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Contract Task Order 0236

Prepared For:

Department of the Navy, Engineering Field Activity West
Naval Facilities Engineering Command

Navy Engineer-in-Charge: Stephen Chao, PE

PRC Project Manager: Michael Young

PRC Project Engineers: Brian Werle, Deirdre O'Dwyer, and Steve Annecone

MOFFETT FEDERAL AIRFIELD
CALIFORNIA

FINAL
INSTALLATION RESTORATION PROGRAM
PETROLEUM SITES
(AND WASTEWATER TANKS AND SUMPS)
CORRECTIVE ACTION PLAN

Prepared by:

PRC ENVIRONMENTAL MANAGEMENT, INC.
1099 18th Street, Suite 1960
Denver, Colorado 80202
(303) 295-1101

November 7, 1994

PRC Environmental Management, Inc.
1099 18th Street, Suite 1960
Denver, CO 80202
303-295-1101
Fax 303-295-2818

November 7, 1994

Mr. Stephen Chao/Mr. Hubert Chan
Department of the Navy
Engineering Field Activity West
Naval Facilities Engineering Command
900 Commodore Way, Building 101
San Bruno, California 94066-2402

CLEAN Contract Number N62474-88-D-5086
Contract Task Order 0236

Subject: **Final Installation Restoration Program Petroleum Sites (and Wastewater Tanks and Sumps) Corrective Action Plan, Moffett Federal Airfield**

Dear Messrs. Chao and Chan:

Enclosed please find three copies of the above-referenced report prepared by PRC Environmental Management, Inc. This report summarizes potential remedial alternatives for soil and groundwater petroleum contamination at Sites 5, 9, 12, 14, 15, and 19 at Moffett Federal Airfield. By cover of this letter, copies of the report have been sent to the appropriate project personnel and regulatory agencies.

If you have any questions or comments, please call us at (303) 295-1101.

Sincerely,

Brian Werle
Project Engineer

Michael N. Young
Project Manager

Enclosures

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Corrective Action Plan
Moffett Federal Airfield

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ACRONYMS AND ABBREVIATIONS

AAL	Ames Aeronautical Laboratory
AS	Air sparging
AS/SVE	Air sparging/soil vapor extraction
AST	Aboveground storage tank
AVGAS	Aviation gasoline
BAAQMD	Bay Area Air Quality Management District
BRAC	Base Realignment and Closure
bgs	Below ground surface
BTEX	Benzene, toluene, ethylbenzene, and xylene
CAMU	Corrective Action Management Unit
CAP	Corrective action plan
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFU	Colony forming unit
CLEAN	Comprehensive Long-term Environmental Action Navy
CFR	Code of Federal Regulations
cm/sec	Centimeters per second
DOD	Department of Defense
DTSC	California EPA Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
FFA	Federal Facilities Agreement
FS	Feasibility study
ft^2	Square foot
ft/day	Feet per day
GAC	Granular activated carbon
gpd	Gallons per day
gpm	Gallons per minute
HCL	Hydrogen chloride
IAS	Initial assessment study
JP-5	Jet fuel
µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter
MCL	Maximum contaminant level
MEW	Middlefield, Ellis, and Whisman
MEK	Methyl ethyl ketone
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MOU	Memorandum of understanding
MSL	Mean sea level
mV	Millivolt

ACRONYMS AND ABBREVIATIONS (Continued)

NAS	Naval air station
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEX	Naval Exchange
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
O&M	Operation and maintenance
OSHA	Occupational Safety and Health Administration
OU	Operable unit
PAH	Polynuclear aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
PID	Photoionization detector
POTW	Publicly owned treatment works
PRC	PRC Environmental Management, Inc.
PRG	Preliminary remediation goal
PVC	Polyvinyl chloride
QA/QC	Quality assurance and quality control
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial design and remedial action
RI/FS	Remedial investigation and feasibility study
RI	Remedial investigation
RIST	Recirculating in situ treatment
ROD	Record of decision
RWQCB	California Regional Water Quality Control Board, San Francisco Bay Region
SARA	Superfund Amendment and Reauthorization Act
SCM	Source control measure
scfm	Standard cubic feet per minute
SITE	Superfund Innovative Technology Evaluation Program
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
SWRCB	State Water Resources Control Board
TCE	Trichloroethene
TDS	Total dissolved solids
TPH	Total petroleum hydrocarbons
UST	Underground storage tank
V	Volt
VOC	Volatile organic compound
yd^3	Cubic yard

EXECUTIVE SUMMARY

This report presents the corrective action plan (CAP) for petroleum contamination at Installation Restoration Program (IRP) Sites 5, 9, 12, 14, 15, and 19 at Moffett Federal Airfield (Moffett Field). Included in this CAP are 38 underground storage tanks (USTs), five aboveground storage tanks (ASTs), and eight sumps (51 total). Of these tanks and sumps, 9 are active, 9 are inactive, and 33 have been removed.

Removal and investigation activities revealed petroleum contamination at many of the IRP UST and sump sites. The primary types of petroleum contamination above cleanup levels include light-end distillates (such as total petroleum hydrocarbons [TPH] as gasoline), heavy-end distillates (such as TPH as diesel fuel), and benzene and toluene.

The Navy has conducted several source control measures (SCMs) at Moffett Field to begin addressing this contamination, including the Site 12 soil SCM, the Site 14 groundwater SCM, and numerous UST and sump removals. Additionally, the Navy plans several more actions including the Site 9 groundwater SCM, the electron injection pilot study, and potential soil pile treatment (for soils removed from ongoing UST and sump excavations).

Recommendations for IRP tanks and sumps sites fall under four categories: (1) active or inactive tanks and sumps that have no contamination and are recommended for elimination from the IRP petroleum sites program (these sites cannot be closed since they are active or will be active), (2) active or inactive tanks and sumps that have contamination associated with them and corrective measures are required, (3) removed tanks and sumps that have no contamination and are recommended for immediate closure (these will be included in a closure report), and (4) removed tanks and sumps that have contamination and are recommended for corrective measures. The Navy is not seeking closure for active or inactive tanks and sumps, since they are being or will be used in the future; when these tanks and sumps are no longer needed, they will be removed, investigated, and closed following appropriate regulatory guidance. A summary of the tanks and sumps falling into the four categories is provided below.

Active and Inactive Tanks and Sumps Recommended for Elimination

Site 5	USTs 4, 6, 7, 8, 10, 11, 12, and 13 ASTs 72, 73, 74, and 75
Site 15	Sumps 59, 62, 63, 64, and 130

Active and Inactive USTs and Areas Recommended for Corrective Measures

Site 5	USTs 5 and 9 Dry Wells near USTs 11, 12, and 13

Removed USTs and Sumps Recommended for Closure

Site 5	USTs 18 (pending removal data), 26, 30, and 31
Site 15	UST 54
Site 19	UST 14

Removed Tanks/Sumps Recommended for Corrective Measures

Site 9	USTs 47, 48, 49, 50, 56A, 56B, 56C, 56D, 79, 80, 81, 82, 83, 84, 97, 98, and 99 (Building 29 and 31 areas) AST 52
Site 12	No UST or sump (pending additional data)
Site 14	(South) USTs 19 and 20
Site 15	Sumps 25, 42, and 58 (pending additional data for Sump 58)
Site 19	USTs 2, 43, and 53

The Navy is proposing pilot tests to begin addressing the tanks and sumps requiring corrective measures. Pilot tests are necessary to gather site-specific information that can be used to realistically evaluate different alternatives and develop full-scale treatment systems. The tests will provide data in addition to information collected from the SCMs. Combined, these data will assist the Navy in planning, designing, and implementing treatment systems for all petroleum contamination at Moffett Field. The pilot tests will be conducted at three IRP sites. Once the necessary data have been collected from these tests, alternatives will be selected and, if appropriate, treatment systems will be planned and scheduled for the remaining IRP sites (with regulatory agency concurrence).

Sites 5, 9, and 14 are proposed for pilot tests. Based on the descriptions of possible treatment alternatives in this CAP, a system in situ bioventing and biosparging is proposed for soil and groundwater at Site 5, a system incorporating soil vapor extraction and air sparging is proposed for soils at Site 9, and a recirculating in situ treatment system is proposed for Site 14 groundwater.

1.0 INTRODUCTION

The U.S. Department of the Navy, as part of the Installation Restoration Program (IRP), has been identifying and evaluating past hazardous waste sites at Moffett Federal Airfield (Moffett Field) and controlling the spread of contaminants from these sites. Environmental restoration activities are conducted under the Comprehensive Long-term Environmental Action Navy (CLEAN) contract. These activities are coordinated through a Federal Facilities Agreement (FFA) involving the Navy, the U.S. Environmental Protection Agency (EPA) and the California Environmental Protection Agency including the Department of Toxic Substances Control (DTSC) and the San Francisco Bay Regional Water Quality Control Board (RWQCB).

This report presents the corrective action plan (CAP) for petroleum contamination at IRP Sites 5, 9, 12, 14, 15, and 19 at Moffett Field. Included in this CAP are 38 underground storage tanks (USTs), five aboveground storage tanks (ASTs), and eight sumps (51 total). This CAP includes the following tanks and sumps:

Site	Status	Tanks and Sumps
Site 5	Active	USTs 10, 11, 12, and 13 ASTs 72, 73, 74, and 75
	Inactive	USTs 4, 5, 6, 7, 8, and 9
	Removed	USTs 18, 26, 30, and 31
Site 9	Removed	USTs 47, 48, 49, 50, 56A, 56B, 56C, 56D, 79, 80, 81, 82, 83, 84, 97, 98, and 99 AST 52
Site 12	No UST	No UST or sump
Site 14	Removed	USTs 19 and 20
Site 15	Active	Sump 59
	Inactive	Sumps 62, 63, and 130
	Removed	Sumps 25, 42, 58, 64, and UST 54
Site 19	Removed	USTs 2, 14, 43, and 53

Petroleum-related contaminants have been identified at many of these tanks and sumps during removal actions, remedial investigations (RIs), and quarterly monitoring. Several reports have been prepared

detailing the available data for these sites, including summaries of tank and sump data, soil and groundwater data, nature and extent of contamination, and recommendations. These reports are the primary sources of data considered in this CAP and are as follows:

- Revised Final IRP Petroleum Sites (and Wastewater Tanks and Sumps) Characterization Report (PRC 1994a)
- Technical Memorandum on Petroleum Sites Petroleum Cleanup Level Analysis (PRC 1994b)
- Draft Additional Petroleum Sites Investigation Technical Memorandum (PRC 1994c)
- Site 9 Source Control Measure Final Design Report (PRC 1992a)
- Site 12 Source Control Measure Final Action Technical Memorandum (PRC and MW 1994c)
- Site 14 South Evaluation Technical Memorandum (PRC 1994d)

This CAP is divided into 10 sections. In addition to this introduction, Section 1.0 presents the purpose and scope of this report. Section 2.0 summarizes site background information including site history, land and aquifer use, and site hydrogeology. Section 3.0 summarizes regulatory criteria and Section 4.0 summarizes previous investigations. Section 5.0 discusses migration control and interim remediations conducted at the sites included in this CAP and Section 6.0 summarizes remedial process options and technologies. Section 7.0 discusses potential remedial alternatives and Section 8.0 presents the proposed remedial action options. Section 9.0 discusses verification monitoring and references are provided in Section 10.0.

Purpose and Scope

The purpose of this CAP is to evaluate remedial alternatives that can be implemented to address petroleum-related contamination at IRP Sites 5, 9, 12, 14, 15, and 19. The scope of activities discussed in this CAP, therefore, includes completing the necessary remedial activities and closure documents for the 33 tank and sump removal sites, and addressing any contamination at the active and inactive USTs and sumps. Closure documentation will not be prepared for active USTs and sumps until they are no longer needed and scheduled for closure. Additionally, the Navy is currently scheduling the removal of the inactive USTs and will follow the guidance and regulations outlined in this CAP.

Sites 5, 9, 12, 14, 15, and 19 were formerly part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) action implemented at Moffett Field. However, petroleum and petroleum-related constituents are excluded from cleanup under CERCLA (42 USC 9601 Section 101 Part 14). The CERCLA petroleum exclusion applies to petroleum and petroleum-related constituents that are separate and distinguishable from any other hazardous wastes. Although excluded from CERCLA, cleanup of petroleum contamination is required by the Resource Conservation and Recovery Act (RCRA), as well as, state UST regulations (discussed in Section 3.0). Therefore, Sites 5, 9, 12, 14, 15, and 19 were removed from the CERCLA process at Moffett Field and included in the IRP petroleum sites program.

Data collected during preparation of the petroleum sites characterization report (PRC 1994a) revealed that some of the USTs and sumps originally thought to contain petroleum products contained other substances (such as wastewater) in addition to the petroleum products. The petroleum exclusion is not applicable to USTs and sumps that handled other substances in addition to petroleum products (such as wastewater). The Navy has recommended that these USTs and sumps be closed concurrently with, and in a similar manner, to those at the petroleum sites. (State of California UST closure requirements also require consistent UST closures [RWQCB 1990]). Rather than creating a separate process to address wastewater USTs and sumps, they will remain in this corrective action process to expedite closure. Additionally, wastewater tanks and sumps will be evaluated in a manner similar to other CERCLA sites at Moffett Field. Data from these tanks and sumps will be evaluated in the station-wide human health risk assessment, RI and feasibility study reports, and ROD. Human health risks will be evaluated in a manner consistent with other individual sites (such as the operable unit 2 [OU2] soil sites). Wastewater tanks and sumps will be tracked individually, similar to other station-wide sites (such as Zook Road, Patrol Road Ditch, and golf course landfill 2). Therefore, the investigation, cleanup, and closure of all USTs and sumps will follow state UST requirements, and those that contained wastewater will be included in the station-wide CERCLA process. The specific USTs and sumps included in the station-wide CERCLA process are:

Site	Wastewater USTs and Sumps
Site 15	Sumps 58, 59, 62, 63, 64, and 130 UST 54
Site 19	USTs 2 and 43

Commingling of petroleum products with other substances in groundwater under the western side of Moffett Field is of particular concern. Groundwater in this area is contaminated by a regional volatile organic compound (VOC) plume originating from the upgradient Middlefield-Ellis-Whisman (MEW) Superfund site. In some areas, such as Site 9, petroleum contamination is commingled with the VOC plume. The groundwater in this area is being addressed on a regional basis through a CERCLA response action by the companies involved with the MEW site, as well as by expanded source controls being implemented by the Navy (such as the Site 9 source control action [PRC 1992a]). Further actions to address petroleum-contaminated groundwater on the western side of Moffett Field are proposed in this CAP (such as at Sites 9 and 14). These actions, however, will specifically target the petroleum contamination and not the regional VOC plume.

Groundwater under the eastern portion of Moffett Field is not part of the regional VOC plume and is being addressed through the operable unit 5 (OU5) CERCLA remedial investigation/feasibility study (RI/FS) process. Since petroleum is excluded from the CERCLA process, petroleum-contaminated groundwater under the eastern portion will also be addressed in this CAP, except in areas where commingling with other contaminants (such as VOCs) may have occurred. Evaluation of substances not related to petroleum contamination (such as solvent plumes) will continue to be addressed through the OU5 RI/FS process.

2.0 SITE DESCRIPTION

Moffett Field is located approximately 1 mile from the southern end of San Francisco Bay, adjacent to the cities of Mountain View and Sunnyvale, California (Figure 1). The facility encompasses 2,200 acres in Santa Clara County. Moffett Field is bounded by salt evaporation ponds to the north, Stevens Creek to the west, U.S. Highway 101 to the south, and the Lockheed Aerospace Center to the east. Within Moffett Field are two runways, three large aircraft hangars, control facilities, aircraft refueling facilities and storage tanks, office complexes, military housing units, a golf course, automobile fueling and maintenance facilities, and warehouses. Moffett Field also hosts the National Aeronautics and Space Administration's (NASA) Ames Research Center facilities, which include several large scale wind tunnels, laboratories, offices, aircraft hangars, and support facilities.

San Francisco Bay is located approximately 1 mile from the northern boundary of Moffett Field. Historically, tidal salt marsh and mud flats covered extensive areas of the southern portion of the San Francisco Bay near Moffett Field; most of these areas, however, have been eliminated or greatly

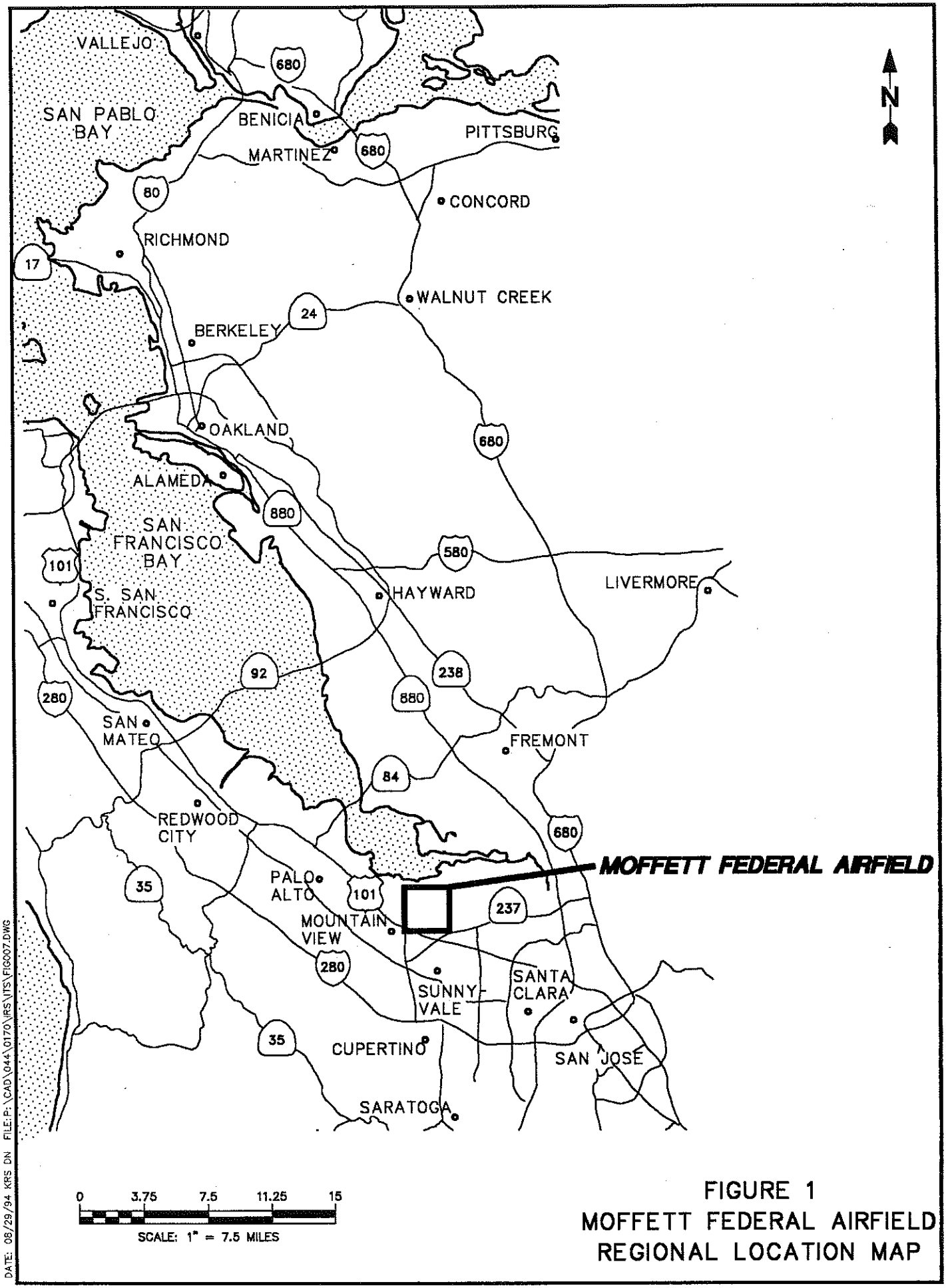

FIGURE 1
MOFFETT FEDERAL AIRFIELD
REGIONAL LOCATION MAP

altered by fill material. The large area to the north and northeast of Moffett Field was diked and is now used as commercial salt evaporation ponds. Coyote Creek and Guadalupe Slough drain into San Francisco Bay to the east of Moffett Field, and Stevens Creek drains into the bay to the west. Wetlands located along the northern portion of Moffett Field are the only natural surface water features at Moffett Field. These wetlands are approximately 40 acres in size. Another wetland area consisting of approximately 80 acres lies north of the Ames Research Center. These areas provide habitats for a variety of mammals, birds, and other species.

2.1 HISTORY

Moffett Field has been continuously operated by the U.S. military since it was commissioned in 1933 to support the West Coast dirigible program. In 1939, a permit was granted to Ames Aeronautical Laboratory to use part of the station. In 1949, the station became home to the Military Air Transport Service Squadron. By 1950, Moffett Field was the largest naval air transport base on the West Coast and became the first all-weather naval air station. In 1953, the station became home to all Navy fixed-wing, land-based antisubmarine efforts. A weapons department was formed on the base in 1954, and in February 1966 the base activated its high-speed refueling facilities. During the station reorganization in 1973, it became the headquarters of the Commander Patrol Wings, U.S. Pacific Fleet.

During the 1980s and early 1990s, the mission of Moffett Field was to support antisubmarine warfare training and patrol squadrons. The station supported more than 70 tenant units, including the Commander Patrol Wings, U.S. Pacific Fleet, and the California Air National Guard. Moffett Field was the largest P-3 Orion patrol aircraft base in the world, with nearly 100 aircraft. These aircraft were assigned to nine squadrons supported by 5,500 military, 1,500 civilian, and 1,000 reservist personnel. No heavy manufacturing or major aircraft maintenance was conducted at Moffett Field, but a significant amount of unit- and intermediate-level maintenance occurred.

In April 1991, Moffett Field was designated for closure as an active military base under the Department of Defense (DOD) Base Realignment and Closure (BRAC) program. In July 1994, the control of Moffett Field was transferred to NASA, which operates the Ames Research Center on the northwestern side of Moffett Field. The Navy will continue with environmental restoration activities and remain responsible for remediating contamination caused by Navy operations in accordance with the memorandum of understanding (MOU) between the Navy and NASA.

Wastes have been generated at Moffett Field through maintenance operations, fuel management, and fire training since the early 1930s. Chemicals of potential concern include waste oils, jet and automobile fuels, solvents and cleaners, washing compounds, and minor amounts of paints, pesticides, battery acid, and polychlorinated biphenyls (PCBs). Some wastes were disposed of in drainage ditches and unpaved areas or stored temporarily in unlined wastewater ponds. However, the primary sources of contaminants at Moffett Field are USTs and sumps (many of them now removed) that handled petroleum products, and lesser amounts of waste oils and solvents.

Environmental studies were initiated at Moffett Field in 1984. The Navy conducted an initial assessment study (IAS) in 1984 to gather data on the past use and disposal of hazardous materials at Moffett Field (NEESA 1984). Nineteen sites (many of them USTs and sumps) were identified as potential sources of wastes, including nine sites identified in the IAS and 10 sites added during subsequent investigations (ESA and AR 1986a, 1986b; ESA and JMM 1986; ERM 1987). EPA proposed Moffett Field as a National Priorities List (NPL) site in June 1986 and placed it on the NPL in 1987. Placement on the NPL initiated the RI/FS process under CERCLA. Data collected during the initial studies were used to plan the RI/FS. The RI/FS work is coordinated through the FFA with the EPA, DTSC, and RWQCB.

In February 1993, the Navy recommended that all sites containing petroleum and petroleum constituents be removed from the CERCLA process and that these sites be addressed in a manner consistent with RCRA and state UST regulations.

2.2 LAND AND AQUIFER USE

This section summarizes land and aquifer use information and identifies potential exposure scenarios for Moffett Field. It presents the current land use for Moffett Field as a baseline condition; the risk management process employed by the Navy and regulatory agencies will consider the likelihood of future land and groundwater use. This information has been summarized from the draft OU5 FS report (PRC 1994e).

2.2.1 Land Use

In April 1991, the DOD BRAC commission voted to (1) decommission Moffett Field, (2) transfer Moffett Field's naval operations to other Navy facilities, and (3) transfer the majority of Moffett Field property to NASA. In December 1992, an MOU between the Navy and NASA was signed. The

MOU documented the major points of agreement regarding the transfer of the majority of Moffett Field property to NASA jurisdiction. Additional, smaller land management responsibilities, including housing areas, were transferred to the DOD, with the Department of the Air Force acting as the DOD housing agency. The MOU documented the following joint goals of the Navy and NASA: (1) achieve a no-cost transfer of all land, buildings, facilities, infrastructure, and other property associated with Moffett Field (excluding base family housing and related community support facilities); and (2) identify NASA as the new federal host agency to all other users. The property transfer took place on July 1, 1994.

NASA's Ames Research Center occupies approximately 430 acres of land directly west of Moffett Field, bordering the City of Mountain View. The U.S. Congress established the facility on August 9, 1939, as the Ames Aeronautical Laboratory (AAL) and, upon the establishment of NASA in 1958, AAL was renamed the Ames Research Center. AAL was initially developed to provide an aeronautical research facility in an area with favorable year-round flying conditions that was near a military facility and near a university of recognized standing (Stanford University). Ames' initial mission was to develop technology for use by aircraft manufacturers, primarily in the area of aerodynamics at high subsonic speeds.

Presently, Ames' major program areas include research and development in aeronautics, space science and exploration, space research and technology, life science, earth systems science, space transportation, and energy. Ames also directs the operations and management of flight research and flight tests. Ames' stated future mission is to conduct research and develop new aerospace technology to support space exploration efforts and improve the safety and performance of aircraft. This research also is applied to biomedicine, life sciences, environmental conditions, and human-based geographic growth patterns. Ames also supports other NASA centers in the research and development of technology for manned spacecraft.

The Navy previously hosted several tenant organizations at Moffett Field (such as the Naval Reserve, the California Air National Guard, and Onizuka Air Force Base). Each tenant has assumed the financial responsibility for their exclusively occupied facility as well as assuming equitable financial agreements for shared airfield assets. To defray the cost of airfield operation, NASA will continue the tenant program. Additional tenants which have recently expanded their presence at the airfield are the Marine Reserve and the Army Reserve. Moffett Field also provides secure runways for the transportation of missiles, satellites, and other weapons systems for businesses in Silicon Valley.

NASA developed a Comprehensive Use Plan for Moffett Field (NASA 1994). This document established baseline (existing) conditions and near-term (1995) and long-range (20-year forecast) plans for additional land uses at Moffett Field. The document also evaluated comprehensive land use alternatives that will be designed to accommodate many growth opportunities. These alternatives are designed to encourage the most facility-, community-, and economy-supportive land uses at Moffett Field.

In summary, Moffett Field is a restricted federal airfield in the heart of Silicon Valley and provides a unique facility for federal and state users. Therefore, the federal government is not likely to relinquish jurisdictional control of Moffett Field and the station will most likely remain an industrially oriented facility for the near future.

2.2.2 Aquifer Uses

Beneficial uses of groundwater in the Santa Clara Valley Basin beneath Moffett Field are outlined in the RWQCB Basin Plan (RWQCB 1991b). According to this plan, potential beneficial uses applicable to the main groundwater basins in the San Francisco Bay region, including the Santa Clara Valley Basin, are municipal supply, industrial service and industrial process water supply, and agricultural supply. Basin Plan aquifer designations are basin-wide and not based on site-specific characteristics.

In the interior part of the Santa Clara Valley Basin, the numerous aquifers have been divided into two broad zones or sequences: the upper-aquifer sequence (A and B aquifers) and the lower-aquifer sequence (C aquifer) (see Section 2.3). The upper aquifers at Moffett Field, with the exception of the northern most portion of Moffett Field, meet the State Water Resources Control Board (SWRCB) definition of a potential drinking water source (SWRCB 1988). This definition states any aquifer that contains groundwater with a total dissolved solids (TDS) concentration below 3,000 milligrams per liter (mg/L) and can yield 200 gallons per day (gpd) is a potential drinking water source. However, there are several inorganic constituents in the Moffett Field upper aquifers that have site-specific background concentrations above maximum contaminant levels (MCLs) and Basin Plan water quality objectives. Therefore, treatment of the groundwater in the upper aquifers would probably be required prior to distribution for drinking water. Generally, the upper aquifer groundwater is also unattractive for use as an agricultural supply due to elevated salinity and metals concentrations. For this CAP, however, the shallow aquifer will be considered as a potential drinking water source since groundwater under the petroleum sites meets the state's definition.

In the past, groundwater for drinking and agricultural purposes was obtained from the deeper aquifer (C-aquifer). However, no drinking water wells are known at Moffett Field. There are eight active C-aquifer wells at Moffett Field; one is a source of irrigation water (agricultural use) for the golf course and seven are used only as monitoring wells. A figure depicting the locations of these wells is provided in Appendix A. Groundwater from the C-aquifer in the area of Moffett Field is confined to agricultural uses. Limited use of the C-aquifer groundwater for agricultural purposes may continue into the future; however, due to withdrawal restrictions, extensive use of the C-aquifer groundwater for agricultural supply is unlikely. Water for domestic use at Moffett Field comes from municipal sources which rely predominantly on surface water sources. Moffett Field is investigating the use of reclaimed water from the Sunnyvale publicly owned treatment works (POTW) for future golf course irrigation needs.

2.3 HYDROGEOLOGY

This hydrogeology summary has been compiled from the Geology and Hydrogeology Technical Memorandum (PRC and MW 1992), the OU4 FS report (PRC 1992b), and the OU5 FS report (PRC 1994e). These documents should be reviewed for additional detail regarding Moffett Field hydrogeology.

The hydrogeologic setting at Moffett Field consists of alluvial sand aquifers or sand and gravel aquifers separated by low permeability silt and clay aquitards. In the interior part of the Santa Clara Valley, the numerous aquifers have been divided into two broad zones or sequences: the upper-aquifer sequence (A and B aquifers) and the lower-aquifer sequence (C aquifer). The distinction between the two aquifer sequences is that the upper-aquifer sequence is generally unconfined, although in places it is semiconfined. The lower-aquifer sequence is confined under a laterally extensive clay aquitard at depths of 140 to 200 feet below ground surface (bgs). Aquifers in the upper zone are generally thin and discontinuous. Aquifer materials range from silty to fine sand to coarse gravel. Figure 2 depicts a schematic diagram of the aquifer system under Moffett Field.

The A aquifer is divided into two aquifer zones: a shallow 5- to 35-foot deep zone referred to as the A1-aquifer zone, and a deeper 35- to 65-foot deep zone referred to as the A2-aquifer zone. Predominant lithologies include fine-grained silt and clay within these zones. Permeable units which comprise the productive parts of these aquifer zones are thin (3 to 20 feet thick) discontinuous channels and lenses of sand and gravel. These sediments were deposited by a branching fluvial

DATE: DATE: 08/23/94 JAY DN FILE NAME: 044\0236\RP\SRP\FIG1-4.DWG

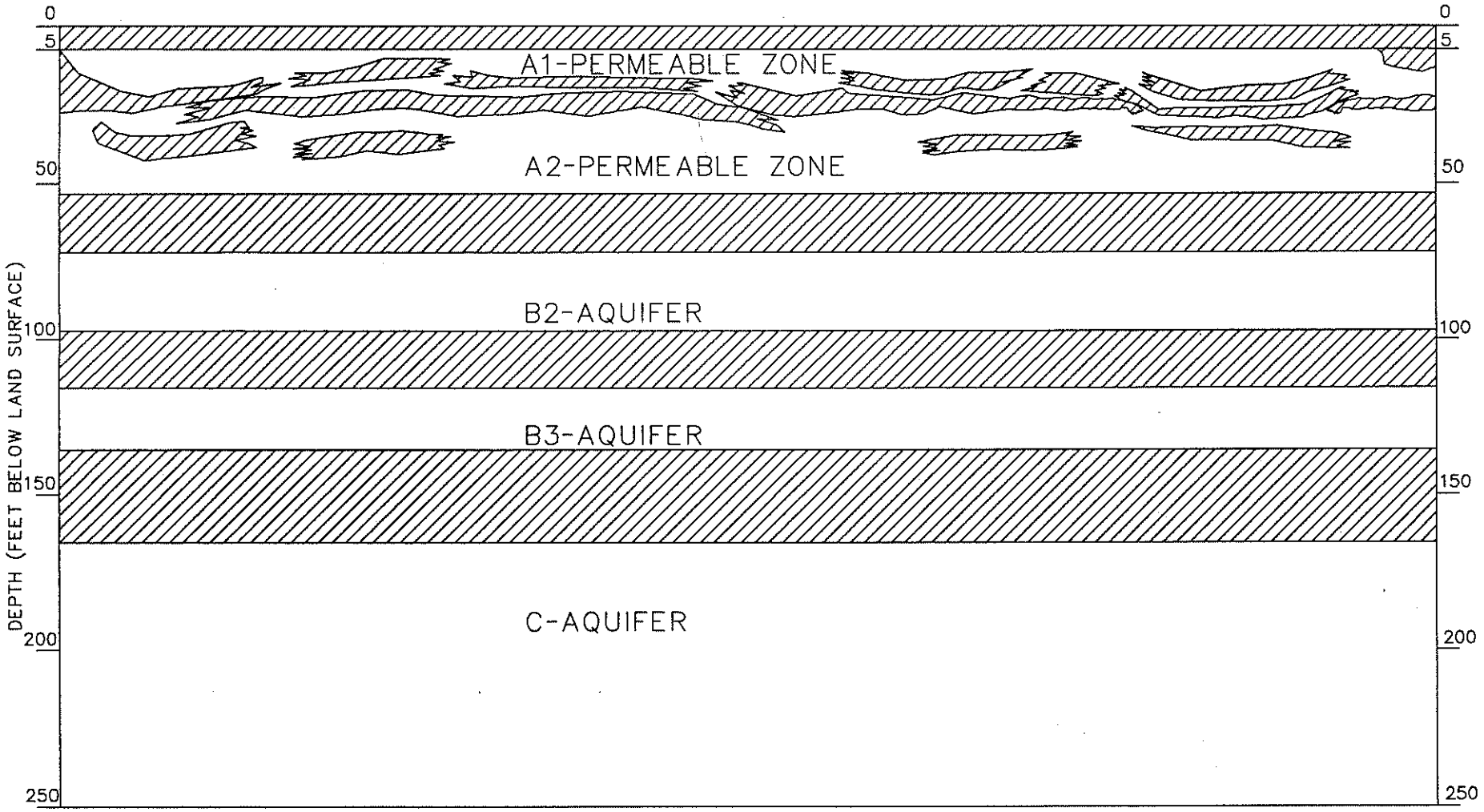

FIGURE 2
MOFFETT FEDERAL AIRFIELD
LOCAL HYDROGEOLOGIC SCHEMATIC DIAGRAM

channel system that traversed alluvial plain and marsh environments, creating discontinuous, lenticular sand bodies that are surrounded by finer-grained deposits. Figure 3 depicts the A1 zone channel system on the western side of Moffett Field; a figure depicting an A1 zone channel on the eastern side of Moffett Field is presented in Section 4.1.

Early investigations (HLA 1988; IT 1991) proposed that a discontinuous confining unit (A1/A2 aquitard) separated the permeable sediments of the A1-aquifer zone from the permeable sediments of the A2-aquifer zone. A later investigation (PRC 1993a) characterized this horizon on the western side of Moffett Field as a zone of reduced channel density, which may, in places, be incised by channels in the overlying A1 zone sediments.

A confining layer (A/B aquitard) separates the permeable deposits of the B aquifer from the channels of the A aquifer zones. The lithologies of the B aquifer sediments are similar in kind and distribution to the lithologies found in the A aquifer. However, the permeable deposits in the B aquifer are generally finer-grained and lack gravel. Permeable channels in the B aquifer have not been as well delineated as channels in the A aquifer due to lower data density at the greater depths of the B aquifer. Permeable units in the B aquifer, however, are characterized by interbedded fine- to medium-grained sand and clayey sand interbedded with silts and clays. At the western side of Moffett Field, the B aquifer was distinguished from the A aquifer by depth below surface, the absence of gravel in the aquifer, and by a 5- to 7-foot thick, laterally extensive clay zone which separated shallower from deeper sand units. This clay zone was encountered between depths of 65 and 70 feet bgs in virtually all of the deep borings at the western side of Moffett Field.

The A/B aquitard on the eastern side of Moffett Field has been less well identified because of fewer soil borings, but appears to exist as a 7- to 20-foot thick clay zone. The thickness of the A/B aquitard varies because of the variable lower surface of the A aquifer. The top of this clay zone ranges from approximately 40 feet bgs at well W19-2 near the northeastern corner of Hangar 3, to approximately 55 feet bgs at the well pair W3-13/W3-7, located near the midpoint of Marriage Road.

At Moffett Field, the A and B aquifers are unconfined to semiconfined to confined aquifers characterized by a heterogeneous distribution of high and low permeability sedimentary units. On the eastern side of Moffett Field, the A aquifer is generally semiconfined to confined and the B aquifer is confined.

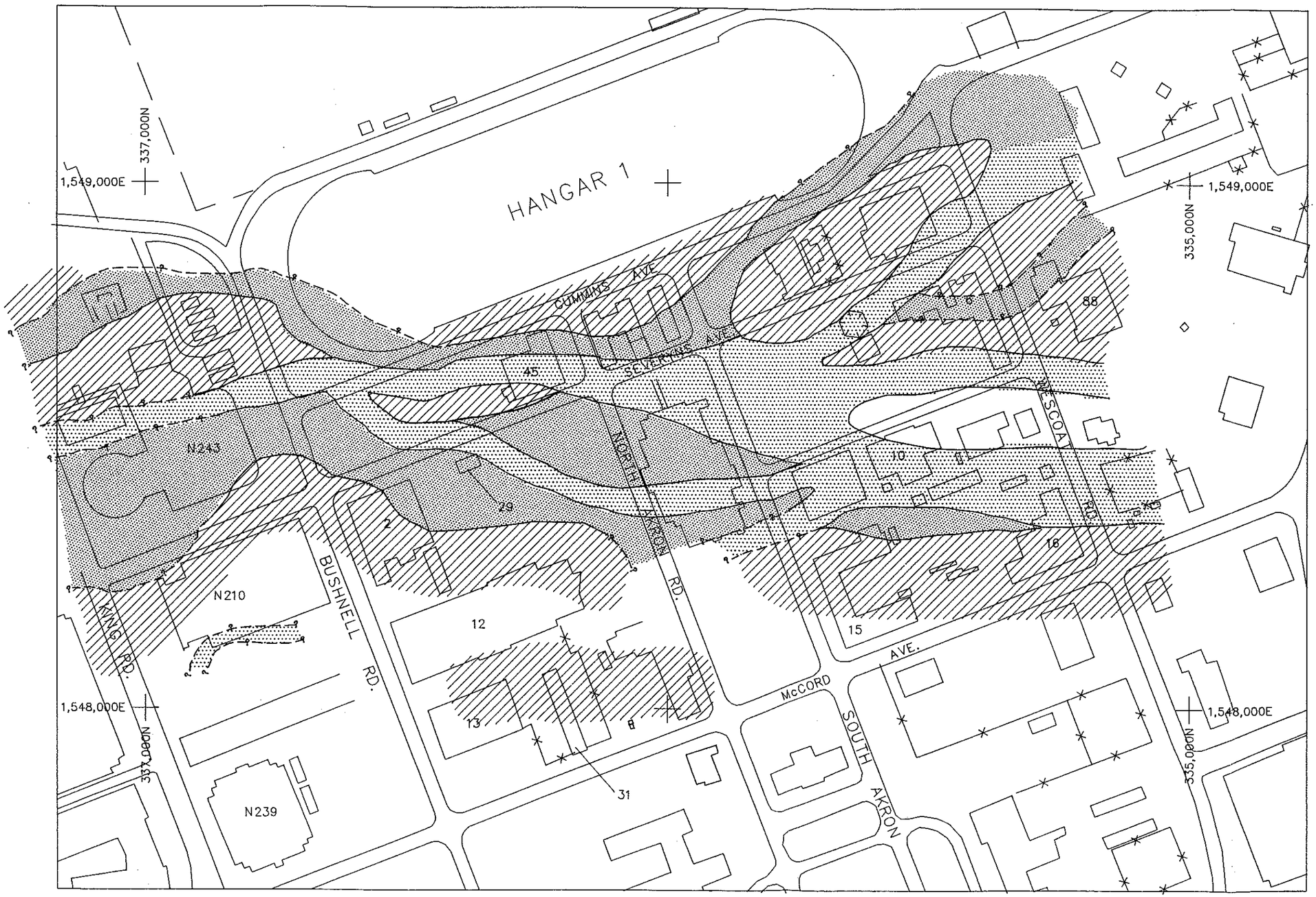

FIGURE 3
MOFFETT FEDERAL AIRFIELD
WEST-SIDE A1-ZONE CHANNEL MAP

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The groundwater flow direction in the A and B aquifers is generally northward toward San Francisco Bay, which is similar to the present topographic surface (Appendix A). Potentiometric surface maps (PRC and MW 1994a and 1994b) indicate that groundwater flow directions change slightly to the northwest near the northeastern side of Moffett Field. The horizontal groundwater flow gradient averages about 0.004 to 0.005 feet per feet (ft/ft) in the A and B aquifers (PRC 1992b). Hydraulic conductivity values estimated from aquifer tests (HLA 1988; PRC 1992b) are greater in the A aquifer (ranging from 5.7 to 420 feet per day [ft/day]) than in the B aquifer (0.35 to 36 ft/day). Analysis of aquifer tests conducted in the A2 zone at Site 9 (IT 1992) indicates hydraulic conductivity values of the coarse-grained material of approximately 30 to 200 ft/day. This is consistent with the overall coarsening-upward of sediment grain size observed from the B aquifer to the A aquifer. The vertical gradients between the B and overlying A aquifers are variable but are generally upward, and are likely the result of localized confining conditions (PRC 1992b).

