAFB-267	1.00757	74		√
MAFB-325	1.00759	75		√
MAFB-273	1.00771	76		√
MAFB-378B	1.00814	77		√
MAFB-355B	1.00848	78		√
MAFB-311	1.00869	79		√
MAFB-383B	1.00875	80		√
MAFB-249	1.00930	81		√
MAFB-322	1.00939	82		√
MAFB-356B	1.01012	83		√
MAFB-248	1.01017	84		√
MAFB-386B	1.01119	85		√
MAFB-268	1.01172	86		√
MAFB-382B	1.01264	87		√
MAFB-313	1.03597	88		√
MAFB-270	1.03710	89		√

[a/] B zone wells not sampled in 2002, or the deeper screened of co-located pair wells were excluded from the analysis.

[b/] ratio of the median "missing well" predicted standard error to median "base case" error

[c/] 1= least relative amount of information; 89= most relative amount of information.

[d/] Tie values receive the median ranking of the set.

[e/] Well in the "intermediate" range and received no recommendation exclusion or retention (see Section 6.3).

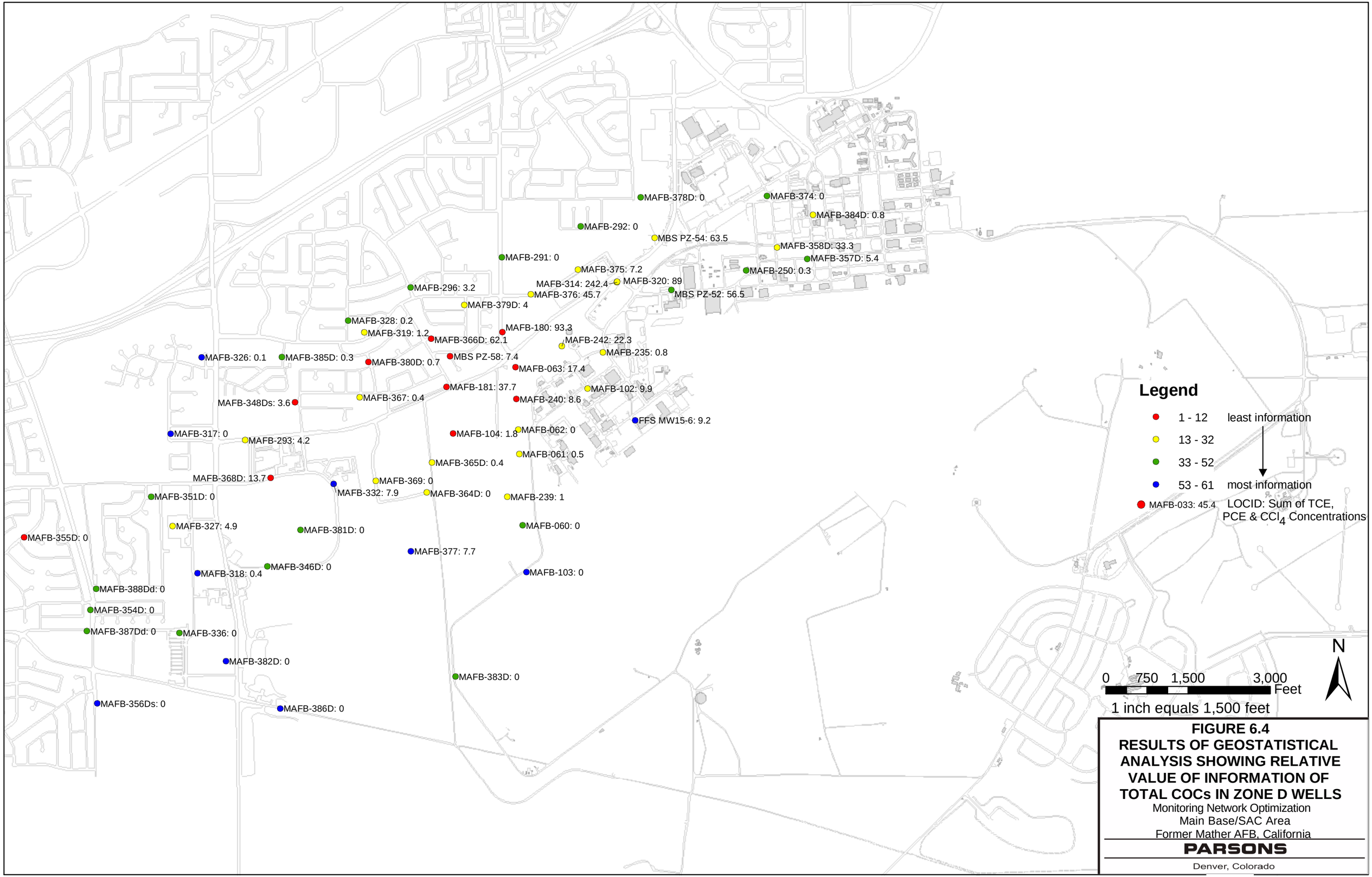


FIGURE 6.4
RESULTS OF GEOSTATISTICAL ANALYSIS SHOWING RELATIVE VALUE OF INFORMATION OF TOTAL COCs IN ZONE D WELLS
Monitoring Network Optimization
Main Base/SAC Area
Former Mather AFB, California
PARSONS
Denver, Colorado

TABLE 6.3

RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF SELECT ZONE D WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION

MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID [a/]	Kriging Test Statistic[b/]	Kriging Ranking [c/]	Exclude	Retain
MAFB-355d	0.98985	1.0	√	
MAFB-368d	0.99997	2.5[c/]	√	
MAFB-380d	0.99997	2.5	√	
MAFB-063	0.99999	5.5	√	
MAFB-104	0.99999	5.5	√	
MAFB-181	0.99999	5.5	√	
MBS PZ-58	0.99999	5.5	√	
MAFB-180	1.00000	9.5	√	--
MAFB-240	1.00000	9.5	√	--
MAFB-348ds	1.00000	9.5	√	--
MAFB-366d	1.00000	9.5	√	--
MAFB-242	1.00001	14.5	--[d/]	--
MAFB-293	1.00001	14.5	--	--
MAFB-314	1.00001	14.5	--	--
MAFB-320	1.00001	14.5	--	--
MAFB-365d	1.00001	14.5	--	--
MAFB-367	1.00001	14.5	--	--
MAFB-376	1.00002	18	--	--
MAFB-375	1.00003	19	--	--
MAFB-062	1.00007	20	--	--
MAFB-319	1.00021	22	--	--
MAFB-379d	1.00021	22	--	--
MAFB-384d	1.00021	22	--	--
MAFB-369	1.00026	24	--	--
MAFB-327	1.00027	25	--	--
MAFB-061	1.00030	26	--	--
MAFB-358d	1.00035	27	--	--
MAFB-364d	1.00048	28	--	--
MBS PZ-54	1.00063	29	--	--
MAFB-239	1.00082	30	--	--
MAFB-102	1.00084	31	--	--
MAFB-235	1.00086	32	--	--

