Trish Morrissey

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN II)

Northern and Central California, Nevada, and Utah
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Prepared for

DEPARTMENT OF THE NAVY
Mr. Hubert Chan, Remedial Project Manager
Engineering Field Activity West
Naval Facilities Engineering Command
San Bruno, California

MOFFETT FEDERAL AIRFIELD, CALIFORNIA
(Formerly Naval Air Station Moffett Field)

DRAFT
BASEWIDE PETROLEUM SITE EVALUATION METHODOLOGY TECHNICAL MEMORANDUM

January 24, 1997

Prepared By

PRC ENVIRONMENTAL MANAGEMENT, INC.
135 Main Street, Suite 1800
San Francisco, California 94105
415/543-4880

Willis Wilcoxon
Willis Wilcoxon, Task Manager

Timothy Mower
Timothy Mower, Project Manager

EDC1179

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

PRC

January 24, 1997

Mr. Stephen Chao and Mr. Hubert Chan
Department of the Navy
Engineering Field Activity West
Naval Facilities Engineering Command
900 Commodore Drive, Building 210
San Bruno, California 94066-5006

CLEAN Contract Number N62474-94-D-7609
Contract Task Order 079

Subject: **Draft Petroleum Sites Evaluation Methodology Technical Memorandum, Moffett Federal Airfield**

Dear Messrs. Chao and Chan:

Enclosed are three copies of the above-referenced document. PRC Environmental Management, Inc. (PRC) prepared this technical memorandum to outline the methodology to be used to evaluate further action requirements for petroleum sites and present general basewide information required in an evaluation report.

The format has been prepared as discussed in a meeting with the San Francisco Bay Area Regional Water Quality Control Board (RWQCB) in March 1996. The proposed methodology incorporates RWQCB guidance for petroleum site evaluations and follows the tiered approach presented by the American Society for Testing and Materials (ASTM) in its risk-based corrective action standard guide. Site-specific evaluations will be forwarded to be attached as appendices to this document as they are completed.

If you have any questions, please call me at (303) 312-8822 or Timothy Mower at (303) 312-8874.

Sincerely,

Willis E. Wilcoxon
Task Manager

Timothy Mower
Project Manager

WEW/jem

Enclosures

cc: Distribution

Draft Petroleum Sites Evaluation Methodology Technical Memorandum
Moffett Federal Airfield

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ACRONYMS AND ABBREVIATIONS

AFESC	Air Force Engineering Services Center
AST	Aboveground storage tank
ASTM	American Society for Testing and Materials
bgs	Below ground surface
BTEX	Benzene, toluene, ethylbenzene, and xylene
Cal/EPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSF	Carcinogenic slope factor
CNS	Central nervous system
CLEAN	Comprehensive Long-term Environmental Action Navy
CPT	Cone penetrometer test
COC	Chemical of concern
COPEC	Chemical of potential ecological concern
CTO	Contract task order
DDT	Dichlorodiphenyl-trichloroethane
DTSC	Department of Toxic Substances Control
ECAO	Environmental Criteria Assessment Office
EPA	U.S. Environmental Protection Agency
FS	Feasibility study
ft/ft	foot per foot
g/L	Grams per liter
HI	Hazard index
HQ	Hazard quotient
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
LLNL	Lawrence Livermore National Laboratory
LUFT	Leaking Underground Fuel Tank
MCL	Maximum contaminant level
μg/L	Micrograms per liter
MFA	Moffett Federal Airfield
MTBE	Methyl tertiary butyl ether
mg/kg	Milligrams per kilograms
mg/kg-day	Milligrams per kilogram per day
mg/L	Milligrams per liter
msl	Mean sea level
NASA	National Aeronautics and Space Administration
NEX	Naval Exchange

ACRONYMS AND ABBREVIATIONS (Continued)

OU	Operable unit
PAH	Polynuclear aromatic hydrocarbon
ppb	Parts per billion
ppm	Parts per million
PRC	PRC Environmental Management, Inc.
PRG	Preliminary remediation goal
RME	Reasonable maximum exposure
RfD	Reference dose
RWQCB	Regional Water Quality Control Board, San Francisco Bay Area
RI	Remedial investigation
RBCA	Risk-based corrective action
RBSL	Risk-based screening level
SHRTSC	Superfund Health Risk Technical Support Center
SVOC	Semivolatile organic compound
SWEA	Site-wide ecological assessment
SSTL	Site-specific target level
SWRCB	State Water Resources Control Board
TPH	Total petroleum hydrocarbons
TPH-e	Total petroleum hydrocarbons extractable
TPH-p	Total petroleum hydrocarbons purgeable
TRV	Toxicity reference value
UCL	Upper confidence limit
UST	Underground storage tank
VOC	Volatile organic compound

1.0 INTRODUCTION

PRC Environmental Management, Inc. (PRC) is providing technical support to the U.S. Navy for investigations at Moffett Federal Airfield (MFA), Santa Clara County, California, under contract task order (CTO) 079. CTO 079 is part of the second Comprehensive Long-term Environmental Action Navy (CLEAN II) contract for the environmental restoration of Navy facilities. Task 9 of CTO 079 includes evaluation of petroleum-contaminated soil and groundwater at the following Installation Restoration Program (IRP) petroleum tank and sump sites at MFA: IRP Sites 5, 9, 12, 14-South, 15, and 19, and tanks at the Naval Exchange (NEX) service station. This technical memorandum presents the methodology that will be used to evaluate the need for further action at sites with petroleum releases and contamination. This proposed methodology follows the interim guidance evaluation criteria outlined by the San Francisco Bay Regional Water Quality Control Board (RWQCB) in a recent letter (RWQCB 1996). Site-specific evaluations will be submitted as separate appendices to this report as they are completed for each petroleum site or area.

This technical memorandum is organized as follows. This section presents the purpose, organization, and regulatory background information, and summarizes the evaluation criteria to be used for each site. The next six sections of the report discuss the specific evaluation criteria in the same order as they are presented in the RWQCB interim guidance. Therefore, Section 2.0 discusses the petroleum contaminant source evaluation. Section 3.0 presents general information on site characterization. Section 4.0 discusses the groundwater impact evaluation. Section 5.0 discusses the sensitive receptor evaluation. Section 6.0 presents the methodology to be used to evaluate risks to human health. Section 7.0 presents the methodology to be used to evaluate risks to the environment. Next, Section 8.0 summarizes the site-specific information to be presented in the forthcoming appendices. Finally, Section 9.0 presents references cited. All figures and tables are located after Section 9.0.

1.1 REGULATORY BACKGROUND

In 1994, the California Environmental Protection Agency (Cal/EPA), including the Department of Toxic Substances Control and RWQCB, and the Navy negotiated cleanup levels (action levels) for petroleum contamination in groundwater and soil at MFA. The action levels were set for individual petroleum components for which the State of California had established risk values, and for total petroleum hydrocarbons (TPH) (Cal/EPA 1994). Constituent-specific action levels for groundwater contamination follow drinking water standards promulgated by the State of California for benzene, toluene, ethylbenzene, and xylenes (collectively known as BTEX) and polynuclear aromatic hydrocarbons (PAHs). Groundwater TPH action levels are separated into two main categories: purgeable-phase TPH (TPH-p) with an action level of 50 micrograms per liter (μg/L), and extractable-phase TPH (TPH-e) with an action level of 700 μg/L. Soil TPH action levels have likewise been separated into two categories: 150 milligrams per kilogram (mg/kg) for TPH-p and 400 mg/kg for TPH-e.

The State of California petroleum corrective action philosophy and approach changed significantly in 1995 when the California State Water Resources Control Board (SWRCB) revised its policy for petroleum sites. The revisions were based in part on recommendations by a petroleum site cleanup evaluation panel led by the Lawrence Livermore National Laboratory (LLNL). In a study funded in part by the U.S. Environmental Protection Agency (EPA), the LLNL panel reviewed records of petroleum sites and corrective actions in California. The panel made the following conclusions and recommendations (Rice and others 1995):

- In the State of California, less than 0.5 percent of leaking underground storage tanks (USTs) containing fuels have contaminated drinking water wells.
- Benzene plumes in groundwater generally attenuate within 250 feet downgradient of the source.
- Petroleum tends to degrade without augmentation when the source has been removed. Source removal, as defined by the panel, is reduction of nonaqueous-phase petroleum to residual levels.
- Active groundwater remediation systems, such as pump and treat systems, rarely accelerate cleanup at petroleum sites.
- Petroleum contamination sites should be evaluated for constituent-specific risks. A tiered assessment approach, such as that presented by the American Society for Testing and Materials (ASTM), should be used to evaluate exposure risks.
- The regulatory agencies should grant no further action notices to sites that do not pose an unacceptable risk to on-site or off-site receptors. Sites with groundwater contamination should be granted no further action status if the site poses no current risk, and future land use would not likely pose a risk.
- Natural attenuation should be the selected remedial alternative at sites where petroleum contamination poses no current human health or environmental risk, contaminants pose no nuisance, and data indicate that the groundwater plume is not migrating farther.

In a December 1995 memorandum, SWRCB (1995) accepted the LLNL recommendations and recommended that each RWQCB close low-risk soil cases. It recommended that long-term groundwater monitoring replace active remediation in low-risk groundwater cases, and it recommended that closure be considered at groundwater-contamination sites that neither currently pose unacceptable risks nor are likely to pose an unacceptable risk before contaminants degrade to concentrations below corrective action levels

(SWRCB 1995). Finally, SWRCB recommended that the risk-based corrective action (RBCA) risk assessment method (ASTM 1995) be used to evaluate risks to human health.

In January 1996, RWQCB presented supplemental instructions to the SWRCB interim guidance (RWQCB 1996). The instructions provided definitions of low-risk soil and low-risk groundwater cases, and included a question and answer fact sheet. The instructions recommended that soil-only cases be closed if they do not present an unacceptable risk, and management of "low-risk groundwater impact cases utilizing natural bioremediation as the preferred remedial alternative." The recommendations were labeled interim guidance and were subject to change pending State of California legislation (California State Bill 1764) and revisions to SWRCB Resolution 92-49.

On October 29, 1996, SWRCB issued a draft policy for cleanup of petroleum discharges (Resolution Number 1021b). The resolution outlines general and specific provisions for site evaluation and corrective action. Specific provisions are broken down into the following four divisions:

- Source Removal
- Initial Site Assessment
- Low Risk Criteria
- Additional Site Assessment and Corrective Action

The low-risk criteria were further broken down into the following three categories:

- Low Risk Inhalation Exposure Sites
- Low Risk Soil Only Sites
- Low Risk Groundwater Sites

The Navy met with RWQCB in March 1996 to discuss implementation of the risk-based corrective action procedure at MFA petroleum sites. RWQCB indicated it prefers that all petroleum sites at MFA be evaluated in one document, if possible. PRC, as the Navy technical representative, recommended submittal of (1) a basewide document that describes the evaluation process and presents basewide information, and (2) site-specific reports as appendices that provide site-specific data and risk assessment summaries. This technical memorandum represents the basewide document. The site-specific reports will be distributed later, under separate cover, as appendices to this technical memorandum as they are completed.

1.2 SITE EVALUATION CRITERIA

Each petroleum site will be evaluated according to the criteria outlined in the RWQCB (1996) interim guidance letter and SWRCB Resolution 1021b. In the RWQCB guidance, six criteria have been identified for soil contamination, and six similar criteria have been selected for sites with groundwater contamination. These criteria are stated as definitions for low-risk sites in the RWQCB guidance; however, whether the site is deemed low risk or not, these criteria will be used to evaluate each site. The definitions for low-risk soil contamination sites are quoted from the letter as follows:

> (1) The leak has stopped and ongoing sources, including free product, have been removed or remediated.
>
> (2) The site has been adequately characterized.
>
> (3) Little or no groundwater impact currently exists and no contaminants are found at levels above established MCLs [maximum contaminant levels] or other applicable water quality objectives.
>
> (4) No water wells, deeper drinking water aquifers, surface water, or other sensitive receptors are likely to be impacted.
>
> (5) The site presents no significant risk to human health.
>
> (6) The site presents no significant risk to the environment.

The definitions for low-risk groundwater contamination sites are quoted from the letter as follows:

> (1) The leak has stopped and ongoing sources, including free product, have been removed or remediated.
>
> (2) The site has been adequately characterized.
>
> (3) The dissolved hydrocarbon plume is not migrating.
>
> (4) No water wells, deeper drinking water aquifers, surface water, or other sensitive receptors are likely to be impacted.
>
> (5) The site presents no significant risk to human health.
>
> (6) The site presents no significant risk to the environment.

The SWRCB policy defines the following action levels for low-risk soil only sites. Actions must be taken to correct the following conditions:

- Petroleum-saturated soils
- Detectable petroleum in soil within 20 feet of waters of the state

The SWRCB policy defines the following action levels for low-risk groundwater sites. Actions must be taken to correct the following conditions:

- Methyl tertiary butyl ether (MTBE) concentrations greater than 35 parts per billion (ppb)
- Benzene concentrations greater than 1 ppb, or
- Benzene concentrations greater than 1 part per million (ppm) and a drinking water well or surface water body within 750 feet of the source of the discharge.

The SWRCB and RWQCB guidance are not contradictory; SWRCB merely imposes quantitative limits on allowable concentrations of benzene and MTBE in groundwater and specifies physical distances between sources and drinking water wells or surface water bodies. This report and forthcoming site-specific evaluations will use the SWRCB and RWQCB definitions of low-risk sites as evaluation criteria. The next six sections of this report discuss each of these evaluation criteria individually.

2.0 CONTAMINANT SOURCE EVALUATION

This contaminant source evaluation criterion assesses whether the leak has been stopped and whether ongoing sources have been removed or remediated. With the exception of the four bulk storage USTs at Site 5, all USTs associated with IRP petroleum sites have been removed. Furthermore, various source control measures and remedial actions have reduced fuel contamination in soils and groundwater at Sites 5, 9, 12, and 14. No known free product or other ongoing sources exist at any of the petroleum sites. Most sumps at petroleum sites have also been removed, although one active sump (Sump 59) and one inactive sump (Sump 130) remain in place.

Each site-specific appendix will present an evaluation of existing contaminant sources in soils and groundwater. This evaluation will include information on the status of USTs or sumps removed (or still in place), the presence of free product or mobile sources in soils if applicable, a summary of prior remediation activities, and conclusions on any remaining contaminant sources at the site.

3.0 SITE CHARACTERIZATION

The site characterization criterion will provide information pertinent to contaminant transport mechanisms so that the impact of contamination can be evaluated. Significant characterization activities have been completed at all IRP petroleum sites, including evaluation of contaminant types, contaminant distribution in soil and groundwater, and presence of contaminant sources, and identification of any preferential migration pathways. Table 1 lists tanks and sumps included in the IRP at MFA, and identifies reports completed by PRC for each tank or sump. The characterization information to be presented is divided into two sections: Section 3.1 discusses contaminant characterization, and Section 3.2 describes the geologic characterization of MFA.

3.1 CONTAMINANT CHARACTERIZATION

The extent of petroleum contamination at all IRP petroleum sites at MFA has been evaluated and characterized to an extent that enables an accurate assessment of whether the site poses a threat to human health, the environment, or other sensitive receptors. Site-specific data will be summarized in site-specific reports. These reports will be attached to this technical memorandum as appendices as they are completed. Soil contamination and groundwater plumes have not been delineated to nondetectable levels at every petroleum site. However, adequate — and generally large amounts of — contaminant data have been collected at each site where potential exposure pathways to sensitive receptors have been identified.

Contaminant characterization of each site will be summarized in each site-specific evaluation to be appended to this report. Each site characterization summary will include, at a minimum, a plan view figure that illustrates sample locations, soil contaminant distribution, location of groundwater plumes (if applicable), and data summary tables.

3.2 GEOLOGIC CHARACTERIZATION

Geologic characterization at a site should be carried out to the extent that exposure pathways to sensitive nearby receptors can be sufficiently and accurately evaluated. Extensive amounts of lithologic and hydrogeologic data have been collected at MFA throughout numerous site investigations conducted over the past 6 years. Figure 1 illustrates the IRP petroleum site locations. Some of the sites are widely dispersed geographically; tanks at these sites were not necessarily located close to one another.

Since general geologic conditions are similar across MFA, the following subsections summarize basewide geology and hydrogeology in detail to facilitate later site-specific evaluations. The site-specific appendices will reference this section and describe only (1) site-specific variations from the information presented below, and (2) site-specific features influencing contaminant transport. Since petroleum releases have affected only unsaturated zone or shallow saturated zone soils and groundwater at MFA, the following discussion focuses on these shallower areas.

3.2.1 Basewide Geology

MFA is located at the northern end of the Santa Clara Valley Basin, about 1 mile south of San Francisco Bay. The land is relatively flat, ranging from 2 feet below to 36 feet above mean sea level (msl). The Santa Clara Valley Basin is a large, northwest-tending structural depression between the San Andreas and Hayward faults. The basin is bordered on the west by the Santa Cruz Mountains and on the east by the Diablo Range (PRC and JMM 1992).