The C aquifer is confined under a laterally extensive clay aquitard (B/C aquitard) present beneath Moffett Field between depths of 130 and 160 feet bgs. The groundwater flow direction for the C aquifer is northeast with a horizontal hydraulic gradient of about 0.0005 ft/ft (PRC 1992b). The vertical hydraulic gradient is directed upward from the C aquifer to the A and B aquifers below Moffett Field. The B/C aquitard is considered to be an effective barrier to any potential downward migration of contaminants from the shallower aquifers because the B/C aquitard is a thick, laterally continuous aquitard and the vertical hydraulic gradient is directed upward between the C and overlying aquifers.

3.0 REGULATORY CRITERIA

This section describes the regulatory requirements and cleanup levels applicable to the USTs and sumps in this CAP.

3.1 REGULATORY REQUIREMENTS

Investigation and closure of USTs and sumps at Moffett Field follow state and federal regulations cited in the FFA:

- Sections 6001, 7003, and 9007 of RCRA
- Title 40 Code of Federal Regulations (CFR) Part 280
- California Health and Safety Code Division 20, Chapters 6.5, 6.7, 6.75, and 6.8

- California Water Code Division 7
- Title 23 California Code of Regulations Division 3, Chapter 16 and water quality control plans, as applicable

Additionally, the state has prepared UST investigation and closure guidance (RWQCB 1990, 1991a, and 1994; SWRCB 1989 and 1993) which have been followed.

In addition to the above requirements, closure of USTs and sumps that contained wastewater will also consider the provisions of CERCLA. Since sampling and data collection activities at all Moffett Field sites have been consistently applied to address CERCLA requirements, the primary remaining CERCLA requirement for the wastewater USTs and sumps is to consider the data in a risk assessment. Therefore, data from wastewater USTs and sumps will be included in the Moffett Field station-wide risk assessment, which will be conducted during late 1994 and early 1995. Additional remedial activities may be recommended if any health risks are revealed.

Other state regulations may apply to the remedial technologies selected such as the Bay Area Air Quality Management District (BAAQMD) regulations, and other federal regulations such as the correction action management unit (CAMU) and temporary treatment tanks rule (Federal Register, Volume 58, page 8658) and the hazardous waste regulations (22 CCR Sections 66260 through 66270). These requirements will be evaluated separately for the various technologies presented in the CAP.

3.2 CLEANUP LEVELS

During June and July 1994, the Navy and regulatory agencies reached an agreement regarding acceptable cleanup levels for petroleum and petroleum-related constituents at Moffett Field. The agreement was reached after the Navy and regulatory agencies evaluated various cleanup levels, considering regulatory requirements, fate and transport, human health risks, social and economic benefits, and costs. The basis of the agreement is documented in a cleanup level analysis technical memorandum prepared by the Navy (PRC 1994b) and an agreement letter dated July 1, 1994 from DTSC to the Navy (DTSC 1994). The technical memorandum outlines general total petroleum hydrocarbon (TPH) cleanup levels for Moffett Field. The agreement letter from DTSC confirms the TPH cleanup levels and adds constituent cleanup levels. The following summarizes the petroleum cleanup levels agreed upon for Moffett Field:

- Soil and groundwater TPH cleanup levels proposed in Scenario B in the cleanup level analysis technical memorandum will be used. Scenario B includes:

  Soil: 150 milligrams per kilogram (mg/kg) for TPH purgeable as gasoline
  400 mg/kg for TPH extractable as diesel fuel or JP-5

  Groundwater: 50 micrograms per liter (μg/L) for TPH purgeable as gasoline
  700 μg/L for TPH extractable as diesel fuel or JP-5

- Individual benzene, toluene, ethylbenzene, and xylene (BTEX) cleanup levels for soils will be included. These levels will coincide with EPA Region 9's most recent risk-based preliminary remediation goals (PRGs) for the industrial scenario (EPA 1994). The EPA Region 9 industrial PRGs for BTEX are:

Benzene:	4.4 mg/kg
Toluene:	2,700 mg/kg
Ethylbenzene:	3,100 mg/kg
Xylene:	980 mg/kg

- The groundwater cleanup goals will be set at MCLs for BTEX and all other constituents of concern. BTEX levels include:

Benzene:	1 μg/L
Toluene:	680 μg/L
Ethylbenzene:	1,000 μg/L
Xylene:	1,750 μg/L

- Data from the petroleum sites revealed one PAH detection (benzo[a]pyrene) in soils at one site (Site 12). Since benzo(a)pyrene has not been detected in soils at other petroleum sites, DTSC agreed with the Navy not to include PAHs with the soil cleanup levels. The decision is based on the site specific information provided by the Navy, and is not contradictory with DTSC's policy of setting risk-based individual constituent cleanup goals. It was agreed, however, that samples would be analyzed for PAHs during future confirmation sampling. Should PAHs be detected (in the near surface soils where exposures could occur), the Navy will cleanup the PAHs to EPA Region 9 industrial based PRGs.

Based on the Navy's evaluation of cleanup level options, the TPH cleanup levels for soil and groundwater represented by Scenario B meet risk-based concentrations for residential scenarios. Individual constituent cleanup levels for groundwater are set at MCLs to meet drinking water standards. Individual constituent cleanup levels for soils are set at EPA's PRGs for industrial scenarios. Therefore, the cleanup levels apply to all land use conditions (residential to industrial), with the exception of individual constituents in soils, which represent industrial use conditions. The current land use at Moffett Field is industrial-based. If future land uses become more conservative (such as residential), individual constituent concentrations remaining in soils should be compared to current EPA residential PRGs or addressed through a health risk analysis to evaluate if remedial activities are warranted.

Additional requirements by the state include using groundwater monitoring systems (at sites with groundwater contamination) capable of monitoring the uppermost (A1)-aquifer zone. Wells will be screened across the water table to detect the presence of petroleum products. Groundwater data will be presented in quarterly groundwater monitoring reports which are currently prepared by the Navy. These reports will be reviewed by the regulatory agencies to evaluate the effectiveness of remedial activities.

4.0 SUMMARY OF INVESTIGATIONS

This section summarizes previous activities and investigations at petroleum Sites 5, 9, 12, 14, 15, and 19. Included are descriptions of the history of each site and brief descriptions of previous sampling results. More detailed information regarding the nature and extent of contamination can be found in the following documents:

- Revised Final Installation Restoration Program Petroleum Sites (and Wastewater Tanks and Sumps) Characterization Report (PRC 1994a)
- Additional Petroleum Sites Investigation Technical Memorandum (PRC 1994c)
- Technical Memorandum Site 14 South Evaluation (PRC 1994d)
- Site 12 Source Control Measure Final Action Technical Memorandum (PRC and MW 1994c)

The IRP petroleum sites are briefly described below along with a summary of conclusions from the associated reports. A summary of contamination at Sites 5, 9, 12, 14, 15, and 19 is provided in Table 1. Figures depicting areas of TPH contamination above cleanup levels for each site have also been provided. The areas of TPH contamination in the figures coincide with detections of other TPH constituents (such as BTEX), and therefore, additional figures depicting the extent of other TPH constituents have not been included. Furthermore, only the data values for sample results above the cleanup levels are presented in the figures; data results for samples outside the contamination areas are below cleanup levels. Additional information regarding all sample locations, analytical results, and detailed explanations of the nature and extent of contamination can be found in the referenced reports. In the future, complete data tables will be provided in closure reports and full-scale corrective measure designs, since these data are required to prepare these documents.

TABLE 1

MOFFETT FEDERAL AIRFIELD
IRP PETROLEUM SITES
SUMMARY OF CONTAMINATION

SITE	IRP TANK/ SUMP	STATUS	SOIL				GROUNDWATER			
			CONTAMINANT TYPE	DEPTH[1] INTERVAL (ft bgs)	SURFACE[3] AREA (ft^2)	VOLUME (yd^3)	CONTAMINANT TYPE	DEPTH[2] INTERVAL (ft bgs)	SURFACE[3] AREA (ft^2)	VOLUME[4] (gal)
SITE 5	4	Inactive (R)	None	0	0	0	None	0	0	0
	5	Inactive (R)					TPH-Ext	7 to 17	7,500	561,000
	6	Inactive (R)					None	0	0	0
	7	Inactive (R)								
	8	Inactive (R)								
	9	Inactive (R)	TPH-Ext	6 to 13	6,000	1,600				
	10	Active	None	0	0	0				
	11	Active								
	12	Active								
	13	Active								
	18	Removed (AI)	Unknown	-	-	-				
	26	Removed	None	0	0	0				
	30	Removed								
	31	Removed								
	72	Active								
	73	Active								
	74	Active								
	75	Active								
	Former Dry Wells		TPH-Ext	6 to 13	165,000	42,800	TPH-Ext	7 to 17	45,400	1,360,000

TABLE 1 (Continued)

MOFFETT FEDERAL AIRFIELD
IRP PETROLEUM SITES
SUMMARY OF CONTAMINATION

SITE	IRP TANK/ SUMP	STATUS	SOIL				GROUNDWATER			
			CONTAMINANT TYPE	DEPTH[1] INTERVAL (ft bgs)	SURFACE[3] AREA (ft^2)	VOLUME (yd^3)	CONTAMINANT TYPE	DEPTH[2] INTERVAL (ft bgs)	SURFACE[3] AREA (ft^2)	VOLUME[4] (gal)
SITE 9	47	Removed	TPH-Pur	8 to 15	166,400	43,100	TPH-Pur, Benzene	9 to 19	256,500	7,674,500
	48	Removed								
	49	Removed								
	50	Removed								
	52	Removed								
	79	Removed								
	80	Removed								
	81	Removed								
	82	Removed								
	83	Removed								
	84	Removed								
	97	Removed								
	98	Removed								
	99	Removed								
	56A	Removed	TPH-Pur	8 to 15	107,100	27,800	TPH-Pur, Benzene	9 to 19	114,800	3,434,800
	56B	Removed								
	56C	Removed								
	56D	Removed								

TABLE 1 (Continued)

MOFFETT FEDERAL AIRFIELD
IRP PETROLEUM SITES
SUMMARY OF CONTAMINATION

SITE	IRP TANK/ SUMP	STATUS	SOIL				GROUNDWATER			
			CONTAMINANT TYPE	DEPTH[1] INTERVAL (ft bgs)	SURFACE[3] AREA (ft^2)	VOLUME (yd^3)	CONTAMINANT TYPE	DEPTH[2] INTERVAL (ft bgs)	SURFACE[3] AREA (ft^2)	VOLUME[4] (gal)
SITE 12	Former Fire Fighting Training Area (AI)		TPH-Ext	7 to 14	Unknown	-	Unknown	-	-	-
SITE 14	19	Removed	TPH-Pur, Benzene	15 - 25	13,500	5,000	TPH-Pur, benzene, toluene	16 to 26	18,700	559,500
	20	Removed								
SITE 15	25	Removed (AI) (NEX)	TPH-Pur	Unknown	-	-	Unknown	-	-	-
	42	Removed (AI) (NEX)								
	54	Removed	None	0	0	0	None	0	0	0
	58	Removed (AI)	TPH-Pur, TPH-Ext	7 - 14	Unknown	-	Unknown	-	-	-
	59	Active	None	0	0	0	None	0	0	0
	62	Inactive								
	63	Inactive								
	64	Removed								
	130	Inactive								

TABLE 1 (Continued)

MOFFETT FEDERAL AIRFIELD
IRP PETROLEUM SITES
SUMMARY OF CONTAMINATION

SITE	IRP TANK/ SUMP	STATUS	SOIL				GROUNDWATER			
			CONTAMINANT TYPE	DEPTH[1] INTERVAL (ft bgs)	SURFACE[3] AREA (ft^2)	VOLUME (yd^3)	CONTAMINANT TYPE	DEPTH[2] INTERVAL (ft bgs)	SURFACE[3] AREA (ft^2)	VOLUME[4] (gal)
SITE 19	2	Removed	TPH-Pur, TPH-Ext	7 to 14	300	80	TPH-Ext (VOC-OU5)	8 to 18	400	12,000
	14	Removed	TPH-Ext	6	<10	<1	None	0	0	0
	43	Removed	TPH-Ext	8 to 15	2,400	600	TPH-Pur, TPH-Ext (VOC-OU5)	9 to 19	9,900	296,200
	53	Removed	TPH-Pur	8 to 15	1,400	360	None	0	0	0

Notes:

[1] Depth intervals for soils were estimated from sample depths and the groundwater potentiometric surface. It was assumed that most of the soil contamination was transported by groundwater and resides from the top of the capillary fringe zone to several feet below the groundwater table (an estimated 7 feet thick). In the immediate vicinity of a source, however, soil contamination may extent from the near surface to several feet below the groundwater table.

[2] Depth intervals for groundwater were estimated using the potentiometric surface and a 10-foot mixing zone.

[3] Surface areas were estimated using the maximum rectangular area of the contaminated areas indicated in the respective figures in this CAP.

[4] Groundwater volumes were estimated using an average porosity of 0.40.

(AI) Additional investigation required.

(NEX) These sites are included with NEX service station investigation and corrective measures.

(R) Scheduled for removal in spring 1995.

(VOC-OU5) Volatile organic compounds detected and being addressed in the Operable Unit 5 remedial investigation/feasibility study.

TPH-Pur Total petroleum hydrocarbon (TPH) purgeable as gasoline

TPH-Ext TPH extractable as diesel/JP-5

bgs Below ground surface

ft^2 Square feet

yd^3 Cubic yards

gal Gallons

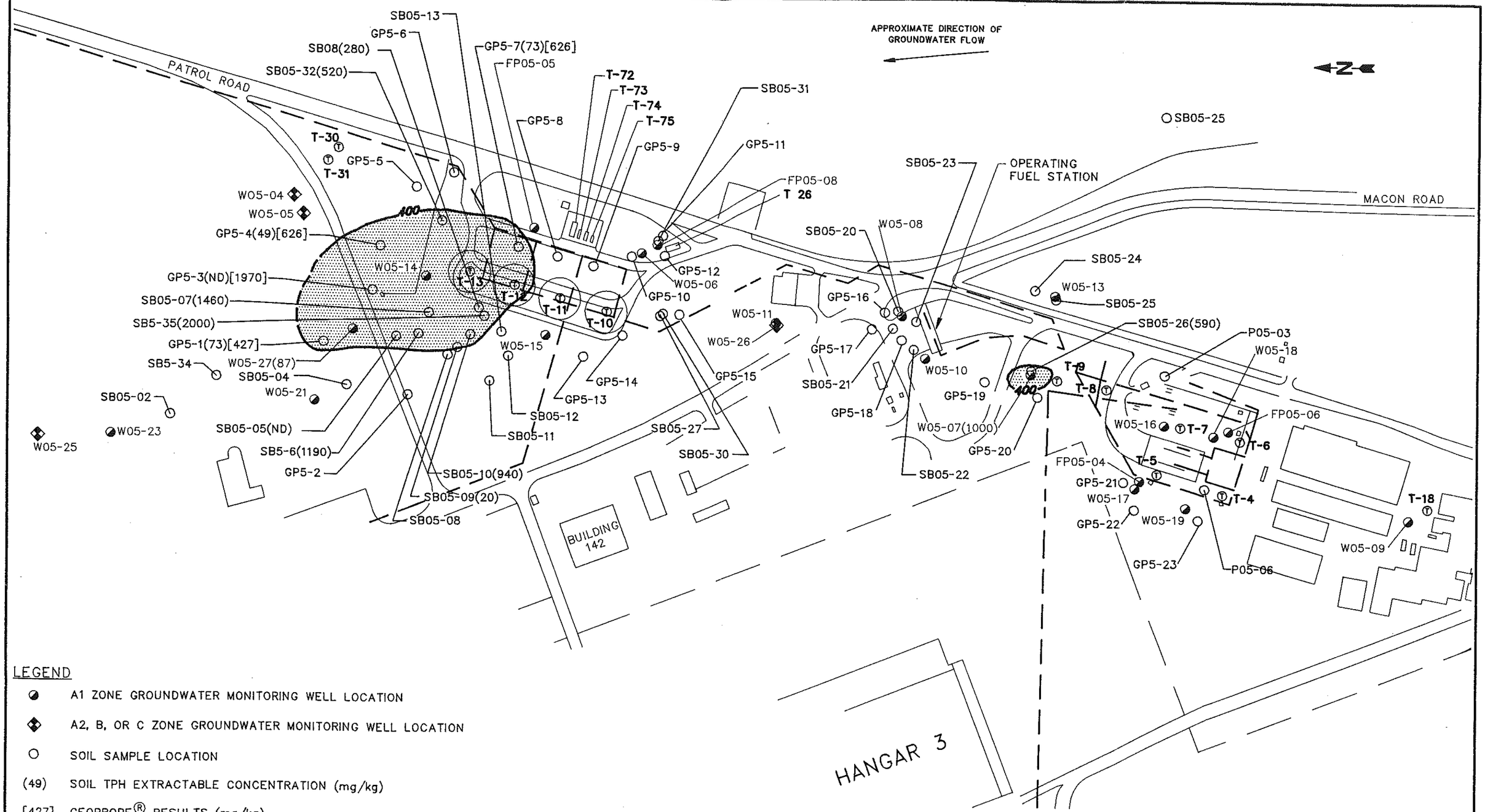
4.1 SITE 5

Site 5, known as the Fuel Farm, operates as the main fuel facility for Moffett Field. This site includes 14 USTs and 4 ASTs; eight of which are active (USTs 10, 11, 12, 13 and ASTs 72, 73, 74, and 75), six are inactive and scheduled for removal (USTs 4, 5, 6, 7, 8, and 9), two were removed (USTs 18 and 26), and two were never used and were also removed (USTs 30 and 31). The site is separated into northern and southern sections. The northern area is located in the triangular area bordered by Macon Road, Patrol Road, and the golf course. The southern area is bounded by a road to the east (unnamed), aircraft aprons to the south and west, and Hangar 3 to the north (Plate 1).

Subsurface soils under the northern area have been affected by TPH extractable contamination. The primary source of contamination is JP-5 jet fuel and diesel which have been released to soils via surface spills, prior use of dry wells for disposal of fuel/water waste, and possibly through leaking fuel lines. USTs 10, 11, 12, and 13 have been tested for leaks and have been found to be in tight condition. No detections of BTEX above soil cleanup levels were found at Site 5. Most of the contaminant mass appears to reside in the capillary fringe zone at depths of 6 to 11 feet bgs, though some shallower contamination also exists near a known surface spill at Tank 12. Figure 4 shows the estimated extent of soil contamination at Site 5.

The largest area of contaminated soils is in the northern half of the fuel farm from former dry wells near USTs 11, 12, and 13. Numerous soil samples downgradient of these USTs had TPH extractable concentrations over 1,000 mg/kg, with the highest concentration of 2,000 mg/kg measured in a sample from boring SB5-35. An area with TPH concentrations greater than 400 mg/kg extends approximately 500 feet from north to south and about 300 feet from east to west around these tanks.

Other soil-contaminated areas above cleanup levels exist at Site 5, though of a more limited extent. Tank 26 had an excavation sidewall sample that measured at 5,200 mg/kg TPH extractable, though nearby soil samples were nondetect or less than 10 mg/kg TPH extractable. (The area of soil contamination near Tank 26 is of such limited extent that it could not be plotted on Figure 4.) Soil TPH extractable concentrations have been measured at 590 mg/kg (SB05-26) and 1,000 mg/kg (W05-07) near Tank 9, probably due to the prior use of an adjacent dry well. Tank 9 will be removed in early 1995; samples will be collected to evaluate the nature and extent of contamination. These soil data have been previously reported in the petroleum sites characterization report (PRC 1994a) and the additional petroleum sites investigation technical memorandum (PRC 1994c).



LEGEND

- A1 ZONE GROUNDWATER MONITORING WELL LOCATION
- A2, B, OR C ZONE GROUNDWATER MONITORING WELL LOCATION
- SOIL SAMPLE LOCATION
- (49) SOIL TPH EXTRACTABLE CONCENTRATION (mg/kg)
- [427] GEOPROPE® RESULTS (mg/kg)
- ESTIMATED AREA EXCEEDING 400 mg/kg TPH-EXTRACTABLE CLEANUP LEVEL
- FUEL LINE
- T-30 UNDERGROUND STORAGE TANK

100' 0 100' 200'
SCALE: 1" = 200'

FIGURE 4
MOFFETT FEDERAL AIRFIELD
SITE 5
AREA OF SOIL CONTAMINATION
ABOVE CLEANUP LEVELS

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Groundwater in the A1-aquifer zone at Site 5 has also been affected by fuel contamination (TPH extractable). The source of the contaminated groundwater regions appears to be contaminated soils in the capillary fringe (smear zone) and free product which has been detected downgradient of Tank 12. Figure 5 shows the estimated TPH contamination plumes for groundwater at Site 5. The A2 and deeper aquifer zones are not affected by petroleum contamination based on available data. No detections of BTEX above groundwater cleanup levels were found.

The region of highest groundwater contamination corresponds to the most contaminated soil region near Tanks 11, 12, and 13. Five groundwater samples had TPH extractable detections of 1,000 μg/L or greater, including 2,000,000 μg/L at FP05-01, 10,000 μg/L at HP5-3, and 6,200 μg/L at HP5-10. Approximately 2 inches of floating free product were recently detected in well FP05-01 (though no measurable product layer currently exists), and high groundwater TPH concentrations there are most likely due to this free product. Lithologic logging of soil borings indicate the presence of a shallow paleochannel just west of groundwater monitoring wells FP05-01 and W5-35 (Figure 6). The channel appears to be variably saturated, with its degree of saturation depending on rainfall and evapotranspiration. This channel may provide a pathway for fuel migration downgradient to the north, and may contribute to the contamination pattern observed in Figure 5. Though less permeable soils surround the tanks, fuels have apparently migrated through thin sand stringers or through finer-grained soils to the paleochannel. A deeper, saturated paleochannel also exists west of the tanks as seen in Figure 6. Regions to the east and west of these channels contain lower permeability aquifer materials and TPH extractable concentrations in groundwater are low or not detected. Figure 7 depicts a cross section of the paleochannel.

The only other region of groundwater contamination above cleanup levels is near Tank 5 with TPH as motor oil detected at 1,900 μg/L (well W05-17). UST 5 will be removed in early 1995; samples will be collected to evaluate the nature and extent of contamination. Additional groundwater monitoring is also recommended to evaluate if corrective measures are warranted at UST 5.

In summary, three areas of TPH extractable soil or groundwater contamination exist at Site 5: (1) former dry wells near USTs 11, 12, and 13; (2) near UST 9; and (3) near UST 5. Corrective measures and monitoring are recommended for these areas. USTs 10, 11, 12, and 13 and ASTs 72, 73, 74, and 75 were not identified as sources; these tanks are recommended for elimination from the petroleum sites program since they are active and cannot be closed. USTs 4, 5, 6, 7, 8, and 9 will be removed and investigated in early 1995. UST 18 was removed during summer 1994 and removal data are not available yet. USTs 30 and 31 were not used and removed and UST 26 was removed and only minor contamination remains; these USTs are recommended for closure.

PATROL ROAD

MACON ROAD

OPERATING FUEL STATION

APPROXIMATE DIRECTION OF GROUNDWATER FLOW

BUILDING 142

HANGAR 3

T-72 T-73 T-74 T-75 T-30 T-31 T-26 T-13 T-12 T-11 T-10 T-9 T-8 T-7 T-6 T-5 T-4 T-18

HP5-1 HP5-2 HP5-3(10,000) HP5-4 HP5-5 HP5-6 HP5-7 HP5-8 HP5-9 HP5-10(6200) HP5-11(1000) HP5-12 HP5-13 HP5-14 HP5-15 HP5-16 HP5-17 HP5-18 HP5-19 HP5-20 HP5-21

FP05-01(2,000,000)[1] FP05-02 FP05-03 FP05-04(740) FP05-05(1200)[1] FP05-06 FP05-07 FP05-08 FP05-09

W05-04 W05-05 W05-06 W05-07 W05-08 W05-09 W05-10 W05-11 W05-12 W05-13 W05-14 W05-15 W05-16 W05-17(1900) W05-18 W05-19 W05-20 W05-21 W05-23 W05-25 W05-26 W05-27 W5-34(57)[1] W5-35

700

LEGEND

- A1 ZONE GROUNDWATER MONITORING WELL LOCATION
- A2, B, OR C ZONE GROUNDWATER MONITORING WELL LOCATION
- (740) GROUNDWATER TPH EXTRACTABLE CONCENTRATION (µg/L)
- ESTIMATED AREA EXCEEDING 700 µg/L TPH-EXTRACTABLE CLEANUP LEVEL
- FUEL LINE
- T-30 UNDERGROUND STORAGE TANK
- HYDROPUNCH SAMPLE LOCATION
- 1 NOVEMBER/DECEMBER 1993 QUARTERLY SAMPLES

100' 0 100' 200'
SCALE: 1" = 200'

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FIGURE 5
MOFFETT FEDERAL AIRFIELD
SITE 5-A1 ZONE
AREA OF GROUNDWATER CONTAMINATION
ABOVE CLEANUP LEVELS

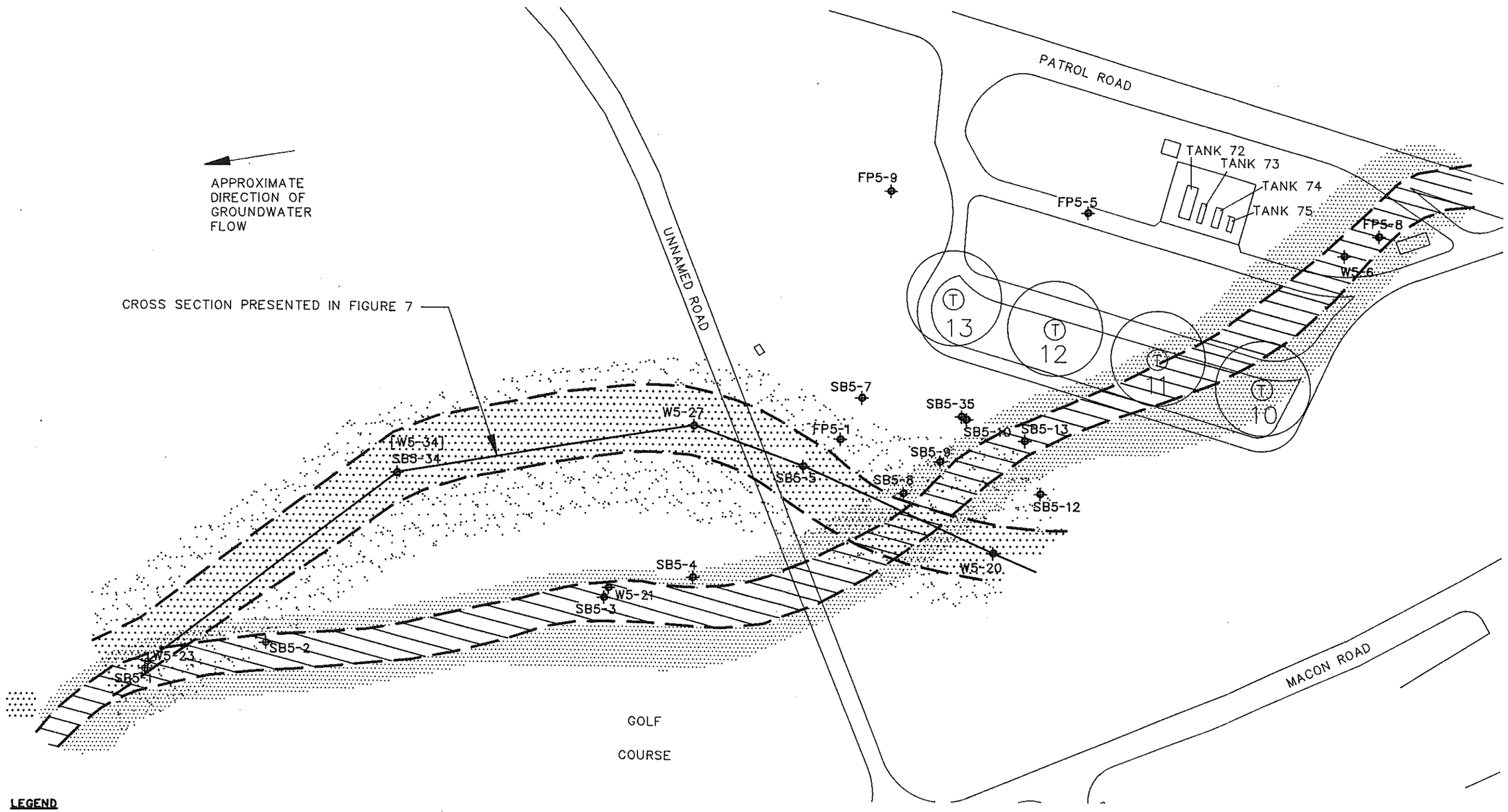

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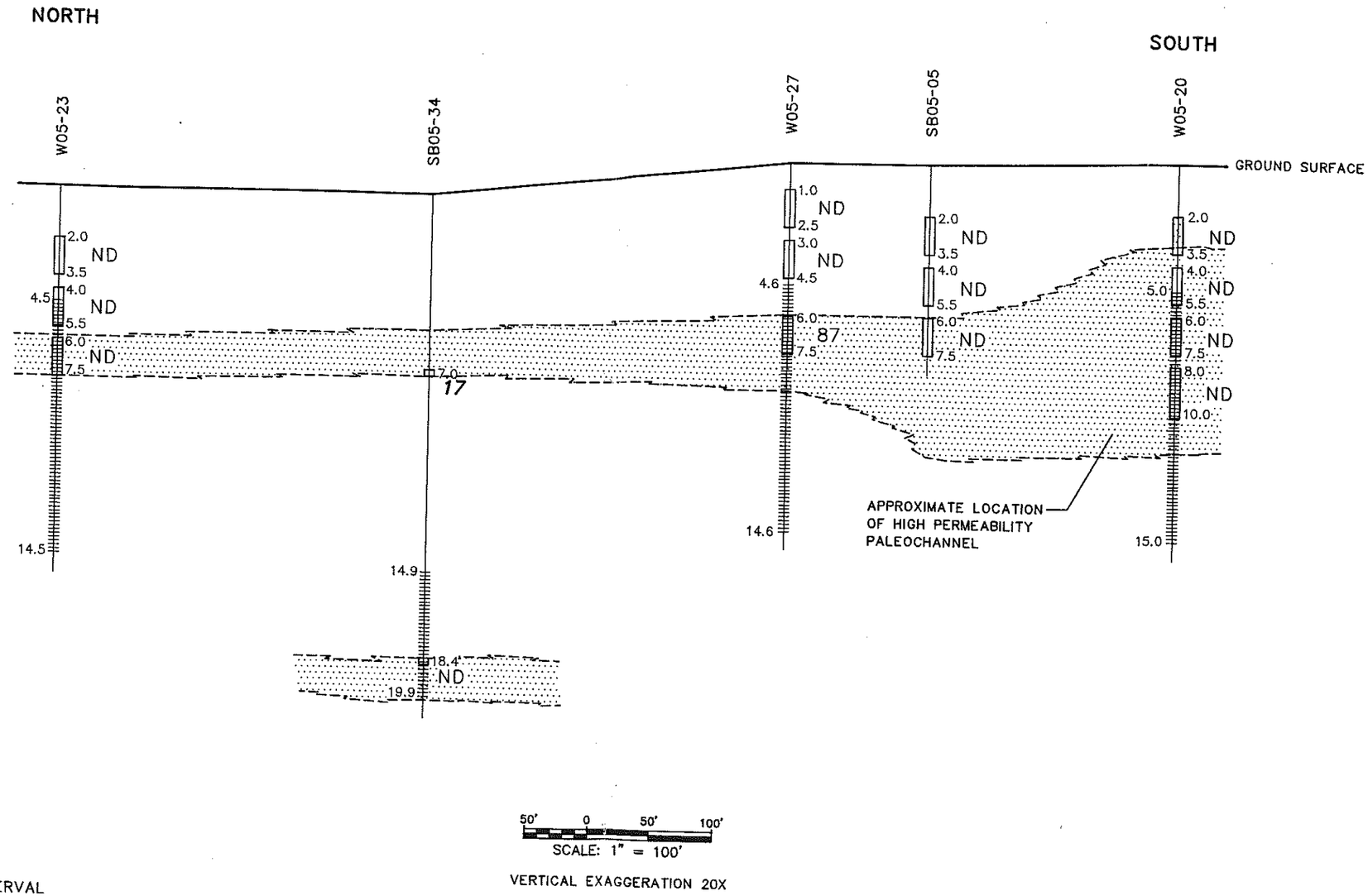
FIGURE 6
MOFFETT FEDERAL AIRFIELD
SITE 5 PALEO CHANNEL MAP



LEGEND

- MONITORING WELL SCREEN INTERVAL
- 14.5 DEPTH BELOW GROUND SURFACE
- *17* TPH CONCENTRATION (mg/kg)
- SOIL SAMPLE INTERVAL
- ND TPH NOT DETECTED

NOTES

1. 26 µg/L TPH OTHER LIGHT COMPONENTS AT W05-23 IN DECEMBER 1992.
2. 57 µg/L TPH OTHER HEAVY COMPONENTS AT W5-34 IN FEBRUARY 1994.
3. TPH NOT DETECTED AT W05-27 IN FEBRUARY 1994.
4. TPH NOT DETECTED AT W05-20 IN DECEMBER 1992.

FIGURE 7
MOFFETT FEDERAL AIRFIELD
SITE 5 - SHALLOW
PALEOCHANNEL CROSS SECTION

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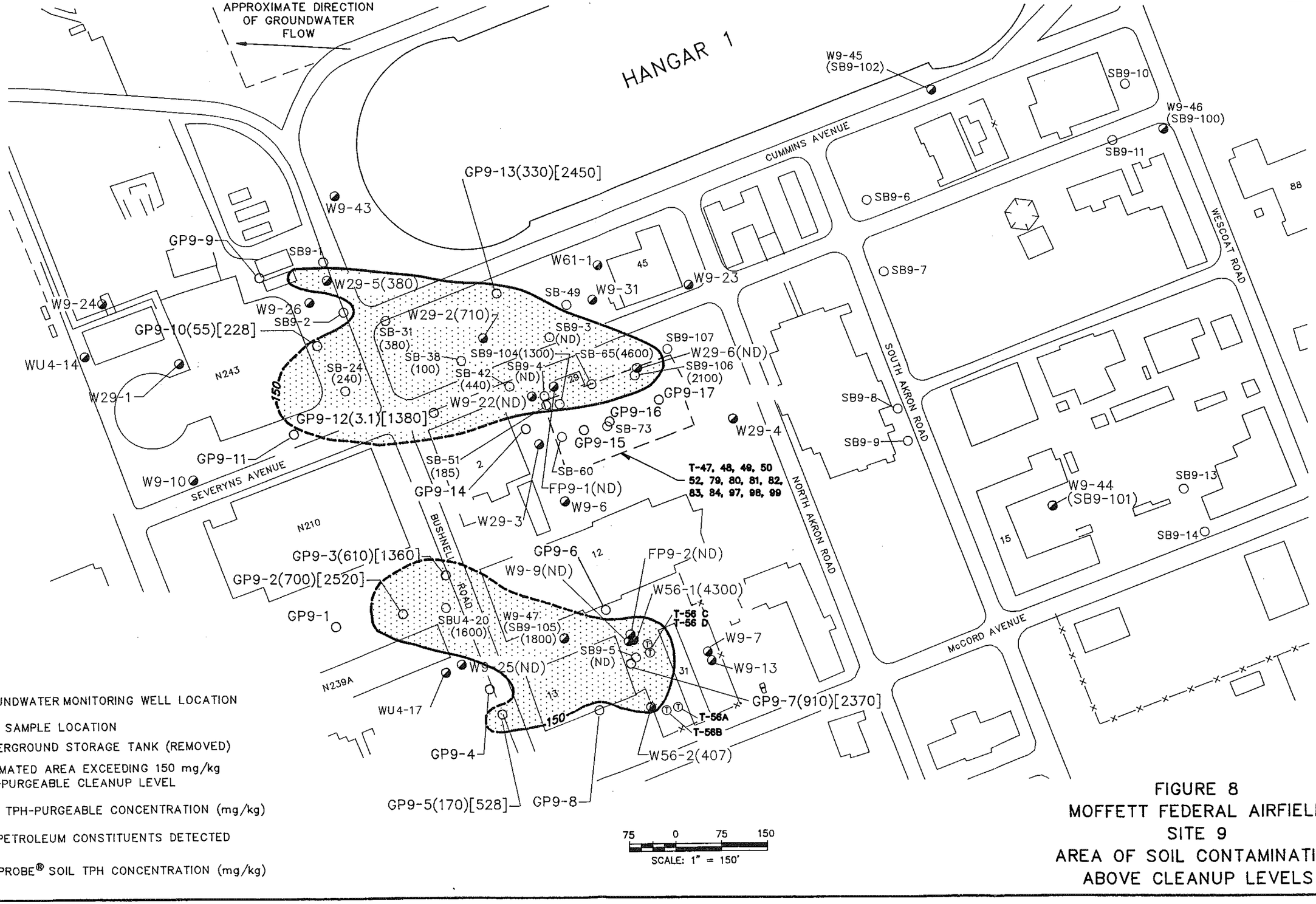
4.2 SITE 9

Site 9 encompasses approximately 11 acres on the western side of Moffett Field. Site 9 generally includes the area approximately bounded by McCord Avenue on the west, Hangar 1 on the east, Bushnell Road on the north, and North Akron Road on the south. Two areas of petroleum storage have previously been located within this area. These two areas are known as the Building 29 and Building 31 areas.

Subsurface soils at Site 9 have been contaminated by fuels from leaking pipes and USTs. Two known areas of soil contamination exist: (1) an area around the old fuel farm at Building 29 and (2) an area around the old naval exchange (NEX) gasoline station near Building 31. (A third area around USTs 1 and 32 next to Building 10 was identified, however, the Building 10 area is not part of IRP Site 9 and will be addressed in a separate CAP). Both of these areas contained USTs which have all been removed. Contamination resides in the capillary fringe at depths of about 8 to 10 feet bgs. Figure 8 shows the estimated extent of soil contamination at Site 9.

Building 29 and the surrounding area is the site of the old fuel farm. Aviation gasoline (AVGAS) was stored in 13 USTs (USTs 47, 48, 49, 50, 79, 80, 81, 82, 83, 84, 97, 98, and 99) and one AST (Tank 52). Numerous soil samples in the vicinity exhibit TPH concentrations in excess of 1,000 mg/kg, including 4,600 mg/kg TPH as diesel at boring SB-65 and 2,450 mg/kg TPH as gasoline at Geoprobe® location GP9-13. Soil contamination apparently has spread north of the Building 29 source area, with an area of approximately 600 feet (north to south) by 250 feet (east to west) with TPH concentrations over 150 mg/kg. No BTEX constituents were detected in soil samples from the Building 29 area above soil cleanup levels.

Four former tanks (Tanks 56A, B, C, and D) and piping just north of Building 31 were potential sources of gasoline contamination in soils. Soil TPH purgeable concentrations have been measured at more than 2,000 mg/kg at four sample locations, including 4,570 mg/kg at the Tanks 56C/D excavation west sidewall and 4,300 mg/kg at the boring for well W56-1 (PRC 1991a and 1993b). An area of soil contaminated at more than 1,000 mg/kg TPH purgeable extends north of the Tanks 56C/D excavation area about 400 feet and is approximately 100 feet wide east to west. No BTEX constituents were detected in soil samples from the Building 31 area above cleanup levels. Site 9 soil data were reported in the petroleum sites characterization report (PRC 1994a) and the additional petroleum sites investigation technical memorandum (PRC 1994c).