TABLE 6.3 (Continued)

RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF SELECT ZONE D WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION

MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID [a/]	Kriging Test Statistic[b/]	Kriging Ranking [c/]	Exclude	Retain
MAFB-354d	1.00123	33	--	--
MAFB-381d	1.00126	34	--	--
MAFB-328	1.00170	35	--	--
MAFB-357d	1.00171	36	--	--
MAFB-292	1.00183	37	--	--
MAFB-378d	1.00190	38	--	--
MBS PZ-52	1.00207	39	--	--
MAFB-250	1.00213	40	--	--
MAFB-387dd	1.00239	41	--	--
MAFB-374	1.00250	42	--	--
MAFB-336	1.00256	43	--	--
MAFB-388dd	1.00273	44	--	--
MAFB-385d	1.00288	45	--	--
MAFB-296	1.00310	46	--	--
MAFB-291	1.00314	47	--	--
MAFB-346d	1.00346	48	--	--
MAFB-060	1.00378	49	--	--
MAFB-351d	1.00455	50	--	--
MAFB-383d	1.00487	51	--	--
MAFB-317	1.00633	52.5		√
MAFB-318	1.00633	52.5		√
MAFB-386d	1.00701	54		√
MAFB-356ds	1.00743	55		√
MAFB-326	1.00756	56		√
MAFB-103	1.00840	57		√
Ffsmw15-6	1.00874	58		√
MAFB-377	1.00940	59		√
MAFB-382d	1.01153	60		√
MAFB-332	1.03081	61		√

[a/] D zone wells not sampled in 2002, or those in deeper hydogeostraphic zones (e.g., LMT) were excluded from the analysis.

[b/] ratio of the median "missing well" predicted standard error to median "base case" error

[c/] 1= least relative amount of information; 61= most relative amount of information.

[d/] Tie values receive the median ranking of the set.

[e/] Well in the "intermediate" range and received no recommendation exclusion or retention (see Section 6.3).

were ranked from 1 to 55 according to their most recent Total COC concentration. Tie values were assigned the median rank of the set of ranked values, for example, if 5 wells had non-detected concentrations, they would each be ranked "3", the median of the set of ranks: [1,2,3,4,5]. Transformations of this type can be less sensitive to outliers, skewed distributions, or clustered data than semivariograms based on raw concentration values, and thus may enable recognition and description of the underlying spatial structure of the data in cases where ordinary data are too "noisy".

The Total COC rank statistics were used to develop semivariograms that most accurately modeled the spatial distribution of the data in the WT/A, B, and D zones. Anisotropy was incorporated into the model to adjust for the directional influence of groundwater flow to the southwest. The parameters for best-fit semivariograms for the three zones are listed in Table 6.4

TABLE 6.4
BEST-FIT SEMVARIOGRAM MODEL PARAMETERS
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA PLUME
FORMER MATHER AIR FORCE BASE, CALIFORNIA

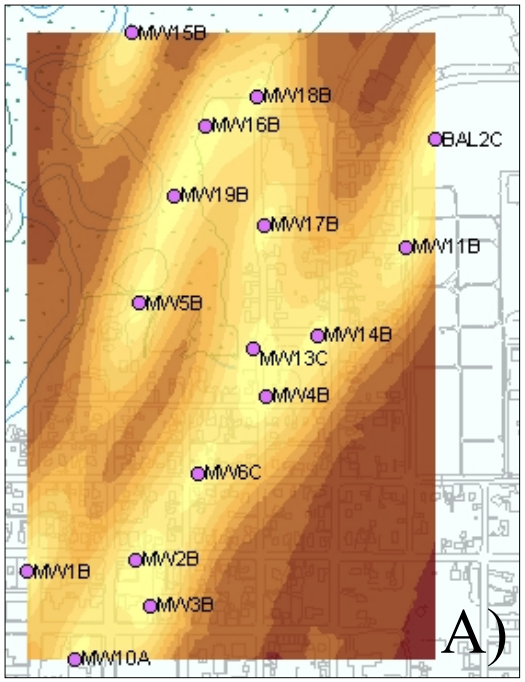
Parameter	Zone WT/A	Zone B	Zone D
Model	Spherical	Spherical	Spherical
Range (ft)	4500	7000	5500
Sill	170	700	200
Nugget	110	100	95
Minor Range (ft)	2500	6000	3500
Direction (°)	232	235	235

After the semivariogram models were developed, they were used in the kriging system implemented by the Geostatistical Analyst™ software package (ESRI, 2001) to develop 2-dimensional kriging realizations (estimates of the spatial distribution of Total COCs in groundwater in the Main Base/SAC Area Plume), and to calculate the associated kriging prediction standard errors. The median kriging standard deviation was obtained from the standard errors calculated using the entire monitoring network for each zone (e.g., the 55 wells screened in Zone WT/A). Next, each of the wells was sequentially removed from

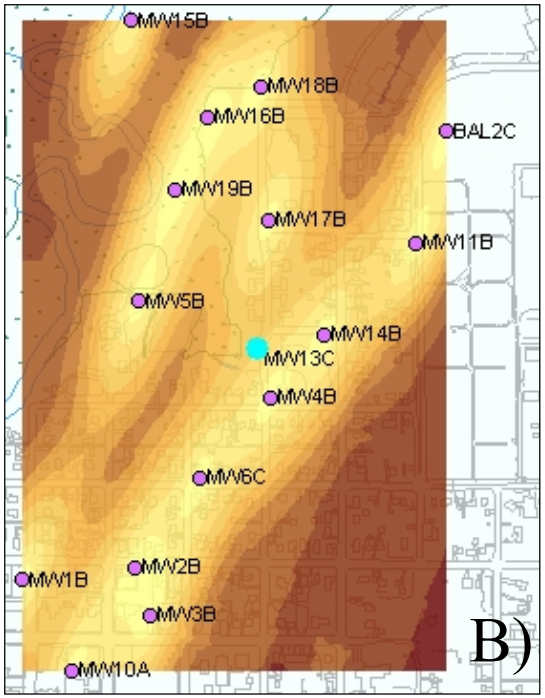
the network, and for each resulting well network configuration, a kriging realization was completed using the Total COC concentration rankings from the remaining wells. The "missing-well" monitoring network realizations were used to calculate prediction standard errors, and the median kriging standard deviations were obtained for each "missing-well" realization and compared with the median kriging standard deviation for the "base-case" realization (obtained using the complete monitoring network), as a means of evaluating the amount of information loss (as indicated by increases in kriging error) resulting from the use of fewer monitoring points.

