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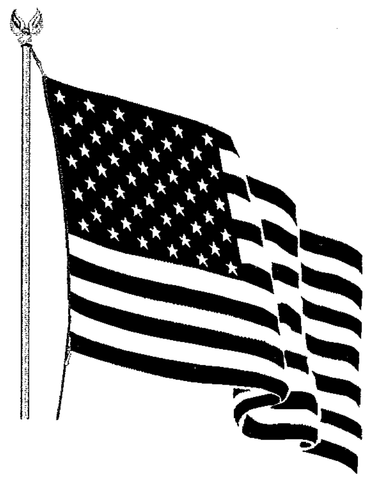

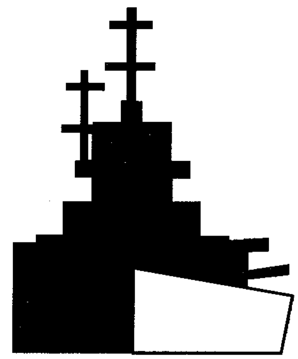

FINAL FEASIBILITY STUDY REPORT IR SITE 27, DOCK ZONE ALAMEDA POINT ALAMEDA, CALIFORNIA

CTO-0069/0488-1
April 2006

Submitted to:

Department of the Navy
Base Realignment and Closure
Program Management Office West
1455 Frazee Road, Suite 900
San Diego, California 92108-4310

Department of the Navy
Base Realignment and Closure
Program Management Office West
1455 Frazee Road, Suite 900
San Diego, California 92108-4310

Contract No. N68711-95-D-7526

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY

CLEAN 3

FINAL
FEASIBILITY STUDY REPORT
IR SITE 27, DOCK ZONE
ALAMEDA POINT
ALAMEDA, CALIFORNIA

CTO-0069/0488-1
April 2006

Prepared by:

BECHTEL ENVIRONMENTAL, INC.
1230 Columbia Street, Suite 400
San Diego, California 92101-8502

Signature: Janet L. Argyres (signed) Date: 4/17/06
Janet L. Argyres, PE 38414

Signature: (signed) Date: 4/24/06
Michele Dermer, CTO Leader

BECHTEL ENVIRONMENTAL, INC.

CLEAN 3 TRANSMITTAL/DELIVERABLE RECEIPT

Contract No. N-68711-95-D-7526 **Document Control No.** CTO-0069/0488-1

File Code. 0214

TO: Contracting Officer
NAVFAC Southwest
Ms. Graciela R. Steinway, AQE.GS
1220 Pacific Highway
San Diego, CA 92132-5190

DATE: April 24, 2006
CTO #: 0069
LOCATION: Alameda, California

FROM: [signature]
Janet L. Argyres, Project Manager

DESCRIPTION: Final Feasibility Study Report, IR Site 27 Dock Zone, Alameda Point – April 2006

TYPE: Contract Deliverable (Cost) ___ CTO Deliverable (Technical) X Other ___

VERSION: Final (e.g., Draft, Draft Final, Final, etc.) REVISION #: 1

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Contract No. N68711-95-D-7526
File Code: 0214
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April 24, 2006

Contracting Officer
NAVFAC Southwest
Ms. Graciela R. Steinway, AQE.GS
1220 Pacific Highway
San Diego, CA 92132-5190

Subject: Final Feasibility Study Report
IR Site 27, Dock Zone
Alameda Point, Alameda, California

Dear Ms. Steinway:

To finalize the Feasibility Study Report for IR Site 27, Dock Zone, Alameda Point, Alameda, California, dated March 2006, we are pleased to submit replacement pages of the spine, cover, and title page, along with a CD of the Final Feasibility Study Report. As directed by the Navy RPM, we are concurrently transmitting copies to Ms. Anna-Marie Cook and Ms. Suzette Leith of U.S. EPA, Ms. Dot Lofstrom, Ms. Michelle Dalrymple, and Mr. Jim Polisini of DTSC, and Ms. Judy Huang of the RWQCB. In addition, we are forwarding copies on behalf of the Navy to the parties listed on the attached transmittal sheet.

If you have any questions, please contact Michele Dermer CTOL, at (415) 768-2832 or me at (415) 768-9917.

Very truly yours,

Janet L. Argyres
Project Manager

Enclosure

BECHTEL ENVIRONMENTAL, INC.

CLEAN 3 TRANSMITTAL/DELIVERABLE RECEIPT

Contract No. N-68711-95-D-7526 **Document Control No.** CTO-0069/0488

File Code. 0214

TO: Contracting Officer
NAVFAC Southwest
Ms. Graciela R. Steinway, AQE.GS
1220 Pacific Highway
San Diego, CA 92132-5190

DATE: March 23, 2006
CTO #: 0069
LOCATION: Alameda, California

FROM: Janet L. Argyres, Project Manager

DESCRIPTION: Draft Final Feasibility Study Report, IR Site 27 Dock Zone, Alameda Point – March 2006

TYPE: Contract Deliverable (Cost) ___ CTO Deliverable (Technical) X Other ___

VERSION: Draft Final (e.g., Draft, Draft Final, Final, etc.) REVISION #: 0

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D. Silva, 05GIH.DS (3C/3E)	D. Carroll (Kleinfelder)	M. Dalrymple (1C/1E)	DTSC
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		P. Russell (1C/1E)	
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File Code: 0214
IN REPLY REFERENCE: CTO-0069/0488

March 23, 2006

Contracting Officer
NAVFAC Southwest
Ms. Graciela R. Steinway, AQE.GS
1220 Pacific Highway
San Diego, CA 92132-5190

Subject: Draft Final Feasibility Study Report
IR Site 27, Dock Zone
Alameda Point, Alameda, California

Dear Ms. Steinway:

Enclosed please find six copies of the Draft Final Feasibility Study Report for IR Site 27, Dock Zone, Alameda Point, Alameda, California, dated March 2006. As directed by the Navy RPM, we are concurrently transmitting copies to Ms. Anna-Marie Cook of U.S. EPA, Ms. Dot Lofstrom, Ms. Michelle Dalrymple, and Mr. Jim Polisini of DTSC, and Ms. Judy Huang of the RWQCB. In addition, we are forwarding copies on behalf of the Navy to the parties listed on the attached transmittal sheet.

If you have any questions, please contact Michele Dermer CTOL, at (415) 768-2832 or me at (415) 768-9917.

Very truly yours,

Janet L. Argyres
Project Manager

Enclosure

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ATTACHMENTS

ACRONYMS/ABBREVIATIONS

ARAR	applicable or relevant and appropriate requirement
ART	Accelerated Remedial Technologies, Inc.
BAAQMD	Bay Area Air Quality Management District
Basin Plan	Comprehensive Water Quality Plan for the San Francisco Bay Basin
BEI	Bechtel Environmental, Inc.
BGMP	basewide groundwater monitoring program
bgs	below ground surface
BIOCHLOR	BIOCHLOR Natural Attenuation Decision Support System
BRAC	Base Realignment and Closure
BSU	Bay Sediment Unit
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAA	corrective action area
Cal. Code Regs.	*California Code of Regulations*
Cal/EPA	California Environmental Protection Agency
Cal. Water Code	*California Water Code*
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C.F.R.	*Code of Federal Regulations*
CLEAN	Comprehensive Long-Term Environmental Action Navy
COC	chemical of concern
COPC	chemical of potential concern
CSM	conceptual site model
CTO	contract task order
CTR	California Toxics Rule
DCA	dichloroethane
DCE	dichloroethene
DERP	Defense Environmental Restoration Program
DGI	data gap investigation
DHE	dehalococcoides
DNA	deoxyribonucleic acid
DNAPL	dense nonaqueous-phase liquid
DON	Department of the Navy
DTSC	(California Environmental Protection Agency) Department of Toxic Substances Control
EBS	environmental baseline survey
EC	engineering control
EDC	economic development conveyance
EPC	exposure point concentration

ERA	ecological risk assessment
ERH	electrical resistive heating
ESA	Endangered Species Act
°F	degrees Fahrenheit
FS	feasibility study
ft/ft	foot per foot
FWBZ	first water-bearing zone
gpd	gallons per day
gpm	gallons per minute
HDD	horizontal directional drilled
HHRA	human-health risk assessment
HI	hazard index
HQ	hazard quotient
HRC	Hydrogen Release Compound
IAS	initial assessment study
IC	institutional control
IR	Installation Restoration (Program)
ISB	*in situ* bioremediation
ISCO	*in situ* chemical oxidation
ISOTEC	In-Situ Oxidation Technologies, Inc.
LUC	land-use control
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	monitored natural attenuation
MOA	memorandum of agreement
MSL	mean sea level
MTBE	methyl tert-butyl ether
NAS	Naval Air Station
NAVFAC	Naval Facilities Engineering Command
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	no further action
NRWQC	National Recommended Water Quality Criteria

O&M	operation and maintenance
ORP	oxidation-reduction potential
OU	operable unit
OWS	oil/water separator
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PG	Professional Geologist
PID	photoionization detector
PRB	permeable reactive barrier
PRG	preliminary remediation goal
RAB	Restoration Advisory Board
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
redox	oxidation-reduction
RI	remedial investigation
RME	reasonable maximum exposure
ROD	record of decision
RWQCB	(California) Regional Water Quality Control Board
§	section
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SI	site inspection
SVE	soil vapor extraction
SWRCB	(California) State Water Resources Control Board
TCE	trichloroethene
TDS	total dissolved solids
TEAP	terminal electron acceptor process
tit.	Title
TOC	total organic carbon
TPH	total petroleum hydrocarbons
U.S.C.	*United States Code*
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound
ZVI	zero-valent iron

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EXECUTIVE SUMMARY

Bechtel Environmental, Inc., has prepared this Feasibility Study (FS) Report on behalf of the Department of the Navy Base Realignment and Closure Program Management Office West, in accordance with Contract Task Order 0069 issued under the Comprehensive Long-Term Environmental Action Navy 3 Program, Contract No. N68711-95-D-7526. The Navy, under the Defense Environmental Restoration Program, follows guidance for FS report preparation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Figures and tables are included at the end of this summary.

Installation Restoration (IR) Program Site 27, referred to as the Dock Zone, is located in Alameda Point (formerly Naval Air Station Alameda). Alameda Point is located on the western tip of Alameda Island, which is on the eastern side of San Francisco Bay (Figure ES-1). IR Site 27 is an approximately 15.8-acre site located in the southeastern area of Alameda Point adjacent to Seaplane Lagoon (Figure ES-2). In September 1993, Naval Air Station Alameda was designated for closure by the United States Congress and the Base Realignment and Closure Commission. The base officially closed in April 1997.

This FS Report develops and evaluates remedial action alternatives to address human-health risks from groundwater underlying IR Site 27 that contains chlorinated volatile organic compounds (VOCs) at concentrations above applicable regulatory comparison criteria. The Remedial Investigation (RI) Report for IR Site 27 recommended preparation of this FS Report to address only the chlorinated VOCs in groundwater. As concluded by the RI Report, no immediate threat to human health or the environment from soil was found at the site. The RI Report also concluded that no further action was warranted for terrestrial or aquatic life ecological receptors.

The chlorinated VOC plume at IR Site 27 is depicted on Figure ES-3. The plume underlies most of the site and is contained within the boundaries of the site. Groundwater underlying the site is not used for domestic purposes. Risk assessment results indicated that only the human-health risk that would be associated with the domestic use of groundwater at the site (specifically, ingestion and showering) would exceed the risk management range of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

SITE BACKGROUND

Potential sources of the VOCs in groundwater at IR Site 27 include the historical and current operations conducted within the boundaries of the site, and, less likely, the release of VOCs to groundwater upgradient of IR Site 27. Historical operations included ship docking, repair, and painting; equipment and materials staging and storage; vehicle washdown; and chemical storage and handling in Building 168. Current operations by tenants leasing space at IR Site 27 are generally similar to historical operations.

Groundwater at IR Site 27 is not used as a drinking water source, but a portion of the first water-bearing zone (inland) is classified as a potential drinking water source for upgradient off-site wells. Sixty wells located upgradient of the southeastern portion of Alameda Point are screened in the Merritt Sand. These wells are located up to 1 mile east of Alameda Point (i.e., east of Main Street). Most of these wells were installed during the

1970s to provide a supplemental source of irrigation water for homeowners on Alameda Island; some of these wells are still in use. A sheet pile bulkhead, installed in conjunction with the construction of Seaplane Lagoon and the hydraulic filling of the area that is now IR Site 27 may still be present beneath IR Site 27 at a location approximately beneath Ferry Point Road (Figure ES-3). Groundwater from shoreline wells (west of the sheet pile bulkhead and Ferry Point Road) does not meet criteria for a drinking water source due to high total dissolved solids (TDS) concentrations and close proximity to the shoreline. Groundwater from wells in the central and eastern portions of IR Site 27 (inland wells) contains freshwater levels of TDS. For FS purposes, the bulkhead is used as the dividing point between groundwater with elevated TDS levels (shoreline wells) and freshwater TDS levels (inland wells).

The human-health risk assessment (HHRA) that was presented in the IR Site 27 RI Report evaluated the risk to receptors based on the planned future use of IR Site 27 as "mixed use," including marina and inner harbor areas that will allow residential, recreational, commercial, and light industrial use. For the occupational and construction scenarios, the cancer risk and noncancer hazard values are within the NCP risk management range. For hypothetical future residents, United States Environmental Protection Agency (U.S. EPA) and California Environmental Protection Agency (Cal/EPA) reasonable maximum exposure cancer risk values exceed the NCP risk management range for two exposure pathways (assuming domestic use of on-site groundwater): ingestion and dermal contact while showering. The primary risk drivers in groundwater are arsenic, vinyl chloride, and PAHs. The primary risk driver in soil gas is TCE. The primary risk driver in soil is arsenic, which is present at concentrations comparable to Alameda Point background.

The ecological risk assessment (ERA) presented in the IR Site 27 RI Report evaluated the risk to ecological receptors through direct soil contact and the food chain as well as through groundwater releases to surface water. The results of the ERA indicate negligible risk to terrestrial wildlife receptors from chemicals in soil and low risk to benthic fish and invertebrates from chemicals in groundwater, based on current conditions and planned future use of IR Site 27. The ERA provides a protective overestimate of the actual risk of adverse ecological effects to aquatic life organisms in surface water adjacent to IR Site 27 because of the conservative nature of the assumptions used (i.e., maximum concentrations of chemicals in groundwater were compared to California Toxics Rule criteria continuing concentrations [CCCs]).

Due to the expansion of the IR Site 27 boundaries to encompass the VOC plume, a washdown area (WD-166 and related oil/water separators) and Building 555 (an electrical substation) were included within the IR Site 27 boundaries. The RI Report identified data gaps associated with testing groundwater at the washdown area and with testing for polychlorinated biphenyls in soil adjacent to Building 555. These data gaps are to be addressed during the remedial design phase.

REMEDIAL ACTION OBJECTIVES

The general response objectives for IR Site 27 are as follows.