LEGEND

- GROUNDWATER MONITORING WELL LOCATION
- SOIL SAMPLE LOCATION
- T-47 (T) UNDERGROUND STORAGE TANK (REMOVED)
- ESTIMATED AREA EXCEEDING 150 mg/kg TPH-PURGEABLE CLEANUP LEVEL
- (610) SOIL TPH-PURGEABLE CONCENTRATION (mg/kg)
- (ND) NO PETROLEUM CONSTITUENTS DETECTED
- [1360] GEOPROBE® SOIL TPH CONCENTRATION (mg/kg)

FIGURE 8
MOFFETT FEDERAL AIRFIELD
SITE 9
AREA OF SOIL CONTAMINATION
ABOVE CLEANUP LEVELS

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Petroleum contamination in the A1-aquifer zone exists at near Buildings 29 and 31 at Site 9. The groundwater plumes correspond with, and generally underlie, the soil contamination areas described above. As with soils, the contaminant of concern is AVGAS, which includes the BTEX constituents. Most TPH detections in groundwater have been qualified as TPH "other light components" because the weathered gasoline in the samples does not match the fresh gasoline standard chromatograms within 90 percent. The A2-aquifer zone appears to be uncontaminated with respect to petroleum.

BTEX constituents were detected in samples collected from wells within both TPH plumes at Site 9. Benzene concentrations ranged from nondetect to a maximum of 940 μg/L in a sample from well FP9-1 collected during July 1994. Toluene concentrations ranged from nondetect to a maximum of 380 μg/L in a sample from well W9-47 collected during August 1994. Ethylbenzene concentrations ranged from nondetect to a maximum of 920 μg/L in a sample also collected from well W9-47 during August 1994. Xylene concentrations ranged from nondetect to a maximum of 990 μg/L in a sample also collected from well W9-47 during August 1994. The maximum BTEX concentrations described above are from wells FP9-1 and W9-47 which are extraction wells for the Buildings 12 and 45 groundwater treatment systems (Site 9 SCM). With the exception of benzene, the BTEX constituent concentrations are below their associated cleanup levels.

The Building 29 TPH groundwater plume has been sampled at numerous points with detections of TPH greater than 1,000 μg/L. The highest recent detection of TPH is 12,000 μg/L in a groundwater sample from well FP9-1. This plume originates at the old fuel farm tank area and extends northward (downgradient) for approximately 850 feet. The Building 31 plume also encompasses samples from wells which have TPH detections greater than 1,000 μg/L. The highest recent TPH concentrations detected are 4,600 μg/L in a sample from well W56-1 and 3,800 μg/L in a sample from well W9-47. This plume originates at the old NEX gasoline station tank area and extends approximately 450 feet downgradient. Figure 9 shows estimated TPH concentration contours for the Buildings 29 and 31 groundwater plumes.

In summary, two areas of TPH purgeable contamination exist at Site 9: (1) near the former USTs at Building 29 and (2) near the former USTs at Building 31. Corrective measures are recommended for these areas.

APPROXIMATE DIRECTION OF GROUNDWATER FLOW

HANGAR 1

CUMMINS AVENUE

SEVERYNS AVENUE

BUSHNELL ROAD

WESCOAT ROAD

SOUTH AKRON ROAD

NORTH AKRON ROAD

McCORD AVENUE

W9-43[1]
W29-5(1200)[2]
W9-27
W9-11
W9-24
W9-26(1200)[2]
W29-2(860)[4]
W29-1(1000)[4]
WU4-14
W29-6(2800)[2]
W9-22
FP9-1(12000)[3]
W9-45 (SB9-102)
W9-46 (SB9-10)
W61-1
W9-28
W9-31
W9-23
W29-4
W9-36
W9-33
W9-3
W9-44
W9-40
W9-8
W29-9
W29-3
W9-6
W9-1
T-47, 48, 49, 50, 52, 79, 80, 81, 82, 83, 84, 97, 98, 99
FP9-2(NS)
W9-10
W9-5
W9-4
WU4-17(2200)[4]
W9-47(3500)[1]
W9-9
W56-1(4600)[2]
T-56C
T-56D
W9-7
W9-13
W9-25
W9-39
T-56A
T-56B
W56-2(1000)[2]

N243
N210
N239A
50
45
29
12
13
31
10
15
88

LEGEND

- A1-ZONE GROUNDWATER MONITORING WELL LOCATION
- (1200) GROUNDWATER TPH CONCENTRATION IN $\mu g/L$
- T-47 (T) UNDERGROUND STORAGE TANK (REMOVED)
- 1 SEPT.-OCT. 1993 QUARTERLY SAMPLING
- 2 MAY-JUNE 1993 QUARTERLY SAMPLING
- 3 MAY-JUNE 1992 QUARTERLY SAMPLING
- 4 FEBRUARY-MARCH 1994 QUARTERLY SAMPLING
- ESTIMATED AREA EXCEEDING 50 mg/L TPH-PURGEABLE CLEANUP LEVEL

75 0 75 150
SCALE: 1" = 150'

FIGURE 9
MOFFETT FEDERAL AIRFIELD
SITE 9 A1-ZONE
AREA OF GROUNDWATER CONTAMINATION ABOVE CLEANUP LEVELS

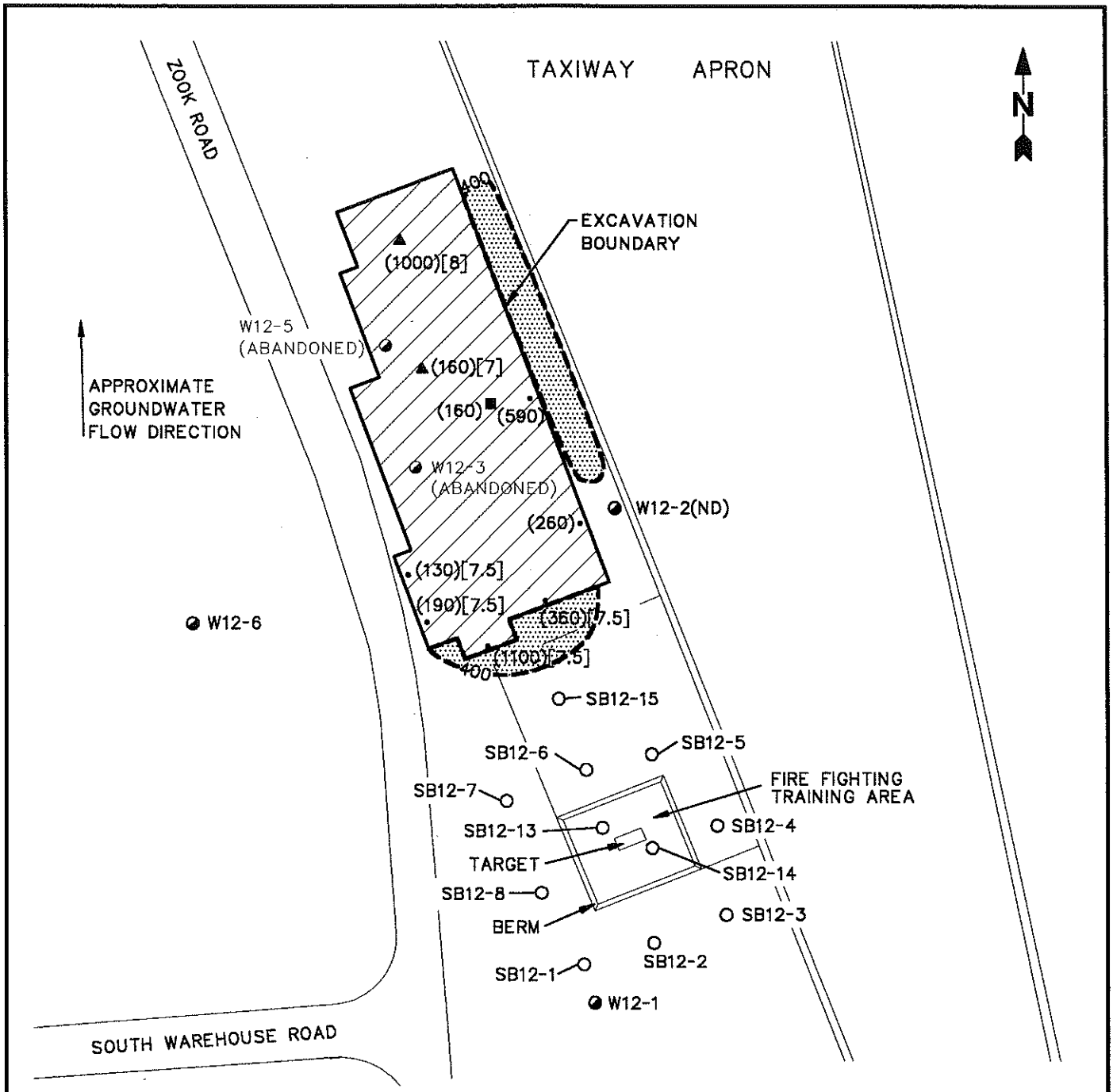
DATE: 08/24/94 KRS DN FILE NAME: 044\0238\RP\SRP\SB-WATER.DWG

4.3 SITE 12

The former Navy fire-fighting training area, known as Site 12, is located north of Hangar 1 between Zook Road and the west parallel taxiway. Subsurface soils have been contaminated with jet fuels spilled during training activities (PRC and MW 1993a). Approximately 5,500 cubic yards of soils were excavated in November and December 1993 as part of a source control measure (SCM) (PRC and MW 1994c). The majority of this soil has been treated to reduce TPH extractable concentrations to less than the 100 mg/kg treatment goal, and these soils have been backfilled. In addition, other soils with TPH extractable levels less than 150 mg/kg were also backfilled after obtaining concurrence from RWQCB. The Site 12 SCM Final Action Technical Memorandum summarizes these activities (PRC and MW 1994c). Not all contaminated soils were removed as excavation limits were imposed by proximity to Zook Road and the west parallel taxiway, and final excavation sidewall samples indicate that soil TPH extractable concentrations above 400 mg/kg remain at Site 12. Soil TPH levels at the northern end of the pit bottom have been measured up to 1,000 mg/kg TPH extractable as kerosene. Sidewall samples adjacent to the taxiway contained up to 590 mg/kg TPH extractable as JP-5. Sidewall samples at the southern end of the pit were measured up to 1,100 mg/kg TPH as kerosene. BTEX constituents were not detected above soil cleanup levels at Site 12. Figure 10 shows excavation boundaries and soil sample TPH concentrations. The TPH contamination extended to approximately 9 feet bgs. The horizontal extent of soil contamination in these areas is not defined because of the proximity of Zook Road and the west parallel taxiway.

Groundwater does not appear affected at Site 12 based on current data. Samples from all six monitoring wells, including two wells formerly located in the excavation area, had no detectable levels of TPH contaminants. One water sample collected from a puddle in the bottom of the excavation pit contained 160 μg/L TPH extractable though it is not clear that this puddle was hydraulically connected to the A1-aquifer zone. No BTEX constituents were detected above groundwater cleanup levels. Additional monitoring wells have been recommended based on the results of the SCM. Existing monitoring well locations are also shown in Figure 10.

In summary, additional investigation and monitoring is recommended at Site 12 before additional corrective measures and closure can be proposed. A work plan for the additional investigation was submitted to the regulatory agencies (PRC 1994h) and field work is scheduled for November 1994.



LEGEND

- SOIL SAMPLE LOCATION
- GROUNDWATER MONITORING WELL LOCATION
- PIT BOTTOM SOIL SAMPLE LOCATION
- SIDE WALL SOIL SAMPLE LOCATION
- PIT BOTTOM WATER SAMPLE LOCATION
- ESTIMATED AREA EXCEEDING 400 mg/kg TPH-EXTRACTABLE CLENUP LEVEL
- (160) SOIL TPH EXTRACTABLE CONCENTRATION (mg/kg)
- [7] DEPTH SAMPLE (FEET)
- AREA EXCAVATED DURING SOURCE CONTROL MEASURE

W12-4(ND)

40' 0 40' 80'
SCALE: 1" = 80'

FIGURE 10
MOFFETT FEDERAL AIRFIELD
SITE 12
AREA OF SOIL CONTAMINATION ABOVE CLEANUP LEVELS

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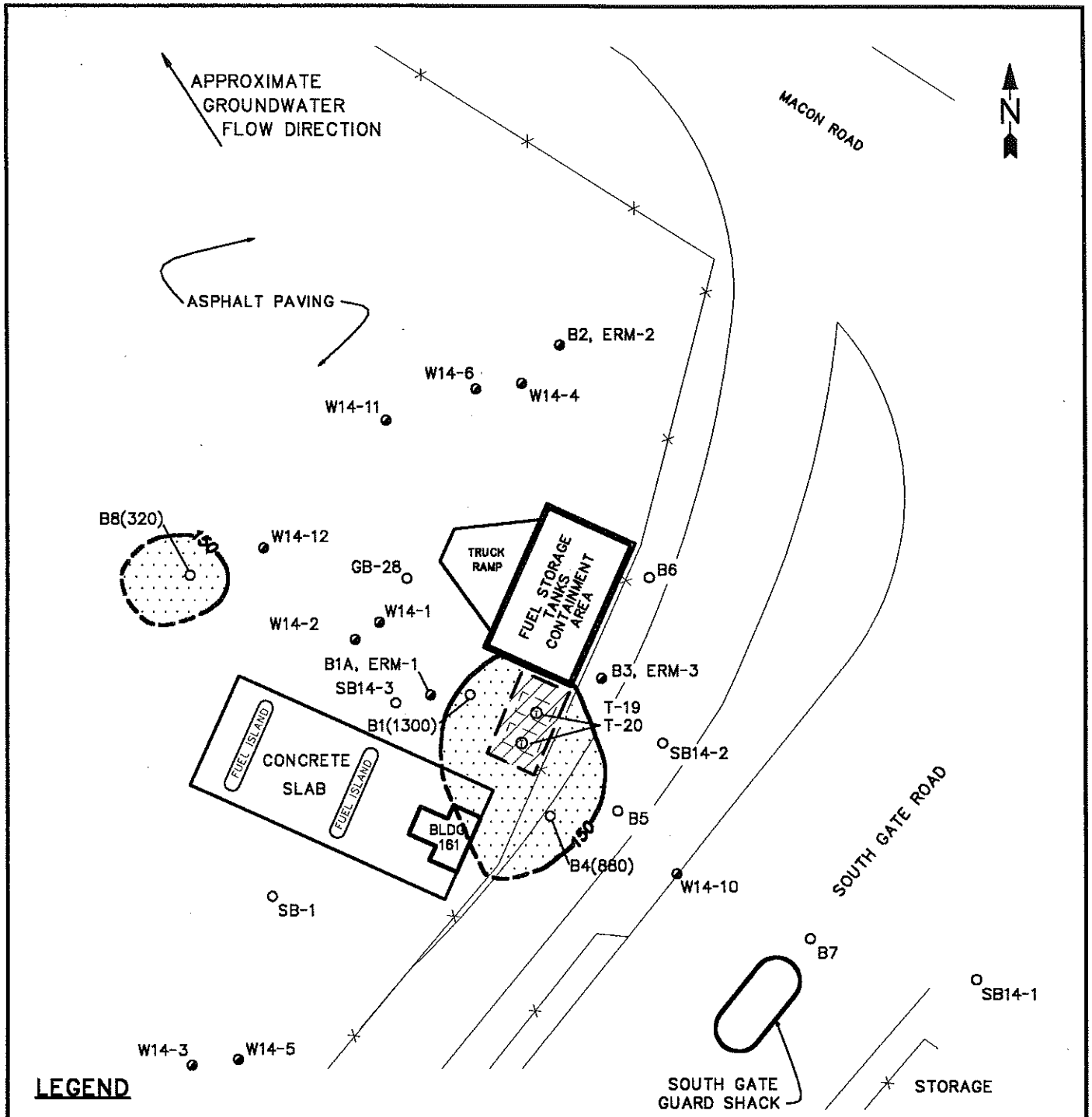
4.4 SITE 14 SOUTH

Site 14 South is an operating vehicle maintenance facility at the intersection of South Gate and Macon roads near Building 146. Leakage from two removed USTs (Tanks 19 and 20) and piping appears to have contributed to soil and groundwater contamination at Site 14 South. The information summarized below was described in the Site 14 South field investigation technical memorandum (PRC 1990a), Site 14 South action memorandum (PRC 1990b), Site 14 South source control final design (PRC 1991b), and Technical Memorandum Site 14 South Evaluation report (PRC 1994d).

Soil contamination at Site 14 South is mainly confined to the 15- to 25-foot bgs depth interval. These are saturated soils within the A1-aquifer zone. The highest concentration of TPH measured in soils was 1,300 mg/kg TPH purgeable in a sample from boring B1 near Tanks 19 and 20. Boring B8 had a TPH purgeable detection of 320 mg/kg that was outside the tank area; this may be attributed to a surface spill or underground piping. Figure 11 shows the distribution of TPH purgeable as gasoline in soil samples from borings at Site 14 South. BTEX was detected in several soil samples taken from borings within the area of TPH contamination depicted in Figure 11. Only one detection exceeded the BTEX cleanup level. A sample from the 18-foot interval of boring B1 had a benzene detection of 7.1 mg/kg. All other benzene detections ranged from 0.002 to 0.5 mg/kg. Detections of toluene ranged from 0.005 to 2.4 mg/kg; detections of ethylbenzene ranged from 0.007 to 34 mg/kg; and detections of xylene ranged 0.022 to 51 mg/kg.

The Site 14 South petroleum-contaminated groundwater is limited to the shallow A1-aquifer zone; no TPH purgeable as gasoline contamination above quantitation limits is present in the deeper A2-aquifer zone. The contaminated capillary fringe and saturated zone soils apparently act as a source for groundwater contamination. Samples from monitoring wells W14-2, W14-11, and W14-12 consistently have detections of TPH purgeable constituents. A sample collected from well W14-2 in December 1993 exhibited the highest concentration in groundwater (42 mg/L TPH purgeable as other compounds) to date. Figure 12 shows well locations and groundwater TPH concentrations at Site 14 South.

BTEX constituents have also been detected in groundwater samples. Benzene was detected at levels above the BTEX cleanup level in samples from wells W14-2, W14-11, and W14-12. Samples from W14-2 had the highest benzene detections ranging from 12,000 μg/L in December 1993 to 2,700 μg/L in February 1994. Toluene was detected in samples from several wells; however, only samples from W14-2 have exceed the BTEX cleanup level (1,300 μg/L in September 1993 to 1,100 μg/L in



LEGEND

- GROUNDWATER MONITORING WELL LOCATION
- SOIL BORING LOCATION
- (4) MAXIMUM SOIL TPH PURGEABLE CONCENTRATION (mg/kg)
- 150 ESTIMATED AREA EXCEEDING 150 mg/kg TPH-PURGEABLE CLEANUP LEVEL (SOIL AREA THAT EXCEEDS BTEX CLEANUP GOALS IS WITHIN THE TPH AREA).
- T-19 UNDERGROUND STORAGE TANK (REMOVED)
- FENCE
- EXCAVATION AREA

40' 0 40' 80'
SCALE: 1" = 80'

FIGURE 11
MOFFETT FEDERAL AIRFIELD
SITE 14 SOUTH
AREA OF SOIL CONTAMINATION ABOVE CLEANUP LEVELS

DATE: 08/30/94 KRS DN FILE NAME: 044\0235\RS\C14\FIG9.DWG

APPROXIMATE GROUNDWATER FLOW DIRECTION

GATE

MACON ROAD

N

BLDG 146

B2, ERM-2

50

W14-6

W14-4(250)

W14-11 (250)

EXTRACTION WELL W14-12 (230)

TRUCK RAMP

FUEL STORAGE TANKS CONTAINMENT AREA

W14-1

W14-2(24,000)

B3, ERM-3 (180 J-T)

B1, ERM-1(19,000) (T)

T-19

T-20

CONCRETE SLAB

BLDG. 161

FUEL ISLAND

ASPHALT PAVING

W14-10

SOUTH GATE ROAD

W14-3

W14-5

SOUTH GATE GUARD SHACK

STORAGE

20' 0 20' 40'

SCALE: 1" = 40'

LEGEND

- GROUNDWATER MONITORING WELL LOCATION
- J-T ESTIMATED VALUE DUE TO TENTATIVE IDENTIFICATION OF TARGET COMPOUND
- (50) ESTIMATED AREA EXCEEDING 50 µg/L TPH PURGEABLE CLEANUP LEVEL (AREA THAT EXCEEDS BTEX CLEANUP LEVELS IS WITHIN TPH PLUME AREA.)
- (250) TPH PURGEABLE OR OTHER LIGHT COMPOUNDS CONCENTRATIONS (ALL DATA FROM THE MAY 1994 QUARTERLY SAMPLING EVENT)

FIGURE 12
MOFFETT FEDERAL AIRFIELD
SITE 14 SOUTH
AREA OF GROUNDWATER CONTAMINATION ABOVE CLEANUP LEVELS

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May 1994). Ethylbenzene and xylene have not been detected in samples from Site 14 South wells above the associated cleanup levels. Detections of ethylbenzene ranged from 6 to 850 μg/L and detections of xylene ranged from 0.3 to 1,700 μg/L. The highest detections of ethylbenzene and xylene were in samples from well W14-2.

In summary, TPH purgeable and some BTEX constituents from USTs 19 and 20 remain in the soils and groundwater and additional corrective measures are recommended.

4.5 SITE 15

Site 15 consists of eight sumps and oil/water separators and one tank at Moffett Field (Plate 1). The sumps were or are currently used to collect liquid wastes accumulated in containment areas from various operational activities. Site 15 sumps are distributed throughout Moffett Field. Sumps 59, 63, and 130 (formerly known as Sump 65); and Tank 54 are located in the eastern portion of the facility. Sumps 25, 42, 58, 62, and 64 are located in the western portion. Of the eight sumps at Site 15, one sump is active (Sumps 59). All of these have been described in the petroleum sites characterization report (PRC 1994a). With the exceptions of Sumps 25 and 42 (near the current NEX service station), no BTEX constituents were detected above soil and groundwater cleanup levels.

Sump 25

Sump 25, an oil/water separator near the current NEX service station at the intersection of Wescoat and Cody roads, was removed in April 1994. This sump was actually composed of two separate chambers. Though high TPH detections were found in excavation sidewall samples, the sumps and piping appeared to be intact and at least some soil contamination is likely due to migration of fuels from leaking USTs from the upgradient NEX service station. One excavation soil sample had detections of TPH extractable at 9,500 mg/kg and TPH purgeable at 5,800 mg/kg. Water in the excavation also exhibited TPH extractable up to a concentration of 3,300 μg/L. Data regarding Sump 25 have been provided here as general background information for completeness. This sump is located near the NEX gasoline station at Moffett Field and will be investigated concurrently. A separate investigation and evaluation of the USTs and sumps (including Sumps 25 and 42) at the NEX gasoline station is underway. Once complete, a separate CAP will be prepared documenting the nature and extent of contamination and proposed corrective measures for all contamination associated with the NEX gasoline station (including Sump 25). Therefore, additional data regarding Sump 25 have not been discussed.

Sump 42

Sump 42 was used as a vapor condensation collection sump at the NEX service station. Though it has been removed and soil samples have been collected and analyzed, TPH contamination in these samples is indistinguishable from soil contamination resulting from adjacent leaking USTs. All samples contain detections of TPH purgeable and BTEX. Therefore, all petroleum contamination resulting from activities at the NEX service station has been investigated collectively. The NEX Gasoline Station Investigation Technical Memorandum (PRC 1994f) describes recent NEX investigation results, including results of sampling around Sump 42. Any future corrective actions pertaining to Sump 42 will be done in conjunction with the NEX corrective actions.

Tank 54

Tank 54 stored wastewater from aircraft maintenance operations at Hangar 3 and was removed in December 1992. Three soil samples from the excavation were collected and analyzed for TPH purgeable and extractable and VOCs. None of the samples had any TPH detections, though methylene chloride (a common laboratory contaminant) was detected in both sidewall samples at 280 μg/kg and trichloroethene (TCE) was detected in the south sidewall sample at 24 μg/kg.

Currently, there are no cleanup levels established for VOCs in soils on the eastern side of Moffett Field where former Tank 54 was located. As a point of comparison, the EPA Region 9 PRG for TCE in soils is 3,300 μg/kg for residential scenarios and 7,300 μg/kg for industrial scenarios (EPA 1994). Although EPA PRGs for VOCs in soils are not agreed upon cleanup levels for Moffett Field, they present a basis for order of magnitude comparisons. Since the TCE detection at Tank 54 is significantly lower than the EPA PRG values, the Navy recommends no further action and closure at this site. This tank will be included in the CERCLA process because of mixed contents.

Sump 58

Sump 58, comprised of a 300-gallon storage tank and two small sumps, was an oil/water separator which was removed in April 1994. Sump 58 was located just north of Building 544 in the transportation yard near the south gate of Moffett Field. Two soil samples collected near the bottom of the excavation pit contained TPH extractable concentrations up to 2,300 mg/kg and TPH purgeable concentrations up to 740 mg/kg. No additional soil or water samples were collected and the extent of

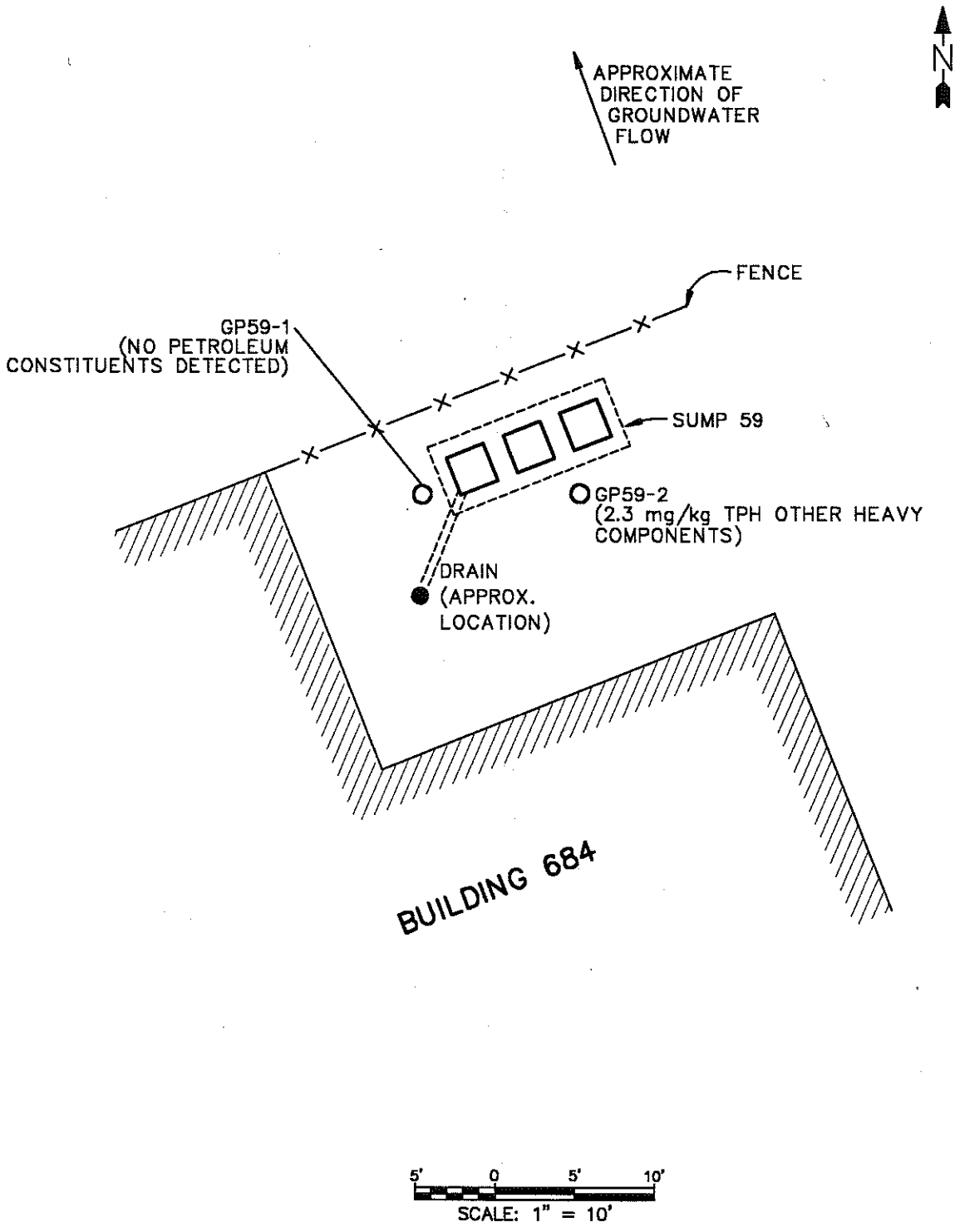
contamination is not known. Additional investigation of this sump is required before corrective measures and closure can be proposed. This sump will be included in the CERCLA process because of mixed contents.

Sump 59

Sump 59 is an active oil/water separator used by the California Air National Guard at Building 684. As previously mentioned, this sump will be included in the CERCLA process because of its contents. Four soil samples were collected at two locations adjacent to the sump in January 1994 during the additional petroleum sites investigation (PRC 1994c). One sample, GP59-2 collected at 5.0 to 7.0 feet bgs, had a TPH other heavy compounds detection of 2.3 mg/kg. The other samples had no indications of petroleum contamination. Figure 13 shows TPH detections and soil sample locations. This sump site has been recommended for elimination from the petroleum sites program since it is active and no constituents above cleanup levels were detected. This sump will be included in the CERCLA process because of mixed contents.

Sump 62

Sump 62 received painting wastewaters from a paint shop spray booth in Building 45. The booth is located directly over the top of the sump. NASA collected soil and water samples near the sump and analyzed them for TPH extractable, TPH purgeable, VOCs, and inorganics (CWMI 1994). Inorganic concentrations were within levels typically seen in soils and groundwater at Moffett Field. Although TCE and other VOCs were detected in many of the samples, the concentrations of the samples were consistent with levels found in soils overlying and within the regional MEW VOC plume. Additionally, inspections revealed that Sump 62 was structurally sound and no indications of leakage were observed. TCE was the only VOC detected in soil samples collected from above the groundwater. TCE concentrations ranged from 7 to a maximum of 54 μg/kg in a sample collected from boring B45/1-6. This sump site has been recommended for elimination from the petroleum sites program since it is inactive, has not been removed, and no constituents above cleanup levels were detected. In addition, it is likely that NASA will reactivate Sump 62 for future painting operations. This sump will be included in the CERCLA process because of mixed contents.



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LEGEND

O SOIL SAMPLE LOCATION

FIGURE 13
MOFFETT FEDERAL AIRFIELD
SITE 15 - SUMP 59
SOIL SAMPLE LOCATION MAP

Sump 63

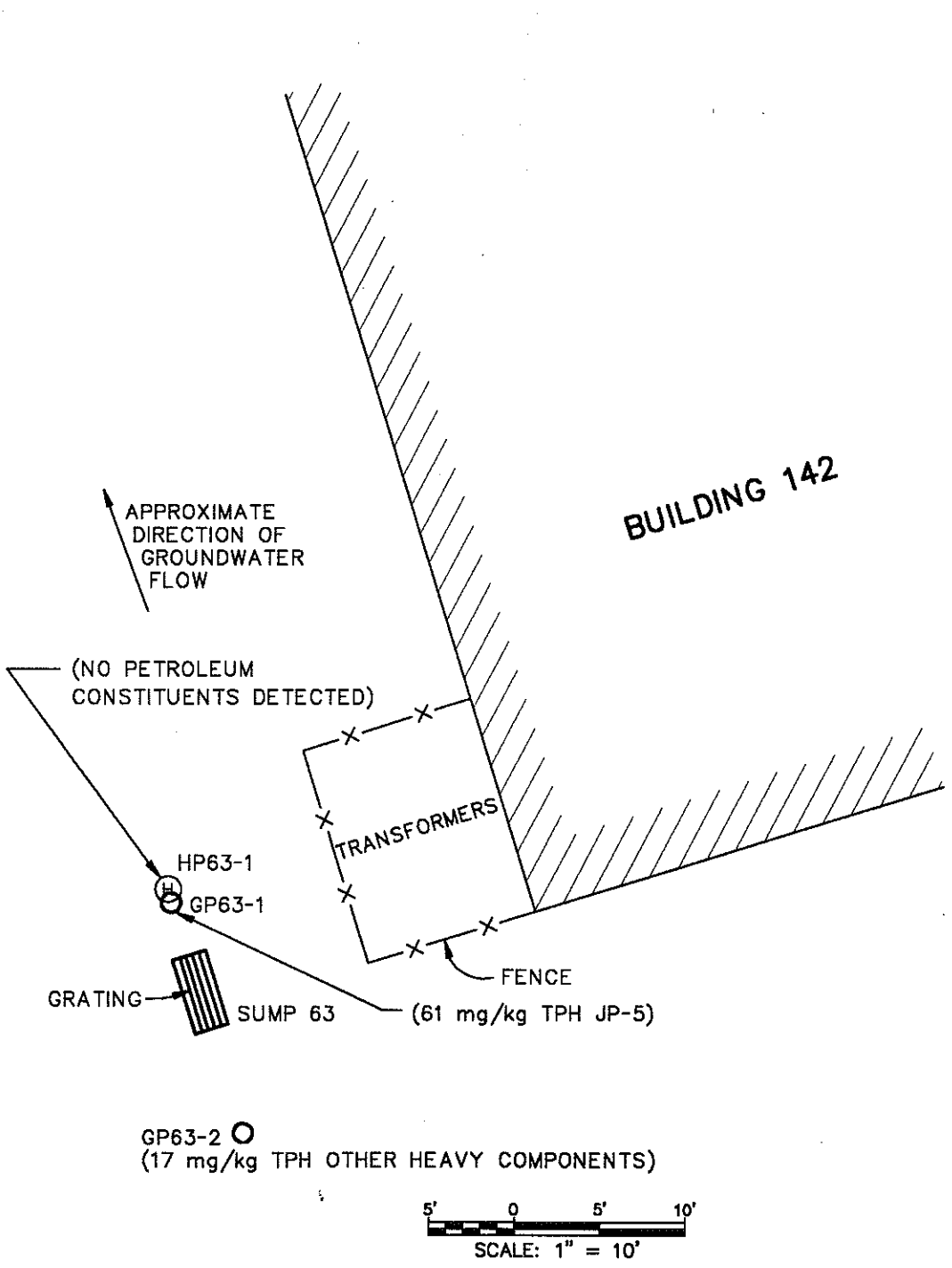
Sump 63 is an inactive catch basin for the ground support equipment area steam cleaning. Effluent from this basin ran through the industrial waste sewer line to the flux ponds where separation and treatment occurred. It is presently being connected to the storm drain system and will act as a catch basin. Four soil samples at two locations and one HydroPunch® groundwater sample were collected in January 1994. The groundwater sample, collected 5 feet downgradient of the sump, had no detections of TPH purgeable and extractable. Two soil samples at 5.0 to 7.0 bgs had low concentrations of TPH extractables, up to 61 mg/kg as JP-5. TPH contamination was not detected in shallower soil samples. Figure 14 shows soil and groundwater sample locations and TPH detections. This sump site has been recommended for elimination from the petroleum sites program since it is active and no constituents above cleanup levels were detected. This sump will be included in the CERCLA process because of mixed contents.

Sump 64

Sump 64, an inactive stormwater diversion box, is located in the Lindburgh Avenue storm channel near the northern end of the runways. This "sump" was not known to ever contain petroleum or waste products and, therefore, is not a suspected source of contamination. The sump was visually inspected in November 1993 by Navy, EPA, and RWQCB staff and was recommended for removal from the petroleum sites program by RWQCB. NASA plans to remove Sump 64 during its remedial activities at the Lindburgh Avenue storm channel area, and removal of Sump 64 is tentatively scheduled for early 1995. This sump site will be recommended for closure once sample results confirm that no constituents above cleanup levels are present. As previously mentioned, this sump will be included in the CERCLA process because of mixed contents.

Sump 130

Although there has been some confusion in the past over the name and location of Sump 130, it has now been positively identified as the sewer manhole/sump located just east of Building 575 (a battery locker). Sump 130 was previously referred to as Sump 65, though a review of Navy records shows that Sump 65 was never installed. Sump 130 neutralized battery acids before discharge into the sanitary sewer. Four soil samples and one HydroPunch® groundwater sample were collected in January and February 1994 during the additional petroleum sites investigation (PRC 1994c). During



LEGEND

- O SOIL SAMPLE LOCATION
- Ⓗ HYDROPUNCH® WATER SAMPLE LOCATION

FIGURE 14
MOFFETT FEDERAL AIRFIELD
SITE 15 - SUMP 63
SOIL AND HYDROPUNCH® SAMPLE LOCATION MAP

DATE: 08/30/94 KRS DN FILE NAME: 044\0236\RP\SRP\SUMP_63.DWG

this investigation four soil samples were collected from two soil borings (GP65-1 and GP65-2) placed on each side of the sump. Sample analyses were consistent with sump contents (battery acids) and included VOCs and inorganics. Analytical results indicated no detections of VOCs and inorganic concentrations within levels typically found in soils at Moffett Field. Additionally, one HydroPunch sample (HP65-1) was collected downgradient of Sump 130 and analyzed for VOCs and inorganics. Analytical results revealed no detections of VOCs and inorganic concentrations within levels typically found in groundwater at Moffett Field. Figure 15 shows soil and groundwater sample locations. This sump site has been recommended for elimination from the petroleum sites program since it is inactive and no constituents above cleanup levels were detected. As previously mentioned, this site will be included in the CERCLA process because of mixed contents.

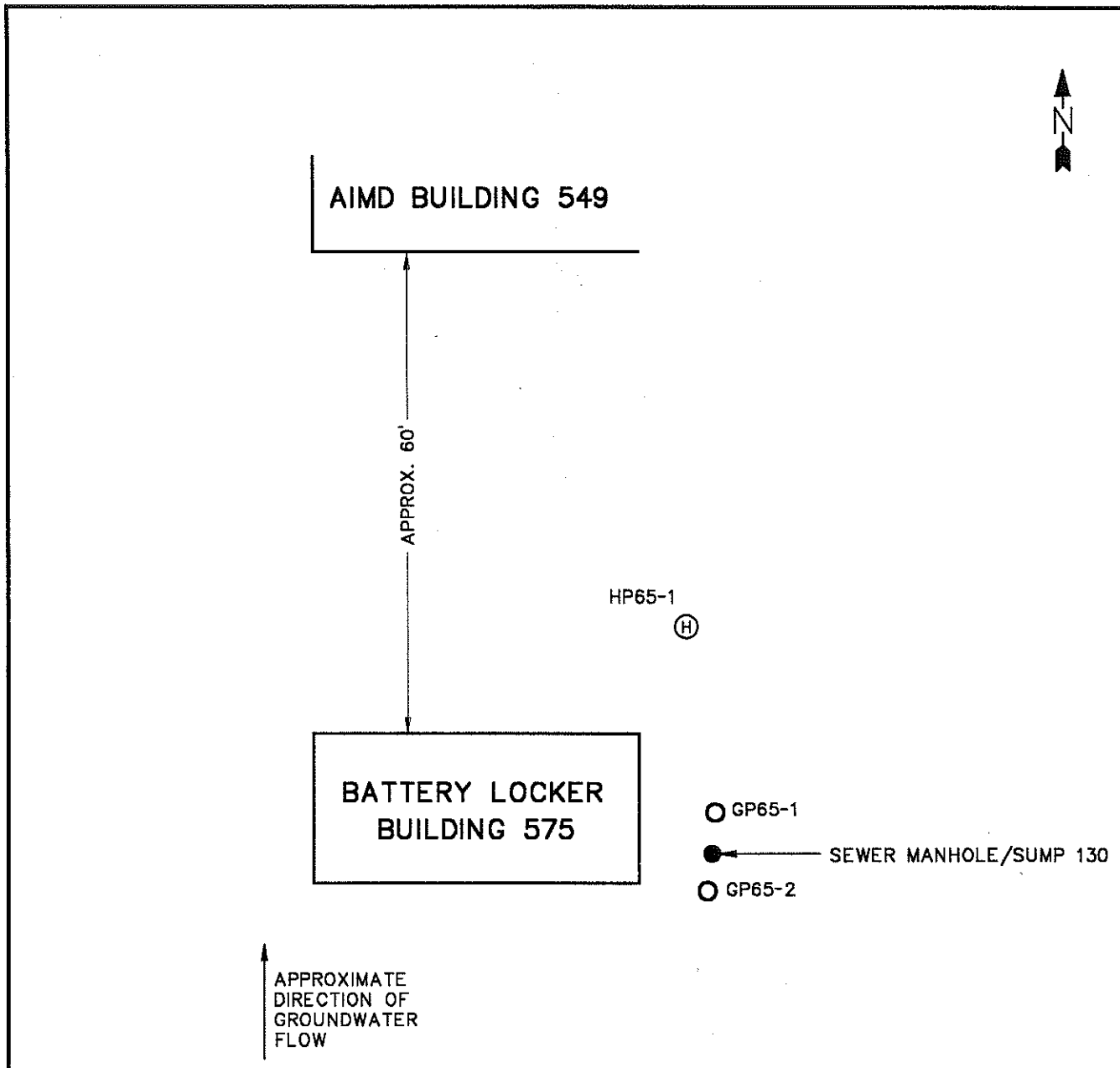
4.6 SITE 19

Site 19 includes Tanks 2, 14, 43, and 53. Tank 2 was a 2,000-gallon tank that stored waste products emanating from the power plant shop in Hangar 3. Wastes may have included spent mixtures of oils, hydraulic fluids, methyl ethyl ketone (MEK), JP fuels, B & B cleaner, PD-680 solvent, toluene, and Stoddard solvent. Tank 14 was a 1,100-gallon standby diesel fuel storage tank for the backup generator in Building 158, the operations building. Tank 43 was a 2,000-gallon tank that collected rinse water from the engine cleaning rack, drains, and sinks in Hangar 3. The tank rinse water may have contained waste oils, waste solvents, waste fuel, paint waste, and battery acids. Tank 53 was an unleaded gasoline tank at the golf course maintenance area.