Regionally, the Santa Clara Valley contains up to 1,500 feet of Tertiary- and Quaternary-age interbedded alluvial, fluvial, and estuarine deposits that directly overlay early Tertiary or older bedrock (Iwamura 1980). Locally, these sediments consist of varying combinations of unconsolidated to moderately consolidated clay, silt, sand, and gravel that represent interfingering of estuarine and fluvial depositional environments. The fluvial sediments were derived from the Santa Cruz highlands west of the basin and deposited on an alluvial plain bounded by alluvial fan deposits to the west and baylands to the northeast (Iwamura 1980). Figure 2 presents a depositional model of the alluvial deposits of the Santa Clara Valley.

A surface geologic map (Figure 3, after Helley and others 1979) indicates that alluvial fan deposits extend north to the northern edge of MFA, where they interfinger with estuarine deposits. These shallow alluvial deposits consist of anastomosing (branching) stream channel (primarily gravel and sand) and floodplain (silt and clay with fine-grained sandy intervals) deposits. Estuarine deposits (organic-rich silt and clay) are found at the extreme northern end of MFA. These sediments most likely were deposited during the Holocene period when the world-wide sea level was rising toward its present elevation.

Figure 3 shows that MFA lies between two primary (trunk) stream channels. Stevens Creek is an active channel that bounds MFA to the west. The outline of an abandoned channel east of MFA (possibly Jaegel Slough) can also be discerned on this map. The area between these channels consists of floodplain and fresh water marsh environments that were repeatedly dissected by secondary (distributary) channels and overlain by crevasse splay deposits. The distributary channel and crevasse splay deposits were formed during floods when water breached the levees of established streams and spread across the adjacent floodplain. Lenticular or stringer-like sand and gravel bodies are deposited along the path of the most concentrated flow, while thin sheets of silty and clayey sands (crevasse splay deposits) radiate from the location where the levee was breached.

A continuous clay layer (A/B aquitard) between 45 and 65 feet below msl has been observed in borings across MFA. This clay layer does not correspond to a world-wide rise in sea level. Its deposition appears to be of late Pleistocene age. Figures 4 and 5 present cross-sectional diagrams of the late Pleistocene and Holocene deposits. Figure 6 illustrates the surficial expressions of the cross-sectional diagrams.

An even deeper (100 to 160 feet below msl) clay layer (B/C aquitard) corresponds to Sangamon-age interglacial deposits (PRC and JMM 1992, Sangines, E.M. and others 1995). Beneath this aquitard are undifferentiated alluvial gravels, sands, silts, and clays that make up the mid- to early Pleistocene-age deposits and the Pliocene/Pleistocene-age Santa Clara Formation.

3.2.2 Basewide Hydrogeology

Within the northern Santa Clara Valley groundwater basin, watershed boundaries are defined by drainage divides in the Santa Cruz Mountains and Diablo Range. The contact between the bedrock and Quaternary alluvium defines the extent of the groundwater basin (PRC and JMM 1992). Regionally, the Quaternary water-bearing deposits are divided into a deep confined aquifer and a shallow unconfined aquifer within the central part of the basin based on the extent of a regional confining layer (SCVWD 1989). Four regional subdivisions of the upper 250 feet of Quaternary sediments (and the corresponding local aquifers) are as follows:

- Holocene (Recent Interglacial Period) alluvium (A aquifer)
- Late Pleistocene (Wisconsinian Glacial Period) alluvium (B aquifer)
- Late Pleistocene (Sangamon) Interglacial deposits (B/C aquitard)
- Pleistocene (Illinoian Glacial Period) alluvium (C aquifer)

The following sections describe the A aquifer, B aquifer and A/B aquitard, and C aquifer and B/C aquitard. The aquifer descriptions are based on existing data and lithologic interpretation of soil borings and cone penetrometer tests (CPTs). The primary sources of data were the Draft West-Side Aquifer Field Investigation Technical Memorandum (PRC 1993), the Draft Final Geology and Hydrogeology Technical Memorandum (PRC and JMM 1992), the Operable Unit (OU) 5 Feasibility Study (FS) report (PRC 1995), U.S. Geological Survey Professional Paper 943 (Helley and others 1979), and the Saltwater Intrusion Investigation in the Santa Clara Valley Baylands Area, California (Iwamura 1980).

The discussion focuses on the A aquifer because it is the most likely to be affected by petroleum contamination from surface spills or leaking USTs. In addition, groundwater at most locations across MFA exhibits an upward vertical gradient. This vertical gradient is evidenced by higher piezometric heads in deeper wells at locations where adjacent wells are screened in different aquifers (hereafter referred to as paired wells). A review of August 1996 water level data (PRC 1996) from paired wells at various locations across MFA indicates a slight upward gradient on the southern end and eastern side of the facility. At the northern end of Site 9 (around the northern end of Hangar 1), piezometric heads in the different aquifers are approximately equal. On the northwestern corner of MFA (primarily on National Aeronautics and Space Administration [NASA] Ames Research Center property) north of Site 9, the piezometric heads in paired wells indicate a slight downward vertical gradient. Figures 4 and 5 illustrate the cross-sectional hydrogeology of the A aquifer and the A/B aquitard at MFA. Figure 6 illustrates the locations depicted by the cross-sectional diagrams.

A Aquifer Hydrogeology

The A aquifer consists of sands and gravels found between depths of about 5 and 65 feet below ground surface (bgs), subdivided into the A1 and A2 zones. Fine-grained sediments in the A aquifer consist of greenish gray to yellow-brown silts and clays that often contain rust-colored staining of oxidized iron. Coarse materials in the A aquifer are sands and gravels. Coarse-grained channel deposits appear to have an individual maximum thickness of 20 feet on the western side of MFA and 10 feet on the eastern side of MFA. The coarse-grained deposits were incised in, and interbedded with, the fine-grained sediments.

Early reports proposed that a discontinuous aquitard (A1/A2 aquitard) separated the permeable A1 and A2 sediments (HLA 1988; IT 1991). The A1/A2 aquitard was later characterized on the western side of MFA as a zone of reduced channel density which may, in places, be incised by channels in the overlying A1 sediments (PRC 1993). This A1/A2 aquitard is found between depths of 27 and 35 feet bgs at MFA. It is likely that most of the sand channels were deposited by floods capable of dissecting fine-grained floodplain deposits (including marsh deposits). However, the flows that deposited the crevasse splay deposits were probably not capable of scouring significant amounts of fine-grained material. Therefore, crevasse splay deposits are interpreted to overlay floodplain (fine-grained) deposits.

Observations indicate incomplete hydraulic connection between the A1 and A2 zones of the A aquifer. Groundwater elevations between the A1 and A2 zones do not differ significantly, as observed in well pairs where well screens for individual wells isolate the A1 and A2 zones. At some locations, water level measurements in A1/A2 well pairs indicate no vertical gradient. Also, drawdown was observed in both zones during a pump test where the pumped well was screened across just one zone. These observations support the depositional model described above.

Horizontal gradients, porosity, and hydraulic conductivity have been estimated for the A aquifer. Potentiometric surface maps also have been generated quarterly since 1990. In general, groundwater flow direction and flow gradients are similar throughout the 6-year monitoring period. Groundwater flow is toward San Francisco Bay (north) with a horizontal gradient of 0.004 to 0.005 feet of drop per foot of distance (ft/ft). The horizontal gradient for the eastern side of MFA has been reported as slightly gentler (0.002 to 0.003 ft/ft) than the western side (PRC 1995). Aquifer porosity, estimated from samples submitted for physical analysis, ranges from 20 to 45 percent (PRC and JMM 1992). Hydraulic conductivity was estimated by aquifer tests to range from 5.7 to 240 feet per day for the A aquifer (PRC 1995). The low to moderate hydraulic conductivity at MFA and the distance from the bay dampen and restrict the effects of tidal fluctuations on groundwater flow direction and velocity such that the effects are negligible (Iwamura 1980; PRC and JMM 1992).

B Aquifer and A/B Aquitard Hydrogeology

The B aquifer extends from approximately 60 to 120 feet bgs in the vicinity of MFA. Permeable deposits in the B aquifer are characterized by interbedded fine- to medium-grained sands and clayey sands. The B aquifer consists of these more permeable deposits along with silts and clays. These deposits are correlated by fossil evidence with the Wisconsin-age glacial period (Brown 1978, PRC and JMM 1992). A lack of abundant gravels distinguishes the B from the A aquifer sediments.

Groundwater flow direction in the B aquifer is generally north, and horizontal gradients are similar to those in the A aquifer (0.004 to 0.005 ft/ft). Vertical gradients between the A and B aquifers are variable as a result of heterogeneous confining conditions in individual channels (PRC and JMM 1992). Aquifer tests typically indicated leaky confined conditions in the B aquifer, and hydraulic conductivities from 0.35 to 36 feet per day (PRC 1995). B aquifer hydraulic conductivities are significantly less than those in the A aquifer, as a result of the generally finer-grained materials within the B aquifer.

The A/B aquitard separates the interbedded sands, silts, and clays of the B aquifer from the sand and gravel channels of the A aquifer. It has been consistently identified in borings from the western side of MFA, but is less well defined on the eastern side.

On the western side, this aquitard is a 5- to 7-foot thick clay encountered between the depths of approximately 65 and 70 feet bgs that appeared to be continuous across the western side of MFA. This clay was encountered at Site 12 at an approximate depth of 55 feet bgs.

The A/B aquitard appears to exist within a 7- to 20-foot thick interval of increased clay, creating a reduced permeability zone on the eastern side of MFA. A continuous aquitard cannot be confirmed within this 7- to 20- foot thick low permeability interval because of the lower density of data points on the eastern side of MFA. However, piezometric head differences between paired wells in the A2 zone of the A aquifer and the upper portion of the B aquifer during baseline flow conditions (August 1996) indicate hydraulic isolation of the two aquifers across the eastern side and the northern half of the western side of MFA (PRC 1996). In these areas, the groundwater piezometric surface in B2 aquifer monitoring wells is higher than the groundwater piezometric surface in adjacent A2 aquifer monitoring wells. In the Site 9 area (on the western side of MFA, just west of the northern end of Hangar 1), piezometric levels between monitoring well pairs that screen the A2 and B2 aquifers are variable, but about equal. The few well pairs farther north (in the NASA Ames Research Center area) indicate a shallow and variable vertical gradient between the A2 and B2 intervals. In this area, the A/B aquitard may be incised by channels of the A aquifer, allowing equilibration between the two aquifers.

C Aquifer and B/C Aquitard Hydrogeology

The C aquifer is a confined aquifer that exists between 155 and greater than 500 feet bgs. This depth correlates with the upper Illinoian alluvium in the vicinity of MFA (PRC and JMM 1992). The Illinoian alluvium was deposited during lower sea levels associated with glacial periods. Silt and clay predominate in the aquifer; only 3 to 13 feet of discontinuous sand and gravel intervals have been encountered at MFA (PRC and JMM 1992; IT 1993b).

The groundwater flow direction for the C aquifer is northeast with a horizontal hydraulic gradient of 0.0005 ft/ft (PRC and JMM 1992). The aquifer exhibits a strong upward vertical hydraulic gradient to the B aquifer. Potentiometric head elevations in the C aquifer are as much as 45 feet higher than potentiometric heads in the overlying A and B aquifers, and several C-aquifer monitoring wells on the eastern and western sides of MFA exhibit artesian flow (PRC 1996).

The C aquifer is confined by the B/C aquitard. The B/C aquitard is a laterally continuous silt and clay interval between about 120 and 160 feet bgs beneath MFA that acts as a regional confining layer. The B/C aquitard can be distinguished from the B and C aquifers by its relatively low electrical resistivity. The B/C aquitard is considered an effective barrier to any potential downward migration of contaminants from the A and B aquifers because the B/C aquitard is continuous and the vertical gradient is from the C aquifer upward to the B aquifer (PRC 1996).

4.0 GROUNDWATER IMPACT EVALUATION

This section discusses the evaluation of impacts to groundwater and assesses whether contaminant levels exceed applicable water quality objectives and whether individual hydrocarbon plumes have stabilized. Although impacts to groundwater have not been identified and do not appear to exist at some petroleum sites at MFA, petroleum constituents have been detected in groundwater at other petroleum sites. However, with the exception of Sites 9 and 14-South, no petroleum-related contaminants above MCLs have been detected at any of the IRP petroleum sites.

Trace estimated concentrations of BTEX have been detected in samples collected from eight monitoring wells screened in the B or C aquifer at MFA. Concentrations are well below California MCLs for each BTEX constituent, and most well locations do not correlate with a petroleum source. As previously stated, an upward gradient exists across most of MFA. There are no recognized contaminant sources for B or C aquifers. Therefore, these detections appear random or due to sample contamination, laboratory error, or sample matrix interferences.

Since petroleum sources have been removed and free product does not appear to exist, groundwater plume stabilization and attenuation is to be expected as reported in the LLNL study (Rice and others 1995). Based on numerous rounds of groundwater sampling and analysis, it appears that most, if not all, petroleum groundwater plumes at MFA are stable, not migrating farther, and likely undergoing natural attenuation via biodegradation. Chemical concentration data from samples collected at nearly all wells in petroleum-contaminated groundwater show stable or decreasing trends in TPH concentrations over time. Additionally, the TPH chromatograms indicate that most fuels have been significantly degraded. Specific information on potential or existing impacts to groundwater at each site will be evaluated and presented in the site-specific appendices.

5.0 SENSITIVE RECEPTOR EVALUATION

This section evaluates whether water wells, deeper drinking water aquifers, surface water, or other sensitive receptors are likely to be affected by petroleum contamination.

There are no drinking water supply wells at or downgradient of MFA. NASA operates one C-aquifer well in the northeastern portion of the station to supply water for irrigation and fire protection. Petroleum contaminants have been found only in the shallow A aquifer and, although the aquifer meets the state definition of a drinking water source, it is unlikely that any water wells will be installed in this aquifer. Obstacles to the development of the A aquifer as a drinking or agricultural water source include high concentrations of ambient metals, very low groundwater yields, potential saltwater intrusion, and potential land subsidence due to groundwater extraction.

It is highly unlikely that deeper drinking water aquifers could be affected by petroleum contamination at MFA because (1) thick, low permeability aquitards lie between the A and B and between the B and C aquifers, (2) a strong upward gradient exists from the C aquifer to upper aquifers, and (3) most fuel products have densities less than water, and (4) dissolved-phase constituents would not be expected to be found in deeper aquifers unless transported there under advective flow. This process would require strong downward groundwater flow and contaminant flow through low permeability clays.

Surface water bodies at MFA include the stormwater retention ponds, wetland and marsh areas, Navy North Patrol Road Channel (formerly the Navy Channel), Northern Channel, and ponds on the golf course. Although shallow groundwater likely discharges to some of these water bodies, most IRP petroleum sites are located far from these areas. Furthermore, petroleum-contaminant plumes do not appear to have migrated or discharged to surface waters from any IRP petroleum sites. Since contaminant sources have been removed and groundwater plumes appear to be stable and not migrating, it is unlikely that surface water or other sensitive receptors will be contaminated at MFA.

The site-specific appendices will include brief summaries to document the specific sensitive receptor evaluation for each site.

6.0 METHODOLOGY FOR EVALUATING HUMAN HEALTH RISKS

This section presents the methodology to be used for evaluating human health risks due to petroleum contamination at MFA. As recommended in the RWQCB interim guidance (1996), the ASTM "Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites" (1995) will be used to evaluate human health risk. The RBCA method is a hierarchical three-tiered decision-making strategy that involves increasing levels of data collection and analysis to develop more site-specific risk-based levels in the higher tiers (Figure 7). The first tier involves using generic risk-based screening levels (RBSLs) based on EPA standard default exposure assumptions. In the second tier, site-specific information is collected and can be used to derive site-specific target levels (SSTLs). In the third tier, more complex analysis requiring additional site information, probabilistic evaluations, and complex chemical fate and transport models can be performed. The site is advanced from tier 1 to tier 3 as warranted.

Sections 6.1 and 6.2 describe the exposure and toxicity assessments, media of concern, petroleum toxicity, and exposure pathways evaluated for application of the RBCA methodology at MFA. Section 6.3 discusses the tier 1 screening evaluation, and Section 6.4 discusses the tier 2 and 3 screening evaluations.

6.1 EXPOSURE ASSESSMENT

A key component in evaluating human health risks and conducting an RBSL assessment is an analysis of site-specific factors that define potential human exposures. According to EPA, an exposure pathway describes the course a chemical takes from the source to the exposed individual (EPA 1989). A complete exposure pathway consists of: (1) a source and mechanism of release, (2) a transport medium, (3) a point of potential human contact known as an exposure point, and (4) an exposure route.