- Protect beneficial uses of groundwater underlying IR Site 27.
- Protect beneficial uses of surface water adjacent to IR Site 27.
- Protect human health by prohibiting domestic use of groundwater that has been impacted by chemicals of concern (COCs) until the Navy, the U.S. EPA, the Cal/EPA Department of Toxic Substances Control (DTSC), and the San Francisco Bay Regional Water Quality Control Board (RWQCB) concur that there is no longer an unacceptable risk from such exposure.

Groundwater beneath the site is not used for drinking water. However, shallow inland groundwater (more than 100 feet from the shoreline and east of Ferry Point Road and the sheet pile bulkhead) currently meets U.S. EPA criteria (i.e., TDS concentration and yield) for a Class II aquifer. Groundwater west of the sheet pile bulkhead (shoreline groundwater) meets both U.S. EPA and RWQCB criteria for a nonpotable (non-drinking) water source.

Remedial action objectives (RAOs) for groundwater inland of the bulkhead were developed based on potential domestic use of groundwater. RAOs for shoreline groundwater are based on California Toxics Rule criteria for human health (consumption of organisms). RAOs are shown in Table ES-1. No surface water RAOs for aquatic receptors are selected for IR Site 27 because of the lack of significant ecological risk to aquatic life organisms, as established by the ERA conducted at IR Site 27.

The current site use is occupational. Health risk associated with indoor air exposure (for occupational use) is within the NCP risk management range. In the context of the general response objectives above, the potential exposure pathways are summarized as follows.

- There are currently no human populations exposed to VOC-impacted shallow groundwater at IR Site 27.
- The RI Report concluded that groundwater discharging to the Seaplane Lagoon may contain VOCs that could impact the surface water of the Seaplane Lagoon/San Francisco Bay.

It is unlikely that future site occupants would extract groundwater for beneficial use at IR Site 27. However, for the purposes of this CERCLA cleanup, maximum contaminant levels (MCLs) are potential ARARs for inland groundwater.

There were no potential ARARs identified related to wetlands protection, floodplain management, hydrologic resources, or geologic characteristics. However, the site is within the coastal zone, so the substantive provisions of the Coastal Zone Management Act are potentially relevant and appropriate. Because of the absence of substantial ecological habitat at IR Site 27, listed species of the federal Endangered Species Act are unlikely to be present; therefore, the Endangered Species Act and California Fish and Game Code Section 2080 are not potential ARARs. The Migratory Bird Treaty Act is potentially relevant and appropriate because listed birds may land on the site.

SCREENING OF REMEDIAL TECHNOLOGIES

Remedial technologies for consideration in this FS Report have been identified based on U.S. EPA guidance, remedial technology literature, and Alameda Point experience. Remedial technologies that were carried forward to the detailed analysis of alternatives in this FS Report are summarized below.

No Action

No action is included as an option because it is the baseline for comparison with other response actions.

Institutional Controls

ICs may restrict the use of groundwater and prohibit activities that could result in unacceptable exposure to groundwater COCs.

Monitored Natural Attenuation

Monitoring may include technical measures such as groundwater sampling and analysis to evaluate the extent and migration of COCs, potential risks, and/or changes in site conditions over time. Groundwater monitoring may be employed for a limited time to document site conditions or over a long-term period to track changes over time.

Monitored natural attenuation (MNA) is a process option that employs monitoring to confirm the effectiveness of naturally occurring *in situ* processes (e.g., biodegradation, chemical transformation, volatilization, dilution, dispersion, and adsorption) in achieving RAOs within a reasonable time frame. Under certain conditions, these natural processes act to reduce the mass, toxicity, mobility, or volume of COC-contaminated groundwater. Monitoring is performed to check the progress of attenuation processes.

In Situ Treatment

In situ treatment refers to technologies used to treat contaminated groundwater in place (below grade), using physical, biological, thermal or chemical treatment technologies.

REMEDIAL ALTERNATIVES

Ten remedial alternatives for groundwater are developed and screened, and six are retained for detailed analysis. The groundwater alternatives that were considered in this FS Report are summarized in Table ES-2. The alternatives retained after screening are described below.

The duration of each alternative is estimated based on groundwater model simulations obtained using the BIOCHLOR Natural Attenuation Decision Support System (BIOCHLOR). BIOCHLOR is a U.S. EPA-accepted screening model that simulates remediation by natural attenuation of dissolved solvents at sites with chlorinated VOC releases.

Alternative 1 – No Action

For this alternative, no further action of any type would be implemented for groundwater. This alternative is included in accordance with the NCP, and serves as a baseline against which the other groundwater alternatives can be evaluated.

Alternative 3 – MNA and ICs

Alternative 3 would utilize MNA and ICs to address the chlorinated-VOC-impacted groundwater. This alternative relies on natural processes to continue to reduce contaminant levels in the plume at IR Site 27. A long-term groundwater monitoring program, including periodic reviews, would be implemented to track the reduction in contaminant concentrations. ICs would prohibit groundwater extraction at the site. ICs would also prohibit actions that would interfere with MNA activities. BIOCHLOR model simulations predict that RAOs would be achieved in 70 years for this alternative.

Alternative 4A – ISB Source Area Treatment, MNA, and ICs

Alternative 4A is similar to Alternative 3, but would additionally employ anaerobic *in situ* bioremediation (ISB) technology to accelerate VOC contaminant degradation in the IR Site 27 plume. It is assumed that Hydrogen Release Compound (HRC) technology would be used to accelerate biodegradation of VOCs. HRC would be injected into the source area aquifer zone in the areas shown on Figure ES-4.

MNA for Alternative 4A would be similar to Alternative 3 except that the duration is assumed to be 60 years, based on BIOCHLOR model simulations. ICs would be similar in scope to Alternative 3.

Alternative 6A – ISCO Source Area Treatment, MNA, and ICs

Alternative 6A would accelerate contaminant concentration reduction using *in situ* chemical oxidation (ISCO) to oxidize VOCs in groundwater in two treatment areas (Figure ES-4) in the IR Site 27 plume. The ISCO process would be employed to destroy contaminants in groundwater. One treatment event for both treatment areas is assumed, plus one additional "hot spot" injection event.

MNA for Alternative 6A would be similar to Alternative 3 except that the duration is assumed to be 45 years, based on BIOCHLOR model simulations. ICs would be similar in scope to Alternative 3.

Alternative 6B – Sitewide ISCO Treatment and Groundwater Confirmation Sampling

Alternative 6B would use ISCO to aggressively treat the entire IR Site 27 plume to reduce VOC concentrations to achieve RAOs. The process assumed for Alternative 6B would be employed across the entire inland area of the estimated 11-acre plume (Figure ES-5). If needed, a subsequent hot spot injection event would be performed at up to one-half of the full-scale injection points.

The assumed duration for Alternative 6B is 3 years. This includes an assumed 75-day treatment period followed by 3 years of groundwater confirmation sampling to document post-ISCO-treatment VOC concentrations in groundwater.

Alternative 7 – Dynamic Circulation Source Area Treatment, MNA, and ICs

Alternative 7 uses an innovative source area treatment technology. Dynamic Subsurface Circulation well technology utilizes in-well air sparging, in-well air stripping, and soil vapor extraction. This combination of technologies creates circulation of treated groundwater outward from the treatment well through capillary fringe soil and returning into the well for treatment. It is assumed that ten 6-inch-diameter remediation wells and two remediation systems would be installed in the two treatment areas (Figure ES-4): one just east of Ferry Point Road and one outside the western edge of Building 168.

MNA for Alternative 7 would be similar to Alternative 3 except that the duration is assumed to be 55 years, based on BIOCHLOR model simulations. ICs would be similar in scope to Alternative 3.

COMPARATIVE ANALYSIS OF ALTERNATIVES

The relative performance of the retained remedial alternatives considered in this FS Report were compared against the NCP evaluation criteria in order to assess the merits of each alternative and identify key trade-offs the Navy must consider when selecting a cleanup remedy. The NCP criteria are as follows:

- threshold criteria
  - overall protection of human health and the environment
  - compliance with ARARs
- primary balancing criteria
  - long-term effectiveness and permanence
  - reduction of toxicity, mobility, or volume through treatment
  - short-term effectiveness
  - implementability
  - cost
- modifying criteria
  - state acceptance
  - community acceptance

Since the NCP threshold criteria must be satisfied for a remedial alternative to be eligible for selection unless an ARAR waiver applies, the selection of eligible remedial alternatives will generally be based on a comparison of how well an alternative meets the five primary balancing criteria and the two modifying criteria. Except for Alternatives 1 and 2, all alternatives meet the threshold criteria.

The alternatives were scored for each of the balancing criteria in terms of their performance relative to other alternatives. Alternatives that performed best relative to other alternatives were assigned a score of "high." Alternatives that received the best combination of relative rankings scored highest overall in the balancing criteria. Therefore, no individual criterion was weighted more heavily than others in this process.

Alternative 6A (ISCO source area treatment, MNA, and ICs) was rated highest using the balancing criteria. Alternatives 3 (MNA and ICs) and 4A (ISB source area treatment, MNA, and ICs) were rated second highest using the balancing criteria. Alternative 6B (sitewide ISCO treatment and groundwater confirmation sampling) was rated next highest using the balancing criteria. Alternative 7 (dynamic circulation source area treatment, MNA, and ICs) was rated lowest using the balancing criteria. Table ES-3 summarizes the results of the comparative analysis by balancing criteria for remedial alternatives. Table ES-4 presents a summary of comparative cost estimates for remedial alternatives.

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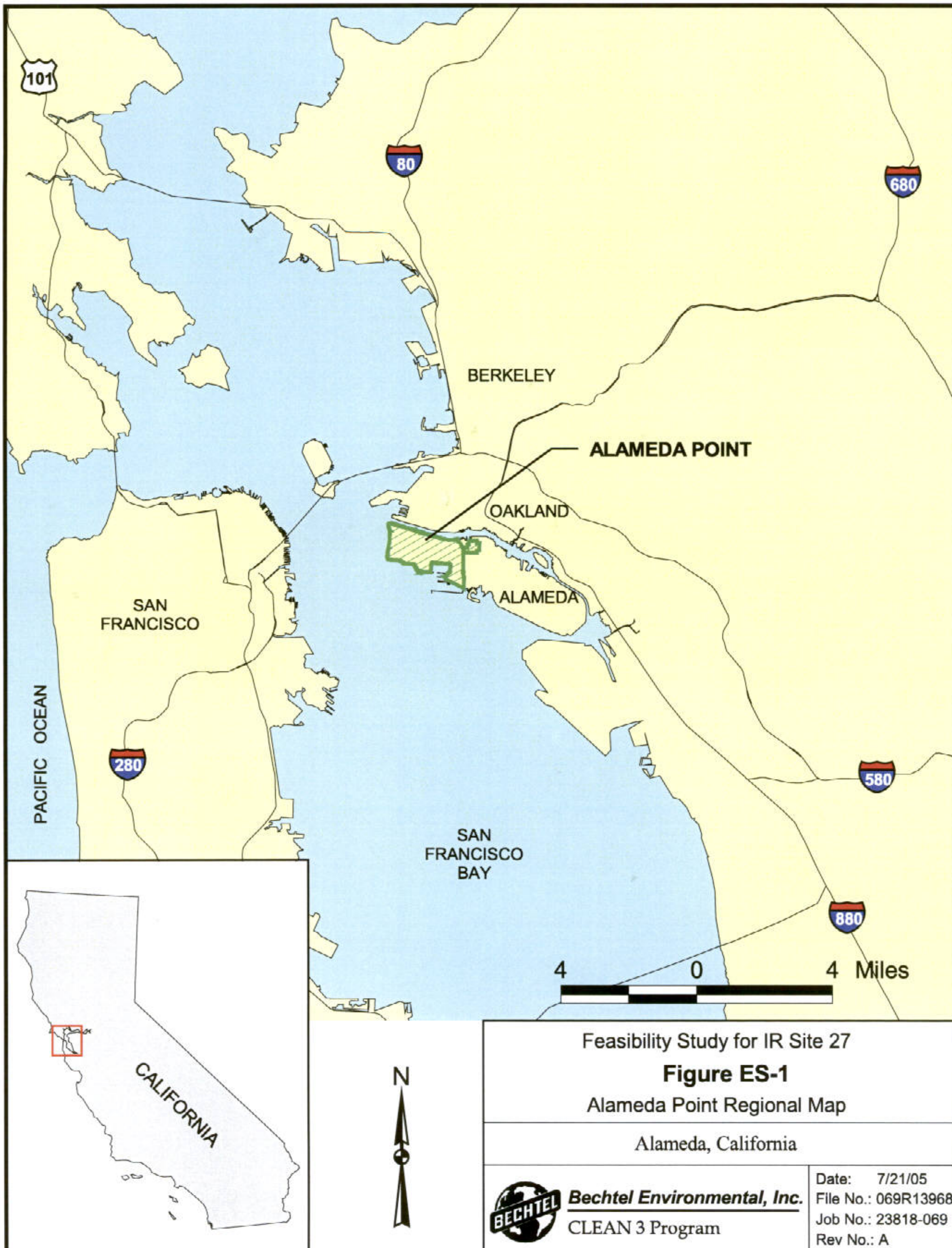
FIGURES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006



Feasibility Study for IR Site 27

Figure ES-1

Alameda Point Regional Map

Alameda, California

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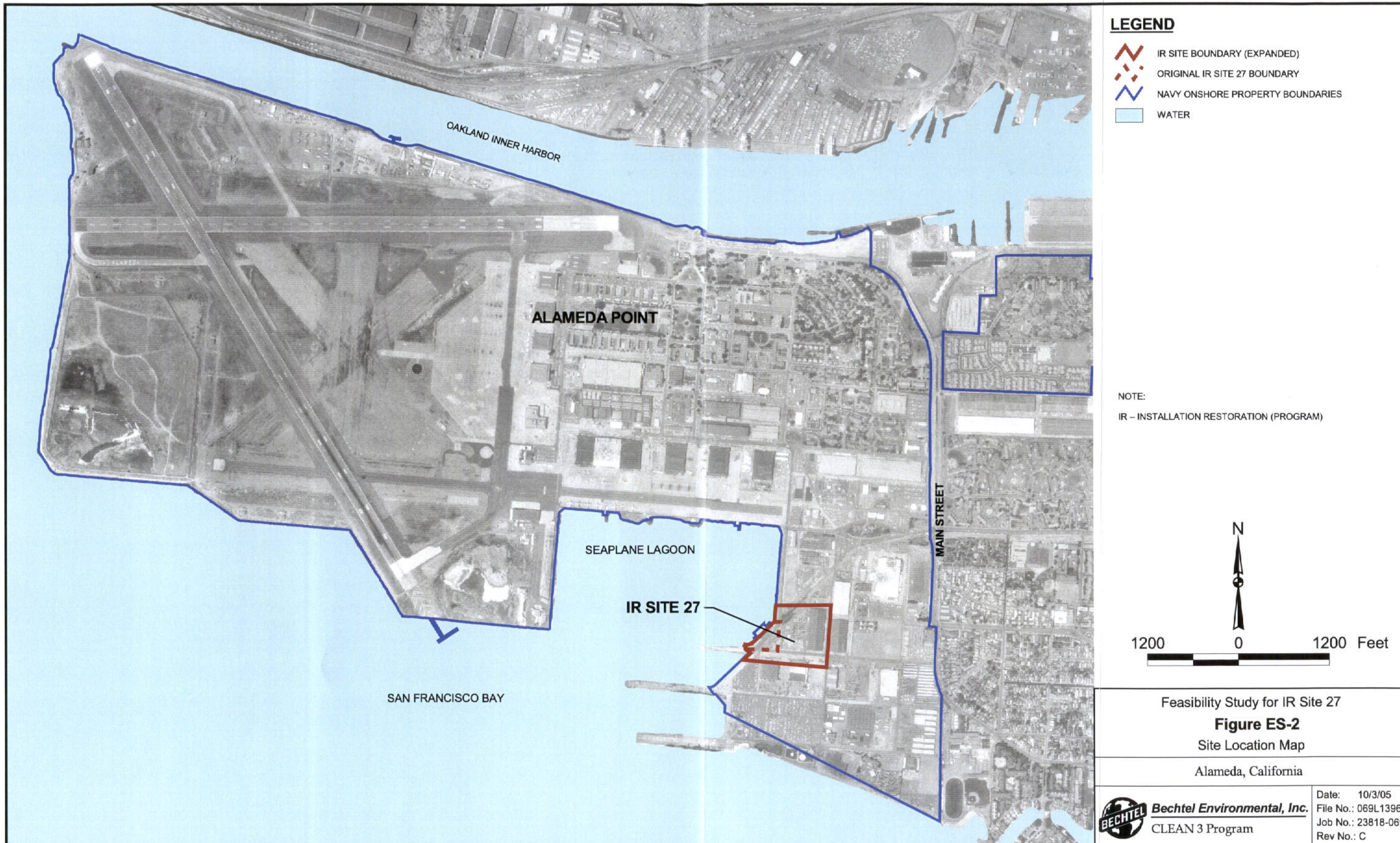
Rev No.: A