Data indicate that three areas of TPH contamination exist at Site 19: (1) the area northeast of former Tank 2; (2) the area around former Tank 43; and (3) the area south of former Tank 53. The soil contamination could originate from previous operational practices (such as accidental overfilling) or some tanks or piping may have leaked. All of the USTs and associated piping in these areas have been removed; therefore, active sources at Site 19 have been eliminated and any contamination identified has most likely resulted from previous activities. No BTEX constituents were detected above soil and groundwater cleanup levels at the former Site 19 USTs.

Tank 2

Soil contamination exists near former Tank 2, though it appears to be limited to areas immediately adjacent to the excavation. The northern excavation sidewall sample had a detection of 1,700 mg/kg



LEGEND

- O SOIL SAMPLE LOCATION
- (H) HYDROPUNCH® WATER SAMPLE LOCATION
- AIMD AIRCRAFT INTERMEDIATE MAINTENANCE DEPARTMENT

NOTES

SOIL AND GROUNDWATER METALS CONCENTRATIONS DO NOT INDICATE CONTAMINATION

SUMP 130 USED TO BE SUMP 65

5' 0 5' 20'

SCALE: 1" = 20'

FIGURE 15
MOFFETT FEDERAL AIRFIELD
SITE 15 - SUMP 130
SOIL AND HYDROPUNCH® SAMPLE
LOCATION MAP

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TPH extractable as diesel, though samples at locations 10 and 20 feet north of the excavation had no TPH detections. Other petroleum detections include 110 mg/kg TPH extractable as JP-5 at location W07-20, 150 mg/kg TPH purgeable as gasoline in the east excavation sidewall sample, and 120 mg/kg TPH extractable as motor oil at sample location TP2-1, about 10 feet south of the excavation in a piping trench. Small concentrations of VOCs and semivolatile organic compounds (SVOCs) were detected in soils, including 8 μg/kg of TCE and 1.42 mg/kg of 4-methylphenol. Figure 16 shows soil sample locations and TPH detections.

Groundwater contamination at Tank 2 appears to be limited based on samples from two groundwater monitoring wells immediately downgradient of the excavation, and two HydroPunch® groundwater samples. A detection of 840 μg/L of TPH extractable as motor oil was found in a sample from HPT2-2 (PRC 1994c). Other detections were 14 μg/L of TPH purgeable as other light components in a sample from well WT2-1, and 0.9 μg/L ethylbenzene at location HPT2-1. Detections of VOCs have been found in water samples taken near former Tank 2. Groundwater in this vicinity is being addressed under the OU5 RI/FS. Figure 17 shows groundwater sample locations and TPH detections.

Corrective measures are recommended for soil and groundwater TPH contamination. This tank will be included in the CERCLA process because of mixed contents.

Tank 14

Only one soil sample taken near Tank 14 indicated an elevated TPH concentration. This sample, collected from the northern excavation sidewall sample, had a detection of 1,700 mg/kg TPH extraction as diesel. However, six additional samples collected along the northern edge of the excavation to evaluate the extent of contamination had no detections of TPH, indicating that contamination was very localized.

One groundwater monitoring well, WT14-1, is located next to former Tank 14. Analyses of groundwater samples for TPH have yielded either nondetections of TPH or small detections at estimated concentrations below the method detection limits.

Soil samples collected at the former Tank 14 area (a total of eleven samples) were analyzed for TPH extractable. A single detection of TPH (1,700 mg/kg) is above the cleanup level of 400 mg/kg. However, analytical results from samples from six samples collected adjacent to this detection revealed no detections of TPH extractable as diesel. These data are discussed in the petroleum sites

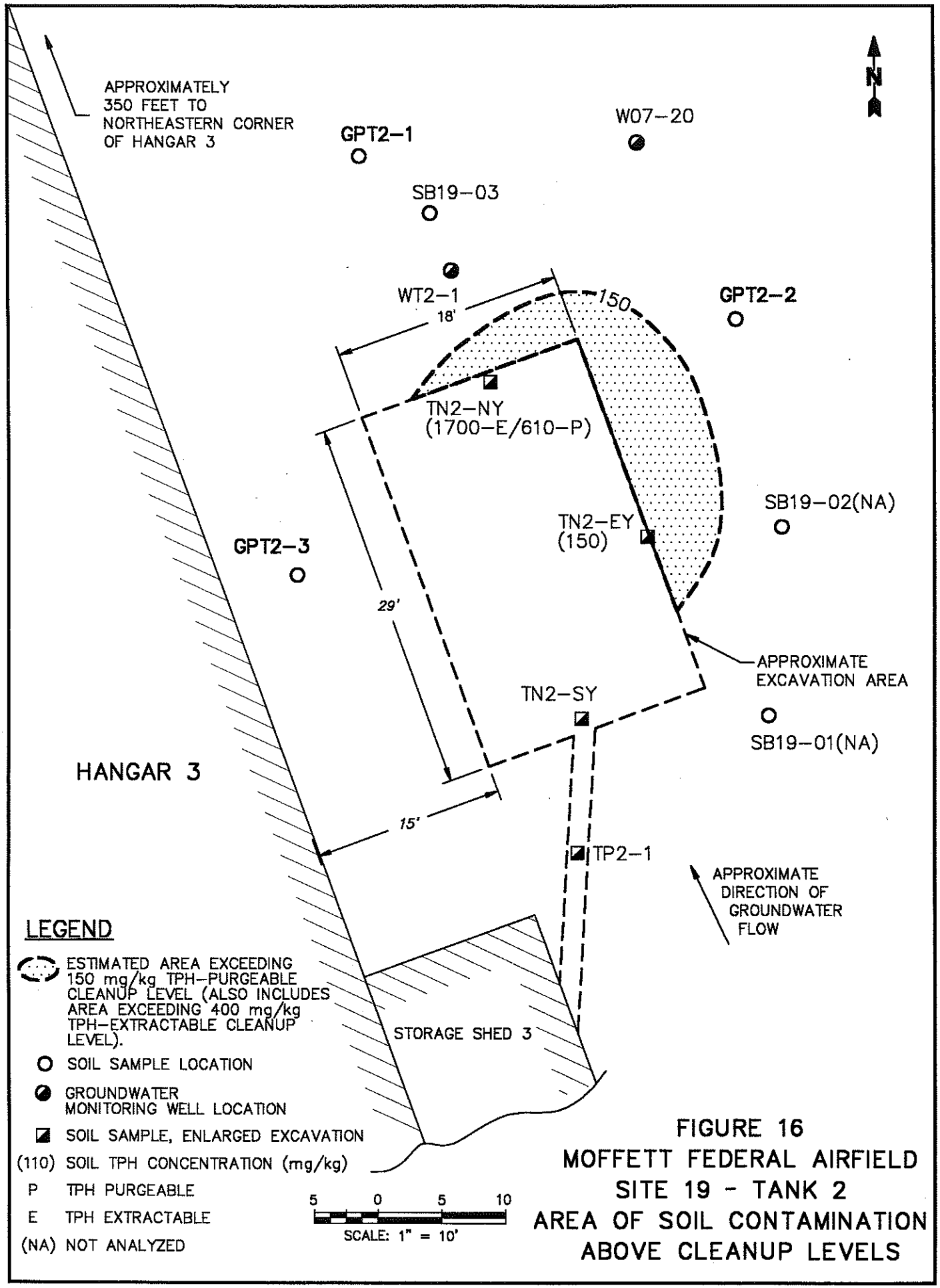


FIGURE 16
MOFFETT FEDERAL AIRFIELD
SITE 19 - TANK 2
AREA OF SOIL CONTAMINATION
ABOVE CLEANUP LEVELS

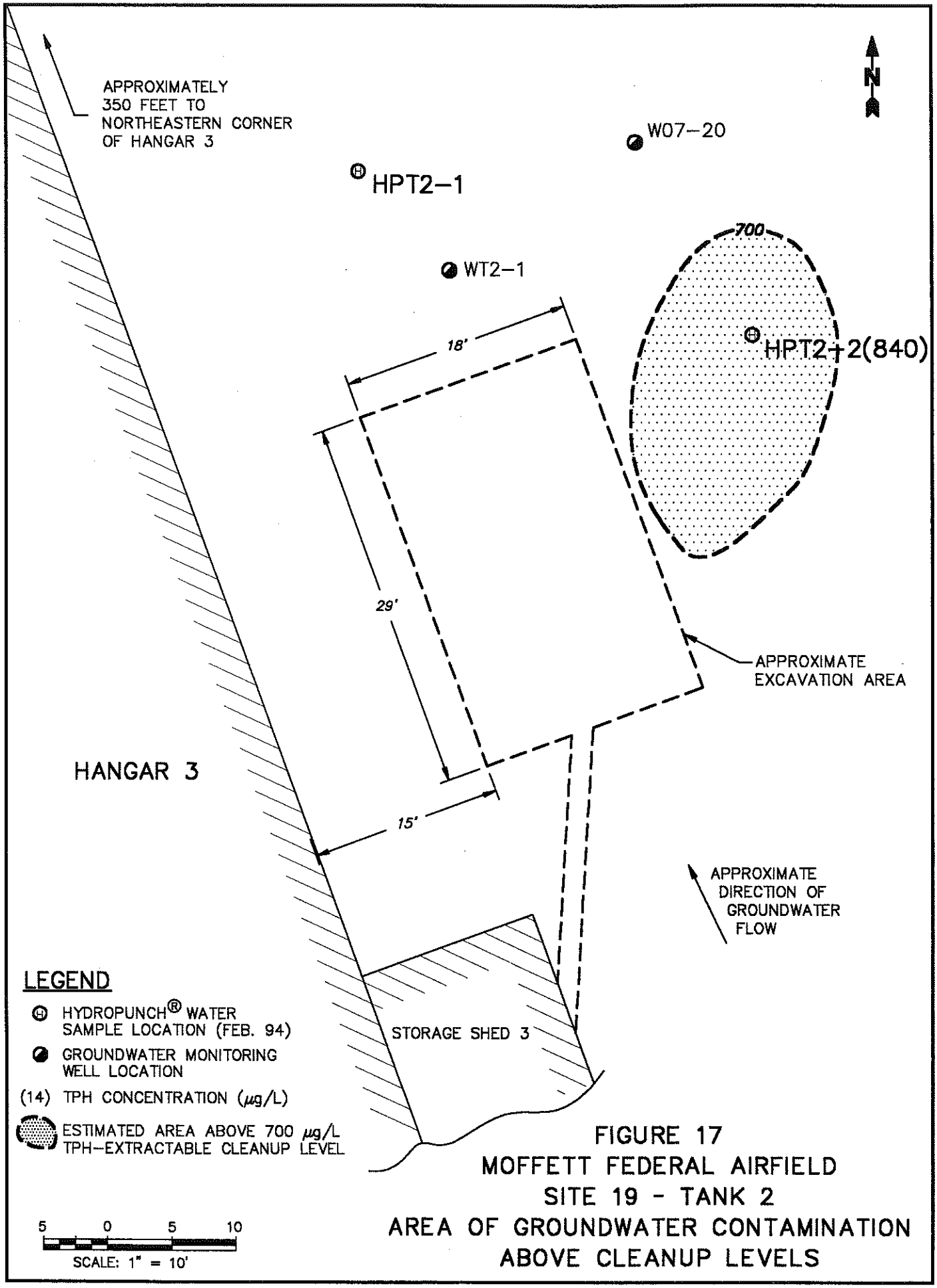


FIGURE 17
MOFFETT FEDERAL AIRFIELD
SITE 19 - TANK 2
AREA OF GROUNDWATER CONTAMINATION
ABOVE CLEANUP LEVELS

characterization report and will also be presented in a closure report. These data indicate that the remaining contamination is very localized and small in extent. Furthermore, samples from a groundwater monitoring well adjacent to former Tank 14 (WT14-1) revealed no detections of TPH. Although a small area of contamination above the cleanup level may remain, the Navy proposes no further action since Tank 14 has been removed, groundwater has not been affected, and the cost of remediation exceeds the benefit of remediating such a small area. Therefore, closure is recommended.

Tank 43

Petroleum soil contamination exists in a limited area around the former Tank 43 location. Two excavation sidewall samples had TPH extractable detections greater than 1,000 mg/kg, including a detection of 2,000 mg/kg of TPH extractable as diesel at the southern sidewall sample. Other detections include 650 mg/kg of TPH extractable as diesel at a soil sample from well W43-1, and 480 mg/kg of TPH extractable as diesel at a soil sample from well W43-2. Petroleum hydrocarbons were not detected at other sample locations north, south, and west of the excavation, nor in the east excavation sidewall sample. VOCs have also been detected, including tetrachloroethene (PCE) up to 23 μg/kg and TCE up to 21 μg/kg from the east sidewall sample. Figure 18 shows soils sample locations and TPH detections.

Tank 43 appears to have contributed to groundwater contamination at this site. Petroleum-contaminated groundwater at TPH concentrations of 50 μg/L or more extends approximately 150 feet downgradient from former Tank 43. Numerous A1-zone wells are in place downgradient and near former Tank 43, and four HydroPunch® groundwater samples were also recently collected and analyzed. Though only five samples had TPH detections greater than 100 μg/L, a sample from well W7-7 had a concentration of 99,000 μg/L of TPH extractable as kerosene in December 1993, and a sample from well W7-6 was measured at 1,900 μg/L TPH purgeable as other light components in June 1993. VOC contamination is also present in groundwater; therefore, this area is being addressed under the OU5 RI/FS process. Figure 19 shows groundwater sample locations and TPH detections.

Corrective measures are recommended for soil and groundwater TPH contamination at Tank 43. This tank will be included in the CERCLA process because of mixed contents.

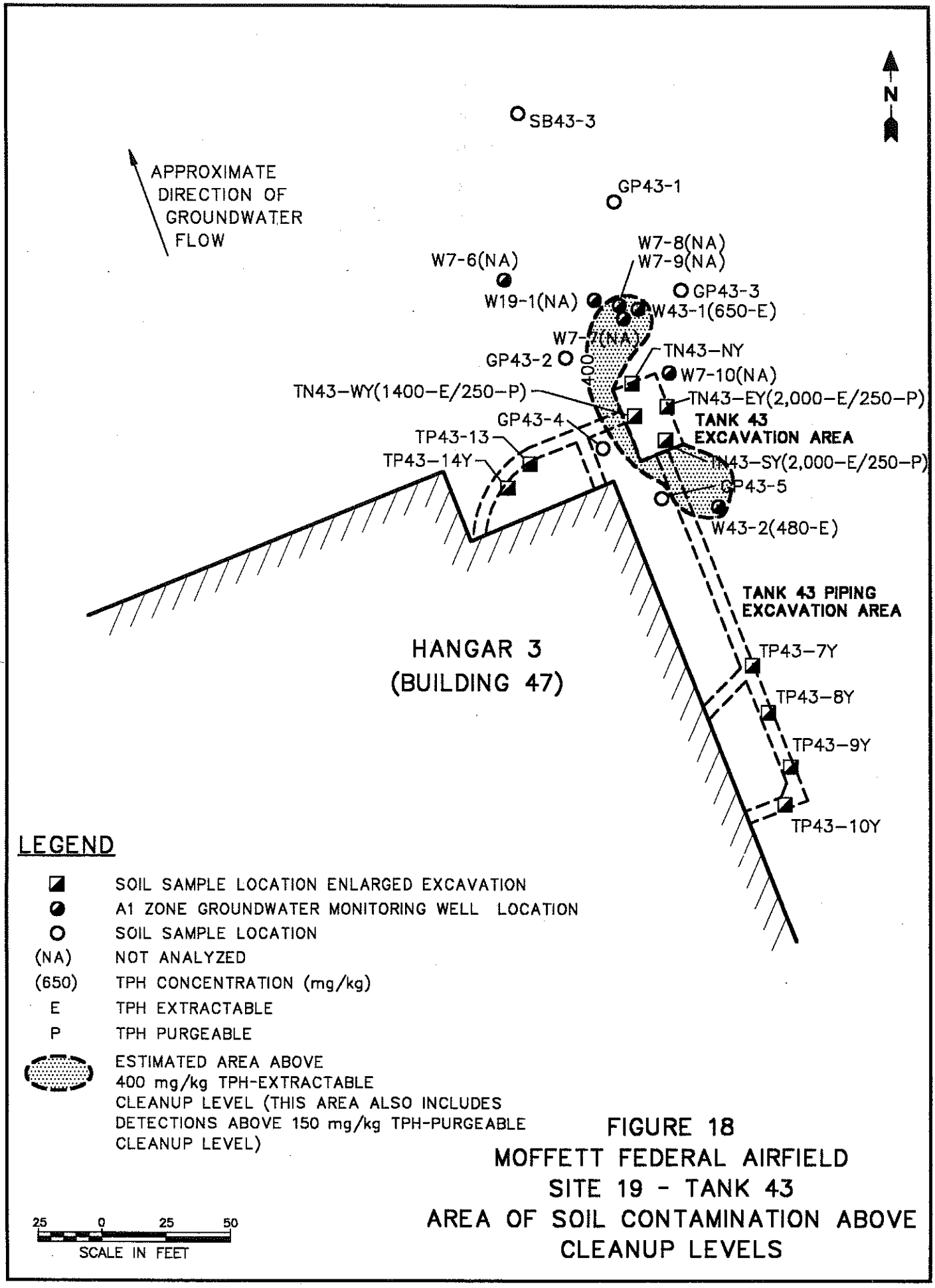
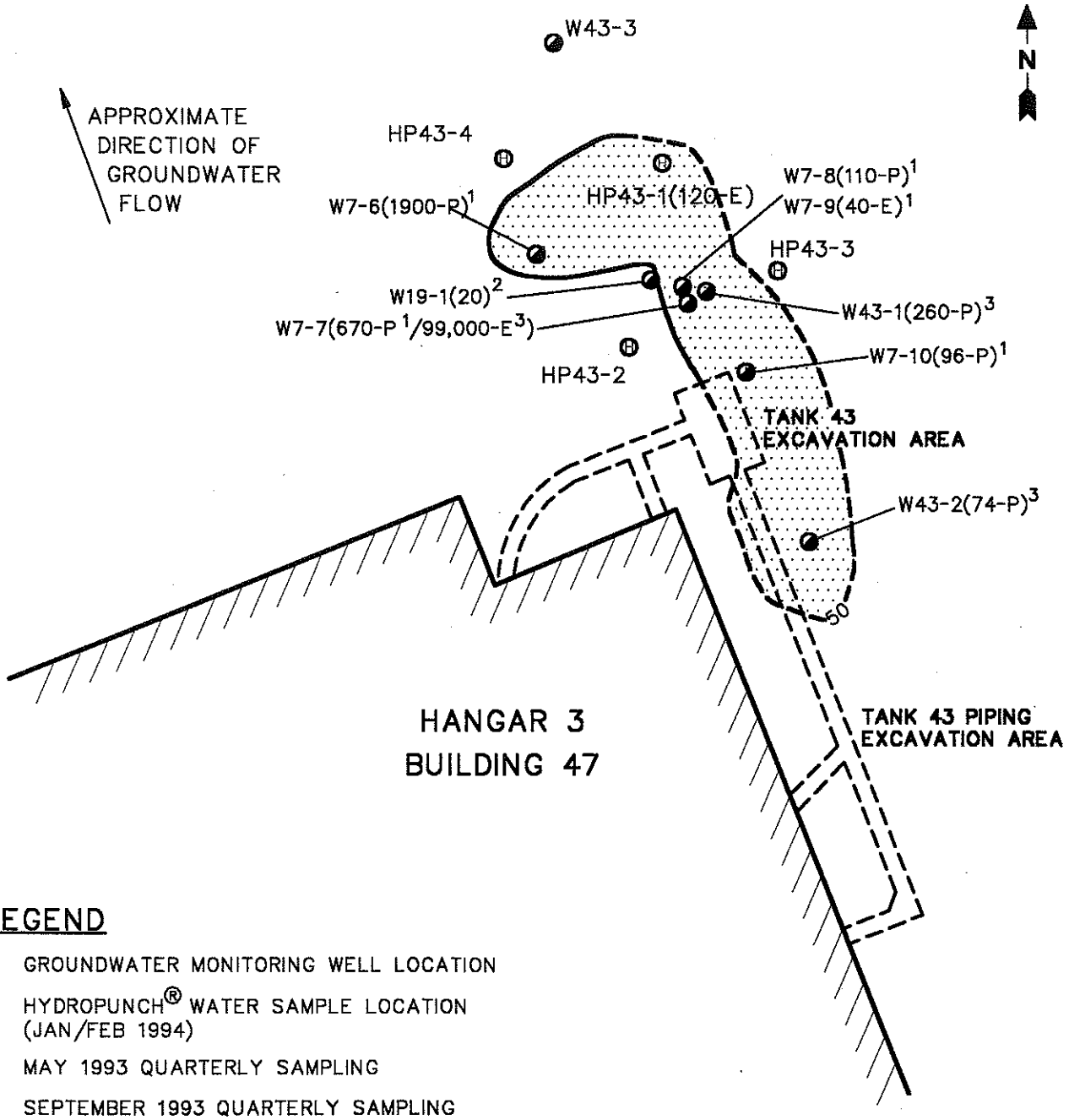


FIGURE 18
MOFFETT FEDERAL AIRFIELD
SITE 19 - TANK 43
AREA OF SOIL CONTAMINATION ABOVE CLEANUP LEVELS



LEGEND

- GROUNDWATER MONITORING WELL LOCATION
- HYDROPUNCH® WATER SAMPLE LOCATION (JAN/FEB 1994)
- 1 MAY 1993 QUARTERLY SAMPLING
- 2 SEPTEMBER 1993 QUARTERLY SAMPLING
- 3 DECEMBER 1993 QUARTERLY SAMPLING
- (74) TPH CONCENTRATION (μg/L)
  P - TPH PURGEABLE
  E - TPH EXTRACTABLE
- ESTIMATED AREA EXCEEDING 50 μg\L TPH - PURGEABLE CLEANUP LEVEL (THIS AREA ALSO INCLUDES AREA EXCEEDING 700 μg\L THP - EXTRACTABLE CLEANUP LEVEL)

25 0 25 50
SCALE IN FEET

FIGURE 19
MOFFETT FEDERAL AIRFIELD
SITE 19 - TANK 43
AREA OF GROUNDWATER CONTAMINATION ABOVE CLEANUP LEVELS

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Tank 53

Tank 53 formerly stored unleaded gasoline and has affected subsurface soils to the south and east of the former tank location. The highest TPH detections include 1,600 mg/kg of TPH purgeable as gasoline at the southern excavation sidewall sample, and 1,160 mg/kg of TPH purgeable as gasoline at sample location T53-23. Soil contamination, mostly at 4.0 to 5.5 feet bgs, appears to be limited to an area of approximately 40 by 40 feet. TPH was not detected in soil samples collected from locations along the edges of the excavation.

Low concentrations of TPH purgeables have been detected in groundwater near former Tank 53, although the detections were at or below cleanup levels. Figure 20 shows soil and groundwater sample locations.

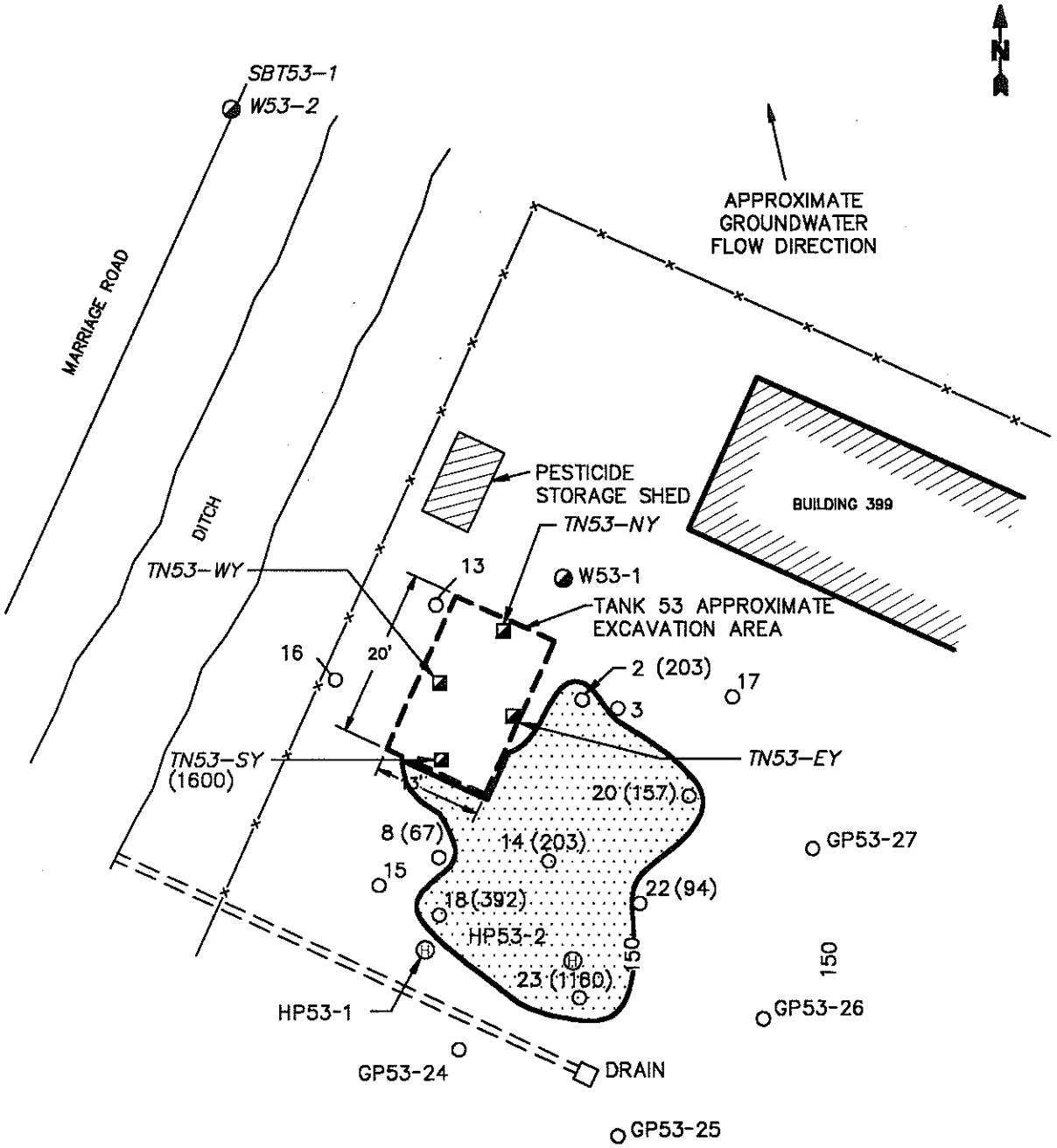
Corrective measures are recommended for soil TPH contamination at Tank 53.

5.0 MIGRATION CONTROL AND INTERIM REMEDIATION

The Navy has begun several actions to begin remediation of petroleum-contaminated material at Moffett Field. This section describes the SCMs and other related studies that have been conducted at IRP Sites 5, 9, 12, and 14. No SCMs, other than tank and sump removal, have been undertaken at Sites 15 and 19.

5.1 TANK AND SUMP REMOVAL

An inventory of all tanks and sumps at Moffett Field indicates that approximately 137 ASTs, oil/water separators, sumps, and USTs were installed to support the various operations and tenants at Moffett Field. The majority of the tanks were installed to store petroleum products. As a result of previous operating practices, fuel products leaked or spilled near some of the USTs and sumps and contaminated the unsaturated soils and shallow groundwater aquifers. The Navy recognized the need to remediate these areas to reduce risks to human health and the environment and to reduce the potential for future releases. To meet this objective, the Navy has actively pursued removal of inactive and leaking USTs and sumps, and tested and repaired active ones. Including the 31 UST and sump removals in this CAP, approximately 63 USTs and sumps have been removed and another 36 are planned for removal in the near future at Moffett Field.



10 0 10 20

SCALE: 1" = 20'

LEGEND

- SOIL SAMPLE LOCATION ENLARGED EXCAVATION (MAY 1990)
- SUBSURFACE SOIL SAMPLE LOCATION
- A1 ZONE GROUNDWATER MONITORING WELL LOCATION
- EXTIMATED AREA EXCEEDING 150 mg/kg TPH - PURGEABLE CLEANUP LEVEL
- HYDROPUNCH® WATER SAMPLE LOCATION
- (35) SOIL TPH – PURGEABLE CONCENTRATION (mg/kg)

FIGURE 20
MOFFETT FEDERAL AIRFIELD
SITE 19 - TANK 53
AREA OF SOIL CONTAMINATION ABOVE CLEANUP LEVELS

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5.2 SITE 5

A free product recovery test was conducted at Site 5 during May 1994 (PRC 1994g) to evaluate recent observations of floating product. Information gathered during the test is being used in the phase I pilot test design (discussed in Section 8.1). The recovery test was conducted by installing a temporary groundwater pump in free product well FP05-01. This well was selected since up to 2 inches of free product had been detected in the well during quarterly groundwater sampling in March 1994. Groundwater was pumped from the well over a 20-hour period. The water was not pumped at a steady rate; instead the rate was increased in a step-wise fashion, from an initial rate of 1 gallon per minute (gpm) to a final rate of 4 gpm. A total of 4,172 gallons of groundwater were pumped from the well as measured with a flow meter connected to the groundwater discharge pipe. Product thickness, product elevation, and groundwater elevation were periodically measured during the test. Measurements were made frequently (about every 3 to 5 minutes) whenever the pump rate was increased. Once the water level in the well stabilized, measurements were made every 30 to 60 minutes. The water level was also measured manually and electronically with a pressure transducer during the test. These data were stored on a data logger. The pump was turned off and groundwater allowed to recover to the prepumped level. Discharged groundwater was stored in a 6,000-gallon container positioned adjacent to the well.

During the test, a consistent layer of JP-5 was observed in the well casing. A small quantity (less than 6 ounces) of JP-5 was recovered from the well. After pumping stopped, the JP-5 layer dissipated. No measurable thickness developed for 18 hours after the test. Subsequent measurements after 2 weeks at FP05-01 indicated no measurable product thickness in the well.

Groundwater recovery data were used to estimate the hydraulic conductivity of the screened interval of well FP05-01. Hydraulic conductivity was estimated at 2×10^{-3} cm/sec, which falls in the upper range for silty fine sand aquifer material. The borehole log for FP05-01 indicates layers of silt, sand, and clay from 6.0 to 14.6 feet bgs, with the sand layer most likely contributing most of the water during the test. Figure 21 presents the recovery data in graphic format.

These data indicate that well FP05-01 can sustain a continued discharge rate of approximately 3 gpm. The discharge and recovery rates indicate at least a portion of the screened saturated interval is hydraulically connected to a higher permeability interval that extends away from the well. The sand interval mentioned above may be connected to a coarse-grained channel deposit adjacent to the well.

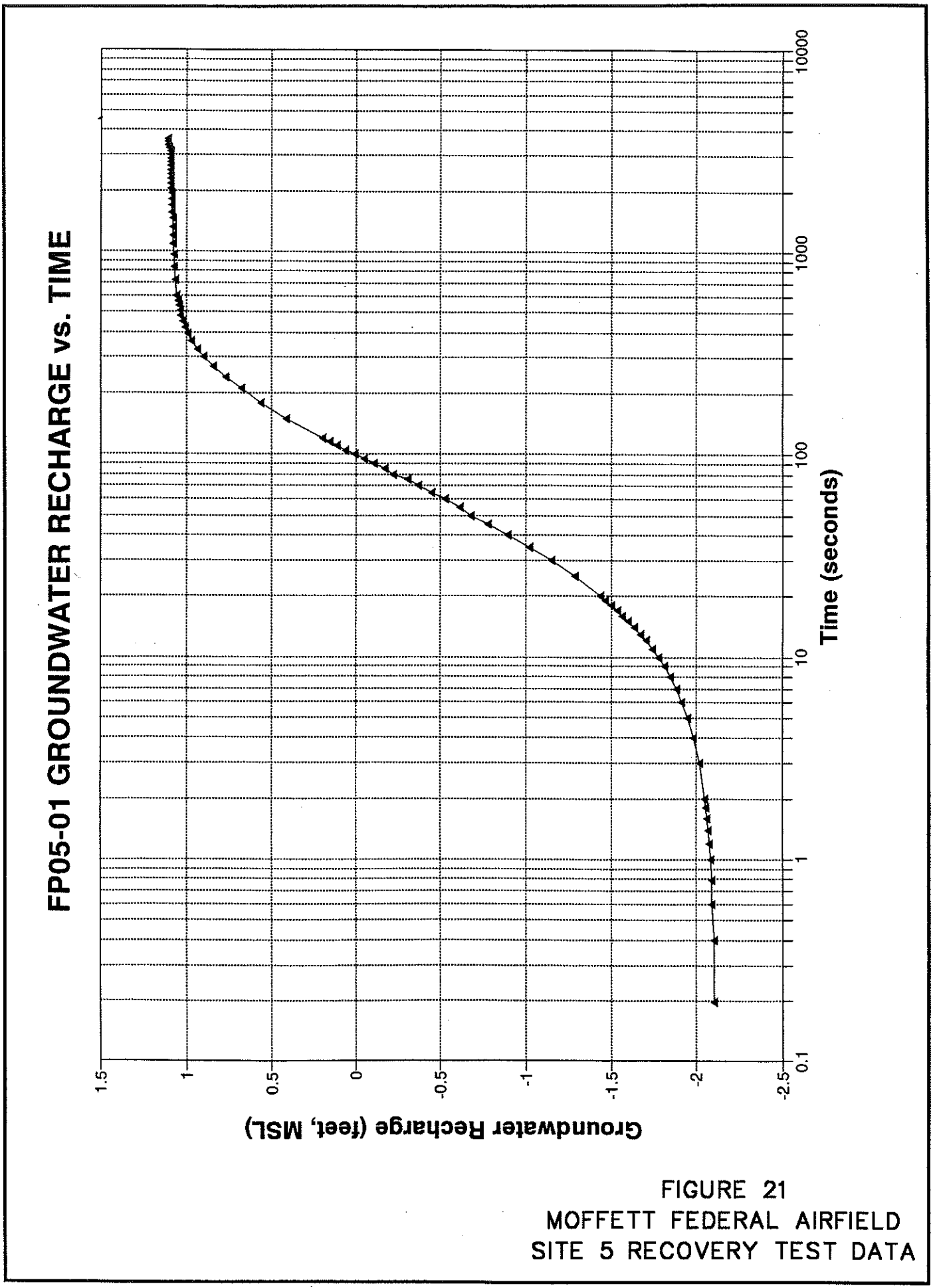

FIGURE 21
MOFFETT FEDERAL AIRFIELD
SITE 5 RECOVERY TEST DATA

Test results also indicate insufficient fuel will flow to the well to warrant installation of a fuel recovery system. This conclusion is based on the fact that the measured fuel thickness did not increase when the water table surrounding the well was lowered through pumping.

5.3 SITE 9

Three source areas are addressed under the Site 9 source control measure (SCM) (PRC 1992a). These areas include the old fuel farm near Building 29, the former NEX gasoline station near Building 31, and Building 88 (the former laundry facility). These areas had USTs and sumps associated with them (all now removed). Shallow groundwater (A1-aquifer zone) and unsaturated soil contamination have been detected at these areas. Contamination includes fuel-related compounds (such as BTEX and TPH) and chlorinated VOCs.

The objective of source control activities at Site 9 is to reduce, to the extent feasible, the lateral and vertical migration of fuel-related and chlorinated VOC contaminants in the A1-aquifer zone at identified sources areas until a comprehensive cleanup plan can be developed and implemented. The Site 9 SCM is the first phase in the Navy's long-term remediation of contaminated groundwater in the west-side aquifers at Moffett Field. The selected SCM is extraction and treatment of groundwater at the source areas.

Under the Site 9 SCM, groundwater will be extracted from four extraction wells (wells W9-47, FP9-1, W61-1, and W9-46). Groundwater from these wells will be treated in one of three treatment systems located near Building 6 (downgradient from Building 88), Building 12 (downgradient from Building 31), and Building 45 (Figure 22). The Buildings 6 and 12 treatment systems both use two granular activated carbon (GAC) units in series to treat contaminated groundwater. The Building 6 system will treat 5 gpm of groundwater from extraction well W9-46, and the Building 12 system will treat 3 gpm of groundwater from extraction well W9-47. The Building 45 treatment system will treat 8 gpm of contaminated groundwater from extraction wells W61-1 and FP9-1 using an air stripper and two GAC units in series. The Site 9 SCM treatment systems were installed during spring and summer 1994 and are anticipated to begin operations in fall 1994.

Groundwater generated during this action will be discharged to the Moffett Field storm water drain system following the requirements of a National Pollutant Discharge Elimination System (NPDES) permit. An actual NPDES permit has not been issued since the Site 9 SCM is being conducted in accordance with the west-side aquifers CERCLA action. CERCLA, however, requires that permit

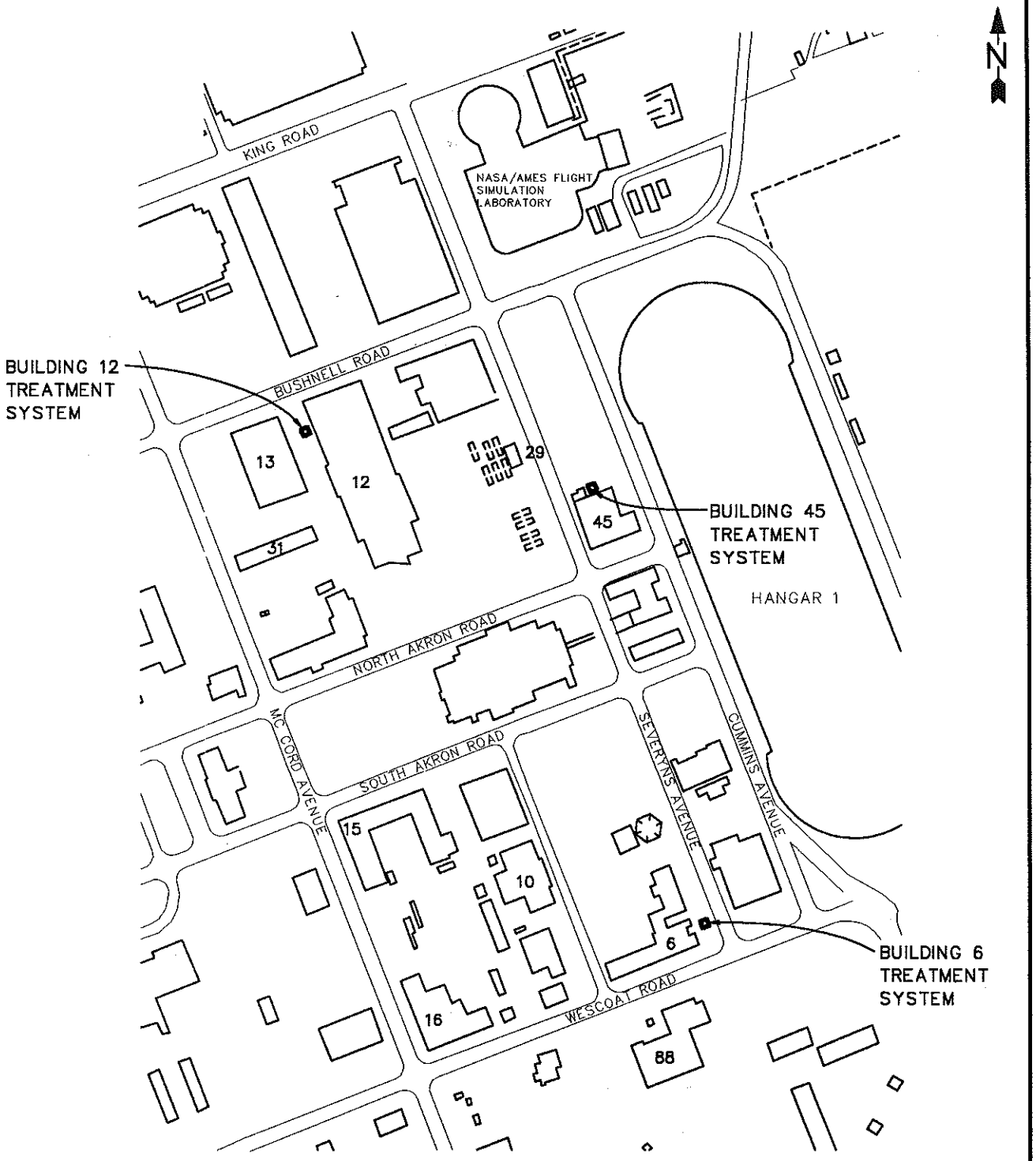

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FIGURE 22
MOFFETT FEDERAL AIRFIELD
SITE 9
TREATMENT SYSTEM LOCATIONS

requirements be followed. Off-gases from the Building 45 treatment system air stripper must comply with the emissions limitations specified by BAAQMD. Air stripper stack samples are collected to verify compliance with BAAQMD permit requirements. Additional details regarding the Site 9 SCM are provided in the design report (PRC 1992a).