Figure 6.5 illustrates and example of the spatial-evaluation procedure by showing kriging prediction standard-error maps for three kriging realizations at a site with fewer wells. Each map shows the predicted standard error associated with a given group of wells based on the semivariogram parameters discussed above. Lighter colors represent areas with lower spatial uncertainty, and darker colors represent areas with higher uncertainty; regions in the vicinity of wells (i.e., data points) have the lowest associated uncertainty. Map A on Figure 6.5 shows the predicted standard error map for the "base-case" realization in which all 16 wells are included. Map B shows the realization in which well MW13C was removed from the monitoring network, and Map C shows the realization in which well MW17B was removed. Figure 6.5 shows that when a well is removed from the network, the predicted standard error in the vicinity of the missing well increases (as indicated by a darkening of the shading in the vicinity of that well). If a "removed" (missing) well is in an area with several other wells (e.g., well MW13C; Map B on Figure 6.5), the predicted standard error may not increase as much as if a well (e.g., MW17B; Map C) is removed from an area with fewer surrounding wells.

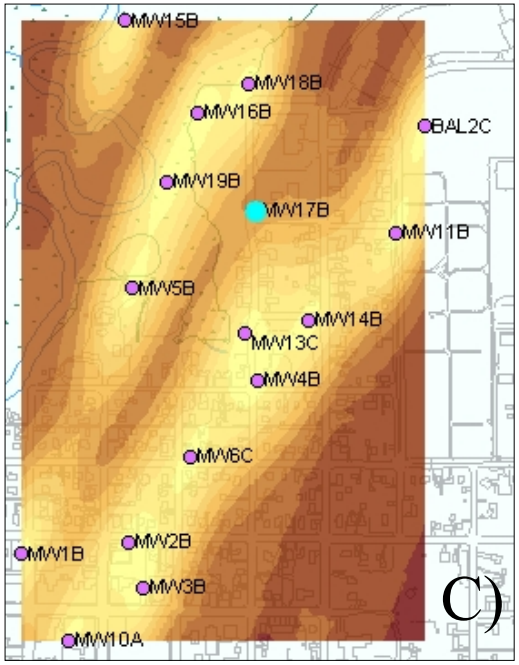
Based on the Kriging evaluation, each well received a relative value of spatial information "test statistic" calculated from the ratio of the median "missing well" error to median "base case" error. If removal of a particular well from the monitoring network caused very little change in the resulting median kriging standard deviation, the test statistic equals one, and that well was regarded as contributing only a limited amount of information to the LTM program. Likewise, if removal of a well from the monitoring



A) Base-case
(All wells)



B) "Missing"
Well MW13C

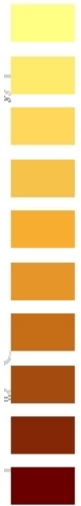


C) "Missing" Well MW17B

Legend

Well missing from kriging realization

Prediction Standard Error Map



Less spatial uncertainty

Greater spatial uncertainty

FIGURE 6.5
IMPACT OF MISSING WELLS ON PREDICTED STANDARD ERROR
Monitoring Network Optimization
Former Mather AFB, California

PARSONS
Denver, Colorado

network produced larger increases in the kriging standard deviation (more than 1 percent), this was regarded as an indication that the well contributes a relatively greater amount of information, and is relatively more important to the monitoring network. At the conclusion of the kriging realizations, each well was ranked from 1 (providing the least information) to the number of wells included in the zone analysis (providing the most information), based on the amount of information (as measured by changes in median kriging standard deviation) the well contributed toward describing the spatial distribution of Total COCs, as shown in Tables 6.1 to 6.3. Wells providing the least amount of information represent possible candidates for removal from the monitoring network in the Main Base/SAC Area Plume.

6.3 SPATIAL STATISTICAL EVALUATION RESULTS

6.3.1 Kriging Ranking Results

Figures 6.2 through 6.4 and Tables 6.1 to 6.3 present the test statistics and associated rankings of the evaluated subset of monitoring locations in zones WT/A, B, and D, respectively, based on the relative value of recent Total COCs information provided by each well, as calculated based on the kriging realizations. Examination of these results indicate that monitoring wells in close proximity to several other monitoring wells (e.g., red color coding on Figures 6.2 to 6.4) generally provide relatively lesser amounts of information than do wells at greater distances from other wells, or wells located in areas having limited numbers of monitoring points (e.g., blue color coding on Figures 6.2 to 6.4). This is intuitively obvious, but the analysis allows the most valuable and least valuable wells to be identified quantitatively. For example, Table 6.1 identifies the 22 wells ranked at or below 18.5 that provide the relative least amount of information, and the nine wells ranked at or above 47 that provide the greatest amount of relative information regarding the occurrence and distribution of Total COCs in groundwater among those wells included in the kriging analysis. The 22 lowest-ranked wells are potential candidates for exclusion from the Main Base/SAC Area Plume groundwater monitoring program, and the nine highest-ranked wells are candidates for retention in the

monitoring program, intermediate-ranked wells receive no recommendation for removal or retention in the monitoring program based on the spatial analysis.

SECTION 7

SUMMARY OF THREE-TIERED MONITORING NETWORK EVALUATION

The 306 wells sampled at the Main Base/SAC Area Plume and screened in zones WT/A, B and D at Mather were evaluated using qualitative hydrogeologic and extraction-system information, temporal statistical techniques, and spatial statistics. As each tier of the evaluation was performed, monitoring points that provide relatively greater amounts of information regarding the occurrence and distribution of COCs in groundwater were identified, and were distinguished from those monitoring points that provide relatively lesser amounts of information. In this section, the results of the evaluations are combined to generate a refined monitoring program that potentially could provide information sufficient to address the primary objectives of monitoring, at reduced cost. Monitoring wells not retained in the refined monitoring network could be removed from the monitoring program with relatively little loss of information. The results of the evaluations were combined and summarized in accordance with the following decision logic:

1. Each well retained in the monitoring network on the basis of the qualitative hydrogeologic evaluation is recommended to be retained in the refined monitoring program.

2. Those wells recommended for removal from the monitoring program on the basis of all three evaluations, or on the basis of the qualitative and temporal evaluations (with no recommendation resulting from the spatial evaluation) should be removed from the monitoring program.