Identification of reasonable exposure pathways is based on current and future land use. The concept of reasonable scenarios underlies the reasonable maximum exposure (RME) concept developed by EPA. The RME is defined as an exposure that is conservative but within a range that could reasonably be expected to occur at a site. Based on a land and aquifer use study for MFA (PRC 1995), the base will likely continue to be an industrial/commercial area and the shallow groundwater will not likely be used as a drinking water source. The RWQCB guidance states that the groundwater ingestion pathway need not be considered if the groundwater is not currently being used as a source of drinking water and is not projected to be used as such for the life of the plume. Therefore, risk estimates based on residential exposures do not represent RME conditions at MFA because it is unlikely that MFA will be developed for future residential use. Occupational and construction worker exposure pathways are the most likely future scenarios and are the RME conditions that will be used for petroleum sites at MFA.

Receptors can be exposed to contaminants in both groundwater and soil via ingestion, dermal contact, or inhalation. Typically, exposure to groundwater and subsurface soil is not evaluated for occupational receptors because most exposure pathways, such as ingestion and dermal contact, are incomplete. However, occupational receptors can be exposed to volatile chemicals (such as BTEX) that potentially migrate from subsurface soil and groundwater and accumulate in buildings. For construction workers, direct ingestion, dermal contact, and inhalation constitute potential exposure pathways.

Exposure conditions are used to estimate intake of petroleum constituents from all environmental media. Exposure assumptions can be based on conservative EPA standard default exposure parameters developed for the general population, or on site-specific information. Both are single-point estimates that are used with EPA-derived algorithms to calculate upper-bound or high-end, chemical-specific RBSLs for the maximum exposed individual. In the tier 1 RBSL assessment (see Section 6.3), conservative EPA standard default exposure parameters are used to derive RBSLs for petroleum products and constituents. If further assessments are required, site-specific information will be used to derive screening levels (see Section 6.4).

6.2 TOXICITY ASSESSMENT

This section summarizes the chemical composition and toxicological characteristics of refined petroleum products. Section 6.2.1 provides a general description of the chemical characteristics of fuels and their constituents. Section 6.2.2 discusses the toxicity of fuels and fuel constituents and presents toxicity values that are used to derive RBSLs.

6.2.1 Chemical Composition

Petroleum products are complex mixtures (solutions) of nearly 200 different hydrocarbons and additives, with each compound exhibiting different physical and chemical properties. The chemical groups that make up the majority of the toxic, mobile, and persistent chemicals in petroleum products include: (1) BTEX; (2) PAHs; and (3) straight and branched-chain alkanes. Because constituents within each of these groups have similar chemical characteristics, these groups will serve as the focus for consideration of the general behavior of fuels. In this discussion, two general fuel types, gasoline and diesel/jet fuel, will be considered since these represent the bulk of fuel contamination at MFA.

Fresh (undegraded) gasoline consists mainly of lower molecular weight alkanes with typically 5 to 10 carbon atoms in the chain (lighter constituents) and BTEX constituents. In gasoline, the most common of these compounds are pentanes and hexanes (about 18 to 31 percent) and BTEX (7 to 36 percent). Only small amounts of PAHs are present in gasoline. Naphthalene is the most abundant PAH at a concentration range of 0.2 to 0.5 percent. Other PAHs, such as anthracene, benzo(a)pyrene, and benzo(b)fluoranthene, are known to occur in some gasolines at minute concentrations, less than 0.0005 percent (Cline and others

1991; State of California 1989). The maximum concentration of lead in unleaded gasoline is 0.013 grams per liter (g/L). Regarding toxicity, aviation gasoline is similar to automotive gasoline.

Fresh diesel and jet fuels are predominantly composed of higher molecular weight alkanes with typically 9 to 19 carbon atoms in the chain (heavier constituents) and small amounts (less than 1.0 percent) of PAHs. Diesel fuel is a middle distillate of petroleum with a low sulfur content. Diesel fuels have various compositions and are used as fuel for trucks, ships, and other automotive engines. JP-5 is a petroleum distillate that is similar to kerosene with a higher percentage of alkanes. JP-4 is a blend of kerosene with lower-molecular weight alkanes. The most abundant alkanes in diesel and jet fuels are decane (10 carbon atoms) through octadecane (18 carbon atoms), which comprise about 65 percent of the product. Naphthalenes are the most abundant PAHs in diesel, typically at concentrations of 0.6 to 0.9 percent. Similar to gasoline, other PAHs such as benzo(a)pyrene occur at concentrations less than 0.0005 percent.

Fresh fuels that are exposed to the environment immediately begin to degrade through a number of processes. Thus, the composition of a fuel spill or release will continuously change over time. Generally, the lighter constituents are more volatile and more easily degraded than the heavier hydrocarbons. Therefore, with time the fuel will increasingly consist of the heavier and more immobile constituents.

6.2.2 Toxicity

The constituents of fuels that pose appreciable health hazards include BTEX and PAHs. Within these groups, toxicity and carcinogenic characteristics vary among compounds. Of most concern in gasoline is the carcinogen benzene, which is present in fresh fuel at a concentration of 0.12 to 3.5 percent. The suspected carcinogenic PAHs that occur in gasoline are in such small concentrations (for example, benzo(a)pyrene at 0.00002 to 0.00028 percent) that they do not add appreciably to gasoline's overall toxicity. In diesel fuel, BTEX compounds are not significant because of their low concentrations relative to PAHs (including naphthalene and benzo(a)pyrene), which are present in small quantities. These PAHs represent the majority of the overall toxicity associated with diesel mixtures.

With the exception of gasoline, all fuel mixtures have been classified by the International Agency for Research on Cancer as Class C carcinogens (possibly carcinogenic in humans) (IARC 1989a, 1989b, and 1989c). Gasoline is classified as a Class B2 carcinogen (probably carcinogenic in humans).

EPA has developed reference doses (RfDs) for gasoline, JP-5/kerosene, and JP-4, and a carcinogenic slope factor (CSF) for gasoline. These values are presented in Table 2. The following subsections summarize the toxicity of these three mixtures and the derivation of their toxicity values.

Gasoline

Acute inhalation exposures to gasoline may cause eye, mucous membrane, throat, and respiratory tract irritation. Overexposure to vapors may lead to bronchopneumonia. Inhalation of high concentrations can cause fatal pulmonary edema. Dermal contact with gasoline can cause dermatitis and blistering of the skin due to its defatting properties. Ingestion or inhalation exposures can cause inebriation, drowsiness, blurred vision, and other central nervous system (CNS) effects. Ingestion may also result in burning of the mouth or throat, gastrointestinal irritation, nausea, vomiting, and diarrhea.

Studies in animals have indicated that the kidney is a target organ for ingested gasoline, while inhalation is damaging to the lungs (EPA 1992a). One study of chronic gasoline exposure found an increased incidence of renal tumors that appeared to have a dose-response relationship. Epidemiological studies in humans have not positively demonstrated an association between gasoline exposure and cancer, although some studies suggest this association. EPA classifies gasoline as a probable human carcinogen (Class B2) and has developed an oral CSF of 1.7E-3 milligram per kilogram per day (mg/kg-day^{-1}).

EPA has also derived an oral RfD$_o$ of 2.0E-1 mg/kg-day for gasoline based on route-to-route extrapolation from inhalation data.

Jet Fuel

Many types of jet fuel exist, but their compositions are sufficiently similar that they cause similar toxic effects. Acute inhalation of jet fuel vapors may produce dizziness, headache, nausea, and fatigue. Dermal contact with jet fuels may produce skin irritation. Eye and respiratory irritation may occur through vapor exposure. Ingestion or inhalation of jet fuels may result in increasing levels of CNS depression that may progress to unconsciousness, coma, and death from respiratory failure. JP-5 and JP-4 are damaging to the lungs and cause inflammation of the lung tissue, which may lead to pulmonary edema and chemical pneumonitis as well as bleeding of the lung tissue.

Chronic inhalation of jet fuels may produce neurasthenic symptoms such as fatigue, anxiety, and memory difficulties. Chronic lung dysfunction may result from aspiration into the lungs. Animal studies have yielded conflicting results on the chronic toxicity of jet fuels (EPA 1992a). Reproductive and developmental toxicity of jet fuels have not been well studied but there was no indication of adverse effects in laboratory animals exposed via inhalation. EPA has not classified jet fuels as to their carcinogenicity. EPA-derived RfDs are 2.0E-2 mg/kg-day for JP-5 and 8.0E-2 mg/kg-day for JP-4.

Diesel Fuel

In general, diesel fuel is a skin irritant and CNS depressant when inhaled. Inhalation, depending on the extent of exposure, can also cause respiratory tract irritation, headache, dizziness, nausea, and vomiting. Secondary effects include hypoxia, pneumatocele formation, and chronic lung dysfunction. In some cases, inhalation may cause respiratory arrest and CNS toxicity. Ingestion of diesel fuel causes gastrointestinal irritation, vomiting, diarrhea, and in severe cases, death from CNS depression.

Chronic effects of exposure to diesel fuel are similar to those produced by JP-4 and JP-5. Diesel fuel is a Class C carcinogen (possibly carcinogenic to humans). RfDs have not been developed for diesel fuel.

6.3 TIER 1 EVALUATION

The tier 1 evaluation is a risk-based analysis that uses nonsite-specific RBSLs. EPA Region 9 has developed preliminary remediation goals (PRGs) for occupational exposure scenarios that may be directly used as RBSLs when constituent-based data are available (see Section 6.3.1). However, for some exposure scenarios and pathways, or when only TPH data are available, generic RBSLs must be calculated for the tier 1 evaluation. These generic RBSLs are calculated based on potentially complete exposure pathways using EPA's standard default exposure parameters for relevant exposure scenarios, such as occupational and construction worker scenarios. Information necessary to derive tier 1 RBSLs includes:

- Historical records of site activities and past releases
- Identification of chemicals of concern (COCs)
- Potential human and environmental receptors
- Local hydrogeologic and geologic characteristics

Once the RBSLs have been developed, site-specific COC concentrations are compared to these screening levels. If COC concentrations are less than RBSLs and it is highly likely that COC concentrations will not exceed RSBLs in the future, the screening evaluation is complete. However, if chemical concentrations exceed the target RBSLs, further tier evaluation should be conducted.

In addition to the potentially exposed receptors and site-specific exposure conditions, the derivation of RBSLs depends on the contaminated environmental medium under consideration. At MFA, three environmental media of concern may be affected by fuel spills or leaks: surficial soil, subsurface soil, and groundwater. The media of concern for this evaluation are selected based on current and potential future activities. For the soil screening evaluations, chemical concentrations in the 0- to 2- and 0- to 10-foot depth intervals were used for the occupational and construction worker exposure scenarios, respectively.

Two general approaches are used in tier 1 evaluations depending on available data. When constituent-based data (such as BTEX) are available, EPA Region 9 PRGs should be preferentially used as RBSLs, as described in Section 6.3.1 below. If constituent-based data are not available and only TPH data are available, then generic TPH RBSLs must be calculated as described in Section 6.3.2. At MFA, constituent-specific data are available for most IRP petroleum sites; therefore, the constituent-based approach will be used whenever possible.

6.3.1 Constituent-Based Approach

The tier 1 constituent-based approach entails a comparison of BTEX and PAH concentrations in soils to EPA Region 9 PRGs. The PRGs are representative of exposure concentrations corresponding to risks of 1E-6 or a hazard index of 1.0 for the constituent in the various exposure scenarios.

Ingestion, dermal contact, and inhalation (particulates and volatiles) exposure pathways are evaluated in EPA Region 9 occupational soil PRGs (EPA 1996) for petroleum constituents (BTEX and PAHs). EPA Region 9 PRGs for occupational exposure to groundwater and subsurface soil based on inhalation of volatile chemicals into buildings are unavailable; therefore, constituent RBSLs were calculated using intake algorithms presented in EPA Region 9 guidance and the ASTM standard (1995). Since PRGs are unavailable for the construction worker scenario, RBSLs were calculated using EPA standard default exposure parameters and intake algorithms presented in EPA Region 9 guidance.

Tables 3 and 4 present exposure assumptions and intake algorithms used to derive constituent chemical RBSLs for the construction worker scenario. Tables 5 and 6 present the exposure assumptions and intake algorithms used to calculate occupational RBSLs based on exposure from inhalation of volatile chemicals from soil and groundwater into buildings. Table 7 summarizes occupational and construction worker tier 1 RBSL values (which include PRGs and derived RBSLs) for soil exposures. Finally, Table 8 summarizes occupational soil and groundwater RBSLs based on inhalation of volatiles in buildings.

6.3.2 TPH Approach

Two methods for deriving TPH RBSLs were used for this tier 1 analysis: (1) RBSLs calculated using provisional toxicity values for petroleum mixtures, referred to as the *mixture approach* below, and (2) RBSLs derived from constituents (such as BTEX) using a weight percentage of constituents to calculate TPH values (referred to as the *indicator chemical approach* below). In all cases, the lower RBSL of the TPH RBSLs calculated using the mixture approach or the indicator chemical approach were used for the tier 1 comparison. As stated above, TPH approaches will be used only when constituent-based data are not available.

Mixture Approach

In the mixture approach, TPH RBSLs are derived using EPA standard default exposure parameters, EPA intake algorithms, and EPA-verified provisional toxicity values for select fuel types. These derived RBSLs correspond to a carcinogenic risk of 1E-6 or a noncarcinogenic hazard index of 1. Tables 9 through 12 present formulas to be used to calculate mixture approach TPH RBSLs, and Table 7 presents calculated RBSL values for diesel under occupational and construction worker scenarios.

The mixture approach is made possible by the recent development of provisional toxicity values by the Environmental Criteria Assessment Office (ECAO) (EPA 1992a) for gasoline, JP-4, and JP-5/kerosene mixtures. ECAO developed these toxicity values based on toxicological information gathered from numerous peer-reviewed toxicology publications. Toxicity values are applicable for recent fuel releases where it can be assumed that all constituents present in the original petroleum mixture are present in the contaminated area. Deriving the RBSL for each petroleum product involves calculating the concentration in soil and groundwater for each fuel mixture that corresponds to a specific risk level.

In the mixture approach, direct ingestion of and dermal contact with soil were considered in developing petroleum soil RBSLs for the occupational and construction worker exposure scenarios. Tables 9 through 12 present the exposure assumptions and intake algorithms used in deriving TPH RBSLs with the mixture approach. Exposure via inhalation of particulates and volatiles from soil cannot be included in RBSLs for petroleum mixtures derived using the mixture approach since inhalation toxicity values are unavailable and volatilization factors cannot be calculated. Table 7 includes TPH RBSLs for gasoline and diesel fuels derived for occupational and construction workers.

When using the mixture approach, RBSLs for petroleum products are calculated using the same default exposure parameters as are used in calculating risk of individual product constituents (such as benzene). The mixture approach is inherently conservative because EPA's provisional toxicity values for the fuel products were derived from fresh fuels and, therefore, do not account for reduced concentrations of fuel components from biological and chemical degradation (weathering).

Initially, concentrations of lighter components of the fuel mixture are reduced through biological and chemical degradation. Over time, longer-chain components of fuels in subsurface soil and groundwater degrade sequentially into complex organic acids and alcohols, and, with time, into carbon dioxide. However, these degradation compounds (organic acids and alcohols) will account for a portion of the TPH concentration in subsequent TPH analyses. At a site with highly weathered fuel contamination, concentrations of the original constituents of the fuel that may have individually or jointly been responsible for the risk likely have decreased relative to the overall TPH value. Therefore, the mixture approach RBSL becomes increasingly conservative for a given site as the fuel weathers.

Indicator Chemical Approach

The second risk-based TPH approach for calculating TPH RBSLs for a tier 1 evaluation involves deriving RBSLs based on indicator chemicals. Indicator chemicals for different petroleum mixtures include BTEX and PAHs. These chemical groups comprise the majority of the toxic, mobile, and persistent chemicals in petroleum mixtures.

In this approach, RBSLs for individual chemicals are first derived (or PRGs are used when applicable) and TPH RBSLs for petroleum products are subsequently developed based on the weight percentage of each indicator chemical in the specific petroleum product. EPA Region 9 PRGs are used in the occupational scenario to calculate TPH RBSLs, and constituent RBSLs are used to calculate TPH RBSLs for construction worker scenarios. Weight percentages (constitution) of indicator chemicals in several petroleum mixtures are presented in Tables 13 through 17.

6.4 TIER 2 AND 3 EVALUATIONS

If constituent chemical or TPH concentrations for a particular site exceed the tier 1 RBSLs, remediation is not necessarily warranted. Instead, it may be necessary to develop tier 2 and 3 criteria, which are site specific. Further tier evaluation is warranted in cases where:

- RBSL values are not representative of site conditions
- SSTLs developed under further tier (tiers 2 and 3) evaluation will differ significantly from the tier 1 RBSLs
- The cost of remedial action will likely be greater than further tier evaluation and subsequent remedial action

If further evaluation is warranted, tier 2 screening evaluation is conducted. The tier 2 evaluation process is a risk-based analysis designed to develop SSTLs, rather than generic RBSLs used in the tier 1 evaluation. In order to derive tier 2 SSTLs, additional site-specific information is required including:

- Site-specific hydrogeologic and geologic characteristics
- COC concentrations in contaminated media of concern
- Temporal changes in COC concentrations

SSTLs are derived for complete exposure pathways, fate and transport mechanisms, and relevant exposure scenarios by using the same methodology for development of tier 1 RBSLs and incorporating additional site-specific information. The site-specific COC concentrations are then compared to the SSTLs. If COC concentrations are lower than SSTLs, the RBCA process is complete. However, if COC concentrations exceed SSTLs, then either remedial action, interim remedial action, or further tier evaluation should be considered. If further tier evaluation is warranted, then the site is advanced to the tier 3 evaluation.