Feasibility Study for IR Site 27

Figure ES-2

Site Location Map

Alameda, California

Bechtel Environmental, Inc.
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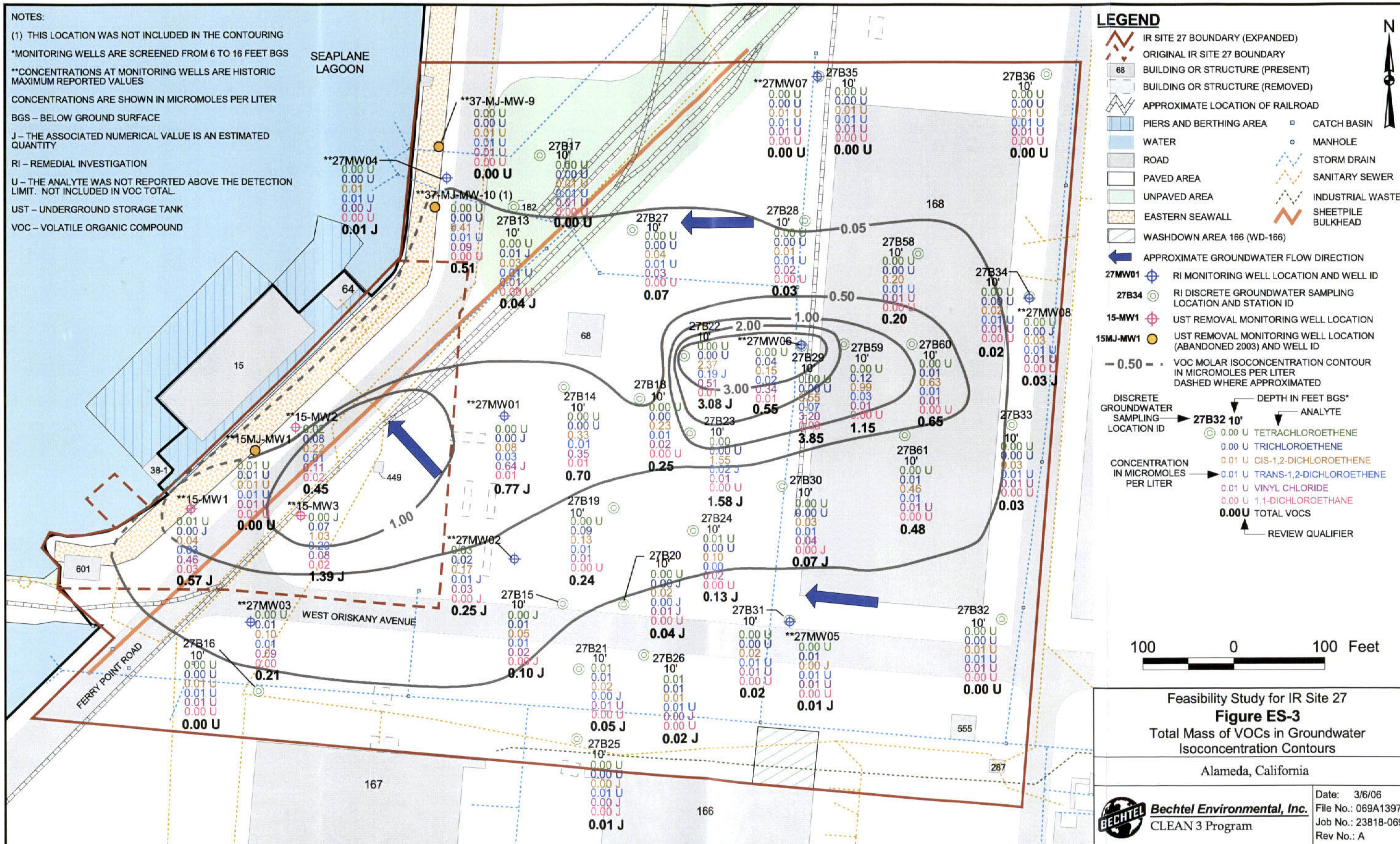
File No.: 069L13969
Job No.: 23818-069
Rev No.: C

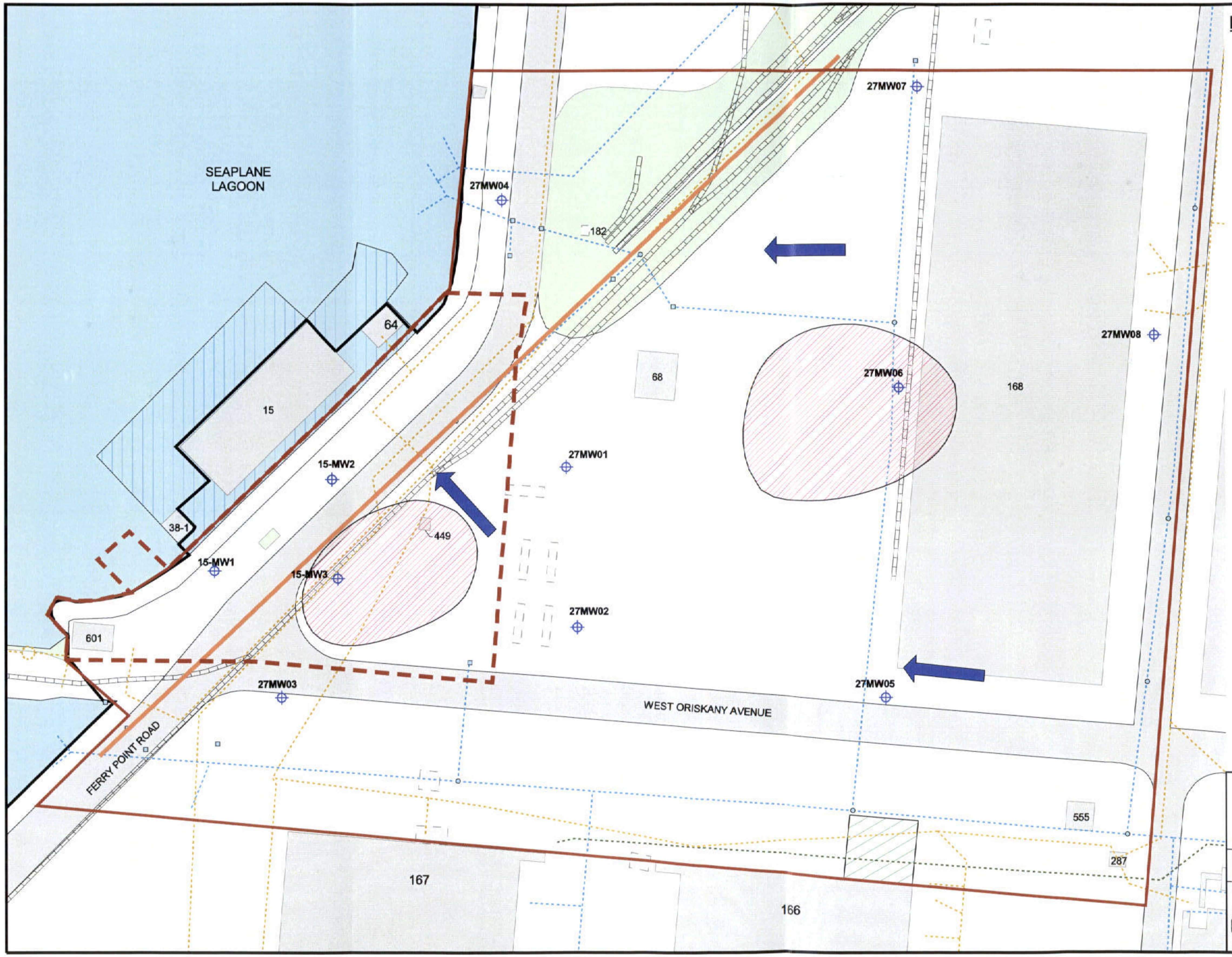


Feasibility Study for IR Site 27

Figure ES-3

Total Mass of VOCs in Groundwater Isoconcentration Contours

Alameda, California



Feasibility Study for IR Site 27

Figure ES-4

Assumed Treatment Areas for Alternatives 4A, 6A, and 7

Alameda, California

Bechtel Environmental, Inc.
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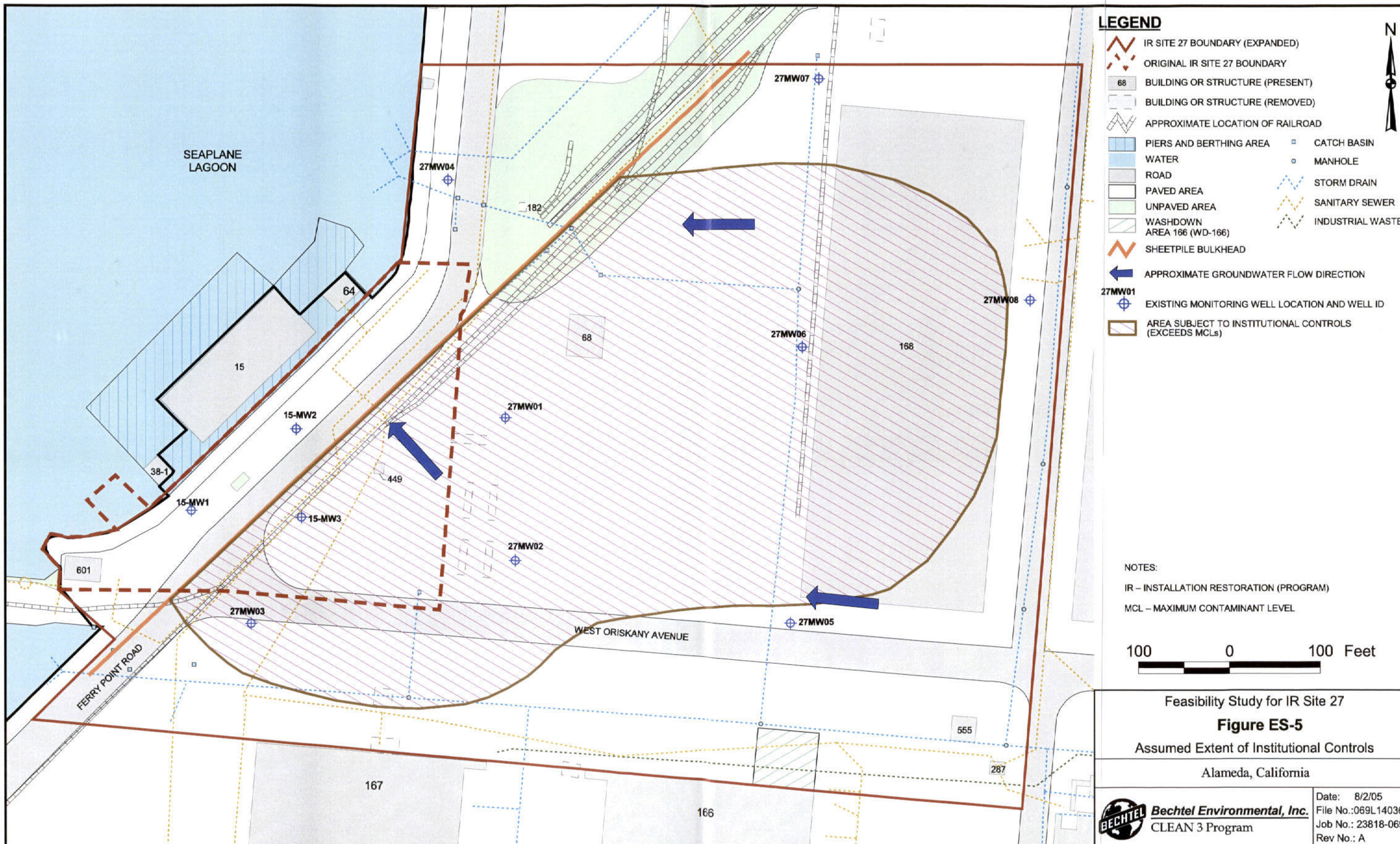

SEAPLANE LAGOON
27MW04
27MW07
182
64
15
15-MW2
38-1
15-MW1
601
15-MW3
449
68
27MW01
27MW02
27MW03
27MW06
27MW05
27MW08
168
WEST ORISKANY AVENUE
FERRY POINT ROAD
167
166
555
287
LEGEND
IR SITE 27 BOUNDARY (EXPANDED)
ORIGINAL IR SITE 27 BOUNDARY
BUILDING OR STRUCTURE (PRESENT)
BUILDING OR STRUCTURE (REMOVED)
APPROXIMATE LOCATION OF RAILROAD
PIERS AND BERTHING AREA
WATER
ROAD
PAVED AREA
UNPAVED AREA
WASHDOWN AREA 166 (WD-166)
SHEETPILE BULKHEAD
CATCH BASIN
MANHOLE
STORM DRAIN
SANITARY SEWER
INDUSTRIAL WASTE
APPROXIMATE GROUNDWATER FLOW DIRECTION
27MW01
EXISTING MONITORING WELL LOCATION AND WELL ID
AREA SUBJECT TO INSTITUTIONAL CONTROLS (EXCEEDS MCLs)
N
NOTES:
IR – INSTALLATION RESTORATION (PROGRAM)
MCL – MAXIMUM CONTAMINANT LEVEL
100 0 100 Feet
Feasibility Study for IR Site 27
Figure ES-5
Assumed Extent of Institutional Controls
Alameda, California
Bechtel Environmental, Inc.
CLEAN 3 Program
Date: 8/2/05
File No.:069L14036
Job No.: 23818-069
Rev No.: A