3. If a well is recommended for removal based on the qualitative evaluation and recommended for retention based on the temporal or spatial evaluation, the final recommendation is based on a case-by-case review of well information.

4. If a well is recommended for retention based on the qualitative evaluation and recommended for removal based on the temporal and spatial evaluation, the recommended sampling frequency is based on a case-by-case review of well information.

It should be noted, as stated in number four above, the final recommended monitoring frequencies shown in Table 7.1 are not, in all cases, the same as those recommended as a result of the qualitative evaluation (Table 4.3). The results of the temporal and spatial statistical evaluations were used in some cases to alter the frequencies listed in Table 4.3. For example, continued annual sampling of cross-gradient, WT/A-zone monitoring well MAFB-037 (Figure 5.4) was recommended as a result of the qualitative evaluation. However, the temporal evaluation indicated no temporal trend in the trace-level TCE concentrations detected in this well after several years of monitoring, and no historical detections of either PCE or CCl_4. The recommended monitoring frequency for this well was therefore reduced from annual to biennial based on all of the available information, which indicates that the results of continued monitoring of this well through time are likely to fall within the historic range of concentrations that have already been detected. Therefore, the utility of obtaining more-frequent data from this well is relatively low.

The results of the qualitative, temporal, and spatial evaluations are summarized in Table 7.1. A breakdown of the final well and frequency recommendations is shown in Table 7.2, along with the original 2003 sampling breakdown (shown in parentheses).

TABLE 7.1
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
WT/A Zone Wells											
MAFB-006	14.3 - -3.7	Not Sampled	√		√		Not included		√		--
MAFB-033	6.88 - -13.12	Semi-Annual		√	√		√			√	Annual
MAFB-037	12.24 - -7.76	Annual		√	√			√		√	Biennial
MAFB-047	0.93 - -19.07	Annual		√	√		√			√	Biennial
MAFB-048	4.26 - -15.74	Annual		√		√		√		√	Annual
MAFB-085	2.78 - -12.22	Semi-Annual		√		√		√		√	Semi-Annual
MAFB-086	8.28 - 4.78	Quarterly		√	√		--[c/]	--		√	Semi-Annual
MAFB-087	4.67 - -10.33	Quarterly		√	√			√		√	Semi-Annual
MAFB-088	5.45 - -9.55	Semi-Annual		√	√		√		√		--
MAFB-089	9.88 - -5.12	Annual		√	√		Not included			√	Annual
MAFB-090	3.39 - -11.61	Semi-Annual		√	√		--	--		√	Annual
MAFB-091	7.09 - -7.91	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-092	5.51 - -9.49	Annual		√	√		--	--		√	Biennial
MAFB-093	6.38 - -8.62	Not Sampled	√		√		Not included		√		--
MAFB-095	10.04 - -4.96	Quarterly		√		√	√			√	Quarterly
MAFB-096	5.93 - -9.07	Annual		√	√		√			√	Annual
MAFB-097	1.03 - -13.97	Annual		√		√	--	--		√	Annual
MAFB-099	7.71 - -7.29	Annual		√		√	--	--		√	Quarterly
MAFB-105	7.47 - -7.53	Annual		√	√		√	--		√	Annual
MAFB-106	11.94 - -3.06	Semi-Annual		√	√		--	--		√	Annual
MAFB-121	0.17 - -14.83	Annual		√		√	--	--		√	Semi-Annual
MAFB-122	2.42 - -12.58	Semi-Annual		√		√		√		√	Annual
MAFB-123	-0.53 - -15.53	Annual		√		√	--	--		√	Annual
MAFB-124	-0.34 - -15.34	Annual	√		√			√		√	Biennial
MAFB-150	8.5 - -6.5	Not Sampled	√		√		Not included		√		--
MAFB-156	-2.05 - -17.05	Not Sampled	√		√		Not included		√		--
MAFB-157	-5.56 - -20.56	Not Sampled	√		√		Not included		√		--
MAFB-158	0.06 - -14.94	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-159	0.73 - -14.27	Semi-Annual		√	√		√			√	Biennial
MAFB-160	7.35 - -7.65	Annual		√		√	--	--		√	Annual
MAFB-161	6.4 - -8.6	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-162	12.52 - -2.48	Annual		√	√		--	--		√	Biennial
MAFB-163	11.89 - -3.11	Not Sampled	√		Not Analyzed		Not included		√		--

TABLE 7.1 (Continued)
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
MAFB-186	9.14 - -5.86	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-187	8.14 - -6.86	Not Sampled	√		√		Not included		√		--
MAFB-188	6.64 - -8.36	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-199	-3.9 - -18.9	Annual		√	√		√			√	Biennial
MAFB-200	-2.8 - -17.8	Annual	√		√		√		√		--
MAFB-201	-1.0 - -16.0	Quarterly		√		√	--	--		√	Semi-Annual
MAFB-202	-0.5 - -15.5	Semi-Annual		√	√		√			√	Semi-Annual
MAFB-203	-1.0 - -16.0	Quarterly		√		√	√			√	Quarterly
MAFB-204	0.3 - -14.7	Semi-Annual		√		√	√			√	Annual
MAFB-205	-2.6 - -17.6	Annual	√		Not Analyzed		Not included		√		--
MAFB-206	1.6 - -13.4	Semi-Annual		√		√	√			√	Semi-Annual
MAFB-207	-0.4 - -15.4	Semi-Annual		√		√	√			√	Semi-Annual
MAFB-208	0.4 - -14.6	Quarterly	√		√		--	--	√		--
MAFB-209	1.7 - -13.3	Annual		√		√	--	--		√	Annual
MAFB-210	0.2 - -14.8	Not Sampled		√	√		--	--		√	Biennial
MAFB-211	-1.3 - -16.3	Semi-Annual		√	√		--	--		√	Annual
MAFB-212	3.4 - -11.6	Annual		√		√	√			√	Annual
MAFB-213	5.5 - -4.5	Quarterly		√		√	Not included			√	Semi-Annual
MAFB-214	5.1 - -9.9	Semi-Annual		√	√		--	--		√	Annual
MAFB-244	4.0 - -11.0	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-245	1.7 - -8.3	Not Sampled		√	√			√		√	Biennial
MAFB-246	-5.5 - -15.5	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-251	1.8 - -13.2	Not Sampled	√		Not Analyzed			√	√		--
MAFB-252	9.7 - -5.3	Annual		√	√		--	--		√	Biennial
MAFB-253	13.6 - -1.4	Annual		√		√	√			√	Annual
MAFB-258	-18.5 - -33.5	Annual		√		√		√		√	Annual
MAFB-275	8.4 - -6.6	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MAFB-339	11.15 - -8.85	Quarterly		√		√	--	--		√	Quarterly
MAFB-340	11.16 - -8.84	Semi-Annual		√		√	√			√	Semi-Annual
MAFB-341	8.74 - -11.26	Quarterly		√		√	--	--		√	Quarterly
MAFB-342	9.7 - -10.3	Quarterly		√		√	--	--		√	Quarterly
MAFB-343	12.32 - -7.68	Semi-Annual		√	√		√			√	Annual
MAFB-344	11.65 - -8.35	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-359	2.93 - -37.07	Annual		√	√		√			√	Annual