5.4 SITE 12

Approximately 5,500 cubic yards of petroleum contaminated soils were excavated in November and December 1993 as part of the Site 12 SCM (PRC and MW 1993a and 1994c). The Site 12 SCM employed a chemical oxidation treatment system to reduce TPH concentrations in the soils. The majority of this soil has been treated to meet a 100 mg/kg treatment goal, and these soils have been backfilled. Figure 10 depicts the Site 12 excavation area. In addition, other soils with TPH levels up to 150 mg/kg were also backfilled after obtaining concurrence from RWQCB. The Site 12 SCM Final Action Technical Memorandum summarizes these activities (PRC and MW 1994c). Not all contaminated soils were removed, however, as excavation limits were imposed by proximity to Zook Road and the west parallel taxiway. The horizontal extent of contamination remaining in these areas is not defined.

5.5 SITE 14 SOUTH

The SCM at Site 14 South entailed extracting groundwater from an existing monitoring well (W14-12), treating the extracted water using GAC and discharging the effluent to the Sunnyvale POTW. The GAC unit was preceded by a filtration unit that removed particles larger than 100 micrometers in diameter. The GAC unit operated in a downflow mode (that is, the water entered the top of the unit and flowed by gravity to the bottom, with effluent discharged from the bottom). The residence time for water within this unit was approximately 6 hours, based on the average operational flow rate (1.2 gpm). Figure 23 depicts the location for the SCM system.

Water entering the GAC unit and water exiting the GAC unit were sampled once a month to monitor system performance and meet POTW permit requirements. The samples were analyzed for VOCs, TPH purgeable (including BTEX), and total metals. The influent concentrations remained relatively constant (an average of 250 μg/L TPH purgeable). The effluent stream had no detections of organic compounds in any of the samples collected. The Site 14 South Evaluation Technical Memorandum provides detailed discussion of all analytical results (PRC 1994d).

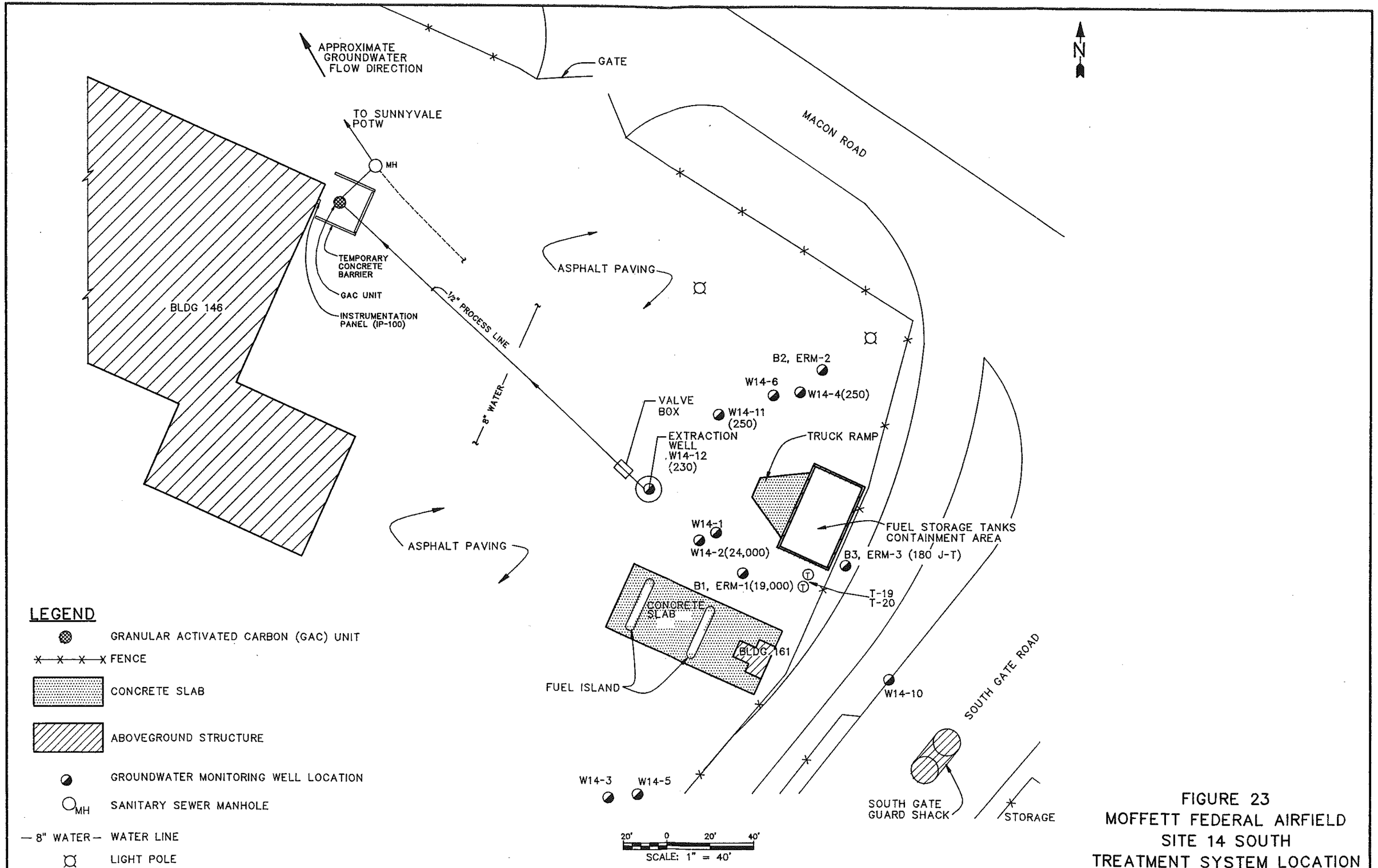


FIGURE 23
MOFFETT FEDERAL AIRFIELD
SITE 14 SOUTH
TREATMENT SYSTEM LOCATION

The GAC material was also sampled to assess the loading rate of contaminants onto the GAC, and to assist in predicting the GAC changeout time. Only the uppermost sample had VOC detections (170 micrograms per kilogram [μg/kg] of 1,2-dichloroethene and 190 μg/kg of benzene). This sample also had the highest microbial plate count (2.6 million colony forming units [CFU] per gram). Apparently, the GAC was not only adsorbing contaminants from the water, but was providing a contact mechanism for microbes and contaminants, which allowed microbial growth and organic chemical degradation. The Site 14 South system treated approximately 240,000 gallons of contaminated water from December 1992 through October 1993. The average extraction rate was approximately 1.2 gpm. Higher flow rates dewatered the extraction well.

Because of aquifer heterogeneity, preferential flow pathways, and the abundance of fine-grained aquifer material, the capture zone for the extraction well was limited. Based on analytical modeling of the aquifer, the expected drawdown in the closest monitoring well (W14-2) after extracting water at 1.2 gpm for a month should have been 1 to 2 feet. Significant drawdown of the water level was not observed in the existing monitoring wells even after approximately 5 months of continuous operation at 1.2 gallons per minute. The drawdown in the extraction well was approximately 4 feet. The system has not been operated since October 1993.

6.0 PROCESS OPTIONS AND REMEDIAL TECHNOLOGIES

State of California guidance recommends evaluating 12 remedial technologies that consider removal and disposal, removal and treatment, in situ treatment, and no-action process options (RWQCB 1991a). The technologies under these process options include (1) excavation, (2) on-site soil aeration, (3) off-site soil treatment, (4) landfilling, (5) soil venting, (6) groundwater extraction and treatment by aeration, carbon filtration, or other means, (7) biodegradation of soil and groundwater, (8) physical containment, (9) chemical neutralization or oxidation, (10) incineration, (11) no action and (12) other new technologies. The following subsections describe these potential technologies. Viable process options are assembled into potential remedial alternatives and further discussed in Section 7.0.

6.1 EXCAVATION

Excavation involves the physical removal of contaminated soils and is a common technology employed in corrective actions. Excavation by itself is not a remedy. It must be accompanied by some type of treatment or disposal option.

Excavation of contaminated soils is a feasible and effective means of removing the source of contamination when the contaminants are limited to shallow depths in undeveloped areas. Conventional excavation methods are adequate for these conditions. The implementability of excavation depends on site-specific characteristics. Complications may arise at locations where underground utilities or storage facilities exist. Excavation around or near buildings may also add complications, such as the need for underpinning or sheet piling to stabilize the structure, and rerouting of utility lines. Monitoring for air quality may be required during excavation. When fugitive air emissions exceed air quality standards, limitations on the quantity of soil that can be excavated per day may be imposed.

Conventional excavation is effective, can be implemented, and requires moderate capital costs. Therefore, excavation was considered further in subsequent sections of this CAP.

6.2 ON-SITE SOIL AERATION

Soil aeration relies on the volatilization of contaminants. Soil is excavated then mechanically mixed to enhance volatilization. Aeration is effective for light-end fuel constituents. This technology can be integrated with ex situ biodegradation to promote as much mineralization of the contaminants as possible. Soil aeration is implementable if excavation is implementable and has low costs. This technology was considered in subsequent sections of this CAP as an augmentation to biodegradation.

6.3 OFF-SITE SOIL TREATMENT

Off-site soil treatment is generally effective and can be implemented if excavation is possible. The costs associated with this options depend on the amount of soil transported off-site and the type of treatment selected. Typically, the costs for this option are prohibitive for large quantities of soil. The Navy anticipates that the contaminated soil at Moffett Field can be treated more efficiently on-site; therefore, this option was not considered further.

6.4 LANDFILLING

This option entails excavating contaminated soils and either building an on-site landfill or shipping the wastes off-site and disposing of the material in the landfill without any treatment other than solidification or stabilization. This option is effective in removing and containing the contaminated soil, but does not reduce the toxicity or volume of contamination. Implementation of an on-site landfill is contingent on future land use. Land use restrictions will accompany an on-site landfill

option. One benefit of an on-site landfill is no off-site transportation of contaminated soil. However, implementation of an off-site landfill is easier than an on-site landfill because no landfill design or construction activities are necessary. Generally, the Navy considers it more appropriate to dispose of any materials off-site. Therefore, only off-site landfilling disposal options will be discussed further in this CAP. The ultimate feasibility of this option would be dependent on the volume of soil excavated and disposed.

6.5 SOIL VENTING

Soil vapor extraction (SVE) is an in situ soil venting process that promotes the mass transfer of volatile compounds from the soil or liquid media to the more mobile vapor phase. It uses vapor extraction wells and a vacuum pump to exert a pressure difference and induce volatilization of contaminants. Clean air may be injected into the contaminated soil through injection wells to enhance the vacuum extraction system. SVE systems are designed to yield a maximum recovery rate of volatile compounds from contaminated soil. SVE is effective for in situ removal of light-end fuels from soils. Therefore, this option was retained for further consideration.

Soil venting can also be designed and operated to optimize oxygen transfer to the subsurface, where indigenous organisms are stimulated to metabolize fuel constituents. These systems are referred to as bioventing systems. They are operated at much lower flow rates and with configurations different than those of conventional SVE systems. The major consideration for bioventing systems are whether the contaminants are amenable to biodegradation, bioinhibitors are present at the site, and oxygen can be effectively transported within the soil to encourage microbial activity. The contamination at Moffett Field is appropriate for this technology. Generally, migration of contaminants through the soil occurs in the more permeable channel zones underlying the sites. These channels would also transport oxygen to the microorganisms and, thus, this technology can be effective. Consequently, this option was retained for further consideration.

6.6 GROUNDWATER EXTRACTION AND TREATMENT

Groundwater extraction and treatment or ex situ technologies rely on groundwater extraction to contain the migration of the contaminated plume and remove contaminants. Ex situ treatment (pump and treat) systems address localized groundwater contamination. This alternative is the most common technology historically employed for site remediations. Pump and treat systems have been implemented for Sites 9 and 14 at Moffett Field. A variety of treatment alternatives are possible for groundwater remediation, such as air stripping, biodegradation, and carbon adsorption.

Ex situ treatment relies primarily on extracting groundwater containing dissolved contaminants to reduce the level of contamination in the aquifer. Contaminants are then removed from the extracted groundwater using a variety of treatment options. The extracted groundwater is removed primarily from the permeable zones within the aquifer. However, since the A1-aquifer zone consists of a predominance of silts and clays; remediating this aquifer zone must also include these materials. The petroleum-related constituents will adsorb to the silts and clays within the aquifer zone and these materials will continue to act as contaminant source areas over time. Ex situ treatment, therefore, also relies on inducing a concentration gradient in the less permeable aquifer zone materials that promotes desorption of the contaminants. Once desorbed, the contaminants can be extracted from the aquifer material via the groundwater and removed from the water using a variety of treatment options.

The effectiveness of pump and treat systems at Moffett Field depends on the ability to extract or move water through the silts and clays or induce a concentration gradient within these materials. The primary restoration limiting factors for remediating petroleum contamination within the A1-aquifer zone at Moffett Field are the contaminant desorption and advection rates. Contaminants can only be extracted after they are desorbed and move into permeable zones. The effectiveness of pumping will be evaluated with the operation of the Site 9 SCM systems. Therefore, this option was retained for further consideration.

The petroleum contamination at Moffett Field is confined to the upper A1-aquifer zone. This aquifer zone currently acts to reduce salt water intrusion. Therefore, using extensive groundwater extraction wells could undermine this current beneficial use of the aquifer. The detrimental effect could be compensated by reinjecting treated water into the upper aquifer, thereby minimizing changes to current hydraulic conditions.

6.7 BIODEGRADATION

TPH contamination can be most cost-effectively remediated using biodegradation or bioremediation technologies. Stimulation of microbial growth and activity for TPH removal is accomplished primarily through the addition of oxygen and nutrients. Bioremediation can be employed for remediating both contaminated soils and groundwater and it can be implemented either in situ or ex situ.

6.7.1 In Situ Bioremediation

In situ bioremediation involves stimulating microorganisms to enhance microbial growth. Microorganisms use organic constituents in water and soil as a food source and ultimately oxidize the organic compounds to carbon dioxide and water. Nutrients and oxygen are critical to maintaining microbial activity. In situ bioremediation typically involves some type of nutrient and/or oxygen transport mechanism to maintain optimal microbial levels in the subsurface environment. This transport can be accomplished by circulating water-based solutions or air streams through the contaminated soil or groundwater. The primary advantages of in situ processes is that contaminated soil does not have to be excavated or groundwater extracted. These options have high feasibility because some contaminated soils exist under buildings or other areas with potential access problems at Moffett Field and extracting groundwater may have limited effectiveness in Moffett Field aquifer materials. Bioventing is the in situ technology for remediating unsaturated zone soils. It is discussed in Section 6.5.

Biosparging is an in situ groundwater technology that relies on injecting air into the saturated zone to promote indigenous microbial activity within the aquifer. This technology can be effective for reducing the concentrations of both light- and heavy-end fuel constituents. This option was retained for further consideration based on the types of fuels and subsurface conditions found at Moffett Field.

6.7.2 Ex Situ Bioremediation

Ex situ bioremediation uses the same fate mechanisms described for in situ bioremediation. The major difference is that the contaminated media are excavated or pumped before treatment.

The excavated soil would be handled on a bioremediation cell (one has been constructed at Moffett Field under the Site 12 SCM activities). Nutrients and oxygen would be added to the contaminated soils to promote optimal microbial growth conditions. Ex situ treatment processes can often effectively treat excavated soils to cleanup levels in a shorter time frame than in situ processes. However, the ex situ process involves excavation activities. Therefore, the implementability of this option is directly related to whether excavation is implementable. Some soil aeration could also be integrated into the ex situ soil bioremediation activities by using tilling actions to transfer oxygen to the microbes. The tilling would also promote volatilization of some constituents. Air emission controls may be required for the bioremediation cell if the amount of contaminated soils exceeds

levels stipulated in BAAQMD regulations. Ex situ soil bioremediation will be considered further since Moffett Field has a bioremediation cell and the petroleum contamination is amenable to biodegradation.

Aboveground biological treatment of contaminated groundwater aboveground can be conducted under aerobic or anaerobic conditions. With this technology, a particular type or combination of microorganisms is selected to decompose a particular contaminant or group of contaminants. Reaction conditions can be optimized to increase the rate and extent of chemical decomposition. Both aerobic and anaerobic biodegradation have been proven effective on a variety of petroleum-related constituents, and both are readily implementable. Biological treatment includes such processes as sequencing batch reactors, trickling filters, rotating biological contactors, packed bed bioreactors, and activated sludge. As stated in Section 6.6, the effectiveness of ex situ groundwater treatment alternatives depends on the effectiveness of the extraction system. The ex situ groundwater biological treatment option was retained for further consideration.

6.8 PHYSICAL CONTAINMENT

Soil containment actions generally consist of capping the soil to prevent direct human exposure and installing impermeable barriers to minimize leaching of compounds into the groundwater. These process options inhibit the infiltration of precipitation into the soil and thereby reduce the potential for soil contaminant leaching from the unsaturated zone into the groundwater. This option is effective in reducing the mobility of the contaminants but does not reduce the toxicity or volume of contamination. Containment will only be considered when evaluating the fate and transport of petroleum contaminants. Much of the land on Moffett Field is capped with asphalt.

Groundwater containment refers to the process of minimizing the spread of a contaminant plume through hydraulic gradient controls. The most common method for maintaining hydraulic control involves the use of groundwater extraction wells. If extraction wells are used, the extracted groundwater will require treatment prior to discharge. Another option for containing groundwater plumes are vertical barriers. Vertical barrier technologies include slurry walls, grout curtains, and sheet piling walls. Vertical barriers are composed of low permeability material (hydraulic conductivity less than 1E-06 cm/sec) that are placed perpendicular to groundwater flow and penetrate to the depth of a naturally occurring aquitards to contain one or more aquifer zones beneath the site. These vertical barrier options are effective only if used in conjunction with a groundwater extraction system. Without the extraction system, the contaminants will eventually flow around or through the barrier. Vertical barriers can be implemented in areas with shallow aquifers; however, they are

effective only for impeding flow and have relatively high capital costs. In addition, vertical barriers are not necessary for containing a groundwater plume if a groundwater extraction system or in situ treatment system that targets the leading edge of the plume are in place. Therefore, the vertical barrier options are eliminated from further consideration in this CAP.

6.9 CHEMICAL NEUTRALIZATION OR OXIDATION

In addition to biodegradation, chemical oxidation is also an effective technology for remediating petroleum constituents. This technology involves using abiotic oxidation processes to detoxify contaminants. Oxidation processes can use a combination of ultraviolet light (UV) and a chemical oxidizing agent, either ozone (O_3) or hydrogen peroxide (H_2O_2), to chemically decompose organic contaminants. The contaminated water is mixed with O_3 or H_2O_2 or both in a reaction chamber in the presence of UV light. Hydroxyl radicals (•OH) formed in the reaction chamber effectively oxidize organic contaminants in water to form carbon dioxide and water.

This process option can be implemented in situ or ex situ. However, the implementation of in situ chemical oxidation requires very good control of subsurface conditions. This control is problematic with heterogeneous aquifer materials, which predominate at Moffett Field. Therefore, in situ chemical oxidation is not retained for further consideration.

For ex situ chemical oxidation process options, the contaminated media must by excavated or extracted then contacted with solutions containing oxidizing agents. Abiotic oxidation can reduce the concentration of petroleum-related constituents. Chemical oxidation was the technology chosen for remediating TPH contamination at Site 12 (PRC 1993b). However, during the implementation of this technology, there were problems reaching cleanup goals. The contaminant profile at Site 12 consisted of heavy-end distillates and apparently some of these constituents were not amenable to oxidation. This option will not be considered for heavy distillate contamination. This option is implementable if excavation or extraction is implementable and it was retained in this CAP.

6.10 INCINERATION

Incineration is a thermal oxidation process effective for treating soils with high contaminant concentrations; however, it is very costly. Incineration may not have the support of community groups and, thus, can be difficult to implement. There are other options that are feasible for the petroleum soils at Moffett Field; therefore, incineration will not be considered further.

6.11 NO ACTION

Under the no-action option, natural attenuation process and transport mechanisms would be considered to evaluate whether cleanup goals would be achieved within a certain time frame. The groundwater on the western side of Moffett Field has been contaminated by a regional VOC plume. The design for remediation of the regional plume indicates that cleanup goals will be achieved in approximately 47 years (Canonie 1994). Therefore, it is possible that a no-action alternative, which considers natural attenuation, will achieve Navy cleanup goals. The no-action alternative may include continued monitoring and some institutional controls (for example, restricting installation of water supply wells at Moffett Field). Since natural biological attenuation may already be occurring, the no-action option will be considered further.

6.12 OTHER NEW TECHNOLOGIES

The Navy believes that remediation of contaminated media at Moffett Field may require an innovative approach due to the predominance of contaminated clay and silt at the site. Other technologies will be integrated into the CAP if the alternatives presented in this version are not cost effective.

One additional ex situ groundwater technology considered is electron injection. Electron injection technology involves the irradiation of aqueous waste with high-energy electrons resulting in the formation aqueous electrons (e_{aq}), hydrogen radicals (H•), and hydroxyl radicals (•OH). These reactive species initiate chemical reactions capable of destroying organic compounds in aqueous solution, in most cases, oxidizing them to carbon dioxide, water, and salt. Organic contamination appears to be amenable to treatment using this treatment system based on the results of bench- and pilot-scale studies (EPA 1992). A pilot-scale trial of this technology is scheduled for petroleum-contaminated groundwater at Moffett Field before the end of 1994. This field trial at Moffett Field will be used to assess whether the system is effective to treat petroleum-related constituents. Electron injection was retained for further consideration.

7.0 POTENTIAL REMEDIAL ALTERNATIVES

This section describes potential remedial alternatives for remediating petroleum contamination in soils and groundwater. The alternatives either target unsaturated soils, groundwater only, or both soils and groundwater (combination technologies). The following sections describe an array of soil,

groundwater, and combination remedial options that are considered potentially applicable for remediating petroleum contamination at Moffett Field. This section forms the basis for recommendations at each petroleum site.

Each alternative description includes information on effectiveness, implementability, and relative cost. Effectiveness focuses on (1) the ability of the alternative to handle the estimated areas or volumes of contaminated soil and groundwater and to meet the remediation goals; and (2) how proven and reliable the process options that comprise the alternative are with respect to the contaminants and conditions at the site. Implementability encompasses both the technical and administrative feasibility of implementing a treatment technology. Cost ranges are provided for each alternative based on a unit volume or unit area of contamination. The ranges are order-of-magnitude estimates and based on cost data prepared for other studies. Appendix B provides the calculations for deriving these cost ranges.

7.1 SOIL

The potential options considered for remediating soils are divided into two major categories: ex situ and in situ. Ex situ technologies involve excavating the soil followed by treatment or disposal, which can take place on or off site. Generally, the Navy considers it more appropriate to treat the soils on site and dispose of any materials off site. Therefore, only on-site treatment and off-site disposal options will be discussed further in this CAP. Several alternatives for remediating soil were assembled from the process options discussed in Section 6.1, including:

- Excavation and disposal
- Excavation, bioremediation, and backfill
- Excavation, low temperature thermal desorption, and backfill
- Excavation, chemical oxidation, and backfill
- Soil vapor extraction (SVE)
- Bioventing

These alternatives will be discussed in the following subsections.

7.1.1 Excavation and Disposal

This alternative consists of soil removal by excavation and disposal at an off-site landfill. This alternative does not include treatment of the excavated contaminated soil. Excavation and removal followed by land disposal are commonly used in site remediation. There are no absolute limitations on the types of waste which can be excavated and removed. However, worker health and safety is an important consideration when excavating explosive, reactive, or highly toxic waste material. Other factors considered include the mobility of the wastes, the feasibility of on-site containment or in situ treatment, and the cost of disposing of the waste. A frequent practice at hazardous waste sites is to excavate and remove contaminant hot spots and to use other remedial measures for less contaminated soils. Some soil excavation has already taken place at Moffett Field during the tank and sump removal activities and SCM activities (PRC 1991f, PRC and MW 1994c).

There are a number of activities which are performed prior to and as part of excavation activities. These include design and construction of site operating areas, implementation of controls to minimize environmental releases and protect worker safety, and equipment selection and mobilization.

Proper layout of the work area is critical to safe and cost-effective excavation activities. The layout should include a contaminated zone where any staging of contaminated soil takes place, a transition zone for personnel decontamination, and a clean zone where administrative and emergency medical care can be carried out. Air monitoring should be conducted at all times during excavation to evaluate the presence of unsafe levels of various hazardous constituents. As contaminated soils are excavated, they should be transferred to box trucks or to a temporary storage area. Frequently, hand-held vapor analyzers (such as photoionization detectors [PIDs]) are used to assess the approximate level of soil contamination. Soils can then be segregated based on approximate contaminant levels.

This alternative is amenable for sites where the extent of contamination is shallow and the areas of attainment are accessible. Excavation at sites located in developed areas that contain buildings and underground obstructions will be more difficult to implement.

Effectiveness

Excavation involves the physical removal of contaminated soils, a common technology often employed as part of corrective actions. Excavation of contaminated soils is a feasible and effective means of removing the source of contamination when the contaminants are limited to shallow depths in undeveloped areas. Conventional excavation methods are adequate for these conditions. Excavation can mitigate the contamination at a site and the need for long-term monitoring. Once excavation has begun, the time to achieve beneficial results can be short relative to alternatives such as in situ treatment. This reduces the mobility and volume of contamination at the site, but does not reduce the toxicity. In addition, short-term impacts such as fugitive dust and toxic gas emissions (for example, benzene) can be a concern.

Off-site disposal of contaminated soil would effectively minimize further mobility of and exposure to contamination. Off-site disposal would reduce the volume of contaminants. Even though the contaminated soil would be removed from the site, the Navy would have continued liability associated with the off-site disposal facility. In addition, recent statistics indicate that the greatest risk from remediation is often associated with the off-site transportation of contaminated material.

Implementability

Excavation and disposal of contaminated soil are implementable. The implementability of excavation depends on site-specific characteristics. Complications may arise at locations where underground utilities or storage facilities exist. Excavation around or near buildings may also add complications, such as the need for underpinning or sheet piling to stabilize the structure and rerouting of utility lines. Moffett Field is still active, has many buildings, and is underlain by a significant number of buried obstructions. Therefore, extensive excavation activities would be difficult to implement in many areas (especially Sites 5 and 9).

The excavated soil concentrations dictate the type of disposal unit that must be used (that is, Subtitle C or D under the federal system; or Class I, II, or III under the state system). They also dictate the feasibility of disposing the soil without treatment. For example, some petroleum-contaminated media being addressed under a corrective action program are exempted from the federal hazardous waste regulations [40 CFR 261.4 (b)(10)]. However, the soils may be classified as non-RCRA hazardous wastes under SWRCB regulations (23 CCR). These petroleum-contaminated materials probably can be handled in a federal Subtitle D or state Class II unit.

Disposal can be accomplished using either an on-site or off-site landfill. At this time, the Navy only considers an off-site landfill. The primary problems associated with off-site landfills are locating a permitted facility that will accept the contaminated soil and transporting the soil off site. If the soil is classified as containing a hazardous waste, the management and transportation of the soils must be in accordance with the hazardous waste generator and transporter regulations.

Cost

The costs associated with excavation and disposal range from moderate to high. They primarily depend on the area of contamination, the amount of subsurface obstructions, and the type of landfill that can accept the contaminated soils. The estimated cost range for this alternative is from $380 to $560 per cubic yard ($yd^3$). There are no long-term O&M costs associated with this alternative.

7.1.2 Excavation, Bioremediation, and Backfill

This alternative includes excavating unsaturated soils using conventional construction methods, treating the soils on site, and backfilling the treated soils. The viability of this alternative depends on the ability to excavate the contaminated material and the ability of the selected ex situ treatment process to meet remediation goals. The effectiveness and implementability of excavation is discussed in detail in Section 7.1.1. Therefore, this section will focus on different ex situ treatment options.

Petroleum contamination is often remediated using bioremediation technologies. Stimulation of microbial growth and activity for TPH removal is accomplished primarily through the addition of oxygen. In addition, nutrients can be the rate limiting parameter and can be added to enhance biodegradation. Ex situ bioremediation involves handling excavated soil within a bioremediation cell (one has been constructed at Moffett Field as part of the Site 12 SCM).

Oxygen can be added to the soil by tilling or using an aeration system to continuously draw air through the soil. The aeration system typically consists of a perforated piping system buried in gravel, and is connected by a manifold to a regenerative blower which pulls a constant vacuum through the pipes and gravel. The bioremediation aeration system draws low pressure air through the soil and does not strip (volatilize) contaminants as with high velocity vacuum extraction methods.

This aeration system may include emissions control to clean the VOC-contaminated air released upon volatilization. The vapor emissions from petroleum contaminated soils at Moffett Field are expected to be low; in fact, emissions are anticipated to be below BAAQMD levels that mandate control devices because the aeration system is not intended to strip the soil of VOCs.

Nutrients can be added through an irrigation system, while maintaining the optimal moisture content in the soil. In addition, the soil can be inoculated with ammonium nitrogen, orthophosphate, micronutrients, and pH buffers to optimize biodegradation before placement in the cell and irrigated with unamended water to maintain optimal moisture content.

Effectiveness

Bioremediation has been shown to be effective in removing petroleum-related contaminants. The process targets organic constituents such as those found in petroleum mixtures. Treatability testing may be required to determine optimum conditions such as oxygen and nutrient requirements, temperature, moisture content, and pH. The treatability test also will indicate the duration of treatment required.

The by-products generated in this process are generally low in volume and concentration. The releases of greatest concern may be VOC emissions during construction and the subsequent treatment period. VOC emissions during construction will require monitoring to verify worker safety, use of personal protective equipment, and quick and efficient placement of soil in the cells. During bioremediation operations, any emissions blower exhaust system may include carbon adsorption devices to capture volatilized VOCs.

Runoff of water used to maintain the optimum moisture content could be a source of residual contamination, but the treatment cell is designed to control all liquids used within the system. This residual liquid can be recycled in the system until biodegradation of the contaminants in the water occurs.

The time required to reach treatment goals primarily depends on the type of fuel contamination and the amount of nutrients, oxygen, and water that must be added.

Implementability

This process is readily implementable. The bioremediation pad constructed for the Site 12 SCM could be used and should be available. The Site 12 bioremediation pad consists of a concrete pad measuring 225 feet by 80 feet with runoff control system.

The ex situ bioremediation system may have an irrigation and aeration system to supply water and oxygen. The aeration system will consist of a pipe network which draws air (or oxygen) down through the soil and into a vapor control system before it is released to the atmosphere. The system also will have a leachate collection and disposal system to control aqueous residues. The materials required for ex situ bioremediation (such as nutrients, piping, and blowers) are easily obtained.

Cost

The capital costs associated with this process option for equipment such as blowers, and piping for the aerating and irrigation systems. The Site 12 SCM will provide the bioremediation pad. The cost depends on the type of oxygen transfer system used and the amount of time to reach remediation goals. The estimated cost range for this alternative is \$130 to \$560 per yd^3.

7.1.3 Excavation, Low Temperature Thermal Desorption Treatment, and Backfill

This alternative includes excavating unsaturated soils using conventional methods, treating the soils on site using low temperature thermal desorption treatment, and backfilling the treated soils. The viability of this alternative depends on the ability to excavate the contaminated material and the ability of the selected ex situ treatment process to meet remediation goals. The effectiveness and implementability of excavation are discussed in detail in Section 7.1.1. Therefore, this section will focus on the treatment component of the alternative.

Thermal desorption involves physically separating volatile and semivolatile organic compounds by vaporization. A variety of thermal desorption processes are available for mitigating hazardous waste sites. Depending on the specific thermal-desorption system selected, the process heats contaminated media between 200 to 1,000 °F, driving off water and organic constituents. Offgases may be burned in an afterburner, condensed to reduce the disposal volume, or captured by carbon adsorption. Dust and particulates may be controlled with cyclones, baghouses, or venturi scrubbers.

Generally, there are two types of thermal desorption: directly heated desorption and indirectly heated desorption. Directly heated systems use a fuel burner as a heat source which may be either internal or external to the primary soil-heating chamber. The internally fired units resemble rotary kilns, operate at temperatures less than 800 °F, and have generally been limited to treatment of nonchlorinated organic compounds such as petroleum constituents.

Indirectly heated systems transfer heat through metal surfaces to the waste. They produce a lower volume of exhaust gas minimizing loading to offgas treatment units. These systems operate at temperatures less than 600 °F for VOCs and greater than 600 °F for SVOCs and PCBs. Some SVOCs, however, may be removed at the lower operating range as a result of stripping in the presence of water vapor and volatiles (EPA 1991a).

A typical thermal desorption system consists of a soil feed hopper, a thermal processor, a cyclone, a baghouse, scrubbers, an offgas collection or treatment unit, and holding tanks. Excavated soil is screened to remove objects greater than 1.5 inches in diameter. The soil is then delivered by gravity to the desorber inlet or conveyed by augers to a feed hopper. Depending on the system, the desorption step can vary. The waste contacts a heat transfer surface where VOCs and water are driven off. The offgas is treated and the organic compounds are either collected on activated carbon, recovered in condensation equipment, or burned in an afterburner.

Typical residues of thermal desorption systems are treated soils, oversized soil particles, particulate control system dust, clean offgas, condensed contaminants and water, and spent carbon (EPA 1991a). Some of these residues will require further treatment or recovery.

Effectiveness

Thermal desorption is a proven effective technology in treating soils contaminated with hydrocarbons. This technology is effective in treating VOCs and SVOCs found in petroleum mixtures (EPA 1991a).

This technology can be used for both high and low contaminant concentrations. Lower operation temperatures eliminate volatilization of metals such as lead, cadmium, copper, and zinc. However, metals such as mercury and arsenic may volatilize during thermal desorption. The presence of chlorine in the waste stream is believed to adversely affect volatilization of some metals, especially lead (EPA 1991a).

Bed temperature and residence time are the primary factors affecting performance in this process. At least 20 percent solids are required to facilitate placement in the desorption equipment. A high fraction of fine silt or clay in the soil will generate a greater loading on the downstream air pollution control equipment. Soils that are tightly aggregated or largely clay, or soils that contain rock fragments or particles greater than 1.5 inches, can result in poor performance due to caking of soil within the thermal processor.

Implementability

Thermal desorption is readily implementable and commercial-scale units are available. Space requirements are typically less than 150 feet by 50 feet, exclusive of materials handling and decontamination areas. An adequate access road to the site is required for delivering the treatment system on flatbed trailers. Standard 440-volt (V), three-phase electrical service is required. In addition, water must be available and BAAQMD regulations would regulate possible air emissions from the treatment systems. However, administrative implementability should not be a problem.

Cost

Costs for thermal desorption treatment systems are highly variable depending on the quantity of waste to be processed, remediation time, moisture content, organic content of the contaminated medium, and the cleanup standard to be achieved. The overall cost estimate for this alternative varies from \$210 to \$670 per yd^3.

7.1.4 Excavation, Chemical Oxidation, and Backfill

This alternative includes excavating unsaturated soils using conventional construction methods, treating the soils on site using chemical oxidation, and backfilling the treated soils. The viability of this alternative depends on the ability to excavate the contaminated material and the ability of the selected ex situ treatment process to meet remediation goals. The effectiveness and implementability of excavation is discussed in detail in Section 7.1.1. Therefore, this section will focus on the chemical oxidation treatment component.

Chemical oxidation relies on oxidizing agents such as H_2O_2 to detoxify organic contaminants. Following excavation, soils are typically screened to remove large rocks and debris. The screened soil is then fed into a reaction chamber where the oxidants (and perhaps, catalysts) are mixed with the

soil. One vendor uses activated carbon catalysts and oxidants to facilitate the abiotic decomposition of petroleum hydrocarbons (PRC and MW 1994c). The catalysts provide active sites where the hydrocarbon constituents are adsorbed and allow the oxidizing agents to react with these hydrocarbons (PRC and MW 1994c). The retention time in the reaction chamber depends on the concentration of contaminants and the type of soil matrix. After treatment, the soil is available for backfilling.

Reactors are typically operated under a vacuum so that contaminated vapors generated by the mixing action can be captured and treated prior to emission. The offgas can be treated using carbon adsorption, catalytic oxidation, or chemical oxidation. The optimal offgas treatment process depends on the nature of the offgas expected to be generated.

Effectiveness

Chemical oxidation is an effective method to detoxify petroleum-related constituents. However, the effectiveness is limited by the ability to contact contaminants with the oxidizing agent. Clay materials are not amenable to thorough mixing. In addition, the effectiveness depends on the amount of hydroxyl radicals formed in the reactor. The Site 12 SCM used a chemical oxidation reactor. The reactor had difficulties reaching SCM cleanup goals. However, the SCM Site 12 cleanup goals were much lower than the final petroleum cleanup goals contained in this CAP.

Implementability

Chemical oxidation is readily implementable and commercial-scale units are available. Space requirements are typically less than 150 feet by 50 feet, exclusive of materials handling and decontamination areas. An adequate access road to the site is required for delivering the treatment system on flatbed trailers. Standard 440-V, three-phase electrical service is required. In addition, water must be available and BAAQMD regulations would regulate possible air emissions from the treatment systems. However, administrative implementability should not be a problem.

Costs

Costs for chemical oxidation treatment are moderate to high. The primary costs are associated with the excavation activities and the cost of the oxidants. The estimated range for this alternative is $155 to $240 per yd^3.

7.1.5 Soil Vapor Extraction

SVE is an in situ soil venting process that promotes the mass transfer of volatile compounds from soil or liquid media to the more mobile vapor phase. It uses vapor extraction wells and a vacuum pump to exert a pressure difference and induce volatilization of contaminants. Clean air may be injected into the contaminated soil through injection wells to enhance the vacuum extraction system. SVE systems are designed to maximize the recovery rate of VOCs from contaminated soil. Therefore, treatment of the vaporized contaminants is generally required.

In situ vacuum extraction removes VOCs from soils in the unsaturated zone (EPA 1988a). The basic components include monitoring wells, high-vacuum extraction wells, and high-vacuum pumps. The vacuum pumps are connected via a pipe system to a series of production wells. The extraction wells are installed and screened through the contaminated soil zone to just above the groundwater table. Monitoring wells are installed around the extraction wells to monitor the interstitial air pressure.

The system operates by applying a vacuum through the extraction wells. These wells can be either vertical or horizontal. Vertical wells are generally inappropriate for sites where the depth to groundwater is less than 12 feet, due to the potential upwelling of the water table once a vacuum is applied in the soil. Vertical extraction wells are similar in construction to groundwater monitoring wells, and are 4 to 6 inches in diameter for optimum VOC removal (EPA 1991b). Slots are usually sized as small as possible to reduce silt entrainment. A highly permeable sand or gravel packing is placed around the screen for optimal gas flow to the well. Above the gravel pack, bentonite is used to seal the hole. The well is typically located to intercept the center of contamination. The screened interval should also coincide with the depth of highest contaminant concentration. Often, this is just above the water table for products that are lighter than water such as petroleum.

Horizontal wells minimize the upwelling of the groundwater and allow coverage of a greater area than vertical wells. Installation of shallow horizontal wells can be accomplished by the same methods as a french drain, and is best suited in areas where no surface or subsurface impediments exist. Horizontal wells can offer better control of the subsurface in a heterogeneous and low-permeability area (such as the Moffett Field unsaturated soil zone).

Well spacing depends on the radius of influence. The radius of influence is based on the air permeability of the soil. A field test would be required to accurately estimate the radius of influence because each site has unique characteristics. As a rule of thumb, extraction wells should be spaced at 2 times the depth to which they are installed (EPA 1991b).

Once the wells are tightly sealed at the soil surface, a vacuum is created by the vacuum pumps. The vacuum is controlled by bleeding air into the system. Volatiles in the soil diffuse through the air spaces between the soil particles to the production wells because of the pressure gradient created by the vacuum pumps. The vacuum established in the soil continuously draws VOC-contaminated air from the soil pores and draws fresh air from the soil surface down into the soil. The removed volatiles are processed through a liquid-vapor separator. The VOC vapors are then treated by activated carbon beds, biofiltration, catalytic thermal oxidation, direct thermal oxidation, or vapor phase UV/oxidation.