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SSIC NO. 5090.3

TABLES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006

Table ES-1
Groundwater Remedial Action Objectives for IR Site 27

Chemical of Concern	Proposed RAO (µg/L)	Exposure Route	Potential Receptor
Shoreline groundwater			
trans-1,2-dichloroethene	140,000[a]	Ingestion	Recreational fisherman
tetrachloroethene	8.85[a]		
trichloroethene	81[a]		
vinyl chloride	525[a]		
Inland groundwater			
1,1-dichloroethane	5[b]	Ingestion, dermal contact while showering	Hypothetical future resident (as a means to evaluate the unrestricted use scenario)
cis-1,2-dichloroethene	6[b]		
trans-1,2-dichloroethene	10[b]		
tetrachloroethene	5[c]		
trichloroethene	5[c]		
vinyl chloride	0.5[b]		
arsenic	10[d]		

Notes:
[a] RAO based on CTR criterion for human health consumption of organisms (40 C.F.R. § 131.38)
[b] RAO based on California primary MCL
[c] RAO based on federal and California primary MCL of 5 µg/L
[d] RAO based on federal primary MCL of 10 µg/L

Acronyms/Abbreviations:
ARAR – applicable or relevant and appropriate requirement
C.F.R. – *Code of Federal Regulations*
CTR – California Toxics Rule
µg/L – micrograms per liter
MCL – maximum contaminant level
RAO – remedial action objective

Table ES-2
Identification of Remedial Alternatives

Alternative*	Description
1	**no action**
2	ICs
3	**MNA and ICs**
4A	**ISB source area treatment, MNA, and ICs**
4B	sitewide ISB treatment, MNA, and ICs
5	air sparging source area treatment, MNA, and ICs
6A	**ISCO source area treatment, MNA, and ICs**
6B	**sitewide ISCO treatment and groundwater confirmation sampling**
7	**dynamic circulation source area treatment, MNA, and ICs**
8	zero-valent iron source area treatment, MNA, and ICs

Note:
* alternatives retained for detailed evaluation in Section 6 are shown in bold type

Acronyms/Abbreviations:
IC – institutional control
ISB – *in situ* bioremediation
ISCO – *in situ* chemical oxidation
MNA – monitored natural attenuation

Table ES-3
Comparative Analysis of Remedial Alternatives Using Balancing Criteria

Alternative	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost*
	Parameters considered: • residual risk at completion • long-term management of remaining contaminants • reliability of ECs/ ICs • need to replace components • continuing repair/maintenance needs	Parameters considered: • treatment processes • amount of hazardous material • degree of reduction in toxicity, mobility, or volume • degree of irreversibility • treatment residuals	Parameters considered: • short-term risks to community • impacts on workers • environmental impacts • time until protection is achieved	Parameters considered: • technical feasibility • operational reliability • future alternative remedial options • ability to monitor effectiveness • ability to obtain governmental approvals • availability of services and materials	Parameters considered: • net present value • relative capital costs • O&M costs
Alternative 3 – MNA and ICs	**Medium** The assumed duration for ICs and the MNA program for this alternative (70 years) is longer than that assumed for Alternatives 4A, 6A, and 7, and would require a longer period of well maintenance/repair and management of ICs. The long-term effectiveness of ICs would depend on continued adherence.	**Low** Contaminant levels are reduced via natural attenuation processes. No active treatment is conducted under this alternative.	**High** There are no short-term risks associated with this alternative. The time to achieve protection is low because ICs can be implemented readily. Risks to the community should be minimal. Risks to workers during groundwater sampling would be mitigated with adherence to a health and safety plan.	**High** ICs are easy to implement. Groundwater sampling technology is proven. Monitoring results would track progress of MNA.	**Medium** Comparative present value costs associated with this alternative are lower than Alternatives 4A, 6A, 6B, and 7.
Alternative 4A – ISB source area treatment, MNA and ICs	**High** ISB treatment is expected to reduce source area concentrations faster than passive alternatives. The assumed duration for ICs for this alternative (approximately 60 years) is longer than that assumed for Alternative 6A, and would require a longer period of well maintenance/repair and management of ICs.	**Medium** The HRC process should permanently destroy a significant mass of VOCs within the first 2 years under favorable conditions, resulting in innocuous end products. However, the plume is treated less aggressively than for Alternatives 6A and 6B.	**Medium** The HRC product would need to be transported to the site. However, implementation of this alternative is not likely to have adverse impacts on site workers, the surrounding community, or the environment. Source area treatment under this alternative would reduce VOC concentrations within approximately two years.	**High** HRC injection is easy to implement at Alameda Point. Equipment for HRC injection is readily available. This alternative is more complex to implement than Alternative 3 due to design of an *in situ* treatment process, but soil types are fairly uniform (fine sands) in the treatment areas so no difficulties are anticipated with implementation of this alternative.	**Low** Comparative present value costs associated with this alternative are comparable to sitewide Alternative 6B. High present value cost compared to Alternatives 3, 6A, and 7.
Alternative 6A – ISCO source area treatment, MNA and ICs	**High** ISCO treatment is expected to reduce source area concentrations faster than Alternatives 3 and 4A. The assumed duration for ICs for this alternative (approximately 45 years) is shorter than that assumed for Alternatives 3 and 4A.	**Medium** The chemical oxidation process should permanently destroy a significant mass of VOCs within weeks in the treatment area, resulting in innocuous end products. However, less of the plume is aggressively treated than for Alternative 6B.	**Medium** ISCO would destroy the VOCs in the source areas more quickly with this alternative than Alternatives 3, 4A, or 7. However, the ISCO process poses some risks to site workers and the community. Approximately one truck per day of hydrogen peroxide would need to be delivered to the site during treatment.	**High** ISCO was recently implemented successfully at IR Site 9 (near IR Site 27). No difficulties are anticipated with implementation of this alternative. This alternative is judged to be similar in implementability to Alternative 4A.	**Medium** High comparative present value cost compared to Alternative 3; however, comparative cost is lower than Alternatives 4A, 6B, and 7.

Table ES-3 (continued)

Alternative	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost*
Alternative 6B – sitewide ISCO treatment and groundwater confirmation sampling	**High** Most or all of the contamination would be eliminated within 6 months; therefore, only a limited time frame would be necessary for groundwater confirmation sampling to confirm that MCL-equivalent concentrations have been reached.	**High** This sitewide chemical oxidation alternative should permanently destroy virtually all of the VOCs in groundwater within weeks, resulting in innocuous by-products.	**Medium** ISCO would destroy the VOCs to MCL-equivalent concentrations across the entire plume within an estimated time of 6 months. However, the ISCO process poses some risks to site workers and the community. Approximately one truck per day of hydrogen peroxide would need to be delivered to the site during treatment.	**Low** This alternative is considered the least implementable due to the number of injection points (570) required for sitewide ISCO treatment.	**Low** High present value cost compared to Alternatives 3 and 6A. Cost is comparable to Alternative 4A. Cost is lower than Alternatives 4A and 7.
Alternative 7 – dynamic circulation source area treatment, MNA, and ICs	**Medium** This source area treatment alternative would be expected to reduce VOC concentrations in the source area within a year after implementation, but is relatively less proven than ISB and ISCO treatments. The assumed duration for ICs for this alternative (approximately 55 years) is shorter than that that assumed for Alternatives 3 and 4A and would require a shorter period of well maintenance/repair and management of ICs.	**Medium** This alternative would accomplish VOC reductions similar to Alternative 4A. VOCs would be removed by SVE and carbon adsorption and destroyed at a carbon regeneration facility.	**Low** This alternative requires installation of ten new remediation wells, two treatment compounds, and approximately 600 lineal feet of trenching across paved areas of the site. Air emissions associated with operation of remediation systems could pose some risk to the community.	**Medium** Technologies required to implement this alternative (well installation, trenching, and remediation system construction) are readily available. Remediation wells may need to extend above grade, potentially causing traffic and well security concerns. The proprietary well design is available only from ART.	**Low** High comparative present value cost compared to other source area treatment alternatives

Note:
* a low ranking under the cost criterion means present value costs are comparatively higher, and a high ranking means present value costs are comparatively lower

Acronyms/Abbreviations:
ART – Accelerated Remediation Technologies, LLC
EC – engineering control
HRC – Hydrogen Release Compound
IC – institutional control
IR – Installation Restoration (Program)
ISB – *in situ* bioremediation
ISCO – *in situ* chemical oxidation
MCL – maximum contaminant level
MNA – monitored natural attenuation
SVE – soil vapor extraction
VOC – volatile organic compound

Table ES-4
Summary of Cost Estimates for IR Site 27 Remedial Alternatives

Alternative	Duration of Alternative	Remedial Design Cost	Capital Cost	O&M Cost	Total Cost	Net Present Value*
Alternative 3 – MNA and ICs	70 years	$152,000	$0	$2,144,000	$2,755,000	$1,407,000
Alternative 4A – ISB source area treatment, MNA, and ICs	60 years	$172,000	$210,000	$2,140,000	$3,026,000	$1,962,000
Alternative 6A – ISCO source area treatment, MNA, and ICs	45 years	$172,000	$289,000	$1,390,000	$2,221,000	$1,532,000
Alternative 6B – sitewide ISCO treatment and groundwater confirmation sampling	3 years	$200,000	$1,247,000	$294,000	$2,089,000	$2,050,000
Alternative 7 – dynamic circulation source area treatment, MNA, and ICs	55 years	$272,000	$356,000	$1,902,000	$3,036,000	$2,082,000

Note:
* discount rate of 3.1 percent per year was used to calculate net present value

Acronyms/Abbreviations:
IC – institutional control
ISB – *in situ* bioremediation
ISCO – *in situ* chemical oxidation
MNA – monitored natural attenuation
O&M – operation and maintenance

Section 1
INTRODUCTION

This Report presents the feasibility study (FS) conducted at Installation Restoration (IR) Program Site 27, Dock Zone, Alameda Point (formerly Naval Air Station [NAS] Alameda), Alameda, California (Figures 1-1 and 1-2). Bechtel Environmental, Inc., (BEI) prepared this FS Report for the Department of the Navy (DON) Base Realignment and Closure (BRAC) Program Management Office West under Contract Task Order 0069 of the Comprehensive Long-Term Environmental Action Navy 3 Program, Contract No. N68711-95-D-7526. The Navy follows current United States Environmental Protection Agency (U.S. EPA) guidance for FS report preparation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 *United States Code* (U.S.C.) Sections (§§) 9601–9675 (1988). Figures and tables are presented behind tabs following each section of this report.

1.1 PURPOSE

The purpose of this FS Report is to develop and evaluate remedial action alternatives to address human-health risks from groundwater underlying IR Site 27 that contains chlorinated volatile organic compounds (VOCs) at concentrations above applicable regulatory comparison criteria. The Remedial Investigation (RI) Report (BEI 2005) recommended preparation of this FS Report to address only chlorinated VOCs in groundwater. As concluded by the RI Report, no immediate threat to human health or the environment from soil was found at the site. The RI Report also concluded that no further action was warranted for terrestrial or aquatic life ecological receptors. The Navy will use the results of this evaluation and other site-specific information to select an appropriate remedy for groundwater at IR Site 27.

Due to the expansion of the IR Site 27 boundaries to encompass the VOC plume, a washdown area (WD-166 and related oil/water separators) and Building 555 (an electrical substation) were included within the IR Site 27 boundaries. The RI Report identified data gaps associated with testing groundwater at the washdown area and with testing for polychlorinated biphenyls (PCBs) in soil adjacent to Building 555. These data gaps are to be addressed during the remedial design phase.

CERCLA and the Superfund Amendments and Reauthorization Act (SARA) established a series of federal programs to identify, characterize, and clean up or control contamination from hazardous waste disposal and spill sites. The Defense Environmental Restoration Program (DERP), codified in SARA Section 21 (10 U.S.C. § 2701), is one of these programs. DERP specifies Navy and Marine Corps personnel responsibilities, describes IR Program procedures, and assures consistency with regulatory guidelines for evaluation of hazardous waste site conditions.

The Navy established the IR Program to comply with federal requirements regarding cleanup of hazardous waste sites. Specifically, the task of the program is to reduce the risk to human health and the environment from past waste-disposal operations and hazardous materials spills at Navy and Marine Corps facilities in a cost-effective manner. These federal requirements are outlined in CERCLA, as amended by SARA and its implementing regulation, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

The Navy is responsible for environmental restoration at IR Site 27. The U.S. EPA is the lead oversight agency for environmental restoration. The Navy provides copies of draft reports to the California Environmental Protection Agency (Cal/EPA) Department of Toxic Substances Control (DTSC) and the San Francisco Bay Regional Water Quality Control Board (RWQCB) for comment as part of the CERCLA process.

Alameda Point was added to the U.S. EPA National Priorities List (ID Number CA2170023236) in July 1999. Therefore, U.S. EPA and Navy RI and FS regulations and appropriate policy guidance have been followed in preparing this FS Report for IR Site 27. The RI/FS process involves characterizing the nature and extent of contamination, assessing the risks posed by hazardous waste sites, and identifying options for cleanup. The NCP, promulgated in the *Code of Federal Regulations* (C.F.R.) at 40 C.F.R. § 300, provides the RI/FS regulations.

In September 1993, the United States Congress and the BRAC Commission designated NAS Alameda for closure. The BRAC program goal is to transfer the closing base property and facilities to the community as expeditiously as possible and with minimal impact on the local economy.

1.2 SCOPE

The FS methodology is summarized below and further detailed in subsequent sections of this FS Report. It includes the following steps (U.S. EPA 1988b):

- Establish remedial action objectives (RAOs).
  - Identify applicable or relevant and appropriate requirements (ARARs).
  - Establish response objectives for environmental media of concern (soil, groundwater, and surface water).
- Identify general response actions, including no action, to meet RAOs for each medium of concern.
- Identify volumes or areas of environmental media for which remedial response actions may be needed.
- Identify remedial technologies and representative process options under each general response action based on technical considerations.
- Screen remedial technologies and process options on the basis of effectiveness, implementability, and cost.
- Assemble the retained technologies and process options into remedial alternatives representing a range of treatment and containment combinations.
- Screen assembled alternatives, considering effectiveness, implementability, and cost.

- Evaluate retained remedial alternatives in detail against the following nine criteria specified in the NCP:
  - overall protection of human health and the environment
  - compliance with ARARs
  - long-term effectiveness and permanence
  - reduction of toxicity, mobility, or volume through treatment
  - short-term effectiveness
  - implementability
  - cost
  - state acceptance
  - community acceptance
- Perform a comparative evaluation of remedial alternatives.

This FS Report does not identify or recommend a preferred remedial alternative. Comments made during public (including the Restoration Advisory Board [RAB]) and regulatory agency reviews will be evaluated and considered during the remedy-selection process. As required by the NCP and U.S. EPA guidance (U.S. EPA 1988b), public agency comments will also be addressed in a Proposed Plan as well as in the Record of Decision (ROD).

1.3 REPORT ORGANIZATION

This FS Report is divided into an executive summary, seven sections, three appendices, and two attachments.