TABLE 7.1 (Continued)
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
MAFB-404	-2.3 - 17.7	Quarterly		√	Not Analyzed		--	--		√	Quarterly
MAFB-405	0 - -20	Quarterly		√	Not Analyzed		--	--		√	Quarterly
MAFB-407	-5.0 - -15.0	Quarterly		√	Not Analyzed		√			√	Quarterly
MBS 39ABuB	11.58 - -38.42	Quarterly		√		√	Not included			√	Quarterly
MBS EW-12AB	-1.43 - -41.43	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS EW-1A	14.73 - -5.27	Quarterly		√		√	Not included			√	Quarterly
MBS EW1ABu	4.37 - -30.63	Quarterly		√		√	Not included			√	Quarterly
MBS EW-1Bu	-9.56 - -29.56	Quarterly		√		√	Not included			√	Quarterly
MBS EW-2A	2.63 - -17.37	Quarterly		√		√	Not included			√	Quarterly
MBS EW2ABu	5.04 - -34.96	Quarterly		√		√	Not included			√	Quarterly
MBS EW-3A	3.73 - -16.27	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS EW-4A	10.11 - -29.89	Quarterly		√		√	Not included			√	Quarterly
MBS EW4ABu	4.28 - -35.72	Quarterly		√		√	Not included			√	Quarterly
MBS EW-4Bu	-10.94 - -50.94	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS EW-5A	9.59 - -30.41	Quarterly		√		√	Not included			√	Semi-Annual
MBS EW5ABu	3.04 - -36.96	Quarterly		√		√	Not included			√	Quarterly
MBS EW6ABu	-2.219 - -42.219	Quarterly		√		√	Not included			√	Quarterly
MBS PZ-02	-4.4 - -14.4	Quarterly		√		√	√			√	Quarterly
MBS PZ-03	-3.4 - -13.4	Quarterly		√		√	√			√	Semi-Annual
B Zone Wells											
MAFB-073	-20.38 - -40.38	Not Sampled	√		√		Not included		√		--
MAFB-094	-1.1 - -16.1	Annual		√		√	--	--		√	Annual
MAFB-101	-35.32 - -50.32	Quarterly		√		√	--	--		√	Quarterly
MAFB-154	0.53 - -14.47	Not Sampled	√		√		Not included		√		--
MAFB-155	-0.8 - -15.8	Annual		√		√	√			√	Annual
MAFB-164	-56.87 - -71.87	Quarterly		√		√	--	--		√	Quarterly
MAFB-165	-50.16 - -65.16	Not Sampled	√			√	Not included		√		--
MAFB-166	-41.82 - -56.82	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-167	-41.01 - -56.01	Annual		√		√	√			√	Annual
MAFB-168	-27.22 - -42.22	Quarterly		√		√	--	--		√	Quarterly
MAFB-169	-46.68 - -61.68	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-170	-46.29 - -61.29	Quarterly		√		√	√			√	Quarterly
MAFB-171	-40.15 - -55.15	Annual		√	√		√			√	Biennial
MAFB-172	-19.89 - -34.89	Semi-Annual		√	√		--	--		√	Annual

TABLE 7.1 (Continued)
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
MAFB-173	-51.26 - -66.26	Annual		√		√	--	--		√	Annual
MAFB-174	-24.07 - -39.07	Annual		√	√		--	--		√	Biennial
MAFB-175	-63.46 - -78.46	Annual		√		√	√			√	Semi-Annual
MAFB-176	-28.7 - -43.7	Annual		√		√	--	--		√	Annual
MAFB-177	-67.29 - -82.29	Quarterly		√		√	√			√	Semi-Annual
MAFB-215	-57.8 - -72.8	Annual		√		√	--	--		√	Annual
MAFB-216	-35.9 - -50.9	Quarterly		√		√	--	--		√	Quarterly
MAFB-217	-40.8 - -55.8	Annual		√	√		--	--		√	Biennial
MAFB-218	-47.9 - -62.9	Semi-Annual		√		√	√			√	Semi-Annual
MAFB-219	-44.8 - -59.8	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-220	-47.6 - -62.6	Annual		√	Not Analyzed		√			√	Semi-Annual
MAFB-221	-23.9 - -33.9	Semi-Annual		√	√		Not included			√	Annual
MAFB-222	-42.1 - -57.1	Quarterly		√		√	--	--		√	Quarterly
MAFB-223	-42.4 - -57.4	Semi-Annual		√		√	√			√	Semi-Annual
MAFB-224	-47.3 - -62.3	Semi-Annual		√		√	--	--		√	Annual
MAFB-225	-36.4 - -51.4	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-226	-41.2 - -56.2	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-227	-41.2 - -56.2	Annual		√		√	√			√	Annual
MAFB-228	-36.7 - -51.7	Quarterly		√		√	√			√	Quarterly
MAFB-229	-30.5 - -45.5	Quarterly		√		√	√			√	Quarterly
MAFB-230	-25.9 - -40.9	Annual		√	√		--	--		√	Biennial
MAFB-231	-24.7 - -39.7	Semi-Annual		√		√	√			√	Semi-Annual
MAFB-232	-4.6 - -19.6	Annual		√		√	--	--		√	Annual
MAFB-233	-3.5 - -18.5	Not Sampled	√		√		Not included		√		--
MAFB-234	-19.6 - -34.6	Quarterly		√		√	√			√	Quarterly
MAFB-247	-37.8 - -52.8	Annual		√		√		√		√	Annual
MAFB-248	-29.4 - -44.4	Annual		√		√		√		√	Annual
MAFB-249	-23.8 - -38.8	Annual		√		√		√		√	Annual
MAFB-259	-32.0 - -37.0	Annual		√	√		Not included			√	Biennial
MAFB-260	-31.9 - -41.9	Annual		√	√		√			√	Biennial
MAFB-261	-36.0 - -51.0	Semi-Annual		√		√	√			√	Semi-Annual
MAFB-263	-34.6 - -44.6	Annual		√		√	√			√	Annual
MAFB-264	-11.1 - -26.1	Semi-Annual		√		√	√			√	Semi-Annual
MAFB-265	-38.8 - -53.8	Annual		√	√		--	--		√	Annual