In the tier 3 evaluation, SSTLs are developed on the basis of more sophisticated statistical and chemical fate and transport analyses using site-specific input parameters. The tier 3 evaluation may include additional site assessment, probabilistic evaluations (such as Monte Carlo simulations), and sophisticated fate and transport models. Examples of tier 3 analyses include:

- Numerical groundwater modeling codes that predict time-dependent dissolved contaminant transport under spatially varying permeability fields to estimate exposure point concentrations

- Use of site-specific data, mathematical models, and Monte Carlo simulations to predict a statistical distribution of exposures and risks for a given site
- Additional data requirements to refine site-specific parameter estimates and improve model accuracy in order to minimize future monitoring needs

Tier 3 SSTLs are derived based on site-specific complete exposure pathways, fate and transport mechanisms, and the relevant exposure scenarios. Based on the comparison of COC concentrations to tier 3 SSTLs, COCs may be further eliminated and remediation strategies may be designed and implemented.

7.0 METHODOLOGY FOR EVALUATING ENVIRONMENTAL RISKS

The environmental risk category evaluates whether contamination at the petroleum sites presents a significant risk to ecological receptors. Potential risks associated with chemicals of potential concern (COPECs) at MFA were addressed for ecological receptors in the site-wide ecological assessment (SWEA) report as part of the remedial investigation (RI) and FS process. Although petroleum products are specifically excluded from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and were not considered in the SWEA, petroleum constituents were included in the COPEC evaluation of the SWEA, and the information presented can be used to address potential ecological risks due to petroleum products.

The SWEA was divided into three components: Phase I SWEA, data gap investigation, and Phase II SWEA. The Phase I SWEA consisted of problem formulation through the development of conceptual site models as described in the Framework for Ecological Risk Assessment (EPA 1992b). The data gap investigation addressed chemical and spatial data gaps in the Phase I SWEA. The Phase II SWEA was a quantitative and qualitative evaluation of the potential ecological impacts posed by the COPECs on the assessment endpoint, which is protection of special-status species for wetland and upland soils, identified in Phase I.

The exposure assessment methodology is presented in Section 7.1. Section 7.2 summarizes the risk evaluation process and presents conclusions pertinent to the petroleum sites. Figure 8 shows ecological habitats at MFA and includes known burrowing owl burrow locations.

7.1 EXPOSURE ASSESSMENT

The methods used in the Phase I SWEA and data gap investigations included field investigations, laboratory analysis, and data evaluation processes. The field investigations involved biotic and abiotic sampling, in addition to a reconnaissance survey, to characterize the receptors and habitats at MFA. Laboratory analysis was conducted for surface water, sediment, and soil samples. The data evaluation process involved a review of historical soil and sediment databases in addition to available surface water and groundwater data. Also, as part of the data evaluation process, information on dietary habits of observed or potentially present faunal species was collected, and habitat quality of each wetland classification at MFA was assessed based on the initial site reconnaissance (PRC and MW 1996). In addition, toxicity profiles were prepared that included information on the fate and transport as well as the toxicity of the COPECs.

Assessment endpoints defined in Phase I, followed by a weight-of-evidence approach, were used to select all applicable measurement endpoints. A conceptual model was also developed that summarized the assessment and measurement endpoints. Areas selected for further evaluation in Phase II were identified based on highest habitat quality, presence of ecological receptors, and presence of COPECs.

Although petroleum products have affected groundwater, they do not appear to be present in groundwater at any points of discharge to surface water at MFA. Therefore, exposure to petroleum products in groundwater is an incomplete pathway for ecological receptors at MFA. As a result, the assessment endpoint from the Phase II SWEA applicable to petroleum sites is the protection of special-status species only. Other assessment endpoints identified in the Phase II SWEA include protection of surface water and wetland habitats. These assessment endpoints, however, are associated with surface water exposure, which is a potentially complete transport pathway for ecological receptors at MFA only when considering chemicals from sources other than petroleum products. COPECs associated with petroleum mixtures do not provide a complete exposure pathway for ecological receptors via surface water. Therefore, the assessment endpoints associated with surface water exposure will not be addressed in this technical memorandum. Soil is the medium of concern for ecological receptors at MFA petroleum sites and has been addressed in the SWEA. Indicator receptors selected to assess the risk associated with exposure to soil contamination at MFA included the American kestrel and the western burrowing owl, a special-status species.

7.2 RISK EVALUATION

The Phase I SWEA and data gap investigation address the abiotic and biotic characteristics of the upland and wetland habitats at MFA. Based on the reconnaissance survey, IRP petroleum Sites 9 and 19 were found to be paved or minimally landscaped upland areas that do not provide habitat value for wildlife species. IRP Sites 5, 12, and 15 provide limited habitat. Although all of the IRP sites are substantially disturbed, many sites provide adequate habitat for the western burrowing owl, a California Species of Special Concern, and the American kestrel, a variety of prey species.

Doses were calculated in the exposure assessment for the American kestrel and burrowing owl. Soil ingestion dose estimates were calculated using juvenile exposure parameters for both upland indicator species, and inhalation dose estimates were calculated for the burrowing owl also using juvenile exposure parameters. In addition, a food chain dose model was applied to address chemical transfer through the food chain.

The hazard quotient (HQ) method described in EPA guidance (1994) was used to assess risk to the indicator receptors through construction of a matrix of HQs. Hazard quotients were calculated for the matrix using high and average calculated doses in conjunction with high and low toxicity reference values (TRVs) from the literature. HQs were calculated by combining the results of the exposure assessment (dose) and the toxicity assessment as described in EPA guidance (1994).

Soil vapor was sampled at burrowing owl burrow complexes to assess the potential effect of volatile organic compound (VOC) contamination in groundwater and soil on air quality in the burrows. The evaluation of burrowing owl burrow VOC concentration results showed that burrow BTEX air concentrations were within the range of concentrations detected at control sites and within the range of maximum ambient air concentrations in surrounding cities (PRC and MW 1996). The only VOC COPEC with an HQ greater than 1 was benzene. According to the Phase II SWEA, ingestion-specific hazard indices (HIs) for BTEX, which were presented separately from inhalation-specific HIs, exceeded those calculated for the inhalation route by several orders of magnitude for the burrowing owl. However, according to the Phase II SWEA, "HQs for the American kestrel and the burrowing owl were reviewed to identify patterns indicating which COPECs are more likely to pose risk and which COPECs are unlikely to pose risk" (PRC and MW 1996). A four-step process was used to identify COPECs that may pose the greatest risks to ecological receptors. The steps included:

- Ranking COPEC-specific HQs for each receptor
- Reviewing the ranking in comparison with endpoints for all COPECs
- Reviewing frequency of detection to describe uncertainty in identification of risk drivers
- Reviewing the results of the qualitative assessment for potential risk drivers

Based on this four-step process, total dichlorodiphenyl-trichloroethane (DDT), lead, and zinc may pose the greatest risk to the American kestrel, and lead and zinc pose the greatest risk to the burrowing owl. These COPECs accounted for more than 90 percent of the HI. However, these COPECs are not petroleum constituents related to activities at the petroleum sites. Chromium and chlordane were also identified as potentially associated with impacts to assessment endpoints for the American kestrel and the burrowing owl based on results of the qualitative assessment. However, chromium and chlordane are also not petroleum constituents and are unrelated to activities at the petroleum sites. Although BTEX and PAHs were detected in upland soil, they were not identified in the SWEA as COPECs driving the ecological risk at MFA based on the quantitative assessment. Therefore, based on the SWEA evaluation and the discussion presented here, the IRP petroleum sites do not appear to present an environmental risk.

Each site-specific appendix will reference this section of the report and confirm the risk evaluation presented here, or will re-evaluate the environmental risk if new sites or conditions present completed exposure pathways.

8.0 CONCLUSIONS AND SUMMARY

This report presented the approach for evaluating whether further action should be taken at the petroleum sites. The site evaluation approach includes six criteria outlined in RWQCB interim guidance (1996). This report described general, basewide information pertaining to each of these six evaluation criteria; the forthcoming site-specific appendices will include detailed information for each of these evaluation categories. Each appendix will be organized and will contain site-specific information as follows:

- **Section 1, Contaminant Source Evaluation** — This section of the site-specific appendix will present historical information on prior use and contents of USTs and sumps, discuss the current status of tanks or sumps removed, describe the presence of free product or any mobile contaminant sources in soils if applicable, and summarize any remedial activities that have occurred at the site.
- **Section 2, Site Characterization** — Information to be presented will include the site name, description of local site geology and hydrogeology, description of the nature and extent of petroleum contamination in soils and groundwater, chemical concentration data for soils, groundwater, and soil

gas (if available), and figures showing the extent of contamination in soils and groundwater (if applicable).

- **Section 3, Groundwater Impact Evaluation** — This section will describe existing or potential future impacts to groundwater, including a discussion of contaminant concentrations above water quality objectives (if applicable) and groundwater plume stability.

- **Section 4, Sensitive Receptor Evaluation** — This section will present information used in evaluating sensitive receptors, including status of impacts to drinking water wells and surface water.

- **Section 5, Human Health Risk Evaluation** — Results of the tier 1 evaluations for each COC will be presented here. Additionally, if tier 2 or 3 evaluations are conducted, these results will also be presented here.

- **Section 6, Ecological Risk Evaluation** — A description of potential exposure pathways to environmental receptors will be presented. If exposure pathways exist at the site, then results of the ecological risk evaluation will be presented in this section.

- **Section 7, Conclusions** — Based on information presented in the preceding evaluation, conclusions regarding overall risks posed by the specific petroleum site being evaluated will be presented. Recommendations for further site actions (if warranted) and a request for regulatory concurrence will also be made based on risk conclusions.

It is expected that reviews will be made and regulatory comments will be received by the Navy within 60 days of submittal of each appendix, so that final status determinations or courses of action can be agreed on and carried out for each petroleum site in a timely manner.

9.0 REFERENCES

Air Force Engineering Services Center (AFESC). 1981. Analysis and Environmental Fate of Air Force Distillate and High Density Fuels. Tyndall Air Force Base, Florida. October.

American Society for Testing and Materials (ASTM). 1995. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. Designation E 1739-95. ASTM. West Conshohocken, Pennsylvania. November.

Brown, L.J. 1978. Sedimentology of a Late Pleistocene and Holocene Continental and Estuarine Deposit, Mountain View, California. Masters Thesis, Department of Geology, San Jose State University. December.

California Environmental Protection Agency, Department of Toxic Substances Control (Cal/EPA). 1994. Letter from Mr. C. Joseph Chou (Cal/EPA) to Mr. Stephen Chao (Navy) regarding concurrence of petroleum cleanup levels. July.

Cline, P.V., J.J. Delfino, and P.S.C. Rao. 1991. Partitioning of Aromatic Constituents into Water from Gasoline and Other Complex Solvent Mixtures. Environmental Science and Technology, v. 25, pp. 914-920.

Harding Lawson Associates (HLA). 1988. Remedial Investigation Report, Middlefield-Ellis-Whisman Area, Mountain View, California. June.

Helley, E.J., LaJoie, K.R., Spangle, W.E., and Blair, M.L. 1979. Flatland Deposits of the San Francisco Bay Region, California - Their Geology and Engineering Properties, and Their Importance to Comprehensive Planning. U.S. Geological Survey Professional Paper 943. Washington, D.C.

International Agency for Research on Cancer (IARC) 1989a. Gasoline, Monographs on the Evaluation of Carcinogenic Risks to Humans, Occupational Exposures in Petroleum Refining; Crude Oil and Major Petroleum Fuels. v. 45, World Health Organization, p. 159-201.

IARC 1989b. Jet Fuels, Monographs on the Evaluation of Carcinogenic Risks to Humans, Occupational Exposures in Petroleum Refining; Crude Oil and Major Petroleum Fuels. v. 45, World Health Organization, p. 203-218.

IARC 1989c. Diesel Fuels, Monographs on the Evaluation of Carcinogenic Risks to Humans, Occupational Exposures in Petroleum Refining; Crude Oil and Major Petroleum Fuels. v. 45, World Health Organization, p. 219-237.

International Technology Corporation (IT Corp.). 1991. Phase I Characterization Report, Naval Air Station Moffett Field. Volumes I-V. April.

IT Corp. 1993a. Operable Unit 2 Remedial Investigation Report, Naval Air Station Moffett Field, California. Vol. 1. May.

IT Corp. 1993b. Operable Unit 5 Remedial Investigation Report, Naval Air Station Moffett Field, California. Vol. 1. August.

Iwamura, T. I. 1980. Saltwater Intrusion in the Santa Clara Valley Baylands Area, California. Santa Clara Valley Water District. September.

PRC Environmental Management, Inc. (PRC). 1993. Draft West-Side Aquifers Field Investigation Technical Memorandum, Naval Air Station Moffett Field, California, Vol. I. March.

PRC. 1995. Final Operable Unit 5 Feasibility Study Report, Moffett Federal Airfield, California. August.

PRC. 1996. August 1996 Draft Quarterly Report, Moffett Federal Airfield, California. December.

PRC and James M. Montgomery (JMM). 1992. Draft Final Geology and Hydrogeology Technical Memorandum, Naval Air Station Moffett Field, Mountain View, California. July.

PRC and Montgomery Watson (MW). 1996. Draft Final Phase II Site-Wide Ecological Assessment. Moffett Federal Airfield, California. May.

Regional Water Quality Control Board, San Francisco Bay Region (RWQCB). 1996. Supplemental Instruction to State Water Board December 8, 1995, Interim Guidance on Required Cleanup at Low Risk Fuel Sites. January 5.

Rice, D.W., B. P. Dooher, S.J. Cullen, L.G. Everett, W.E. Kastenberg, R.D. Grose, and M.A. Marino. 1995. Recommendations to Improve the Cleanup Process for California's Leaking Underground Fuel Tanks (LUFTs). Environmental Protection Department, Environmental Restoration Division, Lawrence Livermore Laboratory. Livermore, California. October 16.

Sangines, E.M., D.W. Andersen, and A.V. Buising. 1995. Recent Geologic Studies in the San Francisco Bay Area. Symposium for the Society of Economic Paleontologists and Mineralogists (SEPM), Pacific Section. SEPM, Volume 76. May 3-5.

Santa Clara Valley Water District (SCVWD). 1989. Standards for Construction and Destruction of Wells and Deep Excavations in Santa Clara County.

State of California. 1989. Leaking Underground Fuel Tank (LUFT) Field Manual: Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure. State of California Leaking Underground Fuel Tank Task Force. October.

State Water Resources Control Board (SWRCB). 1995. Memorandum-Interim Guidance on Required Cleanup at Low Risk Fuel Sites. December 8.

SWRCB. 1996. Memorandum-Draft Policy for Cleanup of Petroleum Discharge. October 29.

U.S. Environmental Protection Agency (EPA) 1989. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual, Part A. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002.

EPA. 1991. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. Office of Solid Waste and Emergency Response. OSWER Directive 9355.0-30. April.

EPA. 1992a. Toxicity of Fuels. Environmental Criteria Assessment Office. Health and Environmental Assessment Section, Region 10, Seattle, Washington. April.

EPA. 1992b. Framework for Ecological Risk Assessment. EPA/630/R-92/001. Risk Assessment Forum. Washington, D.C. February.