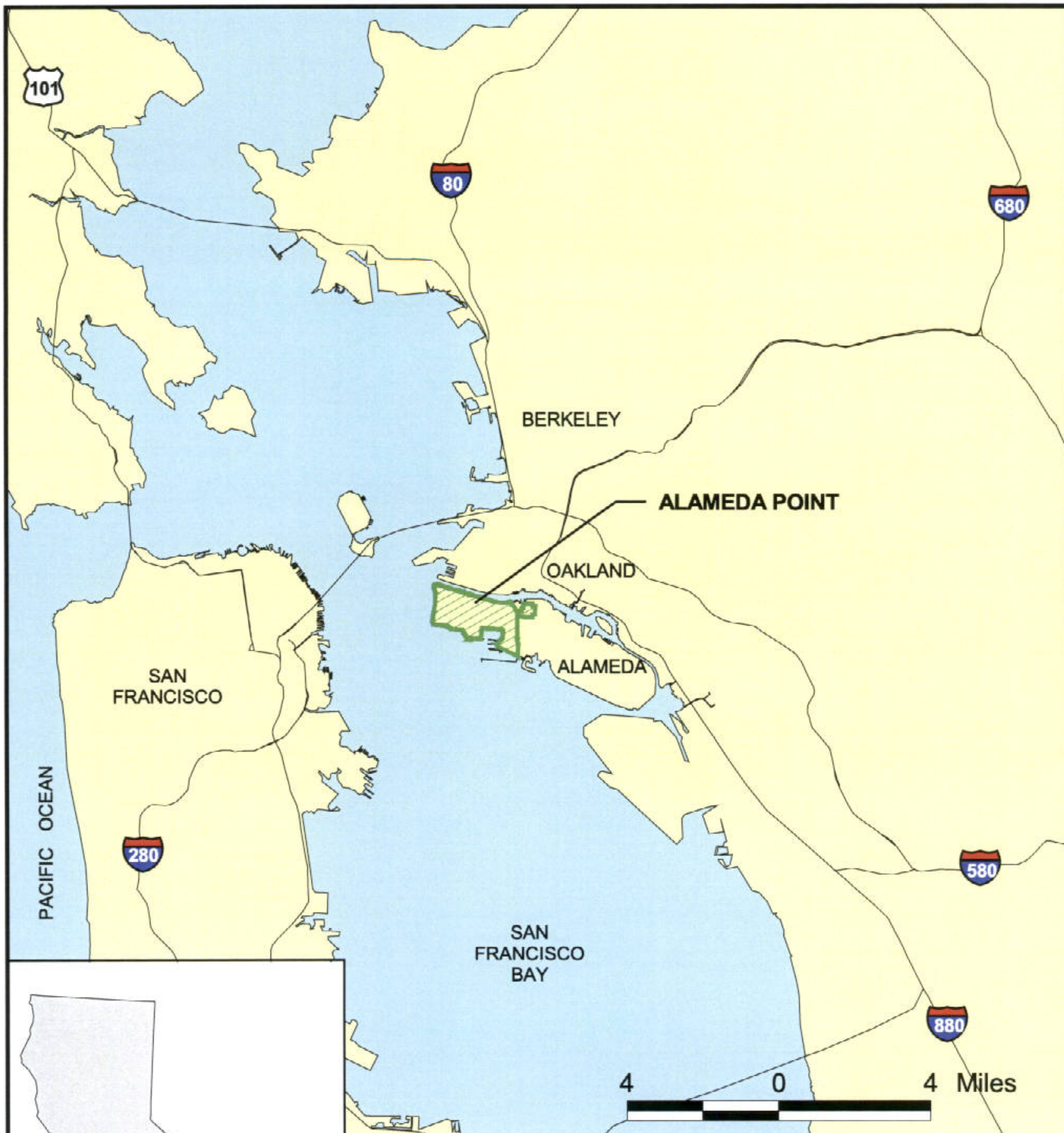
- Section 1 provides an overview of the CERCLA FS process and presents the report organization.
- Section 2 presents background information about Alameda Point and IR Site 27, including beneficial uses of groundwater and relevant results of the RI fieldwork.
- Section 3 outlines RAOs and ARARs for IR Site 27.
- Section 4 identifies and screens various remedial technologies and process options for contaminated groundwater at IR Site 27.
- Section 5 presents the development of alternative remedial actions, which address groundwater contamination associated with IR Site 27, and screens these alternatives as appropriate.
- Section 6 provides a detailed description and analysis of each retained remedial alternative.
- Section 7 compares the remedial alternatives based on NCP criteria.
- Section 8 lists references used in this FS Report.

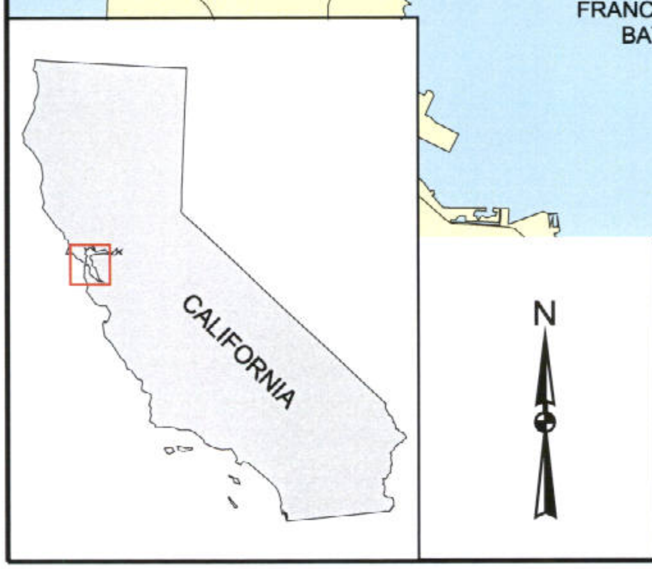
- Appendix A presents an ARARs analysis for IR Site 27 remedial alternatives.
- Appendix B presents the results of a groundwater modeling study used to evaluate natural attenuation.
- Appendix C provides cost development summaries for selected remedial alternatives.
- Appendix D includes the regulatory agency comments on the draft version of this FS Report and responses to these comments.
- Attachment A is the Memorandum of Agreement (MOA) between the DON and the DTSC regarding land-use restrictions.
- Attachment B is the Navy guidance document for land-use controls (LUCs): Principles and Procedures for Specifying, Monitoring, and Enforcement of LUCs and Other Post-ROD Actions.

FIGURES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006





Feasibility Study for IR Site 27

Figure 1-1

Alameda Point Regional Map

Alameda, California

Bechtel Environmental, Inc.
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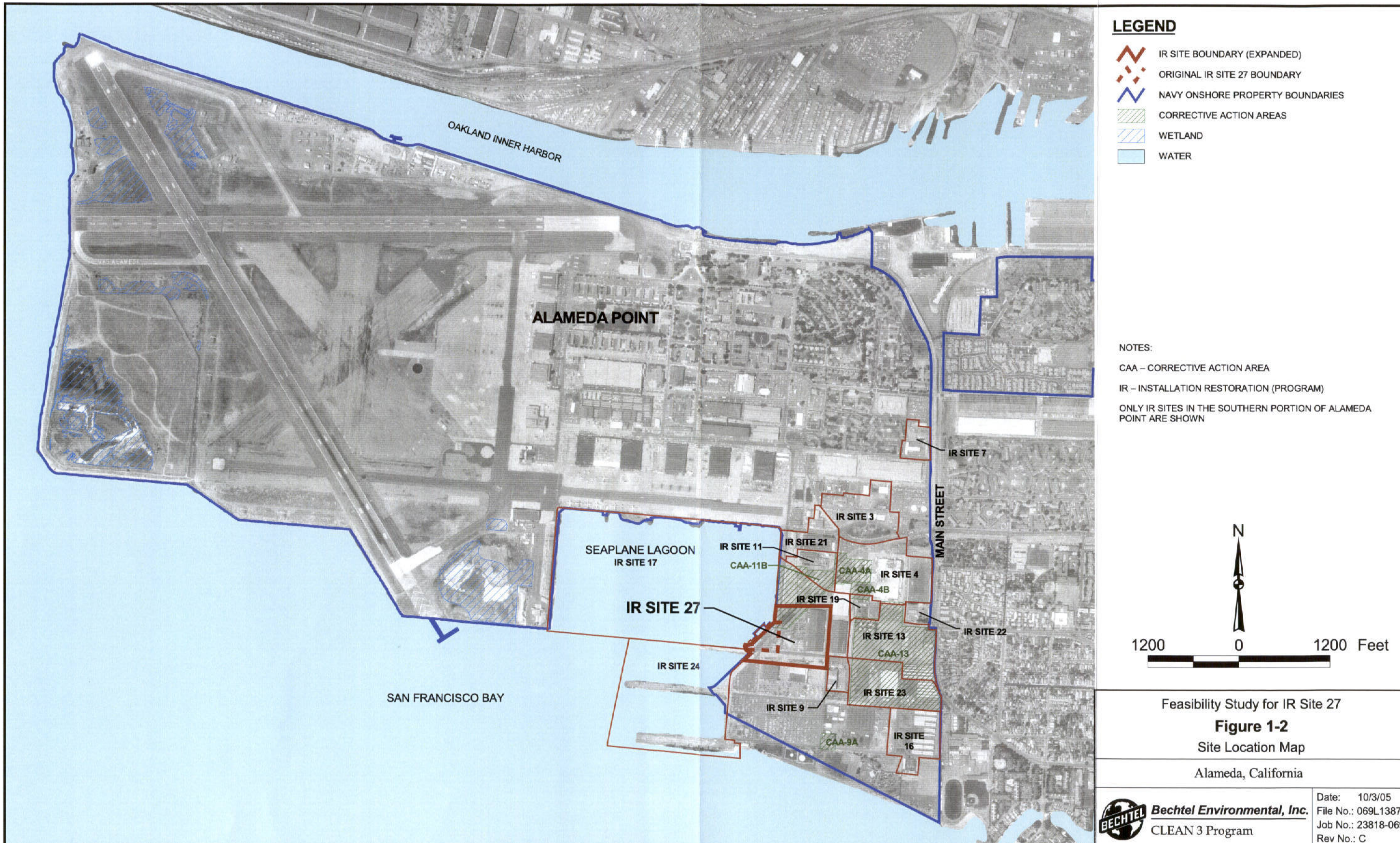
Date: 6/1/05
File No.: 069R13875
Job No.: 23818-069
Rev No.: A



Feasibility Study for IR Site 27

Figure 1-2

Site Location Map

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 10/3/05
File No.: 069L13876
Job No.: 23818-069
Rev No.: C

Section 2
BACKGROUND INFORMATION

This section provides a description of IR Site 27; a summary of IR Site 27 history and previous investigations at Alameda Point that relate to IR Site 27; and an overview of the climate, topography, geology, surface water drainage, tides, and hydrogeology at the site. A discussion of groundwater use and potential beneficial uses is presented as well as a summary of ecological habitats at Alameda Point and the IR Site 27 vicinity. This section also provides a summary of the characterization of the nature and extent of contamination presented in the RI Report (BEI 2005) for IR Site 27 and the human-health and ecological risk assessments for the site.

2.1 SITE BACKGROUND INFORMATION

The following subsections provide a description and history of IR Site 27 and a description of current and past operations at IR Site 27.

2.1.1 Site Description

IR Site 27 is located in Alameda Point, the location of the former NAS Alameda on the western tip of Alameda Island. In 1930, the U.S. Army acquired the original base property from the City of Alameda and began construction activities in 1931. In 1936, the Navy acquired title to the land from the Army and began building an air station in response to the military buildup in Europe before World War II. Construction of the base included several iterations of filling tidelands, marshlands, and sloughs with dredge materials from the San Francisco Bay. NAS Alameda was operated as an active naval facility from 1940 to 1997.

IR Site 27 is approximately 15.8 acres in size and is located in the southeastern area of Alameda Point (Figure 1-2). To the west, it is bounded by Seaplane Lagoon (Figure 2-1). The eastern site boundary is Viking Street. The southern site boundary parallels and is approximately 160 feet south of West Oriskany Street, and is located at the northern edge of Buildings 166 and 167. The northern site boundary is roughly parallel to and approximately 50 feet north of Building 168.

Most of IR Site 27 is paved or covered by buildings. The major features of IR Site 27 are Buildings 68, 168, 555, and 601; Ferry Point Road and West Oriskany Avenue; railroad tracks and sidings; and fenced open space between Building 168 and Ferry Point Road.

2.1.2 Current and Past Operations

During the operational period of NAS Alameda, the area east of Seaplane Lagoon was designated as the Dock Zone, the Dock Support Services Zone, and the Engine Testing Zone. Reportedly, historical operations within the western portion of IR Site 27 included ship docking, ship repair, and marine painting activities (IT 2001a). Building 601 was constructed in 1980 to house an oil/water separator (OWS), which was later removed. Historical operations in the eastern portion of IR Site 27 included materials storage and equipment and vehicle parking in open space areas; warehouse operations in Building 168 (110,000 square feet); and waterfront services, including welding, in Building 68.

Historically, the open space served as an aircraft parking area (IT 2001a). The southern portion of a former fuel farm area is located in the northeast portion of IR Site 27.

Currently, Buildings 68 and 168 are used by tenants for operations similar to historical operations and Building 601 is used by tenants as a machine shop. The fenced open space west of Building 168 is being used by the Department of Transportation for maintenance equipment and vehicle parking, chemical storage, and drum storage. A washdown area WD-166 with two OWS units is located at the southern margin of the site to the north of Building 166 (this building is not within the boundaries of IR Site 27).

2.1.3 Planned Future Use

The City of Alameda General Plan Amendment Environmental Impact Report (City of Alameda 2002) has designated IR Site 27 as future marina and inner harbor areas that may include the following types of potential uses: marina, civic, residential, recreational, light industrial, retail, and commercial. The planned future use of IR Site 27 is also described in the Alameda Point Preliminary Development Concept prepared for the Alameda Reuse and Redevelopment Authority (Roma Design Group 2005).

2.2 PREVIOUS INVESTIGATIONS

A number of previous investigations have been conducted within or adjacent to the current boundaries of IR Site 27. The following is a brief synopsis of these investigations:

- The Initial Assessment Study for all of NAS Alameda was conducted in 1983; this study identified fuel lines crossing the site (Ecology and Environment, Inc. 1983).
- The Resource Conservation and Recovery Act (RCRA) facility assessment for NAS Alameda was completed in 1992; this assessment identified three underground storage tanks (USTs) in the western portion of IR Site 27 inland from Building 15 (USTs 15-1, 15-2, and 15-3) and four USTs in the northwestern portion of IR Site 27 (USTs 37-13 through 37-16) that were part of the fuel farm area (Figure 2-2) (IT 1992).
- The UST removal investigations were conducted for USTs 15-1, 15-2, and 15-3, which were removed in 1994, and fuel farm USTs 37-13 through 37-16, which were removed in 1998. Chlorinated VOCs were discovered in groundwater during removal of USTs 15-1, 15-2, and 15-3 and three monitoring wells were installed in 1995 (15-MW1, 15-MW2, and 15-MW3) (ERM-West 1996). These wells were sampled up to five times during post-UST-removal investigations between 1995 and 1999. Additional monitoring wells were installed in 1997 in the joint vicinity of the two sets of USTs (Moju 1998b). Post-UST-removal investigations identified low concentrations of petroleum hydrocarbons and chlorinated solvents in groundwater. Concentrations of chlorinated solvents generally decreased in wells 15-MW1 through 15-MW3 between 1995 and 2000 (Moju 1998a, 1998b, 1999a, 1999b; TtEMI 2001b).