TABLE 7.1 (Continued)
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
MAFB-266	-62.6 - -77.6	Semi-Annual		√	√		--	--		√	Annual
MAFB-267	-78.7 - -93.7	Annual		√		√		√		√	Annual
MAFB-268	-76.9 - -91.9	Semi-Annual		√		√		√		√	Annual
MAFB-269	-81.0 - -96.0	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-270	-95.5 - -110.5	Quarterly		√		√		√		√	Quarterly
MAFB-271	-78.8 - -93.8	Quarterly		√	√		--	--		√	Quarterly
MAFB-272	-67.1 - -82.1	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-273	-45.2 - -60.2	Not Sampled	√		Not Analyzed			√		√	Biennial
MAFB-274	-30.5 - -45.5	Annual		√	√		--	--		√	Annual
MAFB-280	-17.1 - -27.1	Annual	√		√		--	--	√		--
MAFB-281	-9.7 - -24.7	Annual		√	√		--	--		√	Biennial
MAFB-282	-13.5 - -28.5	Semi-Annual	√		√		--	--	√		--
MAFB-308	-28.44 - -43.44	Annual		√	√		--	--		√	Annual
MAFB-309	-75.36 - -90.36	Not Sampled	√		√		Not included		√		--
MAFB-310	-91.08 - -106.08	Annual		√	√			√		√	Biennial
MAFB-311	-104.92 - -119.92	Quarterly		√	√			√		√	Quarterly
MAFB-312	-124.79 - -139.79	Quarterly		√		√	√			√	Quarterly
MAFB-313	-79.92 - -94.92	Quarterly		√		√		√		√	Quarterly
MAFB-322	-114.14 - -129.14	Quarterly		√	√			√		√	Quarterly
MAFB-323	-122.68 - -132.68	Quarterly		√		√	--	--		√	Quarterly
MAFB-324	-82.26 - -97.26	Quarterly		√		√	--	--		√	Quarterly
MAFB-325	-81.42 - -96.42	Annual		√	√			√		√	Biennial
MAFB-330	-124.19 - -139.19	Quarterly		√		√	--	--		√	Quarterly
MAFB-331	-124.0 - -139.0	Quarterly		√		√	--	--		√	Quarterly
MAFB-346Bd	-122.11 - -132.11	Annual		√		√	√			√	Biennial
MAFB-346Bs	-70.51 - -80.51	Semi-Annual		√		√		√		√	Annual
MAFB-348B	-101.45 - -111.45	Quarterly		√		√	√			√	Quarterly
MAFB-351Bd	-143.39 - -153.39	Semi-Annual		√	√		√			√	Annual
MAFB-351Bs	-66.89 - -76.89	Annual		√		√		√		√	Annual
MAFB-354B	-136.78 - -146.78	Quarterly		√	√		--	--		√	Quarterly
MAFB-355B	-133.4 - -143.4	Annual		√	√			√		√	Biennial
MAFB-356B	-138.42 - -148.42	Semi-Annual		√		√		√		√	Biennial
MAFB-358B	-37.4 - -47.4	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-360	-63.75 - -73.75	Annual		√	√		√			√	Annual

TABLE 7.1 (Continued)
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
MAFB-361	-47.65 - -57.65	Annual		√	√		--	--		√	Biennial
MAFB-362	-56.66 - -66.66	Semi-Annual		√	√		√			√	Semi-Annual
MAFB-363	-59.16 - -69.16	Quarterly		√		√	√			√	Quarterly
MAFB-364B	-75.53 - -85.53	Annual	√		√		√		√		--
MAFB-365B	-82.5 - -92.5	Annual		√		√	Not included			√	Annual
MAFB-366B	-80.72 - -90.72	Annual		√		√	--	--		√	Annual
MAFB-368B	-102.87 - -112.87	Quarterly		√		√	--	--		√	Quarterly
MAFB-378B	-32.52 - -42.52	Quarterly		√	√			√		√	Quarterly
MAFB-379B	-80.579 - -90.579	Annual		√		√	--	--		√	Annual
MAFB-380B	98.299 - -108.299	Annual	√		√		√		√		--
MAFB-381B	-70 - -80	Quarterly		√		√	--	--		√	Semi-Annual
MAFB-382B	-85.87 - -100.87	Quarterly		√		√		√		√	Semi-Annual
MAFB-383B	-69.364 - -79.364	Quarterly		√		√		√		√	Quarterly
MAFB-384B	1.76 - -18.24	Semi-Annual		√	√		--	--		√	Semi-Annual
MAFB-385B	109.678 - -119.67	Quarterly		√	√		--	--		√	Quarterly
MAFB-386B	100.597 - -110.59	Annual		√		√		√		√	Annual
MAFB-387B	119.749 - -139.74	Quarterly		√		√	--	--		√	Quarterly
MAFB-388B	132.229 - -142.22	Quarterly		√	√		--	--		√	Quarterly
MBS EW-10B	-70.38 - -110.38	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS EW-11B	-81.95 - -121.95	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS EW-1B	-23.3 - -63.3	Quarterly		√		√	Not included			√	Quarterly
MBS EW-2B	-54.33 - -79.33	Quarterly		√		√	Not included			√	Quarterly
MBS EW-3B	-24.07 - -84.07	Quarterly		√		√	Not included			√	Quarterly
MBS EW-3Bu	-20.89 - -35.89	Annual		√	√		Not included			√	Annual
MBS EW-4B	-44.84 - -74.84	Quarterly		√		√	Not included			√	Quarterly
MBS EW-5B	-65.72 - -95.72	Quarterly		√		√	Not included			√	Quarterly
MBS EW-6B	-75.91 - -115.91	Quarterly		√		√	Not included			√	Quarterly
MBS EW-7B	-47.703 - -87.703	Quarterly		√		√	Not included			√	Quarterly
MBS EW-8B	-33.3 - -63.3	Quarterly		√		√	Not included			√	Quarterly
MBS EW-9B	-45.42 - -85.42	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS PZ-11	-55.7 - -65.7	Annual		√	√			√		√	Annual
MBS PZ-37	-96.68 - 106.68	Semi-Annual		√	√		√			√	Annual
MBS PZ-38	-74.32 - -93.32	Semi-Annual		√		√	√			√	Semi-Annual
MBS PZ-39	-77.14 - -87.14	Semi-Annual		√	√		√			√	Annual