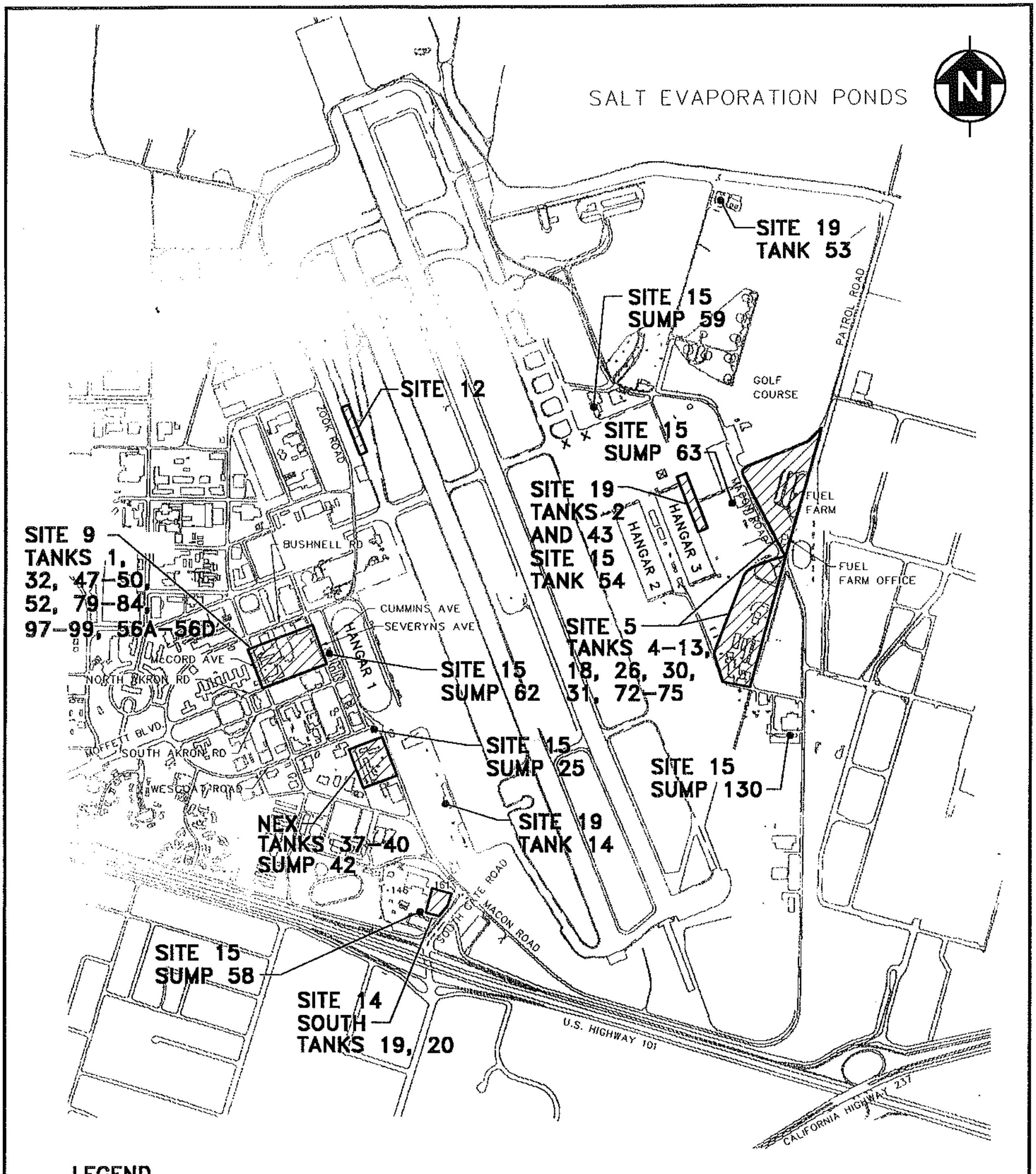
EPA. 1992c. Dermal Exposure Assessment: Principles and Applications. EPA/600/8-91/011B. Office of Health and Environmental Assessment. Washington, D.C. January

EPA. 1994. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Environmental Response Team. Review Draft. September.

EPA. 1997. Integrated Risk Information System (IRIS) Chemical Files. Office of Health and Environmental Assessment, Office of Research and Development, Washington, D.C.

EPA. 1996. Region IX Preliminary Remediation Goals (PRGs) First Half 1995, Technical Support Section, February.

Western Ecological Services Company (WESCO). 1993. Phase I Site-Wide Qualitative Habitat and Receptor Characterization. October.



LEGEND

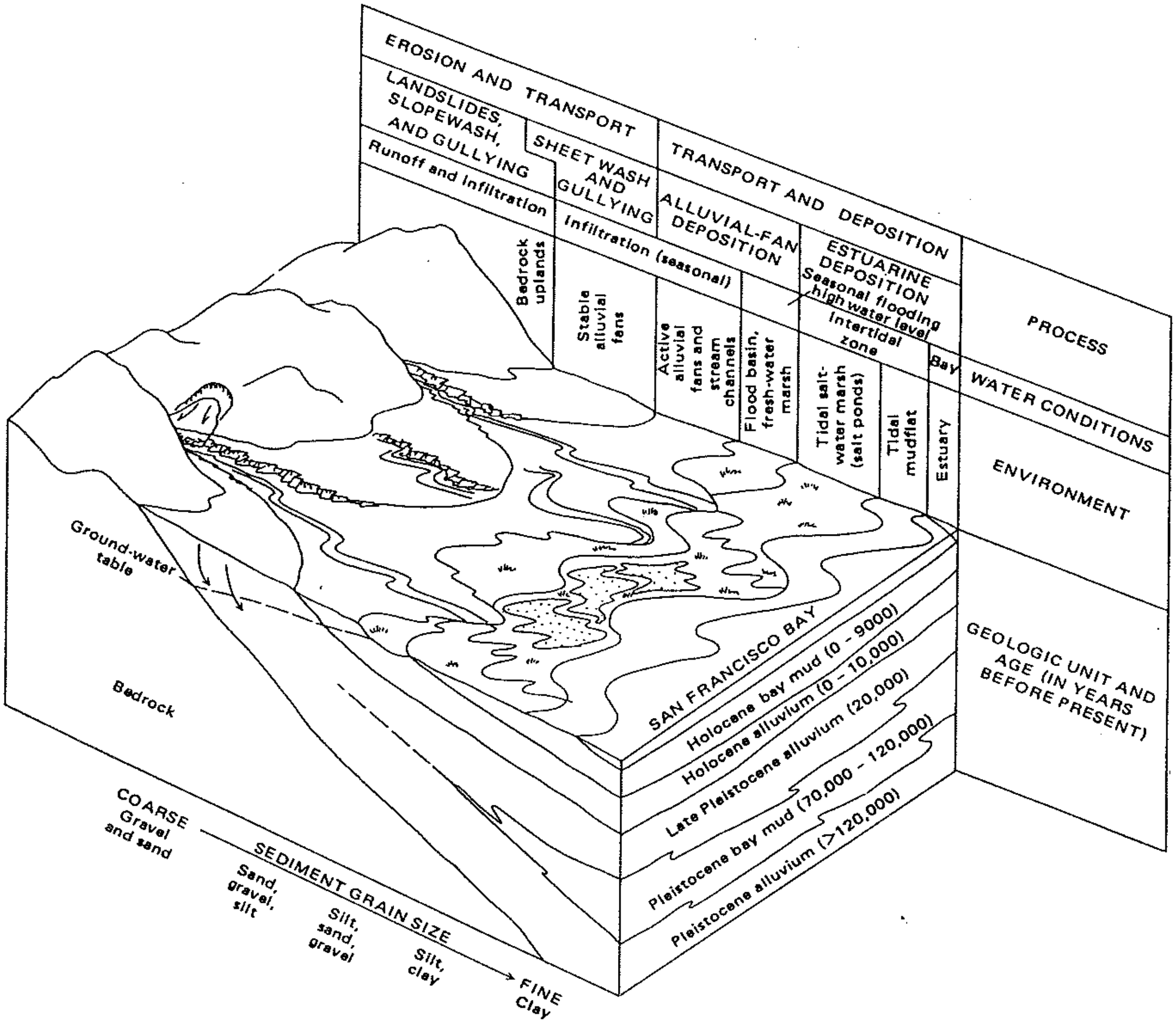
SITE 19 TANK 14	IRP SITE WITH ASSOCIATED TANK(S) OR SUMP(S)

750' 0 750' 1,500'
SCALE IN FEET

FIGURE 1
MOFFETT FEDERAL AIRFIELD
PETROLEUM SITE EVALUATION
SITE LOCATION MAP

FILE NAME: R:\CAD\069\079G\0901\TESTLOC.DWG

DATE: 01/13/96 DMF DN

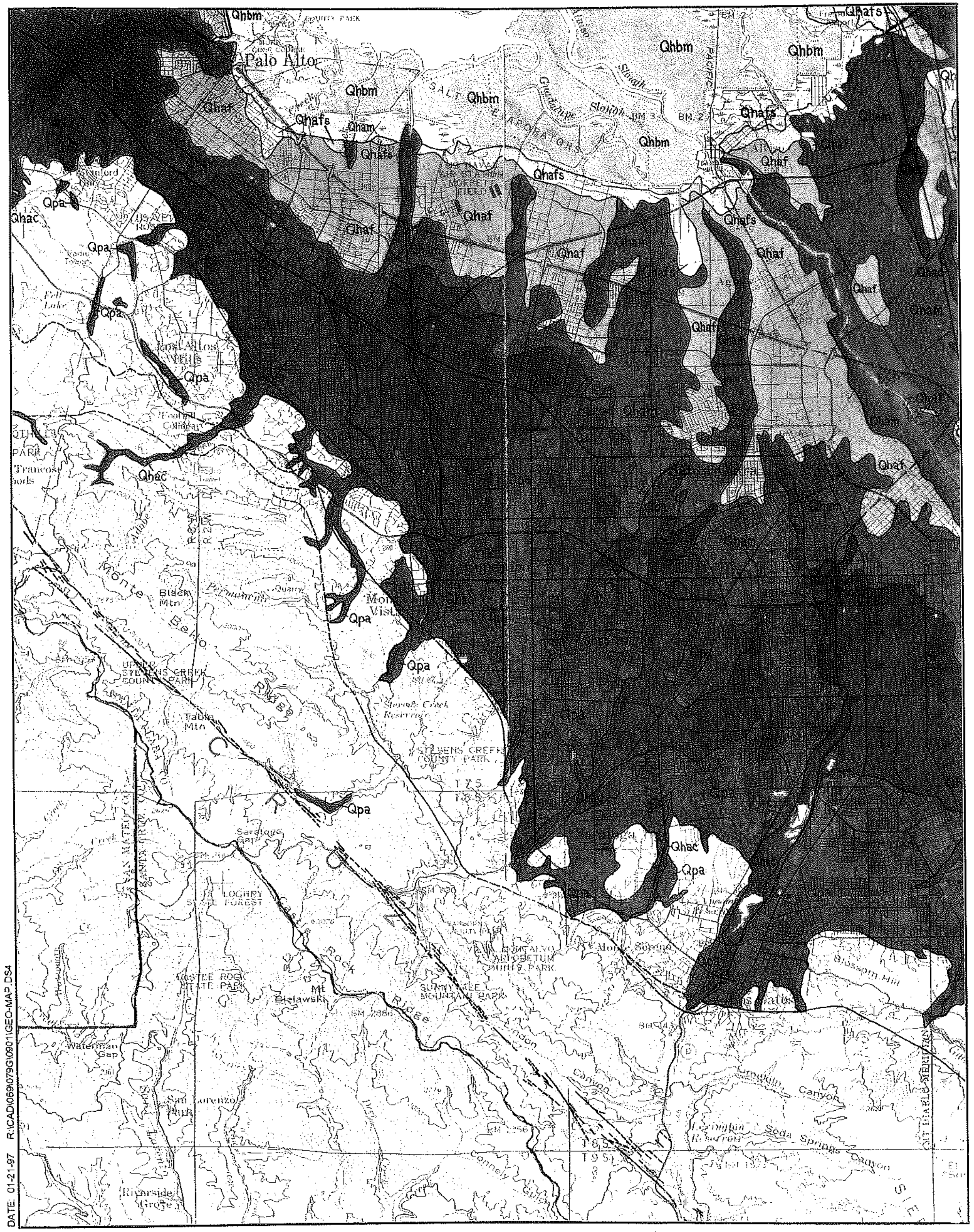


AFTER HELLEY AND OTHERS, 1979

FIGURE 2
MOFFETT FEDERAL AIRFIELD PETROLEUM SITE EVALUATION DEPOSITIONAL MODEL OF SANTA CLARA VALLEY

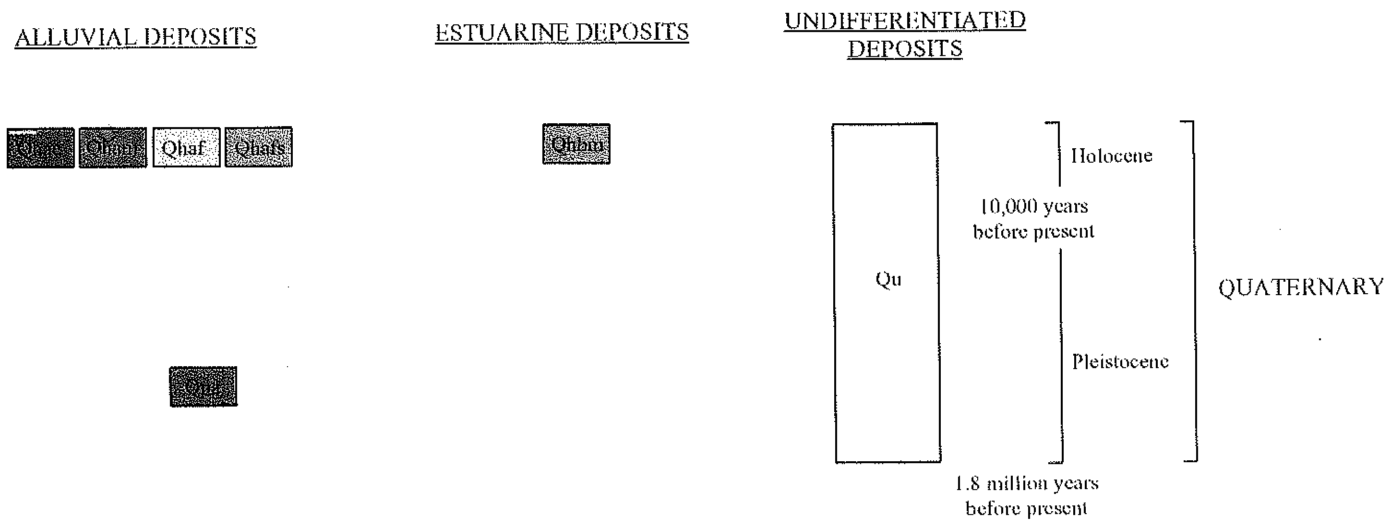
FILE NAME: R:\CAD\069\079G\0901\LOC.DWG

DATE: 01-02-96 JAY DN



DATE: 01-21-97   R:\CAD\069079G\09011GEO-MAP.DS4

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qhac	COARSE-GRAINED ALLUVIUM - Unconsolidated, moderately sorted, permeable sand and silt with coarse sand and gravel; more abundant toward fan heads
Qham	MEDIUM-GRAINED ALLUVIUM - Unconsolidated, moderately sorted, permeable fine sand, silt, and clayey silt with a few thin beds of coarse sand
Qhaf	FINE-GRAINED ALLUVIUM - Unconsolidated, plastic, moderately to poorly sorted, carbonaceous silt and clay
Qhafs	FINE - GRAINED SALT - AFFECTED ALLUVIUM - Unconsolidated, plastic, moderately to poorly sorted, carbonaceous silt and clay, irregularly bedded with carbonate nodules.
Qhbm	BAY MUD - Unconsolidated, water-saturated, dark, plastic, carbonaceous clay and silty clay
Qpa	LATE PLEISTOCENE ALLUVIUM - Weakly consolidated, slightly weathered, poorly sorted, irregularly interbedded clay, silt, sand and gravel
Qu	UNDIVIDED QUATERNARY DEPOSITS - Not recognizable as discrete map units because original form obliterated by urbanization

After Helley and others, 1979

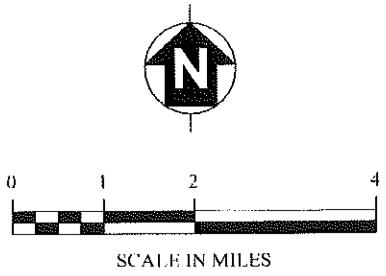
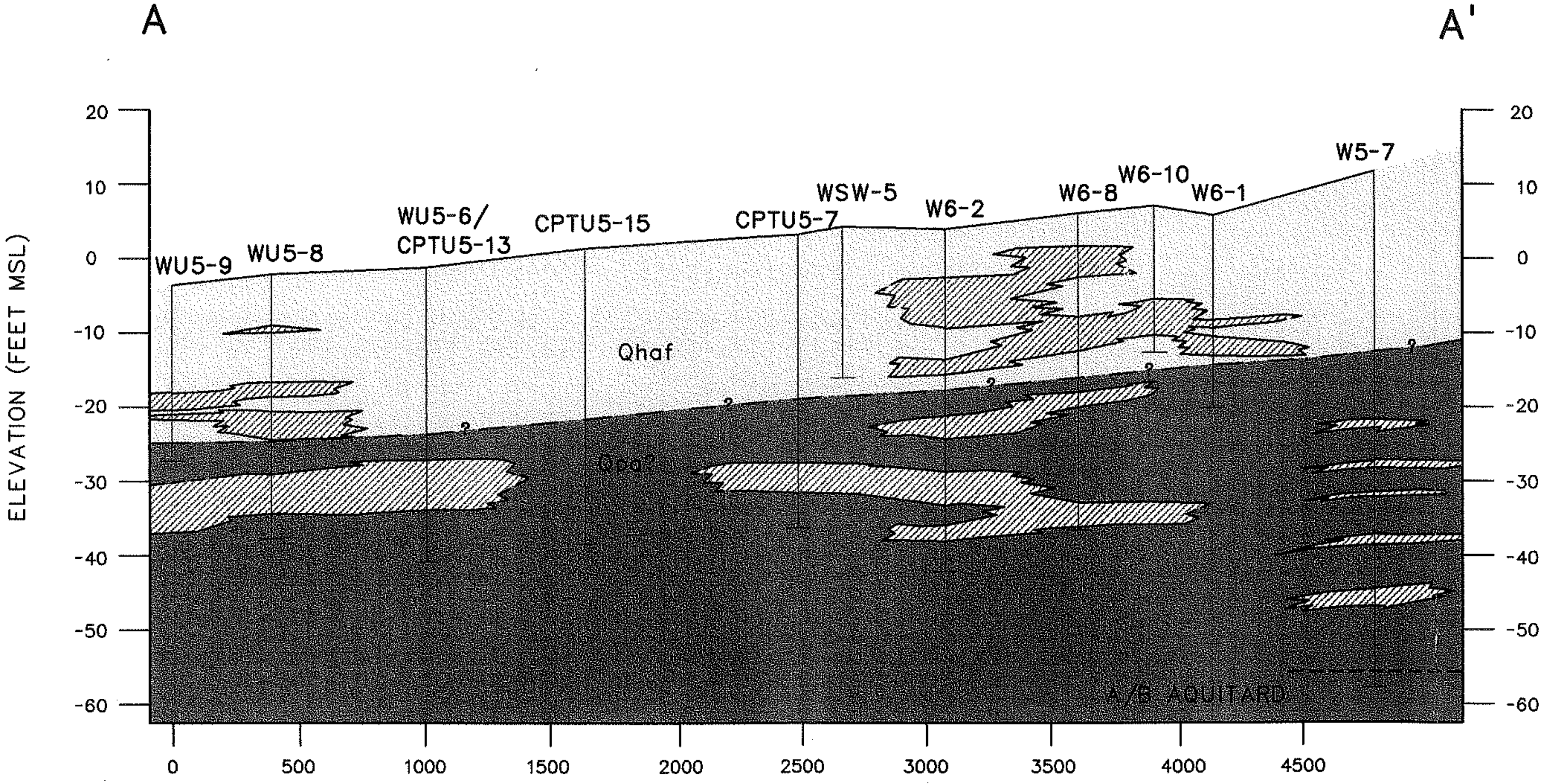