- The environmental baseline survey (EBS) program was initiated in 1993 at Alameda Point including Phase 1 (ERM-West 1994) and Phase 2 (IT 2001a). The EBS program investigated the property that would become IR Site 27 as parts of EBS parcels from Zone 17 (Parcel 138), Zone 18 (Parcel 155), and Zone 19 (Parcels 139, 140, 154, and 201). The original IR Site 27 boundaries, as identified by an evaluation of data performed during the EBS, encompassed approximately 2.2 acres of dry land comprising three EBS subparcels (138B, 139A, and 155B). With the exception of the chlorinated VOCs in groundwater within the original boundaries of IR Site 27, no releases requiring further action under CERCLA were identified in the six EBS parcels that are now within the expanded boundaries (approximately 15.8 acres) of IR Site 27.
- The basewide supplemental EBS completed in August 2002 (TtEMI 2002a) reported that the three EBS subparcels 138B, 139A, and 155B (comprising the original extent of IR Site 27) were classified as an area where a release had been confirmed and further action was required. EBS Parcels 138, 139, 140, 154, 155C, and 201 were classified as buffer zones adjacent to CERCLA sites (TtEMI 2002a, 2003b).
- The Fuel Pipeline Removal Area 4 (Figure 2-2) confirmation soil and groundwater sampling was conducted in 1998 and 1999 to document the concentrations of TPH remaining in soil and groundwater after pipeline excavation and removal, or closure in place (TtEMI 2000a). Samples were analyzed for TPH as diesel, gasoline, motor oil, and jet propellant grade 5, and for BTEX and MTBE, and indicated the continued presence of TPH and/or BTEX constituents in soil and groundwater. The former fuel line area was incorporated into the Alameda Point TPH Program as part of Corrective Action Area (CAA) 11B. The northwestern portion of IR Site 27 is within the CAA 11B boundaries.
- The Storm Sewer Study Report for Alameda Point (TtEMI 2000c) and Storm Sewer Study Report, Total Petroleum Hydrocarbons Addendum for Alameda Point (TtEMI 2001a) were conducted to assess the storm sewer system at Alameda Point as a potential transport pathway for chemicals to reach surface water and sediment associated with the San Francisco Bay. Outfalls I and J are located within the IR Site 27 boundaries. The Outfall J storm drain subsystem has two outfall locations, one located north of Building 15 and one located south of Building 15.
- The data gap investigation (DGI) sampling of soil and groundwater was conducted within the current boundaries of IR Site 27 in conjunction with previous investigations and removal activities at CAA 11B (TtEMI 2001b) and Operable Units (OU) 1 and 2 (TtEMI 2001c).

2.3 REMEDIAL INVESTIGATION AND OTHER RELEVANT INVESTIGATIONS AND ACTIVITIES

The IR Site 27 RI field activities were conducted between March 2002 and June 2004 and consisted of four phases of activities (BEI 2005). RI field activities included the following:

- Phase I
  - Soil sampling for metals and polynuclear aromatic hydrocarbons (PAHs) and soil gas sampling for VOCs were conducted within the original 2.2-acre site boundaries. Soil samples were also collected and analyzed for geotechnical parameters.
  - Monitoring well groundwater sampling was conducted from preexisting wells (15-MW1, 15-MW2, 15-MW3, 15MJ-MW1, 37-MJ-MW-09, and 37-MJ-MW-10). Samples were analyzed for VOCs, fuels, PAHs, metals, and general chemistry parameters.
  - Aquifer testing was conducted in preexisting wells 15-MW1, 15-MW2, and 15-MW3.
- Phase II
  - Three new monitoring wells (27MW01, 27MW02, and 27MW03) were installed upgradient of the original site boundaries. Soil samples were collected from the well borings analyzed for geotechnical parameters.
  - Monitoring well groundwater sampling was conducted from the new and preexisting wells. Samples were analyzed for VOCs, fuels, metals, and general chemistry parameters.
- Phase III
  - Discrete groundwater sampling for VOCs was conducted from 24 temporary well point locations in a step-out program to characterize the extent of VOCs in groundwater beyond the original boundaries of IR Site 27. Groundwater samples were collected at two depths (10 and 20 feet bgs) to characterize the vertical as well as the horizontal extent of VOCs.
  - Five new monitoring wells (27 MW04 through 27MW08) were installed north and east of the original site boundaries.
  - Monitoring well groundwater sampling was conducted from the five new wells. Samples were analyzed for VOCs, fuels, dissolved gases, metals, and general chemistry parameters.
- Phase IV
  - Site boundaries were expanded to include approximately 15.8 acres, encompassing the VOC plume.
  - Soil gas sampling was conducted for VOCs within the expanded site boundaries. Soil gas sampling included sampling beneath Building 168.
  - Soil sampling for VOCs was conducted within the expanded site boundaries. Additional samples were collected within the original site boundaries. Soil samples were also collected and analyzed for geotechnical parameters.
  - Discrete groundwater sampling for VOCs was conducted from four temporary well point locations beneath Building 168.

- Monitoring well groundwater sampling was conducted from eight wells (27MW01 through 27MW08). Samples were analyzed for VOCs, fuels, PAHs, metals, dissolved gases, and general chemistry parameters.

Ongoing basewide investigations at and adjacent to IR Site 27 and investigations concurrent with the IR Site 27 RI include the following.

- The site investigation (SI) for PAHs in soil was conducted in 2002 for Transfer Parcel Economic Development Conveyance (EDC) 12 (BEI 2003), which surrounds the three EBS subparcels (138B, 139A, and 155B) that formed the original IR Site 27 (Figure 2-1). The current IR Site 27 includes portions of Transfer Parcel EDC-12. Transfer Parcel EDC-12 was sampled in a grid pattern over the entire transfer parcel area; eight sampling locations from this investigation are within the current boundaries of IR Site 27.
- The basewide groundwater monitoring program (BGMP) was implemented in 2002 and is ongoing at Alameda Point (Shaw 2004, ITSI 2005). Quarterly groundwater monitoring for IR Site 27 under the BGMP began in June 2002 and included the four existing wells: 15-MW1, 15-MW3, 15-MW3, and 15MJ-MW1. Well 15MJ-MW1 was abandoned in 2003 and well 27MW06 was added to the quarterly monitoring program in April 2004.
- RCRA hazardous waste permitted and nonpermitted units were identified in 1990 by a RCRA facility assessment completed by International Technology Corporation on behalf of DTSC (IT 1992) and by a subsequent review of facilities at Alameda Point. The Navy was issued a RCRA Part A permit in 1980 (U.S. EPA ID CA 2170023236) (Cal/EPA 1980) and a RCRA Part B permit in 1993 (TtEMI 2002b). The EBS identified additional RCRA units (IT 2001a). Four RCRA units (UST[R]-07, AOC 015, NAS GAP 8, and NAS GAP 18/SHWAP 18 NAS) were identified within the current IR Site 27 boundaries and a fifth RCRA unit (M-10) was located just north of the northern boundary of IR Site 27 (TtEMI 2003a, 2003b) (Figure 2-1).
- A washdown area and two OWSs (WD-166, and OWS-166A and -166B) in EBS Parcel 201 within the boundaries of IR Site 27 were recommended for no further action (NFA) under the Alameda Point TPH Program (TtEMI 2002b). However, due to lack of groundwater sampling at this location, the RI identified characterization of groundwater at WD-166 and testing for PCBs in soil adjacent to Building 555 as data gaps. NFA was recommended for Building 601, which was originally built to house OWS-601. OWS-601 was an aboveground OWS inside Building 601 that has been closed; no further action is required. OWS-601 was removed and recent inspection (Foulk, pers. com. 2004) confirms that there is no evidence of an OWS in this building. The locations of the OWSs and the washdown area are shown on Figure 2-1.
- Twelve other IR sites are located within 1,200 feet of IR Site 27 (IR Sites 3, 4, 9, 11, 13, 16, 17, 19, 21, 22, 23, and 24). Two IR sites adjoin IR Site 27: IR Site 17 (Seaplane Lagoon) and IR Site 9. IR Site 9 is part of OU-2A, which includes IR Sites 9, 13, 19, 22, and 23. OU-2A is characterized by chlorinated VOCs in groundwater (IT 2001b). IR Sites 3, 4, 11, and 21 are grouped as OU-2B, which is characterized by chlorinated and fuel-related VOCs in groundwater (IT 2001b). The locations of the nearby IR sites are shown on Figure 1-2.

- Several areas in the vicinity of IR Site 27 are being addressed by the Alameda Point TPH Program. A portion of CAA-11B is located within the IR Site 27 boundaries (Figure 2-2) (TtEMI 2003c). Four other areas (CAA-4A, CAA-4B, CAA-9A, and CAA-13) are located within 1,000 feet of IR Site 27. The locations of the nearby CAA sites are shown on Figure 1-2.

2.4 PHYSICAL SETTING

This subsection provides an overview of the climate, topography, geology, surface water drainage, tides, and hydrogeology of IR Site 27. A discussion of groundwater use and potential beneficial uses, and a summary of ecological habitats at Alameda Point and the IR Site 27 vicinity are also presented.

2.4.1 Climate

The San Francisco Bay area is characterized by a Mediterranean climate with mild summer and winter temperatures. The mean annual precipitation at Alameda Island is 23 inches, with most of the precipitation occurring from October to April. Mean yearly low and high temperatures are 52 degrees Fahrenheit (°F) and 67 °F, respectively. The wind direction is predominantly from the west or northwest, with rare occurrences of gale-force or greater winds. Heavy fog that sometimes impairs visibility for navigation occurs on an average of 21 days per year (National Weather Service 2001). Table 2-1 summarizes maximum and minimum monthly temperatures and average rainfall totals.

2.4.2 Topography

Alameda Island lies at the base of a gently westward-sloping plain that extends from the Oakland-Berkeley hills in the east to the shore of the San Francisco Bay in the west. Alameda Island is characterized by a low topographic profile, with surface elevations varying from mean sea level (MSL) to approximately 30 feet above MSL. The area is flat with ground surface elevations from approximately 9 to 10 feet above MSL.

2.4.3 Geology

Alameda Island is on the east side of the San Francisco Bay. The bay occupies a depression between the Berkeley Hills to the east and the Montara and other mountains to the west. The depression and hills were formed by two active faults, the San Andreas Fault, west of the San Francisco Bay, and the Hayward Fault, east of the San Francisco Bay. The San Andreas and Hayward Faults are approximately 12 miles west and 5 miles east of the island, respectively.

The stratigraphy beneath Alameda Island and the San Francisco Bay consists of unconsolidated sediments approximately 400 to 500 feet thick at the eastern margin of the bay.

2.4.3.1 ALAMEDA ISLAND GEOLOGY

Alameda Island sedimentary deposits consist of five stratigraphic units (Figure 2-3). From oldest to youngest, they are the Alameda Formation, the Lower San Antonio Formation, the Upper San Antonio Formation, the Merritt Sand Formation, and the Bay Sediment Unit (BSU) (upper bay sediment also referred to as the Young Bay Mud). These sediments overlie bedrock consisting of metamorphosed sandstone, siltstone, shale, graywacke, and igneous bedrock of Jurassic to Cretaceous age, all of which represent the Franciscan Formation (Rogers and Figuers 1991, Norfleet Consultants 1998).

The stratigraphy beneath Alameda Point has been characterized with soil borings advanced to 60 to 70 feet below ground surface (bgs) during previous investigations (TtEMI 1999). Alameda Point cross section locations are shown on Figure 2-4; north-south (Figure 2-5) and east-west (Figure 2-6) cross sections incorporate lithologic information and present generalized (schematic) stratigraphy beneath Alameda Point in the vicinity of IR Site 27.

Most of the sedimentary deposits at Alameda Point are overlain by fill material. The location of IR Site 27 was under water in 1937. The Navy began construction of Seaplane Lagoon in 1937 and the location of IR Site 27 was filled following the construction of the eastern seawall of the lagoon, which forms the western boundary of IR Site 27. The steel sheet pile bulkhead, which underlies Ferry Point Road and the railroad tracks running through IR Site 27, was installed at the same time. Figure 2-7 shows the locations of the eastern seawall and the diagonal bulkhead in relation to the current location of IR Site 27. Figure 2-8 shows Seaplane Lagoon under construction in 1940 with the western portion of IR Site 27 filled to the west of the sheet pile bulkhead. The wedge of open water between the diagonal bulkhead at the eastern boundary of Seaplane Lagoon and the western shoreline of Alameda Island was filled after 1940 and before construction of Building 168 in 1946.

A marsh crust layer (2 to 6 inches thick) exists just beneath the hydraulic fill layer and overlies the Young Bay Mud of the BSU across approximately two-thirds of Alameda Point. The marsh crust has been identified east of IR Site 27, and may be present beneath portions of IR Site 27 (DON 2001).

2.4.3.2 IR SITE 27 GEOLOGY

During the RI field activities, artificial fill material thickness found in IR Site 27 borings was 4 to 8 feet. The subsurface materials encountered in IR Site 27 borings were predominantly poorly sorted sands. Figure 2-9 shows the locations of the borings used for preparing cross sections C–C′ and D–D′, which are presented on Figures 2-10 and 2-11, respectively. The three lithologic units encountered are shown in cross sections on Figures 2-10 and 2-11 and were distinguished as follows:

- artificial fill material
  - primarily poorly graded, fine-, medium-, or coarse-grained sand extending from the surface to depths of 4 to 8 feet bgs, with occasional layers of gravelly sand or clay

- distinguished by brown to olive-brown color and variability between borings
- sometimes contains construction debris including angular gravel, brick fragments, and granite cobbles

- BSU
  - predominantly poorly graded, fine to medium sand (a sandy member of the BSU) with a thickness of 7 to 8 feet and extending to depths of 12 to 16 feet bgs, with lenses or a discontinuous layer of clay (Young Bay Mud member) present in some borings
  - distinguished by dark gray to olive-gray or greenish-gray color and consistency between borings
- Merritt Sand Formation
  - poorly sorted, fine- to medium-grained sand encountered at 12 to 16 feet bgs
  - distinguished by characteristic yellow-brown color and homogeneity

The cross sections prepared with data from borings in IR Site 27 (Figures 2-10 and 2-11) indicate that the contacts between the artificial fill material and the BSU and between the BSU and the Merritt Sand Formation are roughly horizontal or slightly dipping to the south. The total thickness of artificial fill material at the western margin of IR Site 27 (adjacent to Seaplane Lagoon) is likely more than 8 feet bgs (the depth the westernmost RI soil borings) (Figure 2-10). Construction diagrams for the eastern seawall of Seaplane Lagoon and the steel sheet pile bulkhead (Figure 2-7) indicate that the site of the seawall was dredged to a depth of 7 feet below mean low low sea level (mean low low sea level is approximately 3 feet below MSL) (DON 1937a, 1937b). Therefore, the artificial fill layer at the western margin of IR Site 27 is likely to be as much as 22 feet thick (extending from current ground surface at 12 feet above MSL to 10 feet below MSL).