Effectiveness

SVE is effective for in situ treatment of low molecular weight fuels and solvents in contaminated unsaturated soils. SVE has not generally been applied to heavier fuels because the larger fraction of high boiling point, high molecular weight constituents are not volatile. However, vendors indicate that SVE is appropriate for this type of contamination also. It is more difficult to remove VOCs that have high water solubilities. Compounds with high water solubilities, such as benzene, may be removed with relative ease from dry soils. However, with normal soils (for example, moisture content ranging from 20 to 30 percent) the likelihood of successful remediation drops significantly because the moisture in the soil acts as a sink for the soluble chemical.

Another factor affecting the effectiveness of vacuum extraction is the organic content of the soil. Increasing organic content generally decreases the effectiveness of vacuum extraction. Moffett Field soils have a relatively high organic content. Soil hydraulic conductivities ranging from 1×10^{-4} cm/sec for sands to 1×10^{-8} cm/sec for clay have been effectively remediated at a Superfund Innovative Technology Evaluation (SITE) program demonstration test in Groveland, Massachusetts (EPA 1989a). Moffett Field unsaturated soils are comprised predominantly of clay or silty clay. Hydraulic conductivities of clays at Moffett Field range from 8.97×10^{-8} to 1.16×10^{-7} cm/sec, and moisture content ranges from 24 to 36 percent (PRC 1992b).

Removal rates vary with soil conditions. For example, a Groveland, Massachusetts site contained sand and clay contaminated with approximately 1,000 mg/kg of TCE. About 200 days of treatment were required to achieve a cleanup level of 60 mg/kg. During the course of this demonstration, there were significant increases of wellhead gas concentrations when the extraction process was restarted after stoppage. This is due to the desorption occurring in the clay. Near the end of the projected

remediation time, it should be possible to determine if the site has been adequately decontaminated by running the vacuum pump intermittently and measuring the wellhead gas concentration. If there is no significant increase in concentration, then the process can be stopped.

The two potential residuals of this process, vapor and water, will require further treatment. Estimation of the effluent chemical concentrations is difficult without a treatability study. These data are needed to assess which vapor treatment is best suited for each site. Vapor phase carbon adsorption is a proven and effective emission control process for removing compounds at efficiencies greater than 99 percent. Biofiltration uses soil or compost as a filter medium where the contaminants are sorbed and biodegraded. The removal efficiency of rapidly biodegradable gases is about 99 percent. Catalytic and direct thermal oxidation systems can achieve greater than 90 percent destruction of the vapor phase organic compounds and, thus, are also effective treatment technologies. The other residual (condensed liquid) would consist of contaminated water. The treatment of this residual probably could be handled in any ex situ groundwater treatment process at Moffett Field.

In general, vacuum extraction works best in well drained soils with low organic carbon content and high air permeability. The soil conditions at Moffett Field have limited permeability. However, the air permeability and hydraulic conductivity are within the range observed at successful demonstrations at other sites. Therefore, a treatability test would be required to evaluate the effectiveness of this process option and the size of the system.

This alternative will be effective in limiting exposure of workers to contaminants since limited disturbance of contaminated media is involved in this alternative. The possibility of entrained contaminants will be significantly lower with this alternative than with any alternative that includes excavation.

Other process options can be added to this alternative to improve removal effectiveness. Pulling steam through the soil would enhance volatilization but may increase moisture content and, therefore, impede air permeability. In addition, by pulling air through the soil, natural bioremediation may be stimulated by providing oxygen to the indigenous microorganisms. Stimulated biodegradation would accelerate the remediation time.

Implementability

This process option would be readily implementable. This alternative is particularly attractive for sites where buildings and underground utility lines are located. No excavation is required and no building or underground utility disturbances are necessary. An area for the vacuum pump and vapor control system would be required. Standard 440-V, three-phase electrical service would also be needed.

The depth to groundwater is an important implementability factor. A vacuum extraction well will cause the water table to rise and will saturate the soil in the area of the contamination. Pumping groundwater to lower the water table may be necessary.

Cost

This alternative may be more cost effective than excavation because of the high cost of excavating in developed areas. The extent to which VOCs are dispersed in the soil vertically and horizontally, and the air permeability of the unsaturated soils, are important considerations in deciding whether vacuum extraction is preferable to other methods. Soil excavation and treatment may be more cost effective when only a few hundred cubic yards of near-surface soils have been contaminated. However, the location of the contaminant on a property and the type and extent of development in the vicinity of the contamination may favor the installation of a vacuum extraction system. For example, this process option should be considered if the contamination exists beneath a building or beneath an extensive utility trench network.

In situ vacuum extraction can treat large volumes of soil at reasonable costs (EPA 1991b). Based on available data, the system cost is estimated to range from $90 to $780 per yd^3.

7.1.6 Bioventing

Bioventing supplies air or oxygen to the subsurface, where indigenous organisms are stimulated to aerobically metabolize fuel constituents. Air can be injected through boreholes screened in the unsaturated zone, or air can be extracted from boreholes, pulling air from the surface into a contaminated area. Generally, it is preferable to inject air, thus reducing the possibility of generating contaminated gas that must be treated. However, vapor migration and accumulation in subsurface areas warrants considering air extraction or monitoring of subsurface structures.

Bioventing systems are composed of blowers or vacuum pumps, injection or extraction wells, and monitoring wells. Bioventing systems are operated at much lower flow rates and with configurations different than those of SVE systems. In general, SVE systems can remediate low molecular weight distillates at a faster rate than bioventing systems because of the higher vacuum used. However, high molecular weight distillates are more apt to biodegrade than volatilize; therefore, bioventing and SVE would have approximately the same restoration time frame. Bioventing system has a lower O&M requirements and costs over the restoration time frame.

As with SVE systems, the placement of bioventing injection or extraction wells depends on the zone of influence. The zone of influence for a bioventing system is the area of increased oxygen transfer. The configuration of wells can be estimated through modeling or pilot scale tests. Pilot-scale tests are highly recommended for areas with heterogeneous and low-permeability lithologies. Vertical or horizontal wells can be constructed to induce the oxygen transfer.

Effectiveness

Bioventing has been reported to be effective for remediating petroleum-contaminated unsaturated soils. The major considerations for bioventing systems are whether the contaminants are amenable to biodegradation, bioinhibitors are present at the site, and oxygen can be effectively transported within the soil to encourage microbial activity. Generally, migration of contaminants through the soil occurs in the more permeable channel sediments underlying the sites. These channels would also transport oxygen to the microorganisms and, thus, this technology can be effective. In addition, recent studies have indicated that oxygen will transfer to a limited extent from the permeable zones into adjacent less permeable zones.

This alternative will be effective in limiting exposure of workers to contaminants since limited disturbance of contaminated media is involved in this alternative. The possibility of entrained contaminants will be significantly lower with this alternative than with any alternative that includes excavation.

Implementability

This alternative is highly implementable. No excavation will be required and, therefore, no building or underground utility disturbances will be necessary for implementation of this option. This is particularly important for sites with buildings and underground utility lines.

Cost

The costs are low to moderate for this option. They range from $60 to $780 per yd^3 of contamination.

7.2 GROUNDWATER

Groundwater treatment technologies are divided into two major categories: ex situ (pump and treat) and in situ (in place treatment). Historically, ex situ treatment technologies have been the preferred alternative for remediating groundwater. However, studies on innovative technologies and ex situ technology performance indicate in situ technologies may be more effective for heterogeneous aquifers, both technically and economically (MacDonald and Kavanaugh 1994).

Several in situ and ex situ alternatives for remediating groundwater were assembled, including:

- Extraction, air stripping, and discharge (ex situ)
- Extraction, chemical oxidation, and discharge (ex situ)
- Extraction, electron injection, and discharge (ex situ)
- Extraction, bioremediation, and discharge (ex situ)
- Permeable bioremediation cell (in situ)
- Air injection (in situ)

Groundwater extraction and discharge of treated water are components common to all the ex situ treatment alternatives and are discussed separately in this section to avoid repetition.

7.2.1 Extraction and Discharge Options

Extraction wells and interceptor trenches are potential groundwater collection methods. The revised draft OU5 FS report (PRC 1994e) screens collection and discharge options for pump and treat systems. Extraction wells are the preferred option because they are generally easier to implement than interceptor trenches. However, extraction wells may be combined with interceptor trenches if additional site-specific data (especially the effectiveness of the Site 9 source control wells) indicate the subsurface aquifer conditions are not amenable to hydraulic control via wells.

Extraction wells are located and operated to hydraulically contain contamination and gradually clean up the plume. Groundwater will be extracted from the A1-aquifer zone at Moffett Field both as part of Navy source control activities and as part of the remediation of the regional VOC plume. This aquifer is heterogeneous with low hydraulic conductivities in some locations and high conductivities in the sand channels.

The effectiveness of any ex situ treatment technology at Moffett Field is related to the desorption and advective transport rates associated with the contaminated low-permeability materials in the saturated zone. Once desorbed, contaminants will move into the more permeable sediments in the sand channels. The extraction wells then serve to capture the desorbed constituents in groundwater in the sand channels. Reinjection and extraction can, theoretically, enhance the movement of clean water through the fine-grained materials. As cleaner water moves through these areas, a concentration gradient is established that promotes desorption of the contaminants. However, since desorption and advective flow through the fine-grained material are slow, the effectiveness of ex situ treatment alternatives is limited by these transport mechanisms and significant enhancement may not occur. The operation of the Site 9 SCM systems will provide information on the effectiveness of extraction systems for remediating heterogeneous saturated zones at Moffett Field.

Five discharge options for treated groundwater were also evaluated in the OU5 FS report (PRC 1994e): discharge to a POTW, discharge to the storm sewer, aquifer reinjection, infiltration, and reuse. Some of the treated groundwater will likely be discharged to the storm sewer system under a NPDES permit and some will be reinjected into the aquifer. In addition, if a viable reuse option is identified, some of the treated water may be reused. The treatment level required for each ex situ treatment process will depend on the discharge option employed.

In the discussions that follow, effectiveness for ex situ alternatives will be assessed on the basis of a technology's ability to remove petroleum-related contaminants from the extracted groundwater. However, as stated above, the overall effectiveness of all ex situ treatment processes primarily depends on the ability to extract contaminants as they desorb and are transported out of the saturated silt and clay materials.

7.2.2 Extraction, Air Stripping, and Discharge

This alternative involves collecting groundwater from the A1-aquifer zone using extraction wells, treating the extracted groundwater using an air stripping system, and discharging the treated water through reinjection wells or through a NPDES discharge permit.

Air stripping is a mass transfer process in which volatile contaminants in water are transferred to the gas phase (air). This transfer is accomplished by bringing the contaminated groundwater into contact with an air stream, where the volatile components that have an affinity for the gas phase leave the aqueous stream and enter the air stream. Process performance is enhanced by providing large surface areas for air to contact the water. Process performance can also be enhanced by heating the influent to the stripper. At higher temperatures, contaminants are more volatile and thus more likely to enter the gas phase.

Treatment of the offgases is often required to meet air emission standards. Standard offgas treatment process such as thermal oxidation, carbon adsorption, and biofiltration can be used to meet BAAQMD requirements.

Effectiveness

Treatment by air stripping is a proven technology and should be effective for removing light-end distillates. Air stripping also treats groundwater that contains other VOC contamination. It is most effective for contaminants with a relatively high volatility and moderate to low water solubility. Conventional air stripping uses a packed column to maximize the air-to-water contact area and increase the stripping efficiency. Treatment by air stripping is a proven technology and should be effective for removing light-end distillates.

Implementability

Air stripping systems are a common, well proven, effective method to treat groundwater contaminated with VOCs. An air stripping system to treat light-end distillates should be readily implementable. The Site 9 SCM includes an air stripping unit.

The equipment for groundwater treatment using air stripping is simple and readily available. The major components include packed towers, air blowers, process controls, pumps, piping, and an offgas treatment system. An offgas treatment system adds significantly to equipment needs but is also readily available. Many standard size units are available that can be easily transported and set up on site.

Site preparation requirements are minimal for the construction and operation of an air stripping treatment system. A relatively small, flat area with an access road is adequate for the treatment site. Power, water, and possibly a natural gas line for incineration of offgases should be available to the site.

The O&M requirements of an air stripper are moderate. The systems are simple to operate. Periodic inspection of the packed bed is required and, if precipitation of inorganic compounds on the packing material is a problem, periodic washing with an acid solution may be required. The requirements of vapor phase treatment and operation of a extraction and reinjection system will add to the O&M requirements of an air stripping system.

Regulatory requirements for operating an air stripping treatment system should not limit its implementability. The requirements are typical for work at a hazardous waste site involving contaminated groundwater. State air quality standards must also be met. Other regulatory requirements involve the treated water, which must meet discharge standards based on the selected method of discharge. In addition, Occupational Safety and Health Administration (OSHA) requirements must be met to protect workers during construction and operation of the air stripping system.

Air stripping systems are compatible with other systems and would be easily integrated with the available extraction and discharge options. Also, should any pretreatment or polishing of the water be required, it could be easily implemented with an air stripping system.

Cost

The major equipment required for this alternative includes pumps, piping, blower, air stripping unit, and surge tanks. The major cost associated with this alternative will be the O&M of the extraction treatment and reinjection systems. The overall cost is dependent on the area of contamination and the length of restoration time. The cost range for this alternative is $5.60 to $11.40 per square foot ($ft^2$) of contaminated area.

7.2.3 Extraction, Chemical Oxidation, and Discharge

Chemical oxidation uses a chemical oxidizing agent, for example, O_3 or H_2O_2, to chemically decompose organic contaminants. UV light can be used to enhance the formation of hydroxyl radicals (•OH). Typically, contaminated water is mixed with O_3 or H_2O_2 or both in a reaction chamber in the presence of UV light. Hydroxyl radicals formed in the reaction chamber effectively oxidize organic contaminants in water to form carbon dioxide and water. With the exception of fluorine, hydroxyl radicals have the highest oxidation potential of any commercially available oxidant. Hydroxyl radicals can be generated by exposing O_3 or H_2O_2 to UV light as shown in the reaction formulas below:

$$O_3 + H_2O \xrightarrow{UV} O_2 + 2\bullet OH$$

$$H_2O_2 \xrightarrow{UV} 2\bullet OH$$

The general configuration of a chemical oxidation system depends on the oxidizing agent used in the process. A system employing O_3 as an oxidant will typically consist of a UV reaction chamber, O_3 generator with air compressor and air preparation system, O_3 decomposer, and associated piping and controls. A UV/H_2O_2 system typically consists of a UV reaction chamber, H_2O_2 feed tank, and associated piping and controls. Systems employing a combination of both O_3 and H_2O_2 in a chemical oxidation process are also available.

Effectiveness

Chemical oxidation has been proven effective for destroying organic contaminants in groundwater. Destruction efficiencies reported by EPA range from 65 percent to greater than 99 percent for various organic contaminants (EPA 1991c). Petroleum-related organic compounds should be amenable to treatment based on previous studies and information from a chemical oxidation equipment manufacturer. A chemical oxidation system has the potential to meet the discharge requirements; however, a treatability study will be required to make a final evaluation. If the chemical oxidation system is not capable of meeting all the treatment requirements, a polishing process (such as a GAC treatment bed) will be required to complete the treatment. The use of GAC polishing units is common in wastewater treatment. GAC units are effective for treating low-concentration organic waste streams. However, since chemical oxidation is a relatively new technology, its effectiveness cannot be predicted as easily as can a well established technology such as air stripping or carbon adsorption. A treatability study should be conducted to evaluate appropriate UV and oxidant dosages as well as other design parameters.

Implementability

Although new, chemical oxidation has been used to treat a variety of contaminants in water and is proven to be implementable. Implementing a chemical oxidation system for treating petroleum contamination should be readily accomplished.

Equipment needs for groundwater treatment using chemical oxidation are relatively simple and all components should be readily available. Prefabricated modular units are also available that are compact and easily transported and set up on site.

Site preparation requirements are minimal for construction and operation of a chemical oxidation system. A relatively small, flat area with an access road is adequate for the treatment site. A standard power source is also required for O_3 generation, UV lamps, pumping, and controls; water should also be available at the site.

O&M requirements for a chemical oxidation system are moderate. Energy requirements are relatively high but can be reduced by using efficient, low-intensity lamps. H_2O_2 must be purchased regularly for use as an oxidant. The systems are automatic and easily operated and thus do not require skilled

labor for operation. Maintenance is not extensive. UV lamps can last more than 9,000 hours (more than 1 year of continuous operation) and the dielectric cell for units with ozone generation requires cleaning approximately once every 2 years (Ultrox 1992).

Regulatory requirements for operating a chemical oxidation system should not pose any implementability obstacles. The requirements are typical for work at a hazardous waste site involving contaminated groundwater. State air quality standards must also be met. Chemical oxidation systems using ozone must control ozone emissions as well as VOC emissions. The treated water, depending on the selected discharge method, may be required to meet standards such as MCLs or discharge standards established in an NPDES permit.

Chemical oxidation systems are compatible with other systems and could be easily integrated with the available extraction and discharge alternatives. Treatability studies would be required to evaluate the effectiveness of chemical oxidation on Moffett Field petroleum-contaminated groundwater. Also, should any pretreatment or polishing of the water be required, it could be easily added to a chemical oxidation system.

Cost

The cost for this alternative is moderate to high. Some of the major components include reactor vessels, O_3 generator, H_2O_2 storage tanks, O_3 decomposer, process control equipment, pumps, and piping. The O&M costs include power, oxidants, and general maintenance. The cost range for this alternative is \$6.00 to \$17.55 per ft^2 of contaminated area.

Chemical oxidation performance and operational costs depend on many influent water quality parameters. The two most significant parameters that affect efficiency and cost are water turbidity and iron concentration. Turbid water, for example, will absorb UV light energy and prevent it from initiating the formation of hydroxyl radicals. Ferrous ions, or iron ions in a reduced state, act as scavengers by consuming oxidants. The additional load for the system caused by turbidity and ferrous ions increases oxidant usage. In addition to scavenging, ferrous ions, when oxidized to less soluble forms, may precipitate in the reactor and cause UV lamp scaling and formation of suspended solids. Both of these result in the transmission of less UV light energy to the organic contaminants, and, therefore, less oxidation of the contaminants.

7.2.4 Extraction, Electron Injection, and Discharge

Electron injection technology involves the irradiation of aqueous waste with high-energy electrons resulting in the formation aqueous electrons (e_{aq}), hydrogen radicals (H●), and hydroxyl radicals (●OH). These reactive species initiate chemical reactions capable of destroying organic compounds in aqueous solution, in most cases, oxidizing them to carbon dioxide, water, and salt.

Effectiveness

The results of a December 1993 bench-scale study conducted on groundwater samples from Moffett Field indicate that the technology is effective in destroying organic contaminants such as DCE, TCE, and PCE. A field trial of this technology is scheduled for petroleum-contaminated groundwater at Moffett Field before the end of 1994. The performance of this technology was also investigated under EPA's SITE program. The results of EPA's investigation indicated that electron injection can treat complex mixtures of hazardous chemicals. The results also indicated that the technology can treat contaminated groundwater containing up to 5 percent suspended solids. The study determined that no sludge is formed and pretreatment is not necessary. The treatment process was found to be pH independent in the pH range from 3 to 11 (EPA 1992). Organic contamination appears to be amenable to treatment using this treatment system based on the results of these studies. The scheduled field trial at Moffett Field will be used to evaluate whether the system is effective to treat organic petroleum-related compounds to MCLs or NPDES discharge standards. Since this treatment system is an emerging technology, its effectiveness cannot be accurately predicted at this time.

Implementability

Electron injection technology, although an emerging technology, should be readily implementable technically. Units capable of processing up to 120 gpm were used under EPA's SITE program.

A typical treatment system will consist of a vacuum electron accelerator, voltage regulator, contaminated media storage chamber, and associated piping system. Components of the treatment unit are readily available.

Regulatory requirements for operating an electron injection system are similar to those for an air stripping system. They should not limit the implementability of this alternative.

Cost

This option will apparently have relatively high capital costs and moderate O&M costs; however, the pilot scale test will provide better cost information. The estimated cost range is $7.65 to $11.40 per ft^2 of contaminated area.

7.2.5 Extraction, Bioremediation, and Discharge

This treatment involves pumping groundwater from the A1-aquifer zone, treatment of the groundwater using an aboveground biological treatment system, and discharge of the treated groundwater using the selected discharge alternative.

Biological treatment uses microorganisms to degrade organic chemicals into less toxic compounds. Microbial degradation of organic compounds can occur under aerobic and anaerobic conditions.

Under aerobic conditions, organic compounds in groundwater come into contact with the microorganisms and dissolved oxygen. The microorganisms use the organic compounds as food and oxidize them to carbon dioxide, water, and cell material if complete degradation occurs. Under certain environmental conditions, complete degradation may not take place, sometimes resulting in intermediary degradation products that may or may not resist further degradation. However, fuel-related components have been shown to be readily degradable under aerobic conditions (EPA 1988b).

Under anaerobic conditions, microorganisms degrade organic compounds in the absence of dissolved oxygen, to methane and carbon dioxide. Anaerobes use chemically bound compounds, such as sulfate, nitrate, or carbon dioxide as terminal electron acceptors. Anaerobes also require an oxidation/reduction potential lower than 330 millivolts (mV). Microorganisms in this group are commonly referred to as "methanogenic consortia." These organisms are important in reductive dehalogenation reactions. The other group of contaminants present at Moffett Field, chlorinated VOCs, may be amenable to anaerobic degradation because dechlorination of organic compounds occurs slowly, if at all, under aerobic conditions (Torpy and others 1989). However, an anaerobic system may result in incomplete degradation of organic compounds, forming more toxic compounds and thus may not be suitable for several petroleum-related constituents.

Biological treatment system technologies include various types of aboveground biological reactors. Biological process reactors available for treatment can be classified according to the nature of their biological growth. Those in which active biomass is suspended as free organisms or microbial aggregates can be regarded as suspended growth reactors, whereas those in which growth occurs on or within a solid medium can be termed supported growth or fixed-film reactors (Cheremisinoff 1990). Examples of suspended growth processes include activated sludge, waste stabilization ponds, sequencing batch reactors, and fluidized-bed reactors. Examples of fixed-film processes include trickling filters, rotating biological discs, and biological towers. Most of these biological treatment systems have been used in treating a wide variety of domestic and industrial wastewaters.

Effectiveness

Studies have indicated that aerobic bioremediation has proven effective for petroleum-related contaminants. The diverse mixture of contaminants and relatively low organic concentrations (compared to industrial wastes) in the groundwater complicate the evaluation of bioremediation. The organic concentrations in the extracted groundwater must be high enough to support biological growth for this alternative to be viable. This problem will be emphasized with time as the permeable zones are remediated, thereby decreasing the concentration of organic compounds in the groundwater. Polishing systems such as carbon adsorption may be required following the bioreactor to meet the treatment goals within a reasonable retention time.

In addition, the effectiveness of a biological system depends on the presence of toxins that inhibit optimal microbial growth (for example, some inorganic compounds). Pretreatment systems can reduce toxins.

Implementability

This treatment alternative technically implementable; however, treatability studies will be required. As with other treatment options, prefabricated units should be available. Site preparation requirements are minimal for construction and operation of a bioreactor system. A level area with an access road is adequate. Potable water and electrical power are also required. An acclimation period for the microorganisms is required before startup of the treatment system. The system may be "seeded" with an inoculum of an organism with a specific capability to degrade target contaminants. The O&M requirements are normally low to medium; however, if a multistep process is required,

system operation would be more difficult. In addition, the bioreactors would produce a sludge that would require proper handling and disposal. Institutional considerations associated with this treatment system are typical for work at a hazardous waste site and include meeting permit requirements to comply with local codes, and compliance with applicable OSHA regulations during construction and implementation.

Cost

The cost for this alternative is moderate. The capital cost includes reactor vessels, pumps, piping, instrumentation and controls, and surge tank. The operating cost includes labor, nutrients, and electricity. The cost for this alternative primarily depends on the residence time required to reach treatment goals and whether a polishing or pretreatment system is required. The estimated cost range for this alternative is $5.35 to $15.30 per ft^2 of contaminated area.

7.2.6 Permeable Bioremediation Cell

Passive flow process options or permeable reaction cells are trenches excavated perpendicular to the contaminated groundwater flow and backfilled with a reactive, permeable matrix. The groundwater is passively treated as it flows through the cells. Since the native lithology is not conducive for manipulation of fluid movement, relying on natural groundwater flow patterns to bring the water into contact with the reactive material is an important option; rather than relying on inducing fluid movement. The reaction cells could be constructed at intervals within the length of the plume area to shorten the time it would take for the contaminated groundwater to reach the reaction wall. The interval spacing would be implementable at Moffett Field since the width of the reaction wall could be shortened to key into the permeable sand channels only. If the entire width of the plume must be bisected (including low permeability areas) only one wall would be constructed and the remediation time would be significantly increased.

Permeable reaction cells can be filled with media that rely on physical adsorption (such as activated carbon) or chemical reactions (such as, metal matrices that promote reductive dehalogenation) to remove contaminants, or can provide increased surface areas to enhance nutrient or oxygen transfer to microorganisms for more effective biodegradation of contaminants (biological reaction cells). For petroleum-related contamination, biological systems are the most favorable.

Biological reaction cells use the permeable cell to enhance the introduction of dissolved substances (for example nutrients, soluble carbon source, and oxygen) into an aquifer. The injected substances are dispersed as the groundwater moves out of the permeable wall into the aquifer material, establishing a bioactive zone. The degradation does not occur within the reaction wall; rather, it occurs in the aquifer material downgradient from the cell, in an area which is referred to as the bioactive zone. Time is required after installation of the cell for adaptation of the microbial population to accommodate the new conditions and establish an effective population.

Effectiveness

This option is innovative and is currently undergoing research (Devline and Barker 1994). The effectiveness of this system is dependent on the biodegradability of the petroleum-related constituents, the characteristics of the downgradient aquifer (whether or not it will promote dispersion), level of contaminants initially present in the groundwater, and the remediation level. Pilot-scale studies would have to be conducted to evaluate the option's viability at Moffett Field.

Petroleum-related contamination is more efficiently degraded by aerobic environments. Therefore, injection of a substances that would promote aerobic activity could be used (such as, injection of oxygen and nutrients).

Implementability

The implementability of this option is related to the ability to build trenches and the regulatory acceptability of injecting the necessary substances into the aquifer. Therefore, this technology is moderately difficult to implement.

Cost

The cost for this alternative is moderate. The capital costs are dependent on the trenching requirements. The O&M costs include maintenance of the injection system. The estimated cost range for this alternative is \$4.45 to \$6.70 per ft^2 of contaminated area.

7.2.7 Air Injection

Air injection involves introducing air (or oxygen) beneath the water table to promote oxidation of contaminants within the aquifer material. Air injection relies on two basic mechanisms: biodegradation and volatilization. These mechanisms typically work in tandem whenever oxygen is introduced. In this CAP, air sparging (AS) refers to the technology that relies predominantly on volatilization to remove contaminants and biosparging refers to the technology that optimizes biodegradation rather than volatilization to detoxify the aquifer material.

Air injection occurs when a well, screened below the water table and hydraulically isolated from the vadose zone, is pressurized sufficiently to allow air flow into the aquifer. The air then migrates up through the aquifer material to the vadose zone where it may or may not captured by vapor extraction wells (see Section 7.3).

AS forces contaminants to transfer from subsurface soil and groundwater into sparged air bubbles. The air streams are then transported into soil pore spaces in the unsaturated zone where the contaminants either biodegrade, are released to the atmosphere, or are captured and treated in an SVE system.

AS and biosparging include blowers and injection wells, either vertical or horizontal (see Section 7.3.1). The wells can be manifolded together to enable transferring air into several wells using one blower. The objective of the system is to form air bubbles within the aquifer to optimize groundwater-air interactions.

<u>Effectiveness</u>

The effectiveness of these two process options are currently being investigated in many site applications. The basic mechanisms controlling air injection are not well understood (Hinchee 1994). Volatilization and biodegradation are effective for remediating petroleum-related constituents. Volatilization applies primarily to light-end distillates (C_3 to C_{10}) and biodegradation to biodegradable heavy-end distillates.

Air injected into aquifer materials may migrate as a separate phase, typically in channels rather than forming bubbles. If bubbles do not form, only contaminated soil within these channels would be aerated. Aquifer material not within these channels would be much less affected. AS and biosparging are subject to the limitations of contaminant desorption, similar to ex situ alternatives.

Implementability

AS and biosparging are readily implementable. The systems are constructed from widely available equipment (that is, well screens and blowers). The site preparation requirements are minimal and regulatory requirements focus on offgas emissions and well construction.

Cost

The cost for AS or biosparging are similar and range from low to moderate. The cost are primarily dependent on the extent of the area of influence for each injection point and the restoration time frame. The estimated cost range is $3.80 to $5.65 per ft^2 of contaminated area.

7.3 COMBINED SOIL AND GROUNDWATER ALTERNATIVES

Treatment technologies that address both soil and groundwater can be a combination of the technologies evaluated in Section 7.1 and 7.2 or other innovative technologies. Typically in situ soil and groundwater treatment technologies would be combined or ex situ soil and groundwater systems would be combined. The assembled alternatives for treating both soil and groundwater evaluated in this CAP include:

- Air sparging/soil vapor extraction (AS/SVE)
- Bioventing/biosparging
- Recirculating in situ treatment (RIST)

7.3.1 Air Sparging/Soil Vapor Extraction

AS, also called in situ air stripping, involves injecting air into saturated soils to form an oxygen-rich zone in which adsorbed and dissolved VOCs are volatilized. SVE wells are then used to collect vapors as they migrate upwards into the unsaturated zone. The combination of AS and SVE (AS/SVE) technologies have been demonstrated to effectively remove volatile compounds from groundwater. Once the contaminant vapors are removed from the subsurface, they are treated using a standard vapor phase treatment system. Typical vapor phase treatments include adsorption onto activated carbon, thermal destruction (incineration or catalytic oxidation), or condensation by refrigeration.

The current design process for AS/SVE is largely empirical due to the numerous variables encountered and the complex multifluid flow processes occurring. Therefore, site-specific pilot tests are commonly performed to evaluate the effectiveness of the treatment system.

Effectiveness

Generally, those chemicals that are easily removed from contaminated groundwater through traditional air-stripping towers are considered optimal for the application of AS/SVE. The compounds most amenable to air stripping and AS/SVE are lighter petroleum compounds (C_3 to C_{10}) and chlorinated solvents. Less strippable compounds may be remediated with enhancements to the standard sparging process. For example, the increased air flow induced through the subsurface environment by the AS/SVE system could potentially enhance the natural biodegradation of petroleum constituents. The AS/SVE should be effective for areas that have light-end distillate contamination in both groundwater and unsaturated soil.

The effectiveness of AS/SVE depends largely on site-specific physical characteristics. AS/SVE is generally more effective in homogeneous, coarse-grained (high permeability) soils. Volatilization from soils that have low permeability or contain a high degree of soil heterogeneity will be more difficult. Given the heterogeneous soils at Moffett Field, it is presently difficult to estimate removal efficiencies and the associated remediation time until after an AS/SVE pilot study is completed.

The effectiveness of AS/SVE can be increased by exposing the groundwater to higher volumes of air. Air flow rates that are typically used in the field are in the range of 3 to 10 standard cubic feet per minute (scfm) per sparge point. Higher pressures will produce higher air injection flow rates, and may be necessary to provide a more uniform gas channeling distribution in heterogeneous soils due to the range of air entry pressures associated with differing grain size distributions in adjacent soil units. However, the higher air injection pressures required in fine-grained soils can cause the formation of significant subsurface gas pockets, due to bubble coalescing. High air injection pressures may also create fractures in the sparging well annular seal or along weak soil horizons in the soil resulting in a loss of system efficiency.

Effectiveness of AS/SVE can also be enhanced by using air diffusers and/or installing a sand pack at the sparging point. Theoretically, a large number of small bubbles will provide better mass transfer characteristics for the removal of VOCs from the aqueous phase than will a smaller number of large

bubbles. Air diffusers may be used to inject smaller bubbles at the sparging point. Any sand pack around the sparging point should have a grain size that will minimize coalescing of the small bubbles prior to entry into the native sediments.

The radius of influence of the injection points will ultimately determine the effectiveness of AS/SVE remediation at Moffett Field. In uniform homogeneous soil, injecting at greater depths with respect to the water table tends to increase the radius of influence of an injection point, but also requires higher air pressures at the well to achieve and maintain the gas flow. Also, with the heterogeneous soils at Moffett Field, there is a potential problem with irregular channeling of gas to the unsaturated zone that is not likely to provide efficient or effective mass transfer of VOCs from the target contaminated areas. Strategically-placed vapor extraction wells could compensate for these irregular channeling patterns. Performance can also be improved by properly placing the injection well screen interval. Short screen intervals, on the order of 1 to 3 feet, are generally used in air-sparging wells because most of the air exits through the top of the screen interval, where the pressure head is at a minimum. Use of longer screen intervals does not significantly add to the effectiveness of the process.

Implementability

AS/SVE equipment is readily available and should be implementable. A major advantage of AS/SVE technology is the relative simplicity of the design of the system. In addition, the equipment that comprises the system consists of commonly used and widely available devices such as polyvinyl chloride (PVC) piping, valves, and blowers. The typical AS/SVE system consists of an air compressor, a blower or vacuum pump, metal pipe or rubber hose, pressure gauges, regulators, and a network of sparging and extraction wells. The pilot study will involve operating a soil vacuum blower, air compressor, and compressor-vacuum blower temporarily connected to pilot-test vapor extraction and air sparge points.

After a successful pilot study, site preparation requirements are minimal and system installation is a relatively easy process. Installation procedures for extraction and sparging wells are common to the industry because of their similarity in construction to monitoring wells. However, in a site with heterogeneous soils such as Moffett Field soils, AS/SVE may require more wells than are typically needed to be effective, and, thus, the proper siting of wells may be the most difficult aspect of system installation.

It is recommended that installation of the AS/SVE portion of this alternative be implemented using a phased approach. By implementing in phases, pertinent site-specific information can be obtained from the first phase. This information can be used to evaluate and optimize the system. The information gained from the first phase can then be used to modify the design of additional phases.

The O&M requirements of an AS/SVE system are fairly low. The systems are easy to operate and maintenance is minimal. Periodic inspection of the network of sparging and extraction wells along with the vapor phase treatment system is required. The additional requirements of vapor phase treatment will add to the O&M of an AS/SVE system. These requirements as well as other implementability issues for vapor phase treatment are discussed below.

Direct and catalytic thermal oxidation systems can substantially increase O&M requirements for the vapor phase treatment portion of this alternative. Aside from their additional operating requirements, the more energy-efficient catalytic thermal oxidation system would require periodic catalyst replacement, which is labor-intensive. In addition, the thermal oxidation of any chlorinated VOCs collected is likely to produce hydrogen chloride (HCL). The HCL emissions may require additional treatment with a scrubber before the air can be discharged to the atmosphere. This additional treatment will increase O&M requirements and capital costs.

Regulatory requirements for operating an AS/SVE system should not limit the implementability of this treatment alternative. There will be regulatory requirements for the groundwater (such as meeting MCLs) and the vapors extracted from the unsaturated zone will be subject to BAAQMD standards.

Cost

The costs for this alternative are moderate to high. The overall costs for this alternative depend on the radius of influence created by the sparge and extraction points. The more points required, the higher the costs. The capital costs include a sparge injection system, blower extraction system, air/water separator, thermal oxidation system, instrumentation, valves, sampling ports, piping, and piping appurtenances. Annual O&M costs include equipment, labor, materials, and analytical costs. The maintenance of the offgas treatment system will be significant. The estimated cost range for this alternative is \$4.55 to \$6.50 per ft^2 of contaminated area.

7.3.2 Bioventing/Biosparging

The bioventing/biosparging alternative involves optimizing oxygen transfer within the aquifer material and unsaturated soils to promote biodegradation of contaminants within both these zones. The primary difference between this alternative and AS/SVE is that oxygen transfer in bioventing/ biosparging is targeted at promoting microbial activity whereas, the AS/SVE alternative is designed to optimize volatilization. As stated previously, both degradation and volatilization removal mechanisms will be part of any technology that increases the pressure gradients within a medium. The type of contamination and the amount of pressure induced (the higher the air flow rate, the higher the induced pressure gradient) will dictate which mechanism predominates.

Effectiveness

The biosparging/bioventing alternative should be effective for both light- and heavy-end distillates within unsaturated and saturated materials. The site-specific effectiveness is dependent on the biodegradability of the contaminants and the ability to transfer oxygen within the less permeable unsaturated and saturated zones. Treatability tests must be conducted to evaluate site-specific effectiveness. Using the bioventing/biosparging alternative to remove light-end distillates would probably require more time than using the AS/SVE system since volatilization can occur much faster than biotic degradation. However, the restoration time frame for heavy-end distillates will probably be approximately equal since the AS/SVE alternative actually relies on biodegradation to remediate these constituents.

Implementability

This alternative's implementability is very similar to the AS/SVE alternative (see Section 7.3.1). However, bioventing will not likely require offgas treatment; therefore, implementation may be a little easier than the AS/SVE alternative.

Cost

The costs for this alternative are moderate. The capital costs include a sparge injection system, a blower system, instrumentation, valves, sampling ports, piping, and piping appurtenances. Annual O&M costs include equipment, labor, materials, and analytical costs. The estimated cost range for this alternative is \$2.80 to \$3.00 ft^2 of contaminated area.

7.3.3 Recirculating In Situ Treatment

In situ bioremediation is an effective technology for remediating petroleum-related contamination. One application of in situ remediation is the recirculating in situ treatment (RIST) technology. This technology involves lifting and aerating contaminated groundwater from the saturated zone and distributing the aerated water into the region of soil contamination above the water table level. The aerated water will enhance the oxygen supply to the distribution area and promote biodegradation of contaminants. The RIST alternative involves installation of an extraction well, an air-lift pump, and a drainage distribution system. The extraction well will be located in the area of the highest groundwater concentrations. An air lift pump will be installed in the extraction well to pump water to a below-ground sump located at the well head. From the sump, the water will be discharged through two buried drain lines that are slotted to allow water to infiltrate back through the soil and into the aquifer. The drain lines will be located in the area of highest soil contaminant concentrations. The water will not be applied continuously to both drain lines; rather, an automatic siphon will be used to periodically and alternately dose each drain line. The water application rate can be adjusted to optimize contact time between the soils and the water, thus promoting biodegradation. The application rate should not be sufficient to induce migration of contaminants. This technology is commonly used to successfully treat septic tank effluent.

<u>Effectiveness</u>

The RIST system creates an in situ biological treatment cell that can effectively treat petroleum contamination. This cell is similar to a trickling filter where, in this case, the bed material is the in-place soil. The air lift pump will pump water at a flow rate that can be maintained by the aquifer and produce a cone of depression. It will also oxygenate the water during pumping. The oxygen-rich water will then be distributed through the drain lines into the soil above the cone of depression. As the water slowly flows down through the soil, contaminants sorbed to soils will biodegrade as will contaminants dissolved in the water. Petroleum-related contaminants are amenable to aerobic biodegradation; thus, by providing an oxygen source, the RIST treatment system should be an effective in situ alternative.

System performance is dependent on the infiltration rate of the soil. This soil characteristic can be tested using a percolation test. If a percolation test shows that the soils have an adequate percolation (infiltration) rate, then the RIST system could be easily implemented and operated.

In addition to the bioremediation accomplished by this system, some VOCs will be stripped from the water. During pumping, the air lift pump mixes air with the groundwater, causing some of the volatile compounds in the groundwater to transfer into the gas phase. If the amount of stripping is significant, it may be necessary to treat the vapors vented from the sump. Although the stripping action increases the contaminant removal from the groundwater, it may also significantly increase the O&M requirements of the system should vapor treatment be required. However, since the primary contaminant-mass-reducing mechanism is biodegradation, volatilization of contaminants will not be maximized (as is the case with air sparging). Therefore, offgas treatment is not expected to be required.

Implementability

The RIST system is easily installed and is constructed of readily available equipment. The implementability is dependent on soil having an adequate percolation rate to allow infiltration of pumped groundwater. A percolation test is required to determine the minimum infiltration area required. If this minimum area is reasonable, this alternative can be implemented. This alternative does not completely remove groundwater from the ground; therefore, the system does not represent a discharge (and a NPDES discharge permit would not be required). The alternative must meet BAAQMD requirements.

Cost

The cost for this alternative is moderate. The primary operating cost associated with this alternative, other than general maintenance, is that of electricity to run the compressor for the air lift pump. If it is necessary to treat vented vapors from the sump, both capital and operation costs will increase. The estimated cost range for this alternative is \$4.55 to \$6.50 per ft^2 of contaminated area.

7.4 NO ACTION

Natural attenuation processes and transport mechanisms are another option for achieving cleanup goals within a certain time frame. The preamble to the revised NCP (EPA 1990) states that:

> "Selection of natural attenuation does not mean that the groundwater has been written off and not cleaned up, but rather that biodegradation, dispersion, dilution, and adsorption will reduce contaminants."