FIGURE 3
MOFFETT FEDERAL AIRFIELD
PETROLEUM SITE EVALUATION
SURFICIAL GEOLOGY
IN THE MOFFETT FEDERAL AIRFIELD VICINITY



10' 0 10' 20'
VERTICAL SCALE: 1" = 20'

300' 0 300' 600'
HORIZONTAL SCALE: 1" = 600'

LEGEND

░ Qhaf HOLOCENE FINE-GRAINED ALLUVIUM (SEE FIGURE 2 FOR COMPLETE DESCRIPTION)

■ Qpa LATE PLEISTOCENE ALLUVIUM (SEE FIGURE 2 FOR COMPLETE DESCRIPTION)

— · — ? — GEOLOGIC UNIT BOUNDARY

▨ HIGHER PERMEABILITY UNITS (SAND, GRAVEL, SILTY AND CLAYEY SAND, SILTY AND CLAYEY GRAVEL)

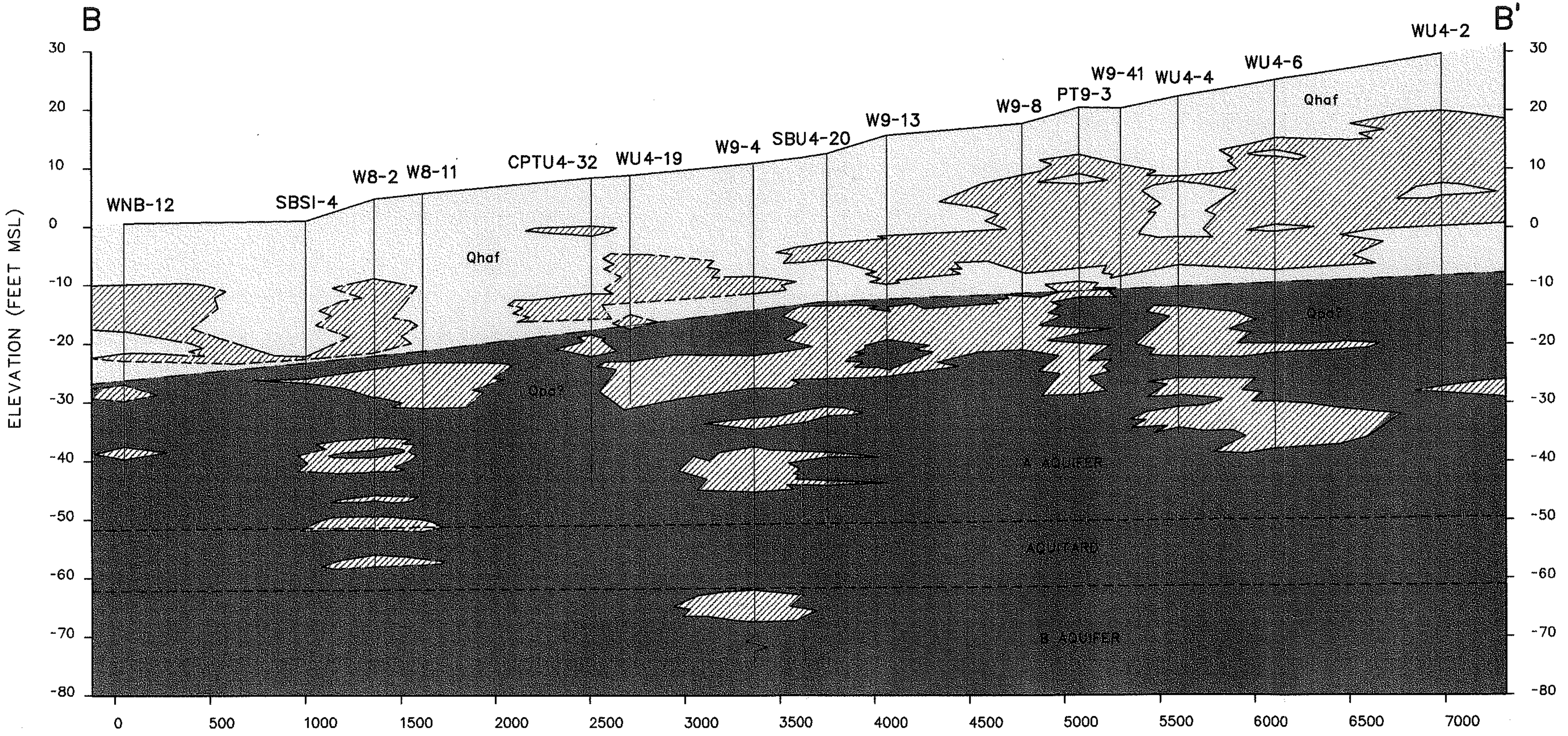
- - - - - HYDROSTRATIGRAPHIC UNIT BOUNDARY

NOTE: HOLOCENE-PLEISTOCENE BOUNDARY BASED ON PALEONTOLOGIC DATA PRESENTED IN BROWN, J.L., 1978.

FIGURE 4
MOFFETT FEDERAL AIRFIELD
PETROLEUM SITE EVALUATION
GEOLOGIC CROSS SECTION A-A'

FILE NAME: R:\CAD\069\079G\0901\SEC-AA

DATE: 01-21-97 JAY DN



HORIZONTAL SCALE: 1" = 600'
VERTICAL SCALE: 1" = 20'

LEGEND

░ Qhaf

■ Qpa

— · — GEOLOGIC UNIT BOUNDARY

▨ HIGHER PERMEABILITY UNITS (CLAY, SILT, SANDY OR GRAVELY CLAYS, SANDY OR GRAVELY SILT)

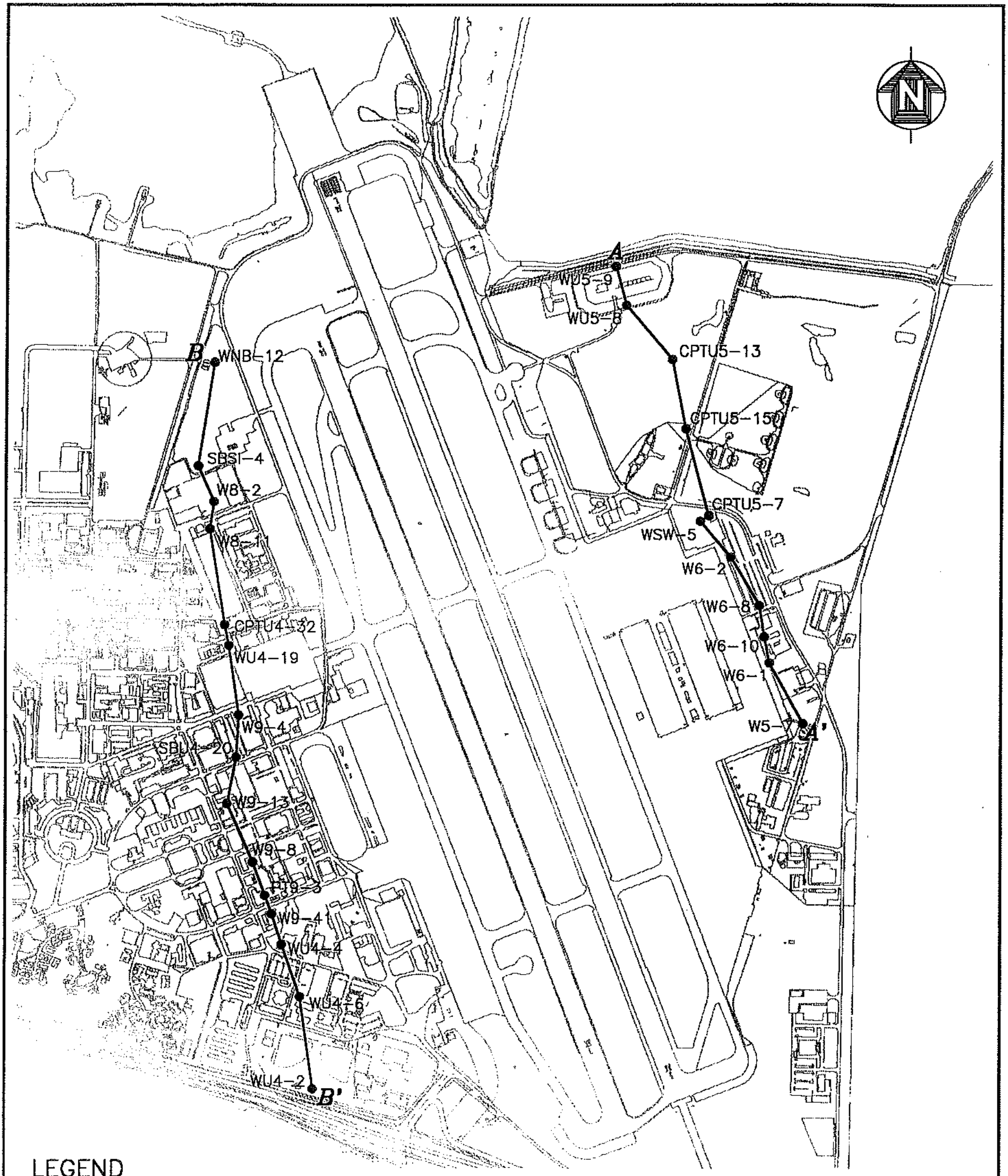
- - - - HYDROSTRATIGRAPHIC UNIT BOUNDARY

NOTE: HOLOCENE-PLEISTOCENE BOUNDARY BASED ON PALEONTOLOGIC DATA PRESENTED IN BROWN, J.L., 1978.

FIGURE 5
MOFFETT FEDERAL AIRFIELD
PETROLEUM SITE EVALUATION
GEOLOGIC CROSS SECTION B-B'

DATE: 01-21-97 JAY DN

FILE NAME: R:\CAD\069\079G\0901\SEC-BB



LEGEND

● SOIL LITHOLOGY DATA POINT

A——A' LINE OF CROSS-SECTION

600' 0 600' 1200'
SCALE: 1" = 1200'