2.4.4 Surface Water Drainage System and Tides

Because there are no naturally occurring streams or ponds at Alameda Point, precipitation evaporates into the atmosphere, infiltrates to groundwater, or runs off into the storm drain network and/or directly into the bay. At IR Site 27, rainfall is likely to cause minor ponding, as well as groundwater infiltration in the limited unpaved areas of the site. Surface runoff flowing directly into the Seaplane Lagoon could also occur.

Seaplane Lagoon is contiguous with the San Francisco Bay. The San Francisco Bay is an estuarine environment in which freshwater from the Sacramento and San Joaquin Rivers mixes with salt water from the Pacific Ocean. The water level in the bay is not affected by seasonal changes, but tidal fluctuations of 4 to 7 feet occur daily.

A groundwater elevation study was conducted as part of the RI at IR Site 27 (BEI 2005) to evaluate the average groundwater flow direction and gradient and to assess the degree, if any, of tidal influence. The study was conducted using three monitoring wells (15 MW1, 15-MW2, and 15-MW3) located between 60 and 120 feet inland from Seaplane Lagoon. Details of the study and results are included in Appendix G of the RI Report (BEI 2005). The maximum groundwater level fluctuation (the difference between the maximum and minimum water levels) measured in wells 15-MW1 and 15-MW2 was 2.57 and 2.90 feet, respectively, indicating a significant tidal influence in these two shoreline wells. The maximum groundwater level fluctuation for well 15-MW3, located 120 feet inland, was 0.10 foot, indicating little tidal influence.

Tidal efficiency is a calculation of the maximum water level response in a well as a percent of high or low tide levels. Calculated tidal efficiency for wells at IR Site 27 ranged from 2 percent in well 15-MW3 (little tidal influence) to over 49 and 50 percent in the two shoreline wells (BEI 2005). These fluctuations indicate the potential for significant changes in the gradient over a 24-hour period. Additionally, there is a potential for reversal of the gradient between high tide and low tide at locations adjacent to the shoreline.

2.4.5 Hydrogeology

This subsection discusses regional hydrogeology at Alameda Point and site-specific hydrogeology at IR Site 27.

2.4.5.1 REGIONAL HYDROGEOLOGY

Alameda Island is underlain by two primary aquifers, the shallow Merritt Sand aquifer that yields brackish to very saline water (20,000 to 35,000 milligrams per liter [mg/L] total dissolved solids [TDS]) (TtEMI 2000b), and the deeper Alameda aquifer that yields freshwater. These aquifers are separated by the San Antonio aquitard, which is approximately 55 to 90 feet thick beneath Alameda Point.

The Merritt Sand unit is a semiconfined aquifer with potentiometric head elevations from 0 to 6 feet above MSL at Alameda Island (TtEMI 1999). Regionally, groundwater recharge occurs in outcrop areas of the Merritt Sand in the southeastern portion of Alameda Point, as well as east of Alameda Point. This groundwater recharge is from irrigation, precipitation, and possibly leaking water supply lines, sewer lines, and storm drains (TtEMI 1999). There is no hydraulic association between the shallow aquifer systems on Alameda Island and the Oakland mainland because of the barrier created by the Oakland Inner Harbor.

The Alameda aquifer is the principal regional aquifer. Depth to the top of the Alameda aquifer ranges from 180 feet bgs at Alameda Point to 220 feet beneath the surface of the sediment in Oakland Inner Harbor. The thickness of the formation is between 230 and 800 feet (Hickenbottom and Muir 1988).

2.4.5.2 ALAMEDA POINT AND IR SITE 27 HYDROGEOLOGY

The shallow hydrostratigraphic units beneath IR Site 27 have been divided into the following three hydrogeologic units:

- upper first water-bearing zone (FWBZ) – artificial fill, sandy member of the BSU, and the Merritt Sand to depths of 15 to 20 feet bgs
- lower FWBZ – Merritt Sand and Upper San Antonio Formation
- regional aquitard – Lower San Antonio Formation, including Yerba Buena Mud

Hydrogeologic characteristics for each water-bearing zone are presented in Table 2-2.

Boring logs from completed RI field activities at IR Site 27 were used to develop site-specific geologic cross sections for IR Site 27, which are presented on Figures 2-10 and 2-11. Site-specific boring logs indicate that there is no continuous semiconfining unit between the upper and lower FWBZ. The clayey member of the BSU (the Young Bay Mud) is absent in many areas of IR Site 27. Table 2-2 provides a comparison between the anticipated thickness of hydrogeologic units and the actual thickness encountered during RI field activities. It is likely that the three lithologic units (artificial fill layer, sandy member of BSU, and Merritt Sand Formation) encountered to depths of 17 feet bgs in borings at IR Site 27 represent a single unconfined FWBZ.

Previous studies indicated that the groundwater table across Alameda Point is typically encountered at 3 to 8 feet bgs in the fill material. A groundwater elevation map for the FWBZ in the southeastern portion of Alameda Point constructed from data collected in the spring of 2004 is reproduced on Figure 2-12. Figure 2-13 provides a groundwater elevation map prepared using IR Site 27 data.

During the RI field activities for IR Site 27, the groundwater table was encountered in soil borings at depths of 4 to 7 feet bgs, with the exception of one boring, 27B08, where saturated materials were encountered at 2 feet bgs. Average depth to water measured in IR Site 27 monitoring wells was 6.9 feet bgs. Hydrographs for water levels measured in IR Site 27 monitoring wells between 2002 and 2004 (Figure 2-14) indicate that wells closest to the shoreline with Seaplane Lagoon (15MJ-MW1, 15-MW1, 15-MW2, and 27MW04) are subject to significant tidal influence, as described. Wells in the central portion of the site (15-MW3, 27MW01, 27MW02, and 27MW03) and in the eastern portion of the site (27MW05 through 27MW08) are subject to little or no tidal influence. Seasonal water level variations are not readily discernable for the one inland well with long-term water level measurements (15-MW3). Water level measurements conducted in 2004 suggest that water levels may be higher in the spring (March 2004) than in other seasons.

As shown on Figure 2-12, groundwater in the southeastern portion of Alameda Point, which contains IR Site 27, generally flows to the west toward Seaplane Lagoon or to the southwest toward San Francisco Bay. Water level measurements collected from newly installed wells during Phases II, III, and IV of the RI activities for IR Site 27 indicate that groundwater flow direction is from the vicinity of Building 168 toward Seaplane Lagoon (from east to west). Figure 2-13 shows groundwater elevation across the expanded IR Site 27 and groundwater flow direction, as indicated by equipotential flow lines, changes across the width of IR Site 27. Flow direction is nearly due west at Building 168, but becomes more northwesterly near the shoreline with Seaplane Lagoon as gradients become oriented perpendicular to the shoreline.

Horizontal gradients at IR Site 27 were estimated using the slope of the equipotential surface developed with water level measurements from IR Site 27 wells. The approximate horizontal gradient at the eastern margin of the site is 0.0016 foot per foot (ft/ft). Adjacent to Seaplane Lagoon, the estimated horizontal gradient is 0.025 ft/ft. Using these horizontal gradients and the average hydraulic conductivity (3.04 feet/day) calculated from IR Site 27 slug test results, groundwater flow velocity at IR Site 27 is between 0.005 and 0.075 foot/day. Table 2-3 presents estimated aquifer hydraulic parameters for IR Site 27 and for OU-2A IR Sites 9 and 13 located to the east of IR Site 27.

Data collected in 2002 and 2003 from wells to the east of IR Site 27 indicated a vertical gradient of 0.03 to -0.06 from the second water-bearing zone to the FWBZ (Shaw 2003). These gradients were calculated using water level measurements collected during OU-2A RI activities in June 2002 and April 2003 from two well pairs: MWD13-2/D19-01, located 400 feet northeast of IR Site 27, and M10B-01/D10B-02, located 700 feet east of IR Site 27. Both of the deeper wells, D19-01 and D10B-02, are screened from 50 to 60 feet bgs in the Merritt Sand. The shallow wells MWD13-2 and MW10B are screened in artificial fill material/BSU from 5 to 15 feet bgs and from 3 to 11 feet bgs, respectively.

2.4.6 Beneficial Use of Groundwater

Groundwater beneath Alameda Point (including IR Site 27) is not used for drinking water, irrigation, or industrial supply. Drinking water is supplied to IR Site 27 and the rest of Alameda Point by the East Bay Municipal Utilities District. The California State Water Resources Control Board (SWRCB) currently classifies groundwater beneath Alameda Point as potentially suitable for municipal or domestic water supply, irrigation, agricultural supply, and industrial supply. A determination of beneficial uses of groundwater for Alameda Point concluded that groundwater in the southeastern region of Alameda Point (including that which underlies IR Site 27) is a Class II aquifer (TtEMI 2000b).

U.S. EPA's Guidelines for Groundwater Classification Under the EPA Groundwater Protection Strategy (U.S. EPA 1988a) are used to classify groundwater as Class I, II, or III. A Class I groundwater is an irreplaceable source of drinking water or is ecologically vital. A Class II groundwater is a current or potential source of drinking water and a water that has other beneficial uses. A Class III groundwater is not a potential source of drinking water and is of limited beneficial use. U.S. EPA classifies groundwater having an existing or potential use as a drinking water supply (Class I or II) using the following criteria: a TDS concentration of less than 10,000 mg/L and a minimum well yield of 150 gallons per day (gpd) or 0.104 gallon per minute (gpm). Under SWRCB Resolution No. 88-63 (SWRCB 1988), all groundwater is considered potentially suitable for municipal or domestic supply unless the TDS content exceeds 3,000 mg/L or a well cannot provide a sustainable yield of 200 gpd or 0.139 gpm. The state identifies other potential beneficial uses of groundwater, including industrial service and industrial supply, agricultural supply, and freshwater replenishment (RWQCB 1995).

In the southeastern portion of Alameda Point, which includes IR Site 27, the FWBZ is connected to a Class II groundwater aquifer (Merritt Sand) that is a potential drinking water source for upgradient off-site wells. Sixty wells located upgradient of the southeastern portion of Alameda Point are screened in the Merritt Sand. These wells are located up to 1 mile east of Alameda Point (i.e., east of Main Street). The nearest domestic well to IR Site 27 is approximately 1,700 feet upgradient. An additional 113 upgradient wells are screened in the Merritt Sand and are located between 1 and 2 miles east-southeast of Alameda Point (TtEMI 2000b). Most of these wells were installed during the 1970s to provide a supplemental source of irrigation water for homeowners on Alameda Island; some of these wells are still in use.

Groundwater from shoreline wells at IR Site 27 has TDS values exceeding 10,000 mg/L. Groundwater from wells inland from the sheet pile bulkhead has TDS values lower than 3,000 mg/L. Groundwater from the shallow inland wells at IR Site 27 has TDS values that meet U.S. EPA and SWRCB criteria for use as a drinking water supply. However, the proximity of the Merritt Sand to San Francisco Bay results in the presence of salt water in the aquifer (TtEMI 2001). Freshwater (TDS less than 3,000 mg/L) at IR Site 27 is limited to a depth of approximately 20 feet bgs (BEI 2005). Because California Water Well Standards, Bulletin 74-81, provides a minimum depth of 20 feet bgs for the annular seal on individual domestic supply wells and 50 feet bgs for community supply wells, such wells would likely be screened in the portion of the aquifer subject to saltwater intrusion. Therefore, although shallow groundwater east of the sheet pile bulkhead at IR Site 27 meets the criteria for a Class II drinking water supply, it is unlikely that drinking water supply wells would be installed at the site. Groundwater west of the sheet pile bulkhead does not meet the requirement for a Class II drinking water supply due to elevated TDS.

2.4.7 Ecological Habitats

No native or natural ecological terrestrial habitat occurs or is expected to occur at IR Site 27. The barren habitat at IR Site 27 offers little value to wildlife; it may serve as a corridor between other habitats or as a place of brief resting, but it is not a significant place of shelter. The following ecological habitats occur at or within a 1-mile vicinity of IR Site 27.

- Barren habitat occurs at IR Site 27 as buildings, roads, and parking and storage areas.
- Urban habitat occurs as ornamental shrubs, trees, and landscaped areas on adjacent land at Alameda Point.
- Nonnative grassland habitat occurs on Alameda Point west of Seaplane Lagoon, to the west of IR Site 27.
- Estuarine habitat occurs at Seaplane Lagoon, to the west of IR Site 27, and at the San Francisco Bay to the south of IR Site 27.

2.5 NATURE AND EXTENT OF CONTAMINATION

This section presents a summary of analytical results from the RI Report (BEI 2005) and describes the characterization of nature and extent of contamination in soil and groundwater at IR Site 27. The evaluation of the nature and extent of soil contamination at IR Site 27 used a combination of data gathered during the RI, the EBS, the Transfer Parcel EDC-12 SI, the post-UST-removal follow-on investigations, and the DGI sampling. The evaluation of the nature and extent of groundwater contamination at IR Site 27 used a combination of data gathered during the RI, the EBS, the post-UST-removal follow-on investigations, the DGI sampling, and the BGMP.

2.5.1 Sources of Contamination

Potential sources of contamination in soil and groundwater at IR Site 27 include the historical and current operations conducted within the boundaries of the site, and, less likely, the release of VOCs to groundwater upgradient of IR Site 27. Historical operations include ship docking, repair, and painting; equipment and material staging and storage; vehicle washdown; and chemical storage and handling in Building 168. Current operations by tenants leasing space at IR Site 27 are generally similar to historical operations by the Navy.

2.5.2 Analytical Results From Soil Samples

Very limited soil contamination is present at IR Site 27. Analytes exceeding residential soil preliminary remediation goal (PRG) screening criteria include two PAHs, benzene and tetraethyl lead (in one sample each), and three metals. The RI identified the following chemicals of potential concern (COPCs) in soil at IR Site 27:

- halogenated VOCs with limited distribution, low concentrations (all with concentrations below residential soil PRGs), and low frequency of occurrence (reported in less than 10 percent of all samples)
- fuel-related VOCs with scattered distribution and generally low concentrations (all with concentrations below residential soil PRGs except one benzene result [660 μg/kg] reported for a sample collected during the EBS)
- the PAHs benzo(a)pyrene and dibenz(a,h)anthracene at concentrations (maximum 170 and 140 μg/kg, respectively) exceeding residential soil PRGs, but with limited distribution and frequency of occurrence (5 of 64 soil samples, a frequency of less than 10 percent); and reported concentrations below residential soil PRGs for all other PAHs
- PCBs with limited distribution and low concentrations (reported in two samples and at concentrations [18 and 110 μg/kg] below the residential soil PRG)
- tetraethyl lead reported in one sample (650 μg/kg) collected during the EBS; subsequent confirmation sampling reported this compound not present at concentrations exceeding detection limits
- arsenic at concentrations (maximum 8.8 milligrams per kilogram [mg/kg]) exceeding the residential soil PRG, but comparable to Alameda Point background concentrations (95th quantile equal to 9.1 mg/kg)
- iron and thallium at concentrations (maximum 56,400 and 6.9 mg/kg, respectively) exceeding PRGs, but with limited distribution and low frequency of occurrence (reported in less than 10 percent of samples)

2.5.3 Analytical Results From Groundwater Samples

Analytical results for TDS demonstrate that shoreline wells (west of the sheet pile bulkhead that underlies Ferry Point Road) have elevated TDS values as the result of contact with the waters of San Francisco Bay. For groundwater east of the sheet pile bulkhead with low TDS levels, maximum contaminant levels (MCLs) are applicable comparison criteria. However, groundwater west of the sheet pile bulkhead is not potable and only the California Toxics Rule (CTR) surface water criteria or NRWQC are applicable comparison criteria. The contaminants in groundwater at IR Site 27 are predominantly chlorinated VOCs. The VOCs most frequently reported at concentrations exceeding comparison criteria (MCLs or CTR surface water criteria) were cis-1,2-dichlorethene (DCE) and vinyl chloride, which are products of active reductive dechlorination of tetrachloroethene (PCE) and trichlorethene (TCE). Analytes exceeding regulatory screening criteria included 11 VOCs, 6 PAHs, and metals.