TABLE 7.1 (Continued)
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
MBS PZ-42D	-130.0 - -105.63	Quarterly		√		√	√			√	Quarterly
MBS PZ-44	-23.37 - -33.37	Semi-Annual		√		√	√			√	Semi-Annual
MBS PZ-55B	-68.7 - -78.7	Annual		√	Not Analyzed		√			√	Annual
MBS PZ-55Bu	-26.7 - -36.7	Semi-Annual		√	Not Analyzed		--	--		√	Semi-Annual
D Zone Wells											
FFS MW15-6	-95.4 - -100.4	Semi-Annual		√	√			√		√	Semi-Annual
MAFB-060	-98.68 - -118.68	Annual		√	Not Analyzed		--	--		√	Annual
MAFB-061	-106.63 - -126.63	Semi-Annual		√		√	--	--		√	Annual
MAFB-062	-102.08 - -122.08	Annual	√		√		--	--	√		--
MAFB-063	-100.4 - -120.4	Quarterly		√		√	√			√	Quarterly
MAFB-066	-154.52 - -174.52	Annual		√	√		Not included			√	Biennial
MAFB-102	-107.45 - -122.45	Annual		√		√	--	--		√	Biennial
MAFB-103	-97.64 - -112.64	Annual		√		√		√		√	Annual
MAFB-104	-122.33 - -137.33	Semi-Annual		√		√	√			√	Annual
MAFB-178	-97.16 - -112.16	Not Sampled	√		√		Not included		√		--
MAFB-180	-97.13 - -112.13	Quarterly		√		√	√	--		√	Quarterly
MAFB-181	-118.58 - -133.58	Quarterly		√		√	√			√	Quarterly
MAFB-235	-81.1 - -91.1	Annual		√		√	--	--		√	Annual
MAFB-239	-103.8 - -118.8	Annual	√		Not Analyzed		--	--	√		--
MAFB-240	-108.5 - -123.5	Semi-Annual		√	√		√	--		√	Annual
MAFB-241	-122.5 - -137.5	Not Sampled	√		Not Analyzed		Not included		√		--
MAFB-242	-91.0 - -106.0	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-243	-135.6 - -145.6	Not Sampled	√		√		Not included		√		--
MAFB-250	-101.4 - -116.4	Semi-Annual		√	Not Analyzed		--	--		√	Annual
MAFB-290	-127.8 - -137.8	Annual	√		√		Not included		√		--
MAFB-291	-98.7 - -113.7	Not Sampled	√		Not Analyzed		--	--	√		--
MAFB-292	-99.2 - -114.2	Not Sampled	√		Not Analyzed		--	--	√		--
MAFB-293	-165.6 - -180.6	Semi-Annual		√	√		--	--		√	Annual
MAFB-296	-96.8 - -106.8	Annual		√		√	--	--		√	Annual
MAFB-314	-93.37 - -108.37	Quarterly		√	√		--	--		√	Quarterly
MAFB-315	-129.39 - -139.39	Not Sampled	√		√		Not included		√		--
MAFB-316	-161.14 - -176.14	Not Sampled	√		√		Not included		√		--
MAFB-317	-175.88 - -185.88	Quarterly		√	√			√		√	Quarterly
MAFB-318	-174.57 - -184.57	Quarterly		√		√		√		√	Quarterly

TABLE 7.1 (Continued)
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
MAFB-319	-134.55 - -149.55	Quarterly		√	√		--	--		√	Quarterly
MAFB-320	-123.25 - -138.25	Quarterly		√	√		--	--		√	Quarterly
MAFB-321	-174.65 - -184.65	Quarterly		√		√	Not included			√	Quarterly
MAFB-326	-170.09 - -185.09	Quarterly		√	√			√		√	Quarterly
MAFB-327	-184.02 - -199.02	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-328	-124.72 - -134.72	Quarterly		√	√		--	--		√	Quarterly
MAFB-329	-126.36 - -136.36	Not Sampled	√		√		Not included		√		--
MAFB-332	-145.3 - -155.3	Semi-Annual		√		√		√		√	Semi-Annual
MAFB-336	-200.13 - -210.13	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-337	-279.99 - -289.99	Quarterly		√	√		Not included			√	Quarterly
MAFB-338	-245.0 - -255.0	Quarterly		√	√		Not included			√	Quarterly
MAFB-345	-315.14 - -325.14	Annual	√		√		Not included		√		--
MAFB-346D	-177.11 - -187.11	Annual		√		√	--	--		√	Annual
MAFB-347	-422.27 - -432.27	Semi-Annual		√	√		Not included			√	Annual
MAFB-348Dd	-245.45 - -255.45	Annual		√	√		Not included			√	Annual
MAFB-348Ds	-171.45 - -181.45	Semi-Annual		√		√	√	--		√	Semi-Annual
MAFB-349	-365.43 - -375.43	Semi-Annual		√	√		Not included			√	Semi-Annual
MAFB-350	-371.06 - -381.06	Annual	√		√		Not included		√		--
MAFB-351D	-191.39 - -201.39	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-352D	-228.33 - -238.33	Annual	√		√		Not included		√		--
MAFB-352LM	-382.33 - -392.33	Annual	√		√		Not included		√		--
MAFB-353	-361.67 - -371.67	Annual		√		√	Not included			√	Biennial
MAFB-354D	-221.78 - -231.78	Semi-Annual		√	√		--	--		√	Semi-Annual
MAFB-355D	-228.7 - -238.7	Annual	√		√		√		√		--
MAFB-356Dd	-284.42 - -294.42	Annual		√	√		Not included			√	Biennial
MAFB-356Ds	-232.42 - -242.42	Annual		√	√			√		√	Biennial
MAFB-357D	-80.57 - -90.57	Annual		√	√		--	--		√	Biennial
MAFB-357Dd	-170.57 - -180.57	Semi-Annual		√		√	Not included			√	Annual
MAFB-357Ds	-120.57 - -130.57	Annual		√		√	Not included			√	Annual
MAFB-358D	-82.4 - -92.4	Semi-Annual		√	√		--	--		√	Annual
MAFB-364D	-118.53 - -128.53	Semi-Annual		√		√	--	--		√	Annual
MAFB-365D	-127.5 - -137.5	Annual	√		√		--	--	√		--
MAFB-366D	-110.72 - -120.72	Quarterly		√	√		√	--		√	Semi-Annual
MAFB-367	-145.08 - -155.08	Semi-Annual		√	√		--	--		√	Annual