FIGURE 6
MOFFETT FEDERAL AIRFIELD
PETROLEUM SITE EVALUATION
GEOLOGIC CROSS-SECTION
LOCATION MAP

DATE: 01-02-97 JAY DIN

DATE: 01\21\97 JAY DN FILE NAME: R:\CAD\089\079C\0901\FLOWCHRT.DWG

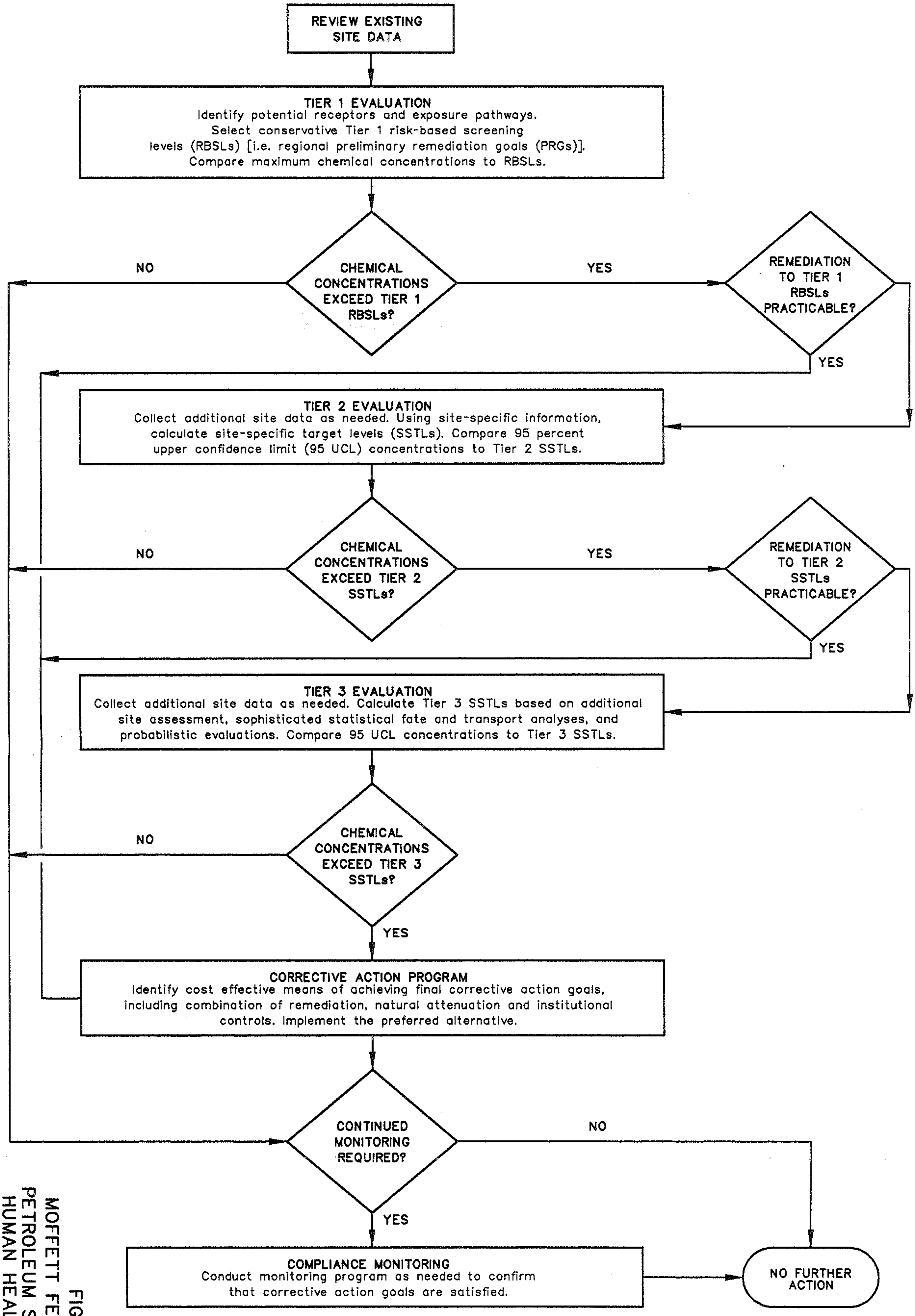


FIGURE 7
MOFFETT FEDERAL AIRFIELD
PETROLEUM SITE EVALUATION
HUMAN HEALTH RISK-BASED
SCREENING EVALUATION FLOW CHART

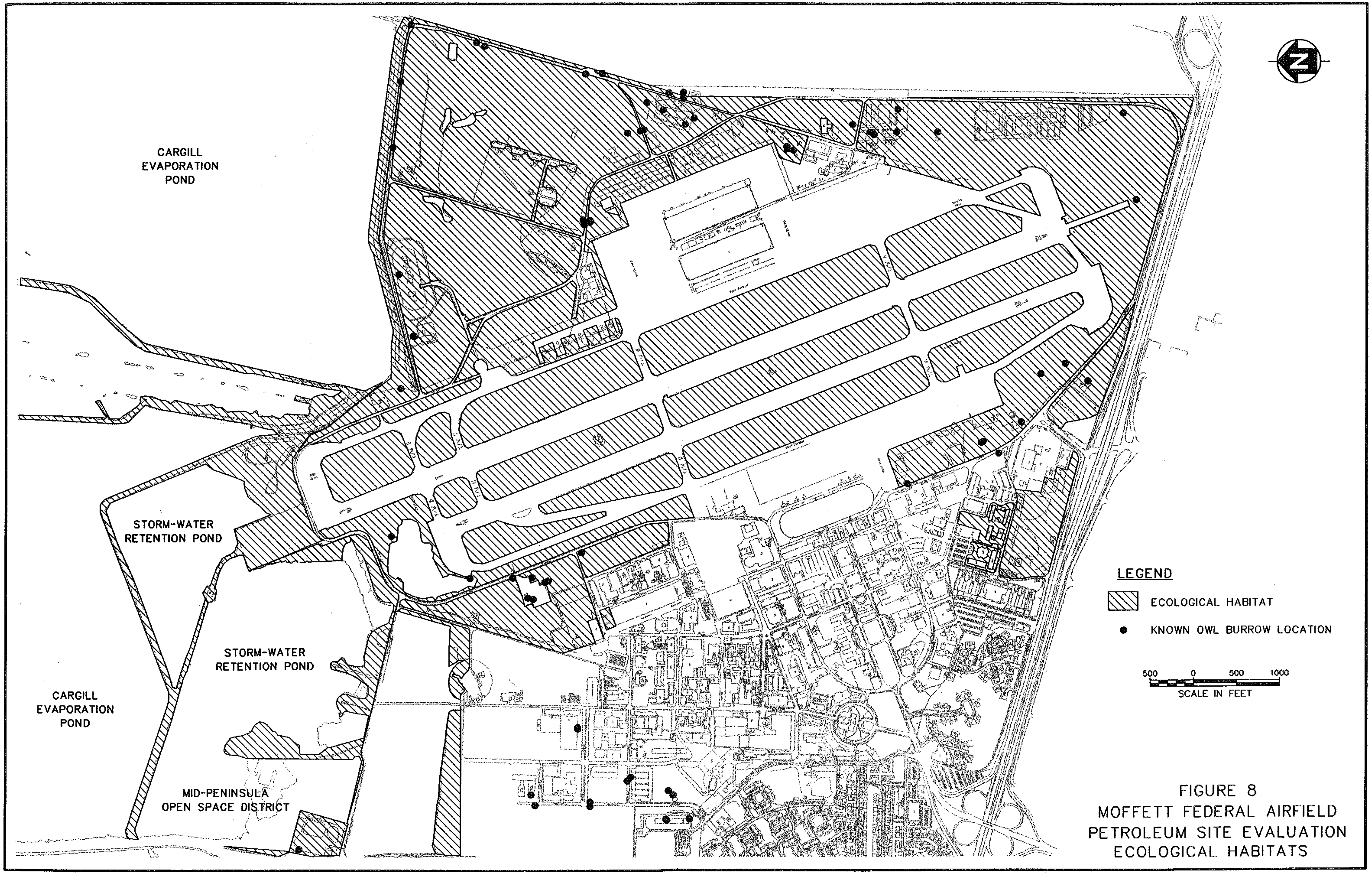


FIGURE 8
MOFFETT FEDERAL AIRFIELD
PETROLEUM SITE EVALUATION
ECOLOGICAL HABITATS

DATE: 10-23-96 DDJ DN FILE NAME: 089\079G\0901\HABITAT1.DWG

TABLE 1

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES IRP PETROLEUM TANK AND SUMP REPORT SUMMARY

Tank or Sump Number	Date Removed	Site-Specific Investigation Reports, Action Plans, and Letters (Reports prepared by PRC unless otherwise indicated)
IRP SITE 5		
T 4	8/1/95	Site 5 Phase I Corrective Actions Technical Memorandum/August 15, 1996 Final Additional Petroleum Sites Investigation Technical Memorandum/ January 1995 Site 5 Groundwater Treatability Study Draft Technical Memorandum/ November 18, 1996 Revised Final IRP Petroleum Sites Characterization Report/January 28, 1994 Final IRP Petroleum Sites Corrective Action Plan/November 1994 Draft IRP Petroleum Sites Closure Report for USTs 14, 30, 31, and 54/ November 1994 Recommendations for Corrective Actions at the IRP Petroleum Sites/Letter from PRC to the U.S. Navy/September 1995 Site 5 Product Recovery Test/Letter from PRC to the U.S. Navy/June 1994. Final Remedial Investigation Report OU5: East-Side Aquifers/IT Corporation/August 1993
T 5	8/1/95	
T 6	9/1/95	
T 7	9/1/95	
T 8	10/1/95	
T 9	10/1/95	
T 10	active	
T 11	active	
T 12	active	
T 13	active	
T 26	6/1/91	
T 30	12/18/92	
T 31	12/18/92	
IRP SITE 9		
T 47	7/15/93	Building 29 Area Field Investigation Technical Memorandum/Volumes I and II/August 23, 1991 Soil Gas and Water Survey of Naval Air Station - Moffett Field/Hydro Geo Chem, Inc./December 12, 1990 Site 9 Action Memorandum/Volumes I and II/July 3, 1991 Final Site 9 Field Investigation Technical Memorandum/Volumes I and II/April 15, 1992 Site 9 Phase I Corrective Actions Technical Memorandum/ April 27, 1995 Site 9 Low-Risk Evaluation Report/March 27, 1996 Draft West-Side Aquifers Field Investigation Technical Memorandum/March 16, 1993 West-Side Groundwater Site Characterization Report/IT Corporation/March 1993 Site 9 Source Control Measure Final Design Report/January 7, 1993
T 48	7/15/93	
T 49	7/15/93	
T 50	7/15/93	
T 52	Unknown	
T 56-A	10/9/90	
T 56-B	10/9/90	
T 56-C	10/9/90	
T 56-D	10/9/90	
T 79	7/23/93	
T 80	7/23/93	
T 81	7/23/93	
T 82	7/23/93	
T 83	7/23/93	
T 84	7/23/93	
T 97	7/28/93	
T 98	7/28/93	
T 99	7/28/93	
T 117[1]	Unknown	

TABLE 1 (Continued)

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES IRP PETROLEUM TANK AND SUMP REPORT SUMMARY

Tank or Sump Number	Date Removed	Site-Specific Investigation Reports, Action Plans, and Letters (Reports prepared by PRC unless otherwise indicated)
IRP SITE 12		
AST	Unknown	Site 12 Fire Fighting Training Area Action Memorandum/April 1993 Site 12 Source Control Measure Final Completion Report/October 26, 1995
IRP SITE 14		
T 19	10/1/86	Site 14 South Fuel Storage Area Field Investigation Revised Technical Memorandum/Volumes I and II/April 12, 1991 Investigation of Potential Soil and Groundwater Contamination Near Tanks 19 and 20, Tank 66 (sump) and Tanks 67 and 68/ERM West/May 1987 Technical Memorandum Site 14 South Evaluation/May 3, 1994 Draft Final Site 14 South Evaluation Report/December 19, 1994
T 20	10/1/86	
IRP SITE 15		
S 25	5/17/94	Additional Petroleum Sites Investigation Technical Memorandum/ Revised Final IRP Petroleum Sites Characterization Report/ Final IRP Petroleum Sites Corrective Action Plan/ Final IRP Petroleum Sites Closure Report For USTs 14, 30, 31, and 54/ Recommendations for Corrective Actions at the IRP Petroleum Sites. Letter from PRC to the U.S. Navy. September 1995 Final Station-Wide RI Report/May 21, 1996
S 42	10/11/90	
T 54	12/18/92	
S 58	4/12/94	
S 59	Active	
S 62	10/23/90	
S 63	Active	
S 64	1995	
S 130[1]	Inactive	
IRP SITE 19		
T 2	5/11/90	Additional Petroleum Sites Investigation Technical Memorandum Revised Final IRP Petroleum Sites Characterization Report Final IRP Petroleum Sites Corrective Action Plan Final IRP Petroleum Sites Closure Report For USTs 14, 30, 31, and 54 Recommendations for Corrective Actions at the IRP Petroleum Sites. Letter from PRC to the U.S. Navy. September 1995 Final Remedial Investigation Report OU5: East-Side Aquifers/IT Corporation/August 1993
T 14	5/11/90	
T 43	5/1/90	
T 53	5/11/90	

TABLE 1 (Continued)

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
IRP PETROLEUM TANK AND SUMP REPORT SUMMARY

Tank or Sump Number	Date Removed	Site-Specific Investigation Reports, Action Plans, and Letters (Reports prepared by PRC unless otherwise indicated)
NEX SERVICE STATION		
T 33	10/11/90	Underground Storage Tank Removal/Interim Remediation Report/February 6, 1991 Naval Exchange Gasoline Station Investigation Final Technical Memorandum/February 13, 1995
T 34	10/11/90	
T 35	10/11/90	
T 36	10/11/90	
T 37	12/18/92	
T 38	12/18/92	
T 39	12/18/92	
T 40	5/6/93	
T 108	Active	
T 109	Active	
T 138	Active	

Notes:

1	This sump has also been identified as Sump 65 in previous reports
AST	Aboveground Storage Tank
IRP	Installation Restoration Program
S	Sump
T	Tank
USTs	Underground Storage Tanks

TABLE 2

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
TIER 1 SCREENING EVALUATION
TOXICITY VALUES FOR PETROLEUM MIXTURES AND INDICATOR CHEMICALS

Chemical	Oral RfD (mg/kg-day)	Inhalation RfD (mg/kg-day)	Oral CSF (mg/kg-day)$^{-1}$	Inhalation CSF (mg/kg-day)$^{-1}$	Uncertainty Factor		Reference
					Oral	Inhalation	
Petroleum Mixtures							
Gasoline	2.0E-01	NA	1.7E-03	NA	1.0E+03	NA	EPA 1992a
JP-5/Diesel/Kerosene	2.0E-02	NA	NA	NA	1.0E+04	NA	EPA 1992a
JP-4	8.0E-02	NA	NA	NA	1.0E+04	NA	EPA 1992a
JP-8(1)	2.0E-02	NA	NA	NA	1.0E+04	NA	EPA 1992a
Indicator Chemicals(2)							
Benzene	NA	NA	2.9E-02	2.9E-02	NA	NA	IRIS; EPA 1997
Benzo(a)pyrene	NA	NA	7.3E+00	NA	NA	NA	IRIS; EPA 1997
Ethylbenzene	1.0E-01	2.9E-01	NA	NA	1.0E+03	3.0E+02	IRIS; EPA 1997
Methylnaphthalene	NA	NA	NA	NA	NA	NA	IRIS; EPA 1997
Naphthalene	4.0E-02	NA	NA	NA	1.0E+03	NA	SHRTSC 1994; EPA 1997
Toluene	2.0E-01	1.1E-01	NA	NA	1.0E+03	3.0E+02	IRIS; EPA 1997
Xylene	2.0E+00	NA	NA	NA	1.0E+02	NA	IRIS; EPA 1997

Notes:

(1) Toxicity values were not available for JP-8, so the most conservative values (JP-5) were used.

(2) Toxicity values presented for indicator chemicals were used in the derivation of EPA Region 9 Preliminary remediation goals (EPA 1996).

CSF	Cancer slope factor
IRIS	Integrated Risk Information System (EPA 1997)
mg/kg	Milligrams per kilogram
NA	Not available
RfD	Reference dose
SHRTSC	Superfund Health Risk Technical Support Center

TABLE 3

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
TIER 1 SCREENING EVALUATION
RISK-BASED SCREENING LEVEL ALGORITHM AND EXPOSURE PARAMETERS FOR NONCARCINOGENIC INDICATOR CHEMICALS
CONSTRUCTION WORKER EXPOSURE: SOIL INGESTION, DERMAL CONTACT WITH SOIL, AND INHALATION OF PARTICULATES AND VOLATILES

$$C\ (mg/kg) = \frac{(TH \times BW \times AT)}{ED \times EF \times \left[\left(\frac{1}{RfD_o} x \frac{IR_s}{CF}\right) + \left(\frac{SA \times AB \times AF}{CF} \times \frac{1}{RfD_o}\right) + \left(\frac{IR \times ET \times PEF \times 1}{RfD_i}\right) + \left(\frac{IR \times ET}{VF} \times \frac{1}{RfD_i}\right)\right]}$$

Parameter			Default Value[(1)]
C	=	Risk-based screening level (mg/kg)	—
TH	=	Target hazard index	1.0
RfD_O RfD_i	= =	Oral reference dose (mg/kg-day) Inhalation reference dose (mg/kg-day)	Chemical-specific Chemical-specific
BW	=	Adult body weight (kg)	70
EF	=	Exposure frequency (days/year)	100
ED	=	Exposure duration (years)	1
IR_s	=	Soil ingestion rate (mg/day)	480
CF	=	Conversion factor (mg/kg)	1E+06
SA	=	Surface area (cm^2)	5,000
AB	=	Absorption factor	Chemical-specific[(2)]
AF	=	Adherence factor (mg/cm^2)	0.2
IR	=	Inhalation rate (m^3/hr)	20
PEF	=	Particulate emission factor (m^3/day)	5E-08
VF	=	Volatilization factor (m^3/kg)	Chemical-specific
AT	=	Averaging time	365

Notes:

(1) EPA 1996.

(2) If chemical-specific absorption factors are unavailable, then the absorption factor for organic chemicals will be conservatively estimated at 1.0 percent (EPA 1992c).

TABLE 4

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
TIER 1 SCREENING EVALUATION
RISK-BASED SCREENING LEVEL AND EXPOSURE PARAMETERS FOR CARCINOGENIC INDICATOR CHEMICALS
CONSTRUCTION WORKER EXPOSURE: SOIL INGESTION, DERMAL CONTACT WITH SOIL, AND INHALATION OF PARTICULATES AND VOLATILES

$$C\ (mg/kg) = \frac{(TR \times BW \times AT)}{ED \times EF \times \left[\left(\frac{CSF_o \times IR_s}{CF}\right) + \left(\frac{SA \times AB \times AF \times CSF_O}{CF}\right) + (IR \times ET \times PEF \times CSF_i) + \left(\frac{IR \times ET \times CSF_i}{VF}\right)\right]}$$

Parameter	Default Value[1]
C = Risk-based screening level (mg/kg)	—
TR = Target risk	1.0E-06
CSF_O = Oral carcinogenic slope factor $(mg/kg\text{-}day)^{-1}$ CSF_D = Dermal carcinogenic slope factor $(mg/kg\text{-}day)^{-1}$ CSF_i = Inhalation carcinogenic slope factor $(mg/kg\text{-}day)^{-1}$	Chemical-specific Chemical-specific Chemical-specific
BW = Adult body weight (kg)	70
EF = Exposure frequency (days/year)	100
ED = Exposure duration (years)	1
IR_s = Soil ingestion rate (mg/day)	480
CF = Conversion factor (mg/kg)	1E+06
SA = Surface area (cm^2)	5,000
AB = Absorption factor	Chemical-specific[2]
AF = Adherence factor (mg/cm^2)	0.2
IR = Inhalation rate (m^3/day)	20
PEF = Particulate emission factor (kg/m^3)	5E-08
VF = Volatilization factor (m^3/kg)	Chemical-specific
AT = Averaging time	25,550

Notes:

[1] EPA 1996.

[2] If chemical-specific absorption factors are unavailable, then the absorption factor for organic chemicals will be conservatively estimated at 1.0 percent (EPA 1992c).