The RI Report identified the following COPCs in groundwater from shoreline wells at IR Site 27:

- four PAHs at concentrations exceeding CTR surface water criteria for human-health consumption of organisms (benz[a]anthracene, benzo[a]pyrene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene); each was reported once at a concentration exceeding the detection limit
- copper, lead, mercury, nickel, and zinc reported at concentrations exceeding CTR surface water criteria but comparable to Alameda Point background concentrations
- five chlorinated VOCs (1,1-dichloroethane [DCA]; cis-1,2-DCE; PCE; TCE; and vinyl chloride) and one fuel-related VOC (benzene) at concentrations exceeding MCLs; however, due to high TDS in groundwater at the shoreline, MCLs are not applicable comparison criteria for shoreline groundwater

The RI Report identified the following COPCs in groundwater from inland wells at IR Site 27:

- four chlorinated VOCs at concentrations exceeding drinking water MCLs, including cis-1,2-DCE; trans-1,2-DCE; TCE; and vinyl chloride
- one fuel-related VOC (MTBE) at concentrations (23 and 38 micrograms per liter [μg/L]) exceeding the federal drinking water MCL for two samples collected in 2004
- arsenic at concentrations exceeding the federal MCL (10 μg/L), but below the California MCL (50 μg/L)

Table 2-4 compares the number and kinds of COPCs reported in groundwater in shoreline wells and inland wells, and also compares COPCs in wells located within and outside of the chlorinated VOC plume. Table 2-4 demonstrates that:

- more of the COPCs are organic compounds than metals,
- more chlorinated VOCs exceed MCLs than fuel-related VOCs, and
- the only metals with concentrations that exceed CTR surface water criteria in shoreline wells are metals that are present at concentrations comparable to Alameda Point background concentrations.

Table 2-5 presents the maximum reported concentrations of analytes exceeding CTR surface water criteria at the shoreline wells and MCLs (state and/or federal) at the inland wells. Table 2-5 also compares the maximum concentrations of analytes exceeding comparison criteria prior to and during the period of the RI.

2.5.3.1 SHORELINE WELLS

Three existing monitoring wells (15-MW1, 15-MW2, and 27MW04) and three monitoring wells abandoned during the RI (15MJ-MW1, 37-MJ-MW-9, and 37-MJ-MW10) are within 30 to 40 feet of the shoreline with Seaplane Lagoon. All six of these wells had TDS concentrations (2,380 to 27,900 mg/L) consistent with intermixing of freshwater with the salt water of the San Francisco Bay. Wells 15-MW1 and 15-MW2, which were part of RI water level fluctuation testing, were found to be subject to tidal influence. Additionally, all of these wells are west of the steel sheet pile bulkhead underlying Ferry Point Road that was installed during construction of Seaplane Lagoon.

Five metals (arsenic, beryllium, iron, molybdenum, selenium) were reported in IR Site 27 groundwater samples at concentrations statistically different from Alameda Point background concentrations (BEI 2005). In 23 of 45 samples collected from shoreline wells, one or more of these metals were present at a concentration exceeding the Alameda Point background 95th quantile. Of these five metals, only arsenic and selenium have CTR surface water criteria, and neither of these metals was reported at a concentration exceeding CTR surface water criteria in samples from shoreline wells. Five metals (copper, lead, mercury, nickel, and zinc) were reported at concentrations exceeding CTR surface water criteria; however, concentrations of these metals were not statistically different from Alameda Point background concentrations.

2.5.3.2 INLAND WELLS

Eight monitoring wells (15-MW3, 27MW01, 27MW02, 27MW03, 27MW05, 27MW06, 27MW07, and 27MW08) are located on the inland side of the steel sheet pile bulkhead. These wells have TDS concentrations (322 to 783 mg/L) consistent with freshwater (Freeze and Cherry 1979). Well 15-MW3, which was part of the RI tidal influence testing and is the closest inland well to Seaplane Lagoon, was found to be subject to little or no tidal influence.

During RI sampling (2002 through 2004), chlorinated VOCs were reported at concentrations exceeding MCLs in samples from inland wells 15-MW3, 27MW01, 27MW02, 27MW03, and 27MW06, and the fuel-related VOC MTBE was reported at concentrations exceeding the MCL in samples from well 15-MW3.

Arsenic was the only metal present at a concentration exceeding the Alameda Point background 95th quantile in samples collected from inland wells, and was reported only in wells located within the boundaries of the chlorinated VOC plume. Also, arsenic was reported at concentrations exceeding the federal MCL.

2.5.3.3 CHLORINATED VOLATILE ORGANIC COMPOUND PLUME

Chlorinated VOCs (primarily TCE and active reductive dechlorination products cis-1,2-DCE and vinyl chloride) are present in groundwater throughout the central portion of IR Site 27, from beneath Building 168 in the east to shoreline wells 15-MW1, 15-MW2, and 27MW04 in the west. There appear to be two areas with higher concentrations of chlorinated VOCs: 1) the vicinity of well 15-MW3 and Structure 449 (a sanitary sewer lift station), located just east of Ferry Point Road and east of the sheet pile bulkhead, and 2) west of Building 168 in the vicinity of well 27MW06. Figure 2-15 shows the horizontal extent of the chlorinated VOC plume as delineated by vinyl chloride isoconcentration contours.

The distribution of chlorinated VOCs in groundwater is generally consistent with the distribution of chlorinated VOCs in soil gas and in soil. However, there does not appear to be a current source of VOCs in soil contributing to the VOC concentrations in groundwater. The low ratio of PCE and TCE to reductive dechlorination products (cis-1,2-DCE and vinyl chloride) suggests that the chlorinated VOC plume represents a release to groundwater that has had time to undergo anaerobic degradation. The source of this release could be historical activities such as washdown of a solvent spill in Building 168, or, less likely, migration of a slug of VOCs in groundwater from a release upgradient of IR Site 27. Structure 449 (a sanitary sewer lift station) is also located within the area of higher VOC concentrations, at well 15-MW3. However, current groundwater data indicate that the horizontal extent of the chlorinated VOC plume is confined to an area within the expanded boundaries of IR Site 27.

The distribution of chlorinated VOCs shown on Figure 2-15, with the highest concentrations in the upgradient portion of the plume in the vicinity of monitoring well 27MW06 and extending downgradient from this location, is most consistent with a release originating at or near Building 168. The upgradient plume center is located roughly between two of the 30-foot-wide rollup doors on the western side of Building 168. If VOCs had been used or spilled on floors in the building, washdown of the floors could have resulted in flushing of diluted VOCs out through the doors and onto the area of the railroad siding adjacent to the western side of the building. It is likely that only diluted concentrations of these VOCs were released because chlorinated VOC concentrations in groundwater at the center of the plume (maximum 230 μg/L) are a small fraction (less than 0.2 percent) of the concentrations that represent the effective solubilities of TCE (1,100,000 μg/L) and PCE (160,000 μg/L).

Figure 2-16 shows the total mass of VOCs in micromoles per liter in groundwater at IR Site 27. The figure illustrates that molar concentrations of VOCs were highest in the vicinity of boring 27B29. Although the concentration of cis-1,2-DCE in μg/L at boring 27B22 was higher than at boring 27B29, the molar mass results indicate that reductive dechlorination in the vicinity of boring 27B22 has not yet progressed to vinyl chloride.

VOC concentrations in shoreline wells have decreased significantly since 1994. Decreases in TCE and cis-1,2-DCE were accompanied by corresponding increases in vinyl chloride concentrations. Based on the spring 2005 monitoring results, concentrations of vinyl chloride have now attenuated to nondetectable levels (ITSI 2005). These observations suggest that the natural attenuation process is at or near completion in the shoreline groundwater. The sheet pile bulkhead, located beneath Ferry Point Road, may be a barrier that retards migration of VOCs in groundwater, as evidenced by higher VOC concentrations on the east side of the bulkhead.

Groundwater data collected at 20 feet bgs indicate that the vertical distribution of chlorinated VOCs in groundwater is generally limited to shallow depths of less than 20 feet bgs. The RI Report (BEI 2005) concluded that there is no significant downward migration of chlorinated VOCs at IR Site 27. To demonstrate the vertical distribution of chlorinated VOCs (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, vinyl chloride, and 1,1-DCA) in groundwater at concentrations exceeding MCLs, a vertical profile (Figure 2-17) through the center of the plume along cross section C-C′ was prepared. The profile displays the summed concentration of the six VOCs at each sampling point. For monitoring well samples collected during the RI and BGMP (2002 through 2004), the maximum concentrations reported were summed for each well location. Individual concentrations of the six chlorinated VOCs for samples collected at each location are presented on Figure 2-15.

The vertical profile shows a reduction in chlorinated VOC concentrations from more than 100 μg/L at 10 feet bgs to either less than 0.5 μg/L or below detection limits at 20 feet bgs. Figure 2-17 includes the approximate location of the saline water interface (at which less dense freshwater sits atop salt water) at Alameda Point (TtEMI 2000b). The presence of a saline layer underlying Alameda Point was documented by the presentation of TDS data collected from wells throughout Alameda Point as part of the Determination of the Beneficial Uses of Groundwater study conducted in 2000 (TtEMI 2000b). This interface, which is approximately 15 to 20 feet bgs in the vicinity of Building 168, appears to limit the VOC plume to shallow depths. A comparable situation has been observed for vertical distribution of chlorinated VOC concentrations across a saline interface at Naval Air Station (NAS) North Island, California (IT 2001b). At NAS North Island, in areas of high VOC concentrations above the interface, concentrations decreased by 80 percent at 4 feet below the interface, and were not detectable at 10 feet below the interface. Results for groundwater samples collected at IR Site 27 are consistent with the NAS North Island findings for vertical distribution of chlorinated VOCs across a freshwater/saline water interface.

Concentrations of fuel-related VOCs in groundwater were generally higher in groundwater samples collected during previous investigations. MTBE is the exception; although MTBE concentrations reported in groundwater samples collected during the period of the RI field activities (2002 through 2004) did not exceed federal MCLs, two groundwater samples collected subsequently from well 15-MW3 under the BGMP (in June and November 2004) had reported MTBE concentrations of 23 and 38 μg/L, respectively. These MTBE values were higher than the previous maximum value (9.2 μg/L) that was reported from this well and exceeded the federal MCL (13 μg/L). These elevated MTBE values likely represent gasoline associated with vehicle parking in the vicinity of well 15-MW3.

2.6 FATE AND TRANSPORT OF CONTAMINANTS

The active reductive dechlorination and possible transport of VOCs in groundwater are the most significant aspects of the fate and transport of contaminants at IR Site 27. The presence of products of active reductive dechlorination of PCE and TCE indicates a potential for continued degradation of chlorinated VOCs.

The presence of arsenic at concentrations exceeding MCLs in groundwater samples from well 15-MW3 likely represents localized mobilization of arsenic present in soil at background concentrations. Mobilization of arsenic from soil to groundwater is likely due to changes in geochemistry (more reducing conditions) associated with the biodegradation of VOCs in groundwater. Upon completion of the dechlorination of VOCs, localized geochemical conditions would be expected to return to more oxidizing conditions and arsenic concentrations in groundwater would be reduced.

2.6.1 Fate of Organic Compounds

The persistence or mobility of organic compounds is governed by their physicochemical properties, transformation mechanisms, and the properties of the soil that act on them.

Chlorinated VOCs (cis-1,2-DCE, trans-1,2-DCE, TCE, and vinyl chloride) are the primary chemical group impacting groundwater at IR Site 27; chlorinated VOCs are simple organic compounds bonded with chlorine. In the subsurface, depending on conditions (e.g., the presence of nutrients, microorganisms, a reducing environment), chlorinated VOCs typically undergo reductive dechlorination, a biological process that breaks down chlorinated ethenes in groundwater.

The chlorinated ethenes PCE and TCE degrade in reducing environments to form 1,2-DCE or 1,1-DCE (the most common intermediate is cis-1,2-DCE), and vinyl chloride. The presence of vinyl chloride, cis-1,2-DCE, and trans-1,2-DCE in groundwater at IR Site 27 indicates that reductive dechlorination of PCE and TCE is occurring. Continued dechlorination of 1,2-DCE may initially cause vinyl chloride concentrations in groundwater to increase over time. However, vinyl chloride can be rapidly degraded (oxidized) under aerobic (in the presence of oxygen) conditions to ethene, carbon dioxide, water, and chlorine, with ethene further degraded to ethane (U.S. EPA 1998). Additionally, in an anaerobic (in the absence of oxygen) environment, microorganisms known as dehalococcoides and several similar organisms can completely dechlorinate TCE, DCE, and vinyl chloride (Major 2002). At least one strain of these microorganisms is present at Alameda Point (Koenigsberg et al. 2002, 2003; Richardson et al. 2002).

Monitoring of dissolved gases under the BGMP confirms the presence of ethene and ethane, which are products of the dechlorination of vinyl chloride in groundwater at IR Site 27; this indicates that the breakdown of vinyl chloride is occurring.

2.6.2 Transport Mechanisms

A summary of the possible transport mechanisms for chemicals of interest considered for IR Site 27 and the level of risk associated with each pathway follows.

- Horizontal transport of chemicals of interest due to groundwater flow is likely; because the site is adjacent to Seaplane Lagoon, it is likely the concentrations of VOCs reported in groundwater in the shoreline wells will reach the harbor, although at reduced concentrations. Arsenic concentrations exceeding MCLs are present in groundwater from inland well 15-MW3 only and does not appear to be migrating to the shoreline. Based on the results of the ecological risk assessment (ERA) (BEI 2005), VOCs and arsenic are not a concern for aquatic receptors.

- Vertical transport of chlorinated VOCs is not considered a significant transport mechanism, based on VOC data and the approximate location of the saline interface.

- Transport of impacted groundwater by migration along or through subsurface conduits is considered possible at IR Site 27 due to the number of buried utilities (Figure 2-1). However, storm drain investigations have ruled out storm drains and storm drain bedding as preferential pathways.

- Volatilization of VOCs from groundwater to soil gas and from soil gas to ambient air or indoor air is considered a possible transport mechanism at