The preamble also indicates that natural attenuation can be a viable remedial option for groundwater that is unlikely to be used in the foreseeable future and, therefore, can be remediated over an extended period of time (EPA 1990).

The groundwater on the western side of Moffett Field has been contaminated by a regional VOC plume. The design for remediation of the regional plume indicates that cleanup goals will be achieved in approximately 47 years (Canonie 1994). Therefore, it is possible that a relying on natural attenuation will achieve moderate cleanup goals within a time frame which is similar to the remediation time for the west-side aquifers. This alternative may include continued monitoring and some institutional controls (for example, restricting installation of water supply wells at Moffett Field). This technology would have the lowest associated costs.

8.0 RECOMMENDATIONS

The Moffett Field areas with petroleum contamination are varied and extensive. Additional areas requiring remediation are expected to be identified. Section 7.0 provides an array of viable treatment technologies that can be considered for any petroleum site at Moffett Field. The alternative selected will depend on technical and economic effectiveness since all the viable alternatives are implementable. Station-specific performance data for each potential technology are required for a realistic comparative analysis of technical and economic factors because of the complex subsurface lithology at Moffett Field.

The Navy has conducted several ex situ actions at Moffett Field, including the Site 12 soil SCM, the Site 14 South groundwater SCM, and numerous tank and sump removals. In addition, the Navy plans several more ex situ actions including the Site 9 groundwater SCM, the electron injection pilot study, and potential soil pile treatment (for soils removed from ongoing tank and sump excavations). Through these actions, the Navy will acquire station-specific information on ex situ alternatives. The Navy also believes that innovative approaches, such as in situ alternatives, must be considered and recommends conducting pilot studies to acquire station-specific performance information. This information can then form the basis of a comparative analysis at each petroleum site.

The characteristics of the clays and silts within the unsaturated and saturated zones at Moffett Field limit restoration because petroleum contaminants will adsorb to these materials. These materials can also inhibit the removal of contaminants by inhibiting fluid flow, both gas and aqueous (that is, the

effectiveness of many remedial technologies is related to the ability to move fluid through subsurface materials). The extent that different fluids can move through these materials will be investigated through operation of the Site 9 SCM and pilot studies recommended in subsequent sections in this report. The Site 9 SCM will gather information on groundwater movement induced by an extraction system. Other promising technologies involve moving gas through the contaminated material to promote volatilization or biodegradation, these fluid movements will be investigated. In addition, movement of an aqueous stream with dissolved oxygen to promote biodegradation and desorption of contaminants will be investigated.

The Navy has two major types of fuel contamination: light-end distillate and heavy-end distillate contamination. The most cost-effective remedial technology for these different fuels may be different. Therefore, pilot studies that investigate technologies effective for each of these categories will be conducted (volatilization for light-end distillates and biodegradation for both light- and heavy-end distillates).

The following sections describe the current recommendations for each petroleum site. The final recommendations will be provided after the pilot tests for in situ alternatives are completed and results compared with ex situ station-specific information (for example, the results of the Site 9 SCM extraction system).

The petroleum sites fall under four categories: (1) active, inactive, and abandoned tanks and sumps that have no contamination and are recommended for elimination from the IRP petroleum sites program (these sites cannot be closed since they are active or have not yet been removed); (2) active or inactive tanks and sumps that have contamination associated with them and require corrective measures, (3) removed tanks and sumps that have no contamination and are recommended for immediate closure (these will be included in a closure report), and (4) removed tanks and sumps that have contamination and are recommended for corrective measures. The Navy is not seeking closure for active or inactive tanks and sumps, since they are being or will be used or removed in the future. When these tanks and sumps are no longer needed, they will be removed, investigated, and closed following appropriate regulatory guidance. The Navy is currently preparing a closure report for removed tanks and sumps with no contamination, which is scheduled to be completed late 1994. A summary of the tanks and sumps falling into the four categories is provided below.

Active and Inactive Tanks and Sumps Recommended for Elimination

Site 5	USTs 4, 6, 7, 8, 10, 11, 12, and 13 ASTs 72, 73, 74, and 75
Site 15	Sumps 59, 62, 63, 64, and 130

Inactive USTs and Areas Recommended for Corrective Measures

Site 5	USTs 5 and 9 Dry Wells near USTs 11, 12, and 13

Removed USTs and Sumps Recommended for Closure

Site 5	USTs 18 (pending removal data), 26, 30, and 31
Site 15	UST 54
Site 19	UST 14

Removed Tanks and Sumps Recommended for Corrective Measures

Site 9	USTs 47, 48, 49, 50, 56A, 56B, 56C, 56D, 79, 80, 81, 82, 83, 84, 97, 98, and 99 (Building 29 and 31 areas) AST 52
Site 12	No UST or sump (pending additional data)
Site 14	(South) USTs 19 and 20
Site 15	Sumps 25, 42, and 58 (pending additional data for Sump 58)
Site 19	USTs 2, 43, and 53

Active and inactive USTs and sumps recommended for elimination from the IRP petroleum sites process will be removed from future IRP petroleum sites reports (that is, this CAP will serve as the decision document for these sites and they will not be addressed in addenda to this CAP). When these USTs and sumps are no longer needed, appropriate closure activities will be scheduled and implemented.

With the exception of Sumps 25 and 42, remedial alternatives for USTs and sumps recommended for corrective measures are discussed below. Sumps 25 and 42 are associated with the current NEX gasoline station. Removal, investigation, and corrective measures are being performed concurrently with the rest of the NEX gasoline station. The NEX gasoline station and all associated USTs and sumps will be included in a followup CAP for additional petroleum sites.

8.1 SITE 5

Soils at Site 5 are contaminated with JP-5 in excess of the 400 mg/kg TPH extractable cleanup level. The horizontal extent of contaminated soil is approximately 600 feet downgradient of the former dry wells near USTs 11, 12, and 13 (see Figure 4). The elevated TPH extractable levels are located both in the capillary fringe and in the aquifer material. In addition, the groundwater exceeds the TPH extractable cleanup level of 700 μg/L in the areas of the former dry wells near Tanks 5, 11, 12, and 13 (see Figure 5).

Site 5 is a good location to investigate station-specific in situ bioremediation of heavy fuel constituents in both the unsaturated and saturated soils. Therefore, a Phase I pilot test consisting of bioventing and biosparging is recommended to initiate soil remediation, to gather radius of influence and other design information necessary for conducting a realistic comparative analysis, and to facilitate the full-scale remedial design at this site and other Moffett Field sites.

The Phase I system will consist of a 50-foot-long bioventing trench near Tank 13, two blowers, two biosparge injection points, six vapor monitoring wells, instrumentation, and related items. Sketches of the proposed system are shown in Figures 24, 25, and 26. This system will be designed, installed, and operated concurrently with the system proposed for Site 9 (discussed below).

The intent of the system is to supply oxygen to petroleum-contaminated unsaturated zone and capillary fringe soils, thus enhancing the biodegradation of contaminants. Though some reduction of petroleum concentrations in groundwater is expected, the primary purpose of the biosparge points will be to maximize petroleum degradation in soils in the smear zone and capillary fringe. Approximately 3 to 6 months of system operation will be required to assess the effectiveness of the Phase I system. The Navy has initiated design of a Phase I bioventing/biosparging system, and is addressing the scope of the required deliverables before completing final design activities.

Once Phase I data results are available, the Navy will use the data to evaluate this alternative with other alternatives. If appropriate, these data will also be used to design a full-scale treatment systems at Site 5 and other UST and sump locations with similar lithologies and contaminants. The current schedule for the Sites 5 and 9 Phase I pilot tests include:

Submittal 100 Percent Design Report	September 1994
Submittal Final Design Report	September 1994
Submittal Draft Field Work Plan	October 1994

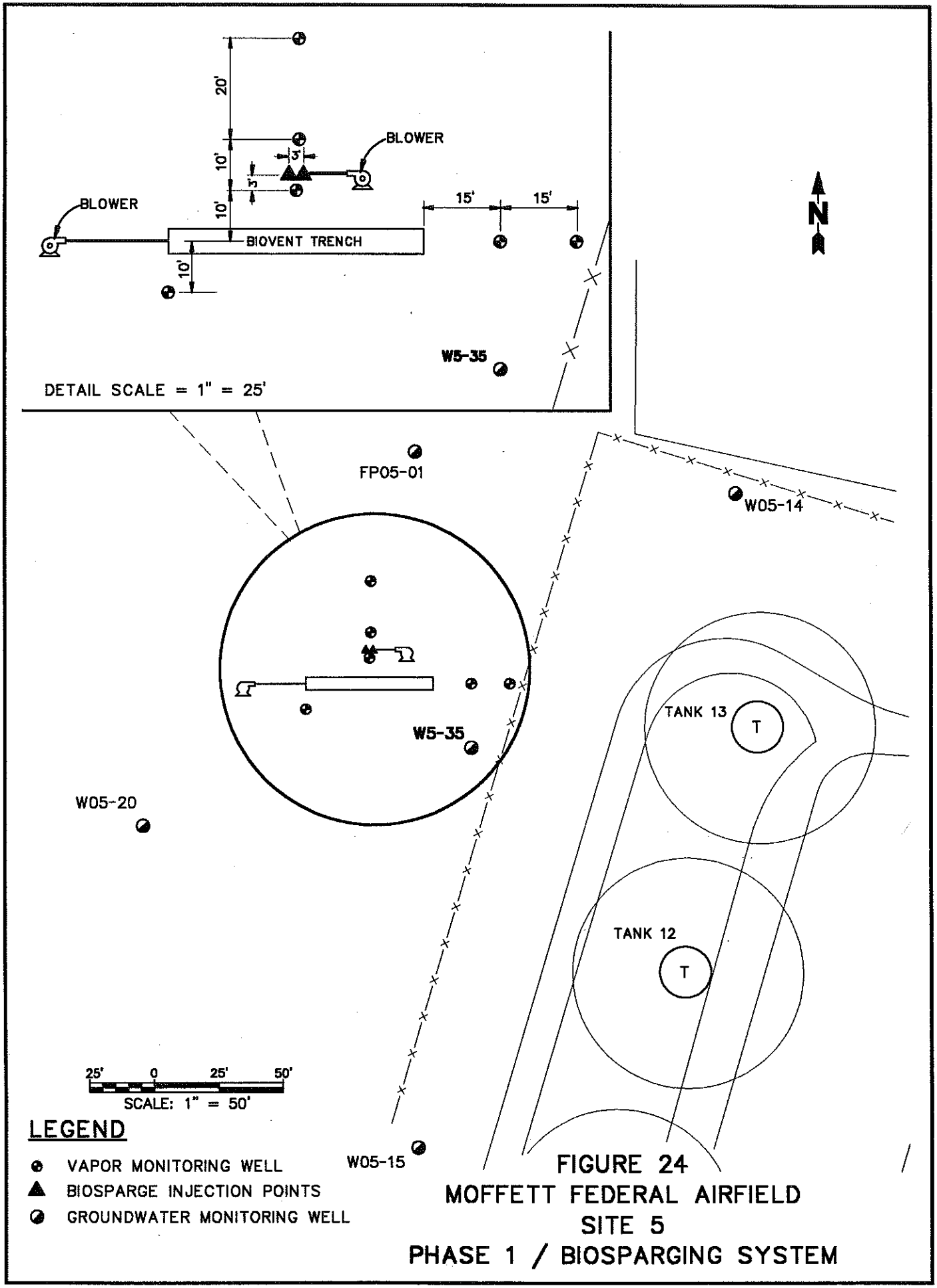
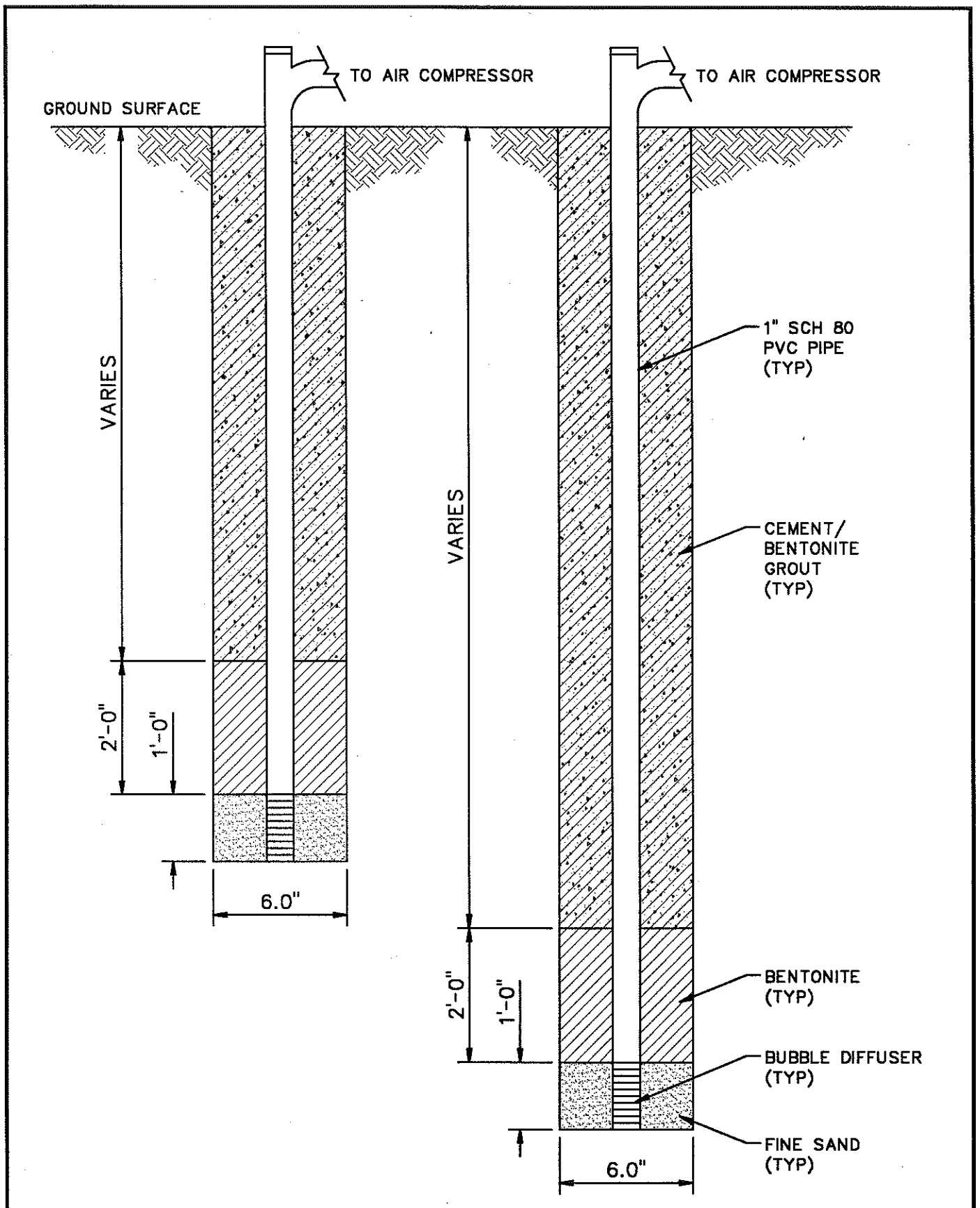


FIGURE 24
MOFFETT FEDERAL AIRFIELD
SITE 5
PHASE 1 / BIOSPARGING SYSTEM



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NOT TO SCALE

FIGURE 25
MOFFETT FEDERAL AIRFIELD
SITES 5 AND 9
PHASE I BIOSPARGE INJECTION WELLS

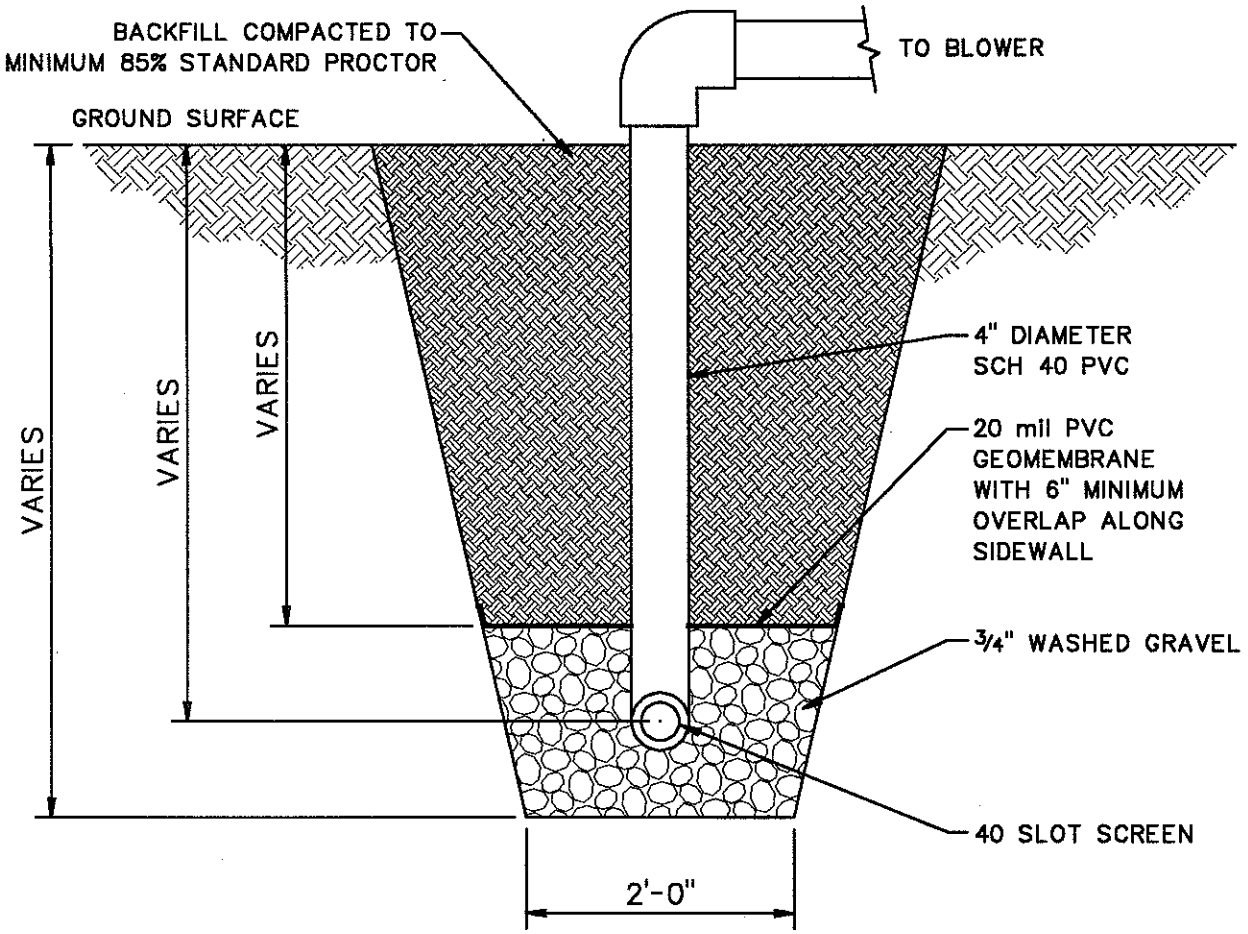

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FIGURE 26
MOFFETT FEDERAL AIRFIELD
SITES 5 AND 9 PHASE 1
SVE/BIOVENT TRENCH CROSS-SECTION

Submittal Final Field Work Plan	January 1995
Construction	December 1994
Field Work and Testing (Site 5)	January to July 1995
Field Work and Testing (Site 9)	January 1995
Evaluation Technical Memorandum	April 1995

The evaluation technical memorandum will contain schedules for full-scale design and construction. Additionally, final recommendations for application of the pilot tests to other petroleum sites will be provided.

8.2 SITE 9

Soils at Site 9 are contaminated with light-end distillates (aviation gasoline) in excess of the 150 mg/kg TPH purgeable cleanup level. An area of soil contamination extends approximately 1,000 feet north (downgradient) from former USTs 47, 48, 49, 50, 52, 79, 80, 81, 82, 83, 84, 97, 98, and 99 at the former fuel farm near Building 29 (see Figure 8). In addition, the groundwater at Site 9 exceeds the groundwater TPH purgeable cleanup level of 50 μg/L (see Figure 9).

Site 9 is a good site to investigate station-specific vapor extraction of light-end distillates from both the unsaturated zone and the A1-aquifer zone. Therefore, a Phase I pilot test consisting of SVE and air sparging is proposed to initiate soil remediation and to gather radius of influence and other design information necessary for conducting a realistic comparative analysis, and to facilitate the full-scale remedial design at this site and other Moffett Field sites.

This Phase I system will consist of a 40-foot-long SVE trench, a blower, two air sparge injection points, an air compressor, six vapor monitoring wells, an air/moisture separator, two vapor phase GAC units in series, instrumentation, and related items. Sketches of the proposed system are shown in Figures 25, 26, and 27.

The system will volatilize gasoline contamination in unsaturated zone, smear zone, and capillary fringe soils by injecting and extracting air through the contaminated soils. Though some biodegradation of petroleum is expected, the primary removal mechanisms will be volatilization and vacuum extraction. As with Site 5, the focus of this Phase I system is on reduction of contamination in soils, though reductions in groundwater concentrations are also expected. The Navy recently completed a conceptual design of an SVE/air sparging system and is currently addressing the scope of required deliverables prior to completing final design activities.

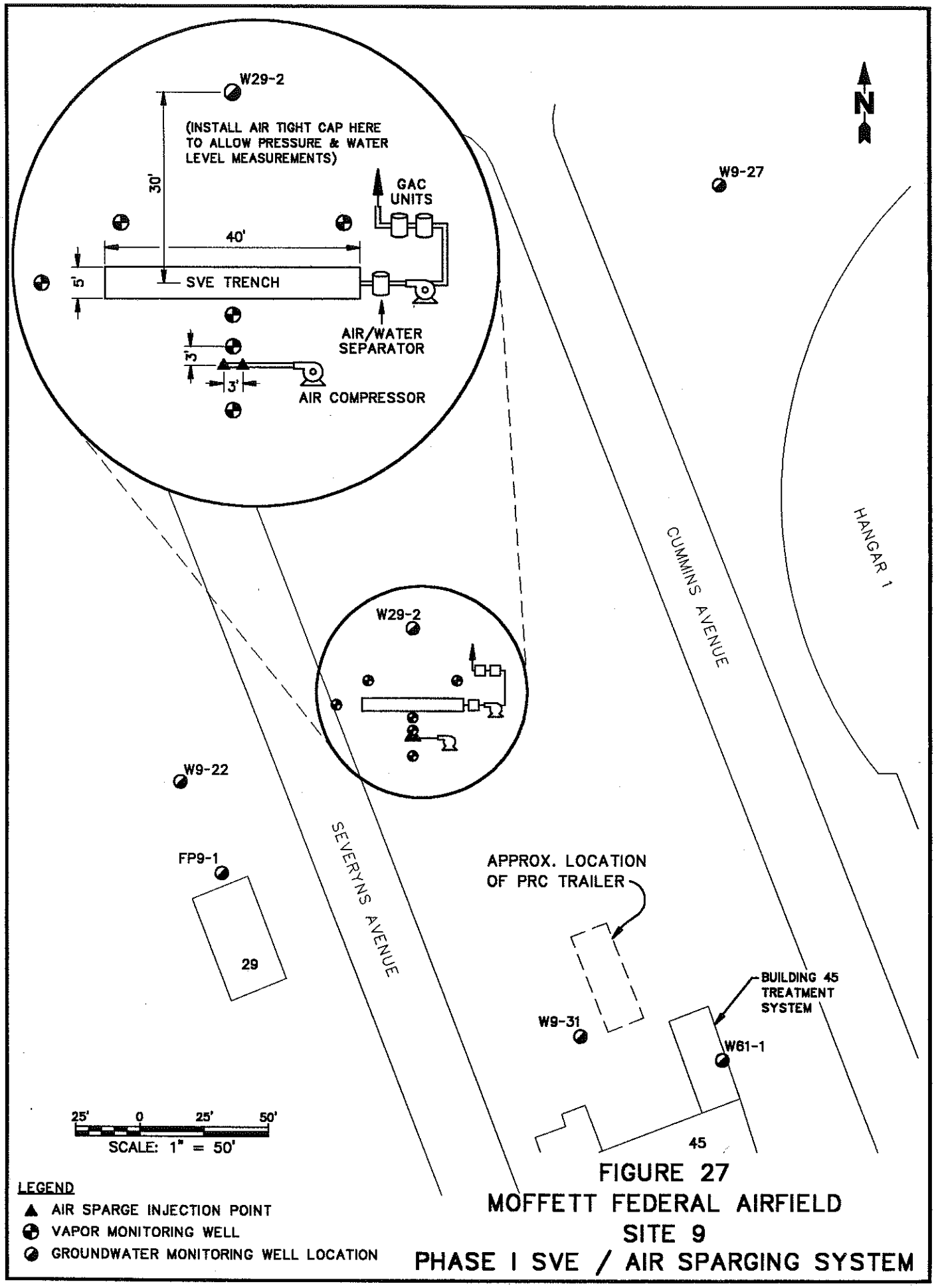

FIGURE 27
MOFFETT FEDERAL AIRFIELD
SITE 9
PHASE I SVE / AIR SPARGING SYSTEM

Once Phase I data are available, the Navy will use the data to evaluate this alternative with other viable alternatives. If appropriate, these data will also be used to design a full-scale treatment system to remediate all petroleum contamination at Site 9 above cleanup levels. Since the former UST areas near Buildings 29 and 31 are similar, it is anticipated that a similar remedial alternative will be used to remediate soil and groundwater petroleum contamination at both areas.

8.3 SITE 12

Currently, the horizontal extent of petroleum contaminated soils above cleanup levels remaining at Site 12 is unknown; some additional soil sampling and groundwater monitoring is required. The quantity of petroleum contamination remaining at Site 12 is an important design consideration for any future corrective measures. Additionally, the limitations caused by the proximity of Zook Road and the west parallel taxiway will affect future corrective measures. Field work for collecting additional data at Site 12 is scheduled for November 1994. Potential alternatives include a bioventing system, additional soil excavation and biological treatment, RIST, and natural attenuation. Selection of the selected alternative will depend on the additional monitoring results and the pilot-scale data from Sites 5 and 14.

8.4 SITE 14 SOUTH

The Site 14 South groundwater and capillary fringe soil exceed cleanup goal criteria for TPH purgeable and BTEX constituents (see Figures 11 and 12). The primary contamination is light-end distillates. The Navy believes that innovative remediation strategies must be employed at Moffett Field to yield cost-effective remediation of petroleum-contaminated media. The Navy will pilot test a variety of different technologies due to the heterogeneity of the Moffett Field subsurface and the abundance of low permeability zones, so that the optimal treatment technologies are employed. The gasoline contamination at Site 14 South would be amenable to the AS/SVE. This technology will be pilot tested at Site 9. However, in the case that the soil air permeability will not accommodate efficient inducement of pressure gradients, other options are being explored. The RIST system does not rely on air permeability; rather, it relies on percolation of an aqueous stream through a saturated matrix to transfer oxygen to indigenous microorganisms both in the capillary fringe and the aquifer material (Figure 28).

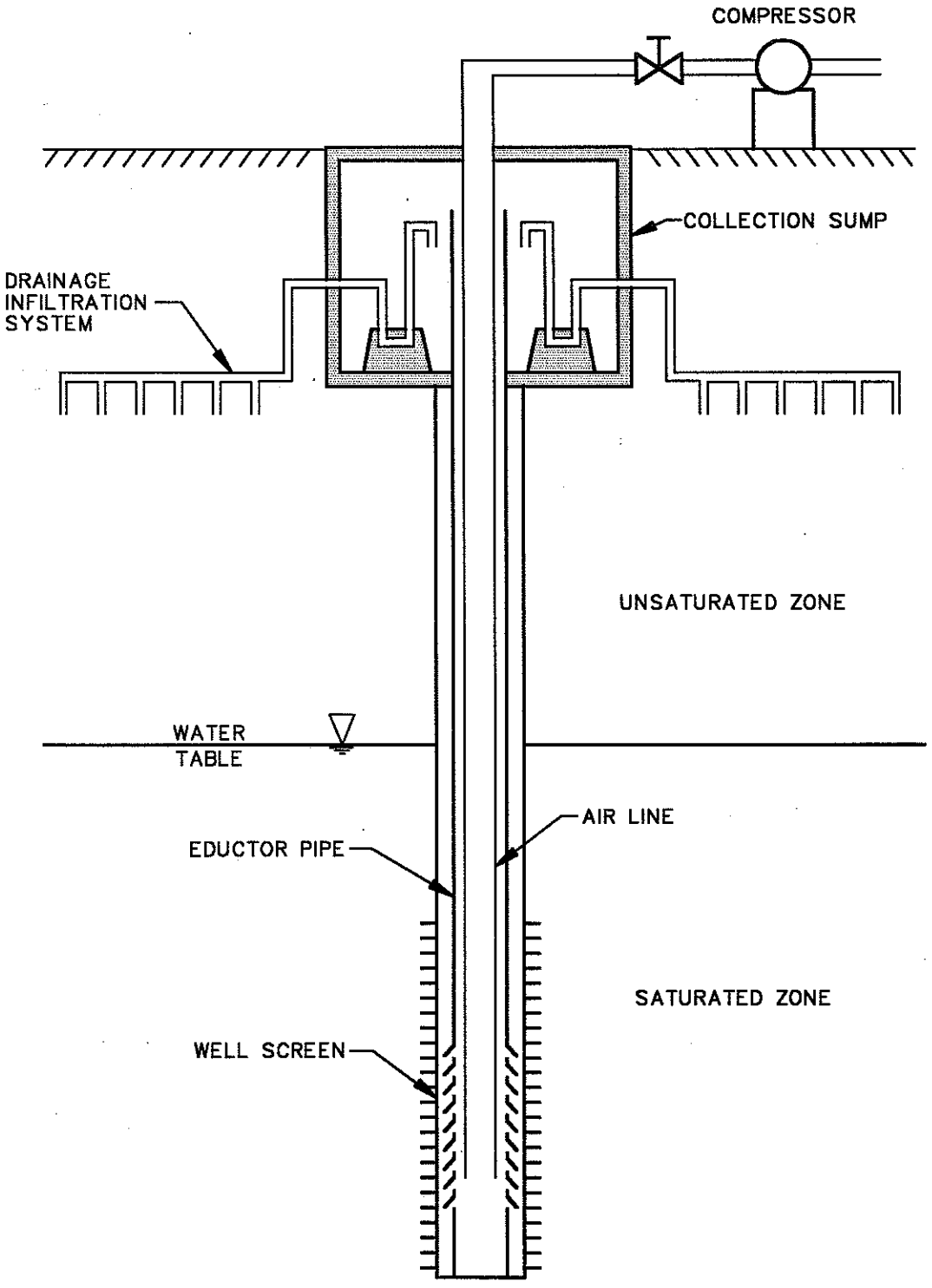

FIGURE 28
MOFFETT FEDERAL AIRFIELD SITE 14 SOUTH
RIST SYSTEM SCHEMATIC

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The RIST system will reduce plume migration by extracting groundwater from the most contaminated section of the aquifer. The percolation of the oxygen enriched water (via the air lift pump) into the soil contamination area will enhance degradation and may also flush residual contaminants from the clays into the groundwater. The extraction well will be located downgradient from the percolation zone so the groundwater continuously can be cycled between the percolation field and the extraction well.

There is not a direct correlation between air permeability through unsaturated media and aqueous percolation through saturated media. Therefore, separate, independent tests must be conducted for each mechanism. The pilot tests at Sites 5 and 9 will investigate the air permeability. In addition, a percolation test was conducted in August 1994 at Site 14 South to evaluate aqueous movement through saturated media and the amount of groundwater that the Site 14 South contaminated zone can receive. The data from the test are being compiled and analyzed. A technical memorandum will be prepared detailing the test procedures and results. The preliminary analysis indicates that the A1-aquifer zone at Site 14 South will accommodate a pumping (and percolation) rate of 2 gpm. A Phase I design will be initiated to gather RIST performance data.

These data will be used to evaluate the applicability of this alternative at other Moffett Field petroleum sites.

8.5 SITE 15

Since Sumps 25 and 42 will be included with the NEX gasoline station corrective measure, only former Sump 58, of all the Site 15 areas, requires additional corrective activities at this time. Some additional data, however, are required from the former Sump 58 area before corrective measures can be planned. These data will be collected in conjunction with the additional Site 12 data. Therefore, no remedial alternatives are proposed for Site 15 at this time. Should significant quantities of contamination be revealed at Sump 58, remedial designs will be scheduled and prepared. Potential alternatives may involve a bioventing system, soil excavation and biological treatment, RIST, and natural attenuation.

8.6 SITE 19

USTs 2, 43, and 53 have contamination associated with them and are recommended for corrective measures. The results of the Phase I pilot tests described for Sites 5, 9, and 14 will be used to evaluate alternatives and develop remedial designs for the Site 19 UST sites. Tanks 2 and 43 have heavier TPH products and SVOCs associated with them (similar to Site 5), and the results from the Phase I tests at Site 5 and 14 will be considered in the remedy design for these USTs. Similarly, Tank 53 has lighter TPH products and BTEX associated with it (similar to Site 9) and results from the Phase I tests at Site 9 and 14 will be considered in the remedy design for Tank 53. Tanks 2 and 43 will most likely be remediated using a bioventing system as described in Section 8.1 and Tank 53 will most likely be remediated using an SVE system described in Section 8.2. Should the pilot test results reveal that these treatment systems are not cost effective for the Site 19 USTs, then excavation and biological treatment of hot spots, the RIST alternative, and natural attenuation will be considered.

9.0 VERIFICATION MONITORING PROGRAM

Soil and groundwater samples will be collected from the contaminated material to evaluate whether performance standards have been achieved. The corrective action design will contain a confirmation sampling plan describing all sample collection and analysis activities that will be conducted to demonstrate that performance standards have been achieved. Confirmation sampling for petroleum USTs and sumps will include TPH extractable and purgeable, BTEX, and SVOCs (for PAHs). Confirmation for wastewater USTs and sumps will also include VOCs. The confirmation sampling plan will reference procedures established in the existing Moffett Field base-wide field sampling plan (PRC and JMM 1992) and include items such as sampling locations and frequencies, sampling techniques and equipment, decontamination procedures, sample handling, preservation and analytical requirements, and analytical quality assurance and quality control (QA/QC) requirements. All analytical results will be documented in a project closeout report. Additionally, Moffett Field quarterly groundwater monitoring reports will be reviewed to evaluate the effectiveness of remedial activities.

The Navy will conduct inspections to evaluate if all requirements have been met. An initial inspection will summarize incomplete work required to be completed prior to project closeout. After incomplete items have been addressed, final inspections and project closeout can proceed. The construction project will be considered complete once the Navy has determined that all equipment,

construction, and performance requirements of the drawings and specifications have been met. Following final inspection, a project completion report will be prepared to document that performance standards have been met and to provide all drawings of record.