TABLE 7.1 (Continued)
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
MAFB-368D	-172.87 - -182.87	Quarterly		√	√		√			√	Quarterly
MAFB-369	-138.28 - -148.28	Quarterly		√	√		--	--		√	Annual
MAFB-374	-83.676 - -93.676	Annual		√	√		--	--		√	Biennial
MAFB-375	102.386 - -112.38	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-376	123.826 - -133.82	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-377	-114.9 - -124.9	Quarterly		√	Not Analyzed			√		√	Quarterly
MAFB-378D	-88.52 - -98.52	Quarterly		√	√		--	--		√	Quarterly
MAFB-379D	-140.58 - -150.58	Semi-Annual		√	√		--	--		√	Semi-Annual
MAFB-380D	-140.58 - -150.58	Semi-Annual		√	√		√			√	Annual
MAFB-381D	-165 - -175	Quarterly		√		√	--	--		√	Semi-Annual
MAFB-382D	-175.87 - -185.87	Quarterly		√		√		√		√	Semi-Annual
MAFB-383D	134.364 - -144.36	Semi-Annual		√		√	--	--		√	Semi-Annual
MAFB-384D	-77.24 - -87.24	Annual		√	√		--	--		√	Annual
MAFB-385D	159.678 - -169.67	Quarterly		√	√		--	--		√	Quarterly
MAFB-386D	180.597 - -190.59	Annual		√		√		√		√	Quarterly
MAFB-387Dd	259.749 - -269.74	Quarterly		√		√	--	--		√	Semi-Annual
MAFB-387Ds	214.749 - -224.74	Semi-Annual		√	√		Not included			√	Semi-Annual
MAFB-388Dd	267.229 - -277.22	Semi-Annual		√		√	--	--		√	Annual
MAFB-388Ds	222.229 - -232.22	Semi-Annual		√		√	Not included			√	Semi-Annual
MAFB-397	-154.0 - -164.0	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS EW-1D	unknown	Quarterly		√		√	Not included			√	Quarterly
MBS EW-2D	-105.11 - -145.11	Quarterly		√		√	Not included			√	Quarterly
MBS EW-3D	85.204 - -125.204	Quarterly		√		√	Not included			√	Quarterly
MBS EW-4D	-78.72 - -103.72	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS EW-5D	-107.17 - -142.17	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS EW-6D	-156.07 - -181.07	Quarterly		√	Not Analyzed		Not included			√	Quarterly
MBS PZ-12	-295.2 - -305.2	Annual		√	√		Not included			√	Annual
MBS PZ-13	-166.0 - -176.0	Semi-Annual		√		√	Not included			√	Semi-Annual
MBS PZ-14	-286.4 - -301.4	Annual		√	√		Not included			√	Annual
MBS PZ-15	-290.8 - -300.8	Annual	√		√		Not included		√		--
MBS PZ-49D	-285.71 - -295.71	Annual		√	√		Not included			√	Annual
MBS PZ-50D	-298.52 - -308.52	Semi-Annual		√	√		Not included			√	Annual
MBS PZ-51	93.638 - -103.638	Annual		√	Not Analyzed		Not included			√	Annual
MBS PZ-52	90.435 - -100.435	Annual		√	Not Analyzed		--	--		√	Annual

TABLE 7.1 (Continued)
SUMMARY OF EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Well ID	Screen Interval (fbtoc)[a/]	2003 Sampling Frequency[b/]	Qualitative Evaluation		Temporal Evaluation		Spatial Evaluation		Final Recommendation		
			Exclude	Retain	Exclude/ Reduce Sampling	Retain	Exclude	Retain	Exclude	Retain	Frequency
MBS PZ-53	101.765 - -116.76	Annual		√	Not Analyzed		Not included			√	Annual
MBS PZ-54	95.625 - -105.62	Annual		√	Not Analyzed		--	--		√	Annual
MBS PZ-58	-99.23 - -109.23	Semi-Annual		√	Not Analyzed		√			√	Semi-Annual

[a/] ftbtoc = feet below top of well casing.
[b/] 2003 sampling frequency based on 2002 Groundwater Monitoring Program Evaluation Report (MWH, 2002b).
[c/] "Intermediate" value of spatial information, no recmmendation given.

TABLE 7.2
SUMMARY OF REVISED AND ORIGINAL MONITORING PROGRAMS
MONITORING NETWORK OPTIMIZATION
MAIN BASE/SAC AREA
FORMER MATHER AIR FORCE BASE, CALIFORNIA

Zone	Type of Well	Monitoring Frequency					Total Wells
		Not Sampled	Biennial	Annual	Semi-Annual	Quarterly	
WT/A	Groundwater Extraction Wells	0 (0)[a/]	0 (0)	0	1 (0)	13 (14)	**14**
WT/A	Monitoring Wells/Piezometers	18 (16)	10 (0)	20 (24)	13 (17)	11 (15)	**72**
B	Groundwater Extraction Wells	0 (0)	0 (0)	1 (1)	0 (0)	11 (11)	**12**
B	Monitoring Wells/Piezometers	15 (12)	14 (0)	33 (41)	17 (23)	29 (32)	**108**
D	Groundwater Extraction Wells	0 (0)	0 (0)	0 (0)	1 (0)	6 (6)	**6**
D	Monitoring Wells/Piezometers	18 (8)	7 (0)	29 (33)	21 (30)	19 (23)	**94**
Total Wells		**51 (36)**	**31 (0)**	**82 (99)**	**53 (70)**	**89 (101)**	**306**

[a/] 2003 sampling frequency corresponding to Table 3.2 shown in parentheses.

The MNO analysis supports the exclusion of 33 of the 36 wells that currently are not included in the monitoring program. Wells MAFB-210 and MAFB-245 are recommended for addition to the LTM program for the reasons listed in Table 4.3. Well MAFB-273 is recommended for addition to the LTM program because its relative spatial importance. Eighteen wells sampled in 2003 are recommended for removal from the monitoring program.

The MNO results indicate that a refined monitoring program consisting of 255 wells (89 to be sampled quarterly, 53 to be sampled semi-annually, 82 to be sampled annually, and 31 to be sampled biennially) would be adequate to address the two primary objectives of monitoring listed in Section 1. This refined monitoring network would result in an average of 559.5 well-sampling events per year, compared to 643 well-sampling events per year under the 2003 monitoring program. A well-sampling event is defined as a single sampling of a single well. ***Implementing these recommendations for optimizing the LTM monitoring program at the Main Base/SAC Area Plume would reduce the number of well-sampling events per year by approximately 13 percent.***

SECTION 8

REFERENCES

Air Force Base Conversion Agency (AFBCA). 1996. *Superfund Record of Decision. Soil Operable Unit Sites and Groundwater Operable Unit Plumes, Mather Air Force Base.*

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