TABLE 5

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
EXPOSURE ALGORITHM AND INPUT PARAMETERS
OCCUPATIONAL EXPOSURE:
INHALATION OF VOLATILE CHEMICALS — MIGRATION FROM SUBSURFACE SOIL INTO BUILDINGS

$$RBSL\ (mg/kg) = \frac{RBSL_{air}\ x\ CF}{VF_{sesp}}$$

Parameter	RME
RBSLair = Risk-based screening level in air ($\mu g/m^3$)	Chemical-specific
CF = Conversion factor ($mg/\mu g$)	1E-03
VFsesp = Volatilization from subsurface soil⁽¹⁾ [(mg/m^3-air)/(mg/kg-soil)]	Chemical-specific

(1) ASTM 1995.

$$RBSLair = \frac{TR\ x\ BW\ x\ AT\ x\ CF}{TF\ x\ IR\ x\ EF\ x\ ED}$$

Parameter	RME
TR = Target risk or hazard	
Carcinogens	1E-06
Noncarcinogens	1.0
BW = Body weight (kg)(1)	70
AT = Average time (days)(2)	
Carcinogens	25,550
Noncarcinogens	9,125
CF = Conversion factor (mg/kg)	1E+03
TF = Toxicity factor	
Carcinogens (CSF)	Chemical-specific
Noncarcinogens (1/RfD)	Chemical-specific
IR = Inhalation rate (m^3/d)(2)	20
EF = Exposure frequency (days/yr)(2)	250
ED = Exposure duration (years)(2)	25

RME = Reasonable maximum exposure

(1) EPA 1991
(2) EPA 1989

TABLE 6

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
EXPOSURE ALGORITHM AND INPUT PARAMETERS
OCCUPATIONAL EXPOSURE:
INHALATION OF VOLATILE CHEMICALS — MIGRATION FROM GROUNDWATER INTO BUILDINGS

$$RBSL\ (mg/kg) = \frac{RBSL_{air}\ x\ CF}{VF}$$

Parameter	RME
$RBSL_{air}$ = Risk-based screening level in air ($\mu g/m^3$)	Chemical-specific
CF = Conversion factor (mg/μg)	1E-03
VF = Volatilization from groundwater[(1)] [(mg/m^3-air)/(mg/L-H_2O)]	Chemical-specific

[(1)] ASTM 1995.

$$RBSLair = \frac{TR\ x\ BW\ x\ AT\ x\ CF}{TF\ x\ IR\ x\ EF\ x\ ED}$$

Parameter	RME
TR = Target risk or hazard	
Carcinogens	1E-06
Noncarcinogens	1.0
BW = Body weight (kg)(1)	70
AT = Average time (days)(2)	
Carcinogens	25,550
Noncarcinogens	9,125
CF = Conversion factor (mg/kg)	1E+03
TF = Toxicity factor	
Carcinogens (CSF)	Chemical-specific
Noncarcinogens (1/RfD)	Chemical-specific
IR = Inhalation rate (m^3/d)(2)	20
EF = Exposure frequency (days/yr)(2)	250
ED = Exposure duration (years)(2)	25

RME = Reasonable maximum exposure

(1) EPA 1991
(2) EPA 1989

TABLE 7

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
TIER 1 SOIL RBSLs
OCCUPATIONAL AND CONSTRUCTION WORKER SCENARIOS

Chemical	Occupational RBSL[1] (mg/kg)	Construction Worker RBSL[2] (mg/kg)
Volatile organic compounds (VOCs)		
Benzene	1.4E+00	8.9E+01
Ethylbenzene[3]	2.3E+02	2.3E+02
Toluene[3]	8.8E+02	8.8E+02
Xylene[3]	3.2E+02	3.2E+02
Semivolatile organic compounds (SVOCs)		
2-Methylnaphthalene[4]	NA	NA
Benzo(a)pyrene	2.6E-01	4.2E+00
Naphthalene	2.4E+02	2.4E+02
Total Petroleum Hydrocarbons (TPH)		
Diesel	1.4E+04	8.8E+03
Gasoline	4.0E+01	2.5E+03

Notes:

mg/kg	Milligrams per kilogram
RBSL	Risk-based screening level
PRG	Preliminary remediation goal
NA	Not available

(1) Occupational soil tier 1 RBSLs for SVOCs and VOCs are EPA Region 9 PRGs (EPA 1996). TPH tier 1 RBSLs for diesel were derived using the mixture approach; gasoline RBSLs were derived using the indicator chemical approach and were based on benzene.

(2) Since EPA Region 9 PRGs are unavailable, tier 1 soil RBSLs for VOCs and SVOCs were calculated using standard default exposure parameters and intake algorithms from EPA Region 9 guidance (EPA 1996) for the construction worker scenarios. Construction worker RBSL for diesel was derived using the mixture approach; gasoline RBSL was derived using the indicator chemical approach and based on benzene.

(3) Concentration is at the saturated condition for this compound in soil.

(4) Chemical toxicity values are unavailable; therefore, RBSLs (or PRGs) cannot be determined.

TABLE 8

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
TIER 1 SOIL AND GROUNDWATER RBSLs
OCCUPATIONAL EXPOSURE SCENARIO
INHALATION OF VOLATILES IN BUILDINGS

Chemical	Soil RBSL(1) (mg/kg)	Groundwater RBSL(1) (mg/L)
Benzene	3.2E-03	2.1E-02
Ethylbenzene	1.1E+03	NA(3)
Toluene	5.5E+01	8.5E+01
Xylene	NA(2)	NA(3)

Notes:

RBSL	Risk-based screening level
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
NA	Not applicable

(1) Occupational soil and groundwater RBSLs, derived based on the inhalation of volatiles in buildings exposure pathway, are from the ASTM tier 1 RBSL Table (ASTM 1995). Benzene RBSLs were adjusted (multiplied by 0.29) to account for differences between EPA and California EPA CSFs.

(2) Selected risk level is not exceeded for pure compound present at any concentration (ASTM 1995).

(3) Selected risk level is not exceeded for all possible dissolved levels (ASTM 1995).

TABLE 9

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
TIER 1 SCREENING EVALUATION
RISK-BASED SCREENING LEVEL AND EXPOSURE PARAMETERS FOR NONCARCINOGENIC PETROLEUM MIXTURES
OCCUPATIONAL EXPOSURE: SOIL INGESTION AND DERMAL CONTACT WITH SOIL[1]

$$C\ (\text{mg/kg}) = \frac{(TH \times BW \times AT)}{ED \times EF \left[\left(\frac{1}{RfD_O} \times \frac{IR_s}{CF} \right) + \left(\frac{SA \times AB \times AF}{CF} \times \frac{1}{RfD_O} \right) \right]}$$

Parameter	Default Value[2]
C = Risk-based screening level (mg/kg)	—
TH = Target hazard	1.0
RfD_o = Oral reference dose (mg/kg-day)	Chemical-specific
BW = Adult body weight (kg)	70
EF = Exposure frequency (days/year)	250
ED = Exposure duration (years)	25
AT = Averaging time (days)	9,125
IR_s = Soil ingestion rate (mg/day)	50
CF = Conversion factor (mg/kg)	1E+06
SA = Surface area (cm^2)	5,000
AB = Absorption factor	Chemical-specific[3]
AF = Adherence factor (mg/cm^2)	0.2

Notes:

(1) Inhalation of particulates and volatiles from soil cannot be included in the RBSL calculation for petroleum mixtures because inhalation toxicity values are unavailable and volatilization factors could not be calculated.

(2) EPA 1996.

(3) If chemical-specific absorption factors are unavailable, then the absorption factor for organic chemicals will be conservatively estimated at 1.0 percent (EPA 1992c).

TABLE 10

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
TIER 1 SCREENING EVALUATION
RISK-BASED SCREENING LEVEL AND EXPOSURE PARAMETERS FOR CARCINOGENIC PETROLEUM MIXTURES
OCCUPATIONAL EXPOSURE: SOIL INGESTION AND DERMAL CONTACT WITH SOIL[1]

$$C\ (\mathrm{mg/kg}) = \frac{(TH \times AT \times BW)}{ED \times EF \left[\left(\frac{CSF_o \times IR_s}{CF} \right) + \left(\frac{SA \times AB \times AF \times CSF_o}{CF} \right) \right]}$$

Parameter	Default Value[2]
C = Risk-based screening level (mg/kg)	—
TR = Target risk	1.0E-06
CSF_O = Oral carcinogenic slope factor $(\mathrm{mg/kg\text{-}day})^{-1}$	Chemical-specific
BW = Body weight (kg)	70
EF = Exposure frequency (days/year)	250
ED = Exposure duration (years)	25
AT = Averaging time (days)	25,550
IR_s = Soil ingestion rate (mg/day)	50
CF = Conversion factor (mg/kg)	1E+06
SA = Surface area (cm^2)	5,000
AB = Absorption factor	Chemical-specific[3]
AF = Adherence factor ($\mathrm{mg/cm}^2$)	0.2

Notes:

(1) Inhalation of particulates and volatiles from soil cannot be included in the RBSL calculation for petroleum mixtures because inhalation toxicity values are unavailable and volatilization factors could not be calculated.

(2) EPA 1996.

(3) If chemical-specific absorption factors are unavailable, then the absorption factor for organic chemicals will be conservatively estimated at 1.0 percent (EPA 1992c).

TABLE 11

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
TIER 1 SCREENING EVALUATION
RISK-BASED SCREENING LEVEL AND EXPOSURE PARAMETERS FOR NONCARCINOGENIC PETROLEUM MIXTURES CONSTRUCTION WORKER EXPOSURE: SOIL INGESTION AND DERMAL CONTACT WITH SOIL[(1)]

$$C\ (\text{mg/kg}) = \frac{(TH \times BW \times AT)}{ED \times EF \left[\left(\frac{1}{RfD_o} \times \frac{IR_s}{CF} \right) + \left(\frac{SA \times AB \times AF}{CF} \times \frac{1}{RfD_o} \right) \right]}$$

Parameter	Default Value[(2)]
C = Risk-based screening level (mg/kg)	—
TH = Target hazard	1.0
RfD_O = Oral reference dose (mg/kg-day)	Chemical-specific
BW = Adult body weight (kg)	70
EF = Exposure frequency (days/year)	100
ED = Exposure duration (years)	1
AT = Averaging time (days)	365
IR_s = Soil ingestion rate (mg/day)	480
CF = Conversion factor (mg/kg)	1E+06
SA = Surface area (cm^2)	5,000
AB = Absorption factor	Chemical-specific[(3)]
AF = Adherence factor (mg/cm^2)	0.2

Notes:

(1) Inhalation of particulates and volatiles from soil cannot be included in the RBSL calculation for petroleum mixtures because inhalation toxicity values are unavailable and volatilization factors could not be calculated.

(2) EPA 1996.

(3) If chemical-specific absorption factors are unavailable, then the absorption factor for organic chemicals will be conservatively estimated at 1.0 percent (EPA 1992c).

TABLE 12

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
TIER 1 SCREENING EVALUATION
RISK-BASED SCREENING LEVEL AND EXPOSURE PARAMETERS FOR CARCINOGENIC PETROLEUM MIXTURES CONSTRUCTION WORKER EXPOSURE: SOIL INGESTION AND DERMAL CONTACT WITH SOIL[1]

$$C\ (\text{mg/kg}) = \frac{(TH \times BW \times AT)}{ED \times EF \times \left[\left(CSF_o \times \frac{IR_s}{CF}\right) + \left(\frac{SA \times AB \times AF \times CSF_o}{CF} \times CSF_o\right)\right]}$$

Parameter	Default Value[2]
C = Risk-based screening level (mg/kg)	—
TR = Target risk	1.0E-06
CSF_o = Oral carcinogenic slope factor $(\text{mg/kg-day})^{-1}$	Chemical-specific
BW = Body weight (kg)	70
EF = Exposure frequency (days/year)	100
ED = Exposure duration (years)	1
AT = Averaging time (days)	25,550
IR_s = Soil ingestion rate (mg/day)	480
CF = Conversion factor (mg/kg)	1E+06
SA = Surface area (cm^2)	5,000
AB = Absorption factor	Chemical-specific[3]
AF = Adherence factor (mg/cm^2)	0.2

Notes:

(1) Inhalation of particulates and volatiles from soil cannot be included in the RBSL calculation for petroleum mixtures because inhalation toxicity values are unavailable and volatilization factors could not be calculated.

(2) EPA 1996.

(3) If chemical-specific absorption factors are unavailable, then the absorption factor for organic chemicals will be conservatively estimated at 1.0 percent (EPA 1992c).

TABLE 13

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
INDICATOR CHEMICAL WEIGHT PERCENTAGES
GASOLINE

Constituent	Weight Percentage[1]
Benzene	3.5
Toluene	21.8
o-xylene	2.86
m-xylene	3.87
p-xylene	1.58
1-methyl-2-ethylbenzene	0.56
1-methyl-4-ethylbenzene	1.00
1-methyl-3-ethylbenzene	2.86
1-methyl-2-n-propylbenzene	0.17
1-methyl-3-n-propylbenzene	0.56
1-methyl-3-isopropylbenzene	0.12
1-methyl-3-t-butylbenzene	0.11
1-methyl-4-t-butylbenzene	0.13
1,2-dimethyl-3-ethylbenzene	0.19
1,2-dimethyl-4-ethylbenzene	0.73
1,3-dimethyl-2-ethylbenzene	0.59
1,3-dimethyl-5-ethylbenzene	0.42
1,3-dimethyl-5-t-butylbenzene	0.19
1,4-dimethyl-2-butylbenzene	0.36
1,2,3-trimethylbenzene	0.48
1,2,4-trimethylbenzene	3.3
1,3,5-trimethylbenzene	1.15
1,2,3,4-tetramethylbenzene	0.19
1,2,3,5-tetramethylbenzene	1.06
1,2,4,5-tetramethylbenzene	0.67
Ethylbenzene	2.86
1,2-diethylbenzene	0.57

TABLE 13 (Continued)

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES INDICATOR CHEMICAL WEIGHT PERCENTAGES GASOLINE

Constituent	Weight Percentage[1]
1,3-diethylbenzene	0.38
n-propylbenzene	0.72
isopropylbenzene	0.23
n-butylbenzene	0.44
Isobutylbenzene	0.08
sec-butylbenzene	0.13
t-butylbenzene	0.12
n-pentylbenzene	0.14
Isopentylbenzene	0.17
Naphthalene	0.49
Pyrene	ND
Benzo(a)anthracene	ND
Benzo(a)pyrene	2.8 mg/kg[2]
Benzo(e)pyrene	ND
Benzo(g,h,i)perylene	ND

Notes:

[1] LUFT Manual (State of California 1989)
[2] Value units reported in LUFT Manual
ND Not detected

TABLE 14

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
INDICATOR CHEMICAL WEIGHT PERCENTAGES
DIESEL

Constituent	Weight Percentage[1]
Benzene	ND
Toluene	ND
o-xylene	ND
m-xylene	ND
2-ethyltoluene	ND
3-ethyltoluene	ND
4-ethyltoluene	ND
Isopropylbenzene	ND
1,2,3-trimethylbenzene	ND
1,2,4-trimethylbenzene	ND
1,3,5-trimethylbenzene	ND
1,2,3,5-trimethylbenzene	ND
1,2,4,5-trimethylbenzene	ND
Pentamethylbenzene	ND
Biphenyl	ND
Naphthalene	0.13
Methylnaphthalene	0.91
2,3,5-trimethylnaphthalene	ND
Fluorene	ND
Phenanthrene	ND
Anthracene	ND
Pyrene	ND
Benzo(a)pyrene	0.07 μg/kg[2]
Benzo(b)fluoranthene	ND
Benzo(g,h,i)perylene	ND

Notes:

ND Not detected

[1] LUFT manual (State of California 1989)

[2] Value units reported in LUFT Manual

TABLE 15

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES INDICATOR CHEMICAL WEIGHT PERCENTAGES

JP-4

Constituent	Weight Percentage[1]
Benzene	0.5
Toluene	0.71
Ethylbenzene	0.37
m-xylene	0.96
o-xylene	1.01
p-xylene	0.35
Isopropylbenzene	0.30
n-propylbenzene	0.71
1-methyl-3-ethylbenzene	0.49
1-methyl-4-ethylbenzene	0.43
1,3,5-trimethylbenzene	0.42
1-methyl-2-ethylbenzene	0.23
1,2,4-trimethylbenzene	1.01
1,3-diethylbenzene	0.46
1-methyl-4-propylenzene	0.40
1,3-dimethyl-5-butylbenzene	0.61
1-methyl-2-I-propylbenzene	0.29
1-4-dimethyl-2-ethylbenzene	0.70
1,2-dimethyl-4-ethylbenzene	0.77
1,2,3,4-tetramethylbenzene	0.75
Naphthalene	0.5
2-methylnaphthalene	0.56
1-methylnaphthalene	0.78
2,6-dimethylnaphthalene	0.25

Notes:

[1] AFESC (1981)

TABLE 16

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
INDICATOR CHEMICAL WEIGHT PERCENTAGES
JP-5

Constituent	Weight Percentage[1]
m-xylene	0.13
o-xylene	0.09
1,2,4-trimethylbenzene	0.37
1,3-diethylbenzene	0.61
1,4-diethylbenzene	0.77
1-ethylpropylbenzene	1.16
1,2,3,4-tetramethylbenzene	1.48
Naphthalene	0.57
1,2,4-triethylbenzene	0.72
2-methylnaphthalene	1.38
1-methylnaphthalene	1.44
1-t-butyl-3,4,5-trimethylbenzene	0.24
n-heptylbenzene	0.27
Biphenyl	0.70
1-ethylnaphthalene	0.32
2,6-dimethylnaphthalene	1.12
2,3-dimethylnaphthalene	0.46
n-octylbenzene	0.78

Notes:

[1] AFESC (1981)

TABLE 17

MOFFETT FEDERAL AIRFIELD PETROLEUM SITES
INDICATOR CHEMICAL WEIGHT PERCENTAGES
JP-8

Constituent	Weight Percentage[1]
m-xylene	0.06
o-xylene	0.06
1,2,4-trimethylbenzene	0.27
1,3-dimethyl-5-ethylbenzene	0.62
1,4-dimethyl-2-ethylbenzene	0.56
1-ethylpropylbenzene	0.99
1,2,3,4-tetramethylbenzene	1.12
1,3,5-triethylbenzene	0.60
1,2,4-triethylbenzene	0.99
n-heptylbenzene	0.25
Biphenyl	0.63
Naphthalene	1.14
2-methylnaphthalene	1.46
1-methylnaphthalene	1.84
1-ethylnaphthalene	0.33
2,6-dimethylnaphthalene	1.34
2,3-dimethylnaphthalene	0.36

Notes:

[1] AFESC (1981).