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APPENDIX A

POTENTIOMETRIC SURFACE MAPS
AND
C-AQUIFER WELL LOCATION MAP

NAS MOFFETT FIELD

HANGAR 1

McCORD AVE

BAYSHORE FREEWAY

91A 4.34
93A 2.04
W12-1 2.46
W12-4 2.85
W12-6 1.62
11N20A 0.11
11N21A1 0.11
WU4-18 2.51
11N22A1 1.43
11N23A 1.45
14D24A 2.92
14D25A1 2.98
14D01A 3.22
14D02A 3.94
14D03A** 5.40
WU4-14 6.37
14D12A 7.70
14D16A 6.79
14D15A 6.04
14D14A 6.57
14D17A 7.37
14D13A 7.49
14D09A 7.30
14C17A** 4.24
14C19A 5.45
14C24A 5.44
14C25A 5.52
14C16A** 8.04
14C18A 6.12
14C27A 5.63
14C06A 5.83
WU4-21 6.29
WU4-8 6.97
WU4-24 8.28
W9-43 7.27
W29-5 7.47
W9-26 7.28
W9-24 7.19
W29-1 6.97
W9-10 7.45
WU4-17 9.81
W9-47 1.30
14D05A 9.33
W9-2 12.13
W56-1 11.68
W56-2** 8.63
120A 10.26
89A 10.26
WU4-25** 8.94
WU4-10 11.93
W9-23 10.89
W9-31 9.90
W29-2 9.23
90A 8.01
W29-3 10.72
W9-6 11.48
W29-4 11.89
W9-1** 12.90
W9-45 12.71
W9-35 12.48
W9-18** 9.96
W9-46** 15.17
ERM-4 14.98
W9-44 14.91
W9-19 15.97
W9-16 16.98
W67-1 15.19
W9-29 14.59
W9-30 15.21
86A 16.61
73A 16.72
66A 15.15
81A 17.11
W91-1** 16.15
W9-37 15.86
W9-38 17.33
WT14-1 20.40
74A 20.40
WU4-3 18.75
65A 18.95
85A 18.46
82A 18.43
W89-1 22.29
W89-2 22.20
75A 21.85
W89-3 23.72
W89-4 24.60
W89-5 19.08
W89-6 19.70
W89-7 18.31
97A 18.50
W89-8 14.51
W89-9 12.41
14E14A 10.52
88A 14.09
W89-10 11.72
15H05A 12.87
15A02A 10.27
15A04A 6.90
10R05A 4.02
15A01A 6.16
15A05A 6.21
15A10A 7.83
15A06A 9.10
15A09A 7.93
15A08A 7.93
15A07A 8.26
15B02A 7.13
15B03A 8.60
W14-4 24.41
ERM-3 24.76
W14-10 25.08
ERM-2 24.38
W14-3 25.28
ERM-1 24.77
W14-11 24.31
W14-12 24.85
W14-2 24.68
W60-2 22.77
W60-1 21.93
64A 23.86
WU4-1** 24.54
63A 21.24

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

LEGEND

W7-8 16.90 — WELL NAME, WATER ELEVATION IN FEET (MSL)

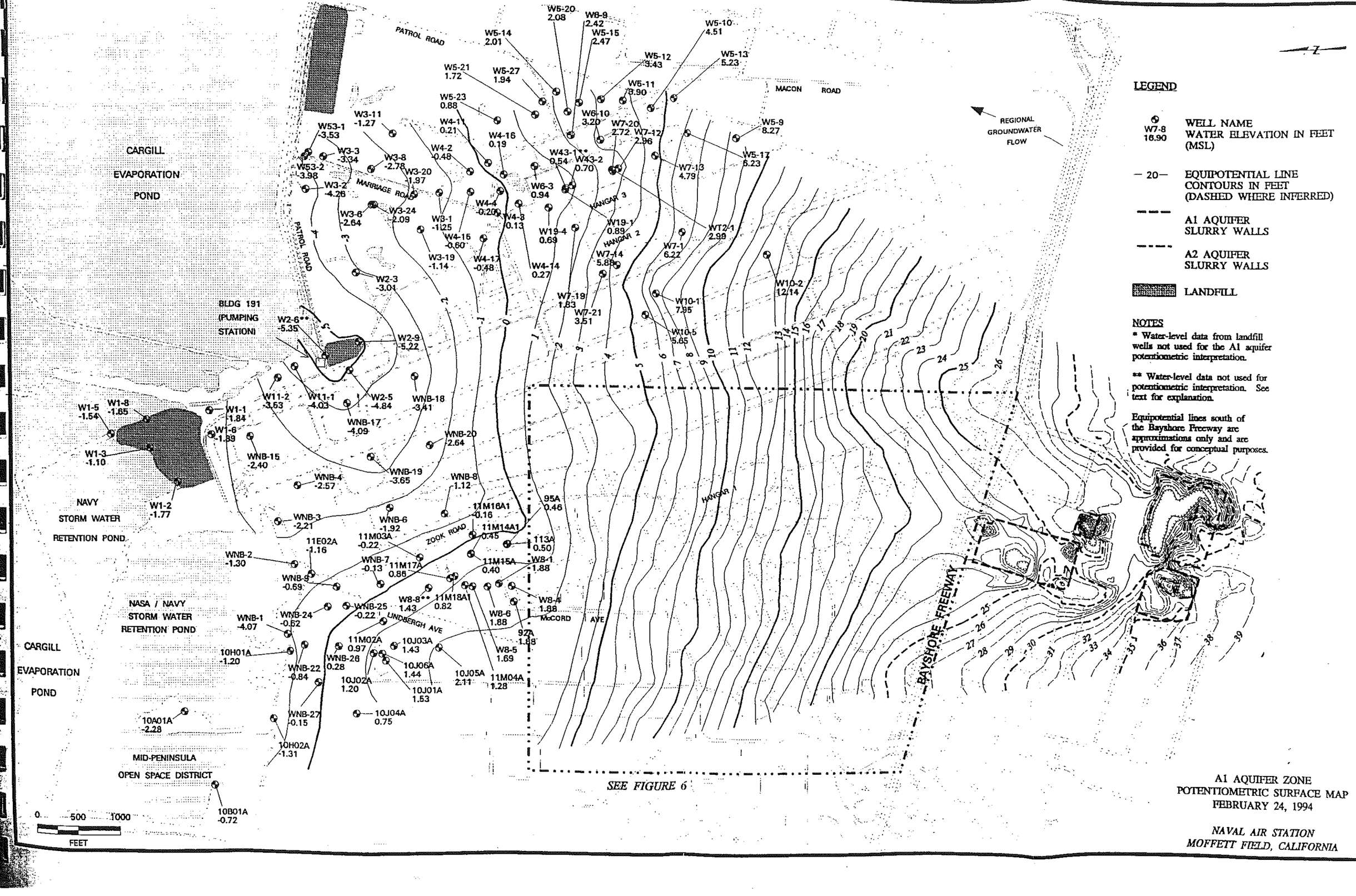
— 20 — EQUIPOTENTIAL LINE, CONTOURS IN FEET (DASHED WHERE INFERRED)

NOTES

** Water-level data not used for potentiometric interpretation see text for explanation.

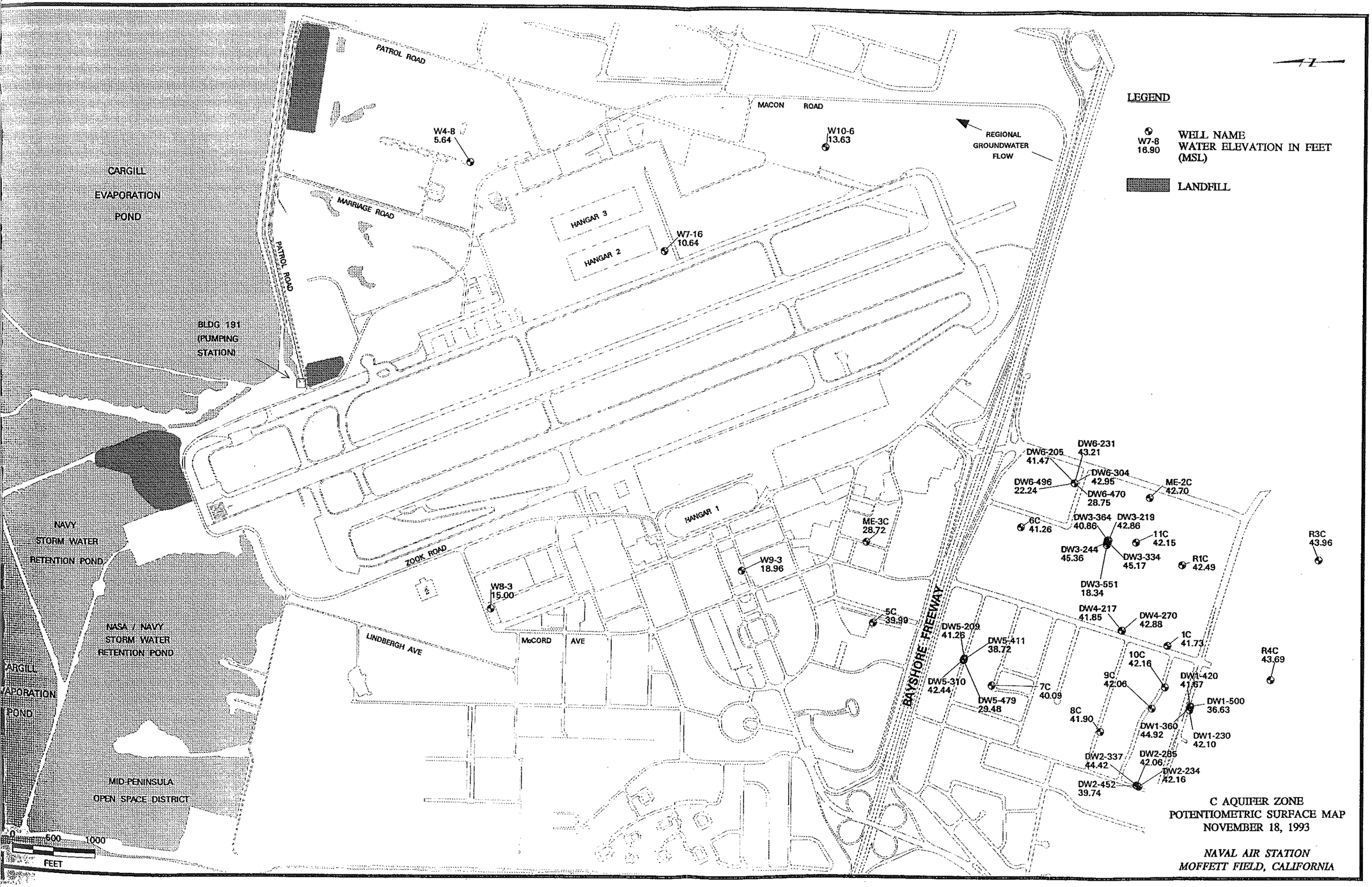
0 250 500 FEET

A1 AQUIFER ZONE
POTENTIOMETRIC SURFACE MAP
(ENLARGEMENT OF AREA NORTH OF BAYSHORE FREEWAY)
NOVEMBER 18, 1993
NAVAL AIR STATION
MOFFETT FIELD, CALIFORNIA



A1 AQUIFER ZONE
POTENTIOMETRIC SURFACE MAP
FEBRUARY 24, 1994

NAVAL AIR STATION
MOFFETT FIELD, CALIFORNIA



C AQUIFER ZONE
POTENTIOMETRIC SURFACE MAP
NOVEMBER 18, 1993

NAVAL AIR STATION
MOFFETT FIELD, CALIFORNIA

MOFFETT FEDERAL AIRFIELD

RESPONSE TO COMMENTS ON DRAFT FINAL INSTALLATION RESTORATION PROGRAM PETROLEUM SITES (AND WASTEWATER TANKS AND SUMPS) CORRECTIVE ACTION PLAN

November 4, 1994

This report presents point-by-point responses to regulatory agency comments on the September 1994 Draft Final Installation Restoration Program Petroleum Sites (and Wastewater Tanks and Sumps) Corrective Action Plan (CAP) prepared by PRC Environmental Management, Inc. (PRC) for Moffett Federal Airfield (Moffett Field), California. Mr. Ron Gervason of the San Francisco Bay Regional Water Quality Control Board (RWQCB) submitted comments in a letter dated October 5, 1994. Mr. Michael Gill of the U.S. Environmental Protection Agency (EPA) submitted comments in a letter dated September 27, 1994.

Comments from Mr. Ron Gervason, RWQCB

GENERAL COMMENTS

Comment 1: The report is well prepared and presented. However, this report is not a stand alone document and relies heavily on references to other documents, especially for analytical results. At a minimum Table 1 should be modified to summarize this information. As an alternative a summary table of analytical results could be included for each site. This table should include number of samples, number of detections, and detection limits. This is intended to provide a basis for statements regarding extent of contamination.

Response: *The effort required to provide complete data tables was discussed during telephone conversations with Mr. Ron Gervason (RWQCB) and Mr. Michael Gill (EPA) and PRC on October 31 and November 1, 1994, respectively. RWQCB and EPA agreed that the effort may not be warranted; however, the regulatory agencies indicated that a plan to present these data should be proposed. The Navy prefers not to provide these tables in this CAP, since the data summarized in the text and contamination*

figures adequately address the areas of concern. Additionally, the requested data have been provided previously in numerous reports and letters. In the future, the Navy recommends providing complete data tables in closure reports and full-scale corrective measure designs, since these data are required to prepare these documents.

Comment 2: The sections of the report on remedial alternative screening is presented at a level of detail greater than usually required for petroleum sites.

Response: Additional detail was provided to make the document more useful to project personnel and to assist with corrective measure planning.

SPECIFIC COMMENTS

Comment 1: Section 1, Page 3, Second Paragraph. The issue of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) integration of wastewater tanks and sumps needs to be addressed more specifically. How will these units be included in the CERCLA process, will they be included in the sitewide remedial investigation (RI) or as part of some specific operable unit (OU)?

Response: Wastewater tanks and sumps will be treated just as any other CERCLA site at Moffett Field. Data from wastewater tanks and sumps will be included in the station-wide human health risk assessment, RI and feasibility study (FS) reports, and record of decision (ROD). Human health risks will be evaluated in a manner constant with the evaluation of other individual sites (such as operable unit 2 soil sites). Tracking of the wastewater tanks and sumps will be on an individual basis similar to other individual station-wide sites (such as Zook Road, Patrol Road Ditch, and golf course landfill 2). This explanation has been added to the CAP.

Comment 2: Section 2.2.2, Page 9, Fourth Paragraph. It may be appropriate to include the location of the nearest C-zone wells, their use (municipal or agricultural) and the current well status.

Response: Information regarding the nearest C-aquifer wells has been added to Section 2.2.2.

Comment 3: Section 2.3, Page 13, Fourth Paragraph. If a discussion of the french drain system is included it should be expanded to include at a minimum a description of drain depth as compared to the aquifer units and some discussion of the density of the drain system.

Response: *The purpose of this paragraph was to provide general hydrogeologic information regarding the A and B aquifers at Moffett Field. Additionally, the sites discussed in this report are not located near the runways. Therefore, details of the french drain system under the runways are not necessary. The referenced sentence has been removed for clarity.*

Comment 4: Section 3.2, Page 15, Second Paragraph. The discussion of cleanup levels should include a description of the intended use conditions to which they apply (commercial/industrial?) and some language to address changes in land use and potential changes in cleanup requirements.

Response: *Based on the Navy's evaluation of cleanup level options (PRC 1994a), the total petroleum hydrocarbon (TPH) cleanup levels for soil and groundwater represented by Scenario B meet risk-based concentrations for residential scenarios. Individual constituent cleanup levels for groundwater are set at maximum contaminant levels (MCLs) to meet drinking water standards. Individual constituent cleanup levels for soils are set a EPA's risk-based preliminary remediation goals (PRGs) for industrial scenarios. Therefore, the cleanup levels apply to all land use conditions (residential to industrial), with the exception of individual constituents in soils, which represent industrial use conditions. The current land use at Moffett Field is industrial-based. If future land uses become more conservative (such as residential), health risks associated with existing individual constituent concentrations in soils should be compared to current EPA residential PRGs or evaluated through a human health risk analysis. This explanation has been added to the cleanup level discussion in Section 3.2 of the CAP.*

Comment 5: Table 1, Pages 18-21. Consideration should be given to including a summary of analytical results in this table. This would eliminate questions about constituent analysis. The summary should include number of samples, description of detection

limits and analytes. Further detail could be referenced to appropriate reports. This suggestion is intended to improve the function of this document as a "stand alone report" and to improve public accessibility to the data.

Response: *Please see the response to RWQCB general comment 1.*

Comment 6: Table 1, Page 21. Please clarify the references to square yard (yd^2) and cubic yard (yd^3) in the notes.

Response: *The footnotes in Table 1 have been clarified.*

Comment 7: Section 4.1, Page 23, First Paragraph. If the soil contamination related to the Tank 26 excavation is of such limited extent that it cannot be plotted on Figure 4, this should be clearly stated.

Response: *The suggested statement has been included.*

Comment 8: Section 4.1, Page 23, Third Paragraph. Does the channel discussed here extend toward HP5-3 and well W5-34? The change in scales between Figures 5 and 6 and the lack of reference points of Figure 6 makes this unclear.

Response: *The channel deposit discussed in this paragraph and shown on Figure 6 does extend toward HydroPunch® sample HP5-3 and monitoring well W5-34. The reference point on Figure 6 is soil boring SB5-34, which is the boring that well W5-34 was constructed in. Well designation W5-34 has been added to Figure 6 for clarity.*

Comment 9: Section 4.1, Page 27, First Paragraph. The summary of contamination apparently does not address the groundwater contamination near HP5-3 and well W5-34. Is this contamination considered to be "minor"?

Response: *Since the groundwater contamination observed near HydroPunch® sample HP5-3 and well W5-34 most likely traveled along the channel deposit under Site 5, the most likely source is the soil contamination from the former dry wells near Tanks 11, 12, and 13 (Figure 4). Therefore, the groundwater contamination near HP5-3 and W5-34 is considered part of the contamination from the former dry wells near Tanks 11, 12, and 13 and it is not considered minor.*

Comment 10: Section 4.2, Page 29, First Paragraph. The statement that no benzene, toluene, ethylbenzene, and xylene (BTEX) compounds were detected should be clarified, either in the text or Table 1, by the inclusion of the number of samples that were analyzed for these compounds.

Response: *The referenced statement did not intend to indicate that BTEX constituents were not detected; rather it stated that no BTEX constituents were detected above cleanup levels. As stated in Section 4.0, only sample results above cleanup levels were presented (since these results indicate the areas requiring corrective action and are the focus of the CAP). Please also see the response to RWQCB general comment 1.*

Comment 11: Section 4.2, Page 29, Third Paragraph. Discussion of contaminants is restricted to TPH. BTEX should be included in the discussion, especially since the plume originates at a gas station.

Response: *A discussion of BTEX detections in groundwater has been added to the paragraph describing the Buildings 29 and 31 TPH contamination plumes.*

Comment 12: Section 4.4, Page 33, Second Paragraph. The correlation between soil and groundwater contamination is low. This should be discussed. Is this an artifact of sampling or is there some other explanation? Additionally, the discussion of contamination should include the BTEX components since the detections are for TPH as gasoline. Again this discussion should be supported by Table 1 or in the text by a summary of the analytical results.

Response: *Figures 11 and 12 depict the areas of soil and groundwater contamination. The area of soil contamination to the north that appears not to correlate with the groundwater contamination may be caused by a surface spill or pipeline leak. This explanation has been included. This area is included as requiring corrective measures. A summary of BTEX constituent concentrations in soil and groundwater samples has been provided in the text.*

Comment 13: Section 4.5, Page 36, First Paragraph. The issue of sampling for volatile organic compounds (VOCs) in Sump 25 should be addressed and a location map of Sump 25 should be included. Did other potential sources of contamination also drain to this sump?

Response: *Data regarding Sump 25 were provided as general background information for completeness. This sump is located near the Naval Exchange (NEX) gasoline station at Moffett Field. A separate investigation and evaluation of the underground storage tanks (USTs) and sumps (including Sumps 25 and 42) at the NEX gasoline station is ongoing. Once complete, a separate CAP will be prepared documenting the nature and extent of contamination and proposed corrective measures for all contamination associated with the NEX gasoline station (including Sump 25). Therefore, additional information regarding Sump 25 will not be provided in this CAP. This explanation has been added to Section 4.5 for clarification.*

Comment 14: Section 4.5, Page 37, Third Paragraph. Metals may also be a constituent of concern for leakage from Sump 62. Was analysis for inorganics included in this investigation? This should be included in any future activities at this location. To eliminate VOCs from concern at this location additional information should be included. This additional information should not be limited to levels of contaminants detected, but should also include specific contaminants detected. Due to the presence of VOCs and possibly inorganics this site should be included in the CERCLA program.

Response: *Data collected at Sump 62 by the National Aeronautics and Space Administration (NASA) have been summarized. These data indicate VOC concentrations beneath Sump 62 are consistent with concentrations in the regional VOC plume that underlies Building 45 and Sump 62. Therefore, Sump 62 is not considered a VOC source. NASA's investigation did include analysis for inorganic constituents; there were no detections above concentrations typically seen in the soils at Moffett Field. As described in Section 1.0, Purpose and Scope, Sump 62 is already listed as one of the petroleum sites that will be included within the CERCLA program, including the station-wide human health risk assessment, RI, and ROD.*

Comment 15: Section 4.5, Page 39, Third Paragraph. Sump 130 should be included in the CERCLA program since the potential contaminants of concern are acids, VOCs, and inorganics. To eliminate Sump 130 from concern additional information will be required. Of particular interest is the basis for the statement that no inorganics present did not represent contamination.

Response: *As described in Section 1.0, Purpose and Scope, Sump 130 is already listed as one of the petroleum sites that will be included within the CERCLA program, including the station-wide human health risk assessment, RI, and ROD. Additionally, Sump 130 was investigated during January and February 1994 as part of the additional petroleum sites investigation. Data from samples collected at this sump are contained and discussed in the Additional Petroleum Sites Investigation Technical Memorandum (PRC 1994b). The sampling and analysis were based on the field work plan approved by the regulatory agencies. During this investigation four soil samples were collected from two soil borings (GP65-1 and GP65-2) placed on each side of the sump. Sample analyses were consistent with sump contents (battery acids) and included VOCs and inorganics. Analytical results indicated no detections of VOCs and inorganic concentrations within levels typically seen in soils at Moffett Field. Additionally, one HydroPunch® sample (HP65-1) was collected downgradient of Sump 130 and analyzed for VOCs and metals. Analytical results revealed no detections of VOCs and inorganic concentrations within levels typically seen in groundwater at Moffett Field. The investigation technical memorandum contains the specific soil and groundwater inorganic concentrations. This explanation has been added to the Sump 130 discussion in Section 4.5 of the CAP. Please also see the response to RWQCB general comment 1.*

Comment 16: Section 4.6, Page 42, First Paragraph. Tank 43 should be included in the CERCLA program since the potential contaminants of concern are acids, VOCs, and inorganics. This discussion of contamination at Site 19 should include presentation of analytical results for pH, VOCs, and inorganics.

Response: *As described in Section 1.0, Purpose and Scope, Tank 43 is already listed as one of the petroleum sites that will be included within the CERCLA program, including the station-wide human risk assessment, RI, and ROD. Please also see the response to RWQCB general comment 1.*

Comment 17: Section 4.6, Page 45, First Paragraph. The discussion of the detection of TPH extractable at Tank 14 should include the total number of soil samples that were collected. It should also be indicated whether the single detection is above the proposed cleanup standards for this compound.

Response: *All soil samples collected at the former Tank 14 area (a total of eleven samples) were analyzed for TPH extractable. The single detection of TPH extractable as diesel, measuring 1,700 milligrams per kilogram (mg/kg), is above the cleanup level of 400 mg/kg. However, analytical results from six additional samples collected adjacent to this detection revealed no detections of TPH extractable as diesel. These data are discussed in the petroleum sites characterization report (PRC 1994c) and will be presented in a closure report. These data indicate that the remaining contamination is very localized and small in extent. Furthermore, a groundwater monitoring well adjacent to former Tank 14 (WT14-1) has revealed no detections of TPH. Although a small area of contamination above the cleanup level may remain, the Navy proposes no further action because Tank 14 has been removed, groundwater has not been affected, and the cost of remediation exceeds the benefit of remediating such a small area. This explanation has been added to the CAP.*

Comment 18: Section 5.3, Page 52, Fourth Paragraph. It is unclear if an actual National Pollutant Discharge Elimination System (NPDES) permit will be required for this treatment system.

Response: *A NPDES permit is not required since the Site 9 source control measure is being conducted in accordance with the west-side aquifers CERCLA action. CERCLA, however, requires that permit requirements be followed. This explanation has been added to the CAP.*

Comments from Mr. Michael Gill, EPA

GENERAL COMMENTS

Comment 1: Overall, this document is a tremendous improvement over the draft version. It is important to note the negotiations held between the Navy and the agencies where agreement on the cleanup levels were reached. It is also a much more complete feasibility study of the proposed alternatives, although many still require treatability studies before a selection is made. EPA encourages this use of innovative technology, but does not want it to unnecessarily postpone the start of remediation. The Navy needs to provide schedules for these activities in the final version of this document. It

is important to note that some of the technologies being tested during the pilot studies are in fact well documented and in use at other sites and may not need additional studies.

Response: *A schedule for the petroleum sites pilot tests has been provided in Section 8.1. These pilot tests are necessary to gather site-specific design parameters. Even well-documented technologies require site-specific information for design evaluation and optimization.*

Comment 2: Is NASA's Comprehensive Use Plan for Moffett Field an approved document? It is dated August of 1993, but I don't believe the regulatory agencies have seen it. Is it a final document? Was Navy in on the review cycle?

Response: *The status of the National Aeronautics and Space Administration's Comprehensive Use Plan was discussed during a telephone conversation with EPA and PRC on November 2, 1994. The final plan was submitted August 1994 after review by the appropriate parties. The CAP was revised to reference the final plan.*

SPECIFIC COMMENTS

Comment 3: Section 4.5, Page 36, Tank 54. Trichloroethene (TCE) detected in a sidewall sample at 24 micrograms per kilogram (µg/kg) is above the MCL of 5 µg/kg, which is the cleanup level. Please correct this statement.

Response: *Currently, there are no cleanup levels established for VOCs in soils on the eastern side of Moffett Field where former Tank 54 was located. Soil cleanup levels established for the petroleum sites include TPH extractable as diesel and JP-5, TPH purgeable as gasoline, BTEX, and semivolatile organic compounds (SVOCs). Cleanup levels for VOCs in soils have been established for the western side of Moffett Field through the Middlefield-Ellis-Whisman record of decision at 100 times the corresponding MCL for a particular VOC constituent. (For TCE, this would equate to a cleanup level of 500 µg/kg, since the MCL for TCE is 5 micrograms per liter [µg/L].)*

As a point of comparison, the EPA Region 9 PRG for TCE in soils is 3,300 µg/kg for residential scenarios and 7,300 µg/kg for industrial scenarios (EPA 1994). Although EPA Region 9 PRGs for VOCs are not agreed upon cleanup levels for Moffett Field, they present a good basis for order of magnitude comparisons. Since the TCE detection at Tank 54 (24 µg/kg) is significantly lower than both established TCE cleanup levels on the western side of Moffett Field (500 µg/kg) and EPA PRGs (3,300 and 7,300 µg/kg), the Navy recommends no further action for this site. This explanation has been included with the Tank 54 description.

Comment 2: EPA Comment 4, Table 1, Page 21. The footnotes for yd^2 and yd^3 appear incorrect.

Response: *The footnote in Table 1 has been corrected.*

Comment 3: EPA Comment 5, Section 4.3, Page 31, Last Paragraph. Please provide a schedule for the additional investigation required for Site 12.

Response: *The additional investigation at Site 12 will occur in conjunction with the station-wide remedial investigation field work, scheduled for November 1994. This explanation has been added to the referenced section.*

Comment 4: EPA Comment 6, Section 4.6, Page 45, Tank 14. If a soil sample shows a detection of 1,700 mg/kg of TPH as diesel, and the cleanup level for diesel is 400 mg/kg, how can closure be recommended? Cleanup must be complete before closure can be approved.

Response: *Please see the response to RWQCB specific comment 17.*

Comment 5: EPA Comment 7, Section 4.6, Figures 16-19. The document states on pages 3 and 14 that CERCLA substances found present in wastewater tanks and sumps at Site 15 and 19 will be addressed in the site-wide documents. The maps in this document should reflect those VOC/SVOC levels found in those areas (that is, Tanks 2 and 43 in Figures 16-19). If the risk does prove to be unacceptable, those tank and sump areas will have to be handled by the CERCLA process.

Response: *These data have been generally summarized in the text and have been previously provided in the referenced reports. Please see the response to RWQCB general comment 1. Therefore, the referenced figures have not been updated. To address CERCLA requirements, all analytical data collected from the wastewater tanks and sumps (listed in Section 1.0 of the CAP) will be included in the station-wide human health risk assessment and RI report. Any remedial actions, if required, will occur through the station-wide FS, ROD, and associated remedial work plans and designs.*

Comment 6: EPA Comment 8, Section 8.0. Please include any treatability study schedules that you intend to perform.

Response: *A schedule for the pilot tests has been provided in Section 8.1.*

Comment 7: EPA Comment 9, Page 109. Please include schedules for the corrective action designs.

Response: *The schedule for full-scale corrective action designs will be determined, in part, by the results of the Phase I pilot tests. A schedule will be proposed in the evaluation technical memorandum that will be prepared to document the test results. An explanation has been added to Section 8.1.*

REFERENCES

U.S. Environmental Protection Agency (EPA). 1994. Region IX Preliminary Remediation Goals (PRGs), Second Half 1994. San Francisco, California. August.

PRC Environmental Management, Inc. (PRC). 1994a. Technical Memorandum Petroleum Sites Petroleum Cleanup Level Analysis. Naval Air Station Moffett Field, California. March.

PRC. 1994b. Draft Additional Petroleum Sites Investigation Technical Memorandum. Naval Air Station Moffett Field, California. June.

PRC. 1994c. Revised Final Installation Restoration Program Petroleum Sites (and Wastewater Tanks and Sumps) Characterization Report. Naval Air Station Moffett Field, California. January.

APPENDIX B

COST ESTIMATE SUPPORT SHEETS

PRC Environmental Management, Inc.

CALCULATION / WORK SHEET SHEET 1 OF 9

PROJECT:		COMPONENT/SYSTEM	
Moffett Field CAP		Technology Cost Range Est.	
PREPARED BY: DAR	DATE: 8/10/94	CHECKED BY: [signature]	DATE: 1 Sep 94

Technology screening in the Corrective Action Plan (CAP) uses cost as one criteria. Cost estimates are site- and technology-specific. Costs of most technologies have economies of scale (the more you treat the less $ per unit volume you spend). Heterogeneous lithologies also impact costs. Assumptions for restoration times and areas of influence are often based on ideal homogeneous conditions thus costs are often underestimated. One study of 28 Superfund sites undergoing remediation indicate that restoration times are often 3 times more than estimated and costs typically are 80% more than estimated. (Olsen, Roger and Kavanaugh, "Can Groundwater Restoration be Achieved? Water Environment & Technology March 1993)

Cost Ranges for each technology are developed based on data presented in EPA guidance (Handbk, Remedial Actions at Waste Disposal Sites EPA/625/6-85/006) and cost estimates developed in other Moffett Field FSs (OU4, OU5, Site 9, Site 12)

The costs will be refined based on actual costs for implementing plot studies

The Alternatives for the CAP are divided into soil, groundwater, & combination (both soil & grndwtr) groups

For soil the Alternatives are: (1) Excavation + Disposal, (2) Excavation, Bioremediation, and Backfill; (3) Excavation, Chemical Oxidation and Backfill; (4) SVE; (5) Bioventing

Costs for Excavation & Backfilling are developed separately to integrate into alternatives (1), (2) & (3)

PRC Environmental Management, Inc.

CALCULATION / WORK SHEET SHEET 2 OF _____

PROJECT: Moffett Field CAP		COMPONENT/SYSTEM: Technology Cost Range Estimate	
PREPARED BY:	DATE: 8/15/94	CHECKED BY:	DATE: 1 Sep 94

(A) SOIL (S) - Alternatives 1S, 2S, ... 6S

Sources: EPA, 1985 Handbook, Remedial Action at Waste Disposal Sites EPA 625/6-85/006

PRC, 1992. Draft OU2 FS Report, NAS Moffett Field October 1.

MW + PRC, 1993. Site 12 Fire Fighting Training Area change in Scope of Response Action Memorandum April 30.

Excavation

assume: (1) backhoe @ $1.64/yd^3 (EPA 1985)
(2) dumptruck @ $1.78/yd^3 (EPA 1985)
(3) loader @ $0.84/yd^3 (EPA 1985)

assume: hauler - ¼ mile rndtrip ; daily output 230yd^3
backhoe - 3.5 yd^3 bucket ; daily output 1200yd^3
loader - 5 yd^3 bucket ; daily output 1,480yd^3

① need at least 5 - haulers to keep pace w/ 1-backhoe + 1-loader ⇒ (5)(1.78) + 1.64 + .84 = $11.38/yd^3

② Mngnt + foreman additive cost
(2)($100/day)(1day/1200yd^3) ≈ $0.20/yd^3

③ Fence + security while excavating ≈ $2.00/yd^3 (Site 12 est.)

④ synth liners for soil piles ≈ 4.80/yd^3
≈ $20/yd^3

PRC 1992 Pg 111

Site 9: $95,200 / 3,400 yd^3 = $28/yd^3

Site 19 $25,200 / 900yd^3 = $28/yd^3

MW + PRC 1993

Site 12: Appendix D $25/yd^3

Excavation range without Contingency, Profit, G+A = **$20/yd^3 to $28/yd^3**

PRC Environmental Management, Inc.

CALCULATION / WORK SHEET SHEET 3 OF _____

PROJECT:		COMPONENT/SYSTEM	
Moffett Field CAP		Technology Cost Range Est.	
PREPARED BY: DDD	DATE: 8/15/94	CHECKED BY: MKZ	DATE: 1sep 94

Backfill w/ clean soil

Clean Soil #22/yd^3 (MW+PRC 1993)

+ Compact Backfill #5/yd^3 (MW+PRC 1993) = #27/yd^3

Backfill w/ Treated Soil

PRC 1992 (pg III) site 9 : $\frac{\$17,000}{4,400 yd^3}$ #4/yd^3

site 19 : $\frac{\$4,500}{900 yd^3}$ #5/yd^3

MW+PRC 1993 (Table II) site 12 #5/yd^3 #5/yd^3

Use #6.00/yd^3

Alternative 1S - Excavating and Disposal

Excavation

Transport + Disposal (assume Class I or II landfill for petroleum soils) ⇒ Range #163/yd^3 to #254/yd^3

(Source: McKittrick Waste Disposal + Chemical Waste Magmt)

Density: 90 to 130 #/ft^3 avg 105 #/ft^3

Alternative 1S Excavation + Transport + Disposal + Backfill w

Low #20 + #163 + #27/yd^3 = #210/yd^3

High #28 + #254 + #27/yd^3 = #309/yd^3

Remed Estimates typically underestimated by 80% ⇒ use 1.8 factor to adjust

⇒ Alternative 1S Range = #378/yd^3 to #556/yd^3

Alternative 2S Excavation, Bioremediation + Backfill

PRC 1992 Pg III

site 9 $\frac{\$1,053,200}{3400 yd^3}$ = ~~#239~~ 310 MKZ /yd^3

site 19 $\frac{\$278,800}{900 yd^3}$ = #310/yd^3

MW+PRC 1993 (Appendix D) $\frac{\$583,752.77}{4,400 yd^3}$ = #133/yd^3

PRC Environmental Management, Inc.

CALCULATION / WORK SHEET SHEET 4 OF _____

PROJECT:		COMPONENT/SYSTEM	
Moffett Field CAP		Technology Cost Range Estimate	
PREPARED BY: DDD	DATE: 8/15/94	CHECKED BY: MAR	DATE: 1Sep 94

Cytoculture Bid for Treatability testing (1991)

Volume : 500 - 999 yd^3 | 1,000 - 2499 | 2,500 - 5000 | 5,000 - 10,000

Cost : $65/$yd^3$ | $55/$yd^3$ | $50/$yd^3$ | $45/$yd^3$

$20 + $45 + $5 = $70/$yd^3$

28 + $65 + $5 = $98/$yd^3$

RZA AGRA (Rittenhouse-Zeman + Associates) Bid for Remediation of Petroleum soils (1993)

$\frac{\$112,161.89}{700\ yd^3} = \$160/yd^3$

Remediation Costs typically underestimated by 80% ⇒ use factor of 1.8 to adjust

→ ⇒ Alternative 2S Range $65(1.8) to $310(1.8)

$126/$yd^3$ to $558/$yd^3$ ←

Alternative 3S - Excavation Thermal Desorption Trmt, + Backfill

CET Environmental Services, Inc. Bid for Treatability Test (1991) does not include excavation, backfill - $\frac{\$61,437}{250 yd^3} = \$246/yd^3$

$20 + $246 + $5 = $271/$yd^3$

PRC 1992 Pg 116

Site 9. $\frac{\$1,259,700}{4,400 yd^3} = \$286/yd^3$

Site 19 $\frac{\$333,500}{900 yd^3} = \$371/yd^3$

VIAGTECH 1992 Symposium cost for petroleum soils 100,000 tons - $65/ton

$65/ton $\left(\frac{ton}{2000\#}\right)\left(\frac{105\#}{yd^3}\right) = \$92/yd^3$

Alternative includes excavation + backfill : $20 + $92 + $5 = $117/$yd^3$

→ Alternative 3S Range : $210/$yd^3$ to $668/$yd^3$ ←

(use 1.8 factor)

PRC Environmental Management, Inc.

CALCULATION / WORK SHEET SHEET 5 OF _____

PROJECT: Moffett Field CAP		COMPONENT/SYSTEM: Technology Cost Range Est	
PREPARED BY: DAD	DATE: 8/15/94	CHECKED BY: MHZ	DATE: 1 Sep 94

Alternative 4S Excavation, Chemical Oxidation, Backfill
Actual Site 12: $\frac{\$1,000,000}{6,600\ yd^3}$ $\$152/yd^3$

Estimated Site 12 $\$133/yd^3$
Use 1.8 for estimated value ⇒ $\$239/yd^3$
→ Alternative 4S range $\$152/yd^3$ to $239/yd^3$ ←

Alternative 5S - SVE
PRC 1992 (Appendix B-5A) Site 9: $\frac{\$448,500}{9,000\ ft^2 \text{ or } 3,400\ yd^3} = \$50/ft^2$ ($\$132/yd^3$)

Site 18: $\frac{\$507,200}{22,800\ ft^2 \text{ or } 10,100\ yd^3} = \$22/ft^2$ ($\$50/yd^3$)

Site 19: $\frac{\$389,200}{4,800\ ft^2 \text{ or } 900\ yd^3} = \$81/ft^2$ ($\$432/yd^3$)

Connor 1988 "Case Study of soil venting" Pollution Engineering July.
Projected Total Cost: $\frac{\$175,000}{10,000\ ft^2\ (2,500\ yd^3)} = \$17/ft^2$ ($\$70/yd^3$)

EPA 1989 Technology Evaluation Report: SITE Program Demonstration Test Terra Vac In situ Vacuum Extraction System Groveland, MA EPA/540/5-89/003a
$47.12/ton $\left(1.3\ \frac{ton}{yd^3}\right)$ $\$61/yd^3$
(tmt goals not reached)
Use factor of 1.8 for estimated values
→ Alternative 5S Range $\$90/yd^3$ to $\$778/yd^3$ ←

Alternative 6 Bioventing - Could be as expensive as SVE
PRC 1992 Using SVE costs eliminate off-gas treatment capital + O+M
Site 9: 448,500 − 84,600 − 79,470 = $\frac{\$284,430}{3,400\ yd^3}$ $\$83/yd^3$
Site 18: $\frac{\$343,130}{10,100\ yd^3} = \$34/yd^3$

PRC Environmental Management, Inc.

CALCULATION / WORK SHEET SHEET 6 OF _____

PROJECT:		COMPONENT/SYSTEM	
Moffett Field CAP		Technology Cost Range Est	
PREPARED BY: DOD	DATE: 8/15/94	CHECKED BY: [signature]	DATE: 1 Sep 94

Site 19: $250/yd^3
Use 1.8 estimate factor
Alternative 6S Range $61/yd^3 to $778/yd^3

(B) GROUNDWATER

Sources: PRC 1994 Revised Draft OUS FS Report NAS Moffett Field, July 11.
PRC 1992 Draft OU4 FS Report, Vol. 1, NAS Moffett Field, August 3.

Alternative GW1 Extraction, Air Stripping, and Discharg

PRC 1994: $\frac{\$6.2 \times 10^6}{2 \times 10^6 \text{ ft}^2} = \$3.11/\text{ft}^2$

PRC 1992: $\frac{\$18,159,100}{\$2.9 \times 10^6 \text{ ft}^2} = \$6.33/\text{ft}^2$
Use 1.8 factor for underestimate

→ Alternative GW1 Range $5.60/ft^2 to $11.39/ft^2 ←

Alternative GW2 Extraction, Chem Oxid and Discharge

PRC 1994: $\frac{\$6,649,000}{2.0 \times 10^6 \text{ ft}^2} = \$3.32/\text{ft}^2$

PRC 1992: $\frac{\$28,245,000}{2.9 \times 10^6 \text{ ft}^2} = \$9.74/\text{ft}^2$

Use 1.8 factor

→ Alternative GW2 Range ~~$6.00~~ 5.98 to $17.55/ft^2 ←

PRC Environmental Management, Inc.

CALCULATION / WORK SHEET SHEET 7 OF _____

PROJECT:		COMPONENT/SYSTEM	
Moffett Field CAP		Technology Cost Rang Est.	
PREPARED BY: DOD	DATE: 8/15/94	CHECKED BY: MM	DATE: 15 Sep 94

Alternative GW3 - Extraction, Election Injection & Discharge

PRC 1994: $\frac{\$8,502,000}{2 \times 10^6 ft^2}$ $\$4.25/ft^2$

Use 1.8 factor for underestimate $\$7.65$

Vender indicates that technology cost competitive w/ air stripping
∴ upper range based on air stripping upper range $\$11.40$

→ Alternative GW3 Range $\$7.65$ to $\$11.40$ ←

Alternative GW4 Extraction, Bioremediation and Discharge

PRC 1992: Pgs 126, 137, 116

$\frac{\$4.7 \times 10^6 (treat + \$3.0 \times 10^6 (disch) + \$900,000 (Extract)}{2.9 \times 10^6 ft^2}$

$\$2.97/ft^2$

PRC 1991 Site 9 Action Memorandum

Pg 124: Capture Zone Area $37,000 ft^2$ based on 1-2gpm well

$\frac{\text{Extract (Pg 129)} + \text{Trmt (Pg 145)} + (3 \times \text{Extract Cost for Discharge see 004})}{37,000 ft^2}$

$\frac{\$24,300 + \$217,000 + \$72,900}{37,000 ft^2} = \$8.49$

Use 1.8 factor for underestimate based on limited effectiveness

→ Alternative GW4 Range $\$5.35$ To $\$15.29$ ←

Alternative GW5

PRC 1992 Cost of IC + O.M. of Air Sparging System

$\$2,993,000 + 18.66 (\$104,000) = \frac{\$4.9E6}{2.0E6 ft^2} = \$2.47/ft^2$

present value factor

order of magnitude estimate

⇒Assume accuracy of -30 +50% ⇒highend = $\$3.71/ft^2$

Use 1.8 factor for underestimate based on limited effectiveness

→ Alternative GW5 Range $\$4.45/ft^2$ To $\$6.67/ft^2$

PRC Environmental Management, Inc.

CALCULATION / WORK SHEET SHEET 8 OF _____

PROJECT:		COMPONENT/SYSTEM	
Moffett Field CAP		Technology Cost Range Est.	
PREPARED BY: DDD	DATE: 8/15/94	CHECKED BY: MKK	DATE: 1 Sep 94

Alternative GWS AS or Biosparge

PRC 1992 AS/SVE costs minus SVE - offgas cost

$5,052,000 - $31,300 (blower) - $3,600 (Air/$H_2O$ separator) - $70,000 (thermal oxid) - $23,500 (Extract well install) - $3,400 (VE wells) - ($39,600) 18.66 (Thermal oxid Unit O+M) = $\frac{\$4,181,000}{2 \times 10^6 ft^2}$ = $2.09/ft^2$

Assume Accuracy of -30 +60% (order-of-mag)

⇒ high end = $3.14

Use 1.8 factor for underestimate

→ Alternative GWS Range $3.76/ft^2 to $5.64 ~~$8.64~~ mod $/ft^2 ←

(C) Both GROUNDWATER + SOIL ALTERNATIVES

Alternative Both 1 - AS/SVE

PRC 1992 $\frac{\$5,052,000}{2 \times 10^6 ft^2}$ = $2.53/ft^2

Assume 10 ft radius of influence (double spanging + extraction wells)

$\frac{\$7,200,000}{2 \times 10^6 ft^2}$ = $3.60/ft^2

→ Alternative Both 1 Range $4.55/ft^2 To ~~$6.60~~ 6.48 mod $/ft ←

Alternative Both 2 - Biosparg/Biovent

Use AS/SVE minus offgas thermal treatment and 1 vent well for each sparge well see spread sheets attached

20 ft radius of influence (25 sparg + 25 vent wells

$\frac{\$3,300,000}{2 \times 10^6 ft^2}$ = $1.65/ft^2

10 ft radius of influence (50 sparge wells

$\frac{\$3,100,000}{2 \times 10^6 ft^2}$ = $1.55/ft^2

Use 1.8 factor

→ Alternative Both 2 Range $2.79/ft^2 to $2.97/ft^2 ←

PRC Environmental Management, Inc.

CALCULATION / WORK SHEET SHEET 9 OF 9

PROJECT:		COMPONENT/SYSTEM	
Moffett Field CAD		Technology Cost Range Es	
PREPARED BY: DOD	DATE: 8/15/94	CHECKED BY: MMB	DATE: 1Sep94

Alternative Both 3 RIST
parallels AS/SVE ∴ similar cost range = $4.55 to $6.50/ft²
Site 14 South Cost Estimate for RIST
PRC 1994 Technical Memorandum Site 19 South Evaluation
NAS Moffett Field, California April
Assume: area of influence 50 by 150 feet ⇒ Area = 7,500 ft²

$\frac{\$22,000}{7500\ ft^2} = \$2.93/ft^2$

Use 1.8 factor for underestimate ⇒ $5.28/ft²

→ Alternative Both 3 $4.55/ft² to $6.50/ft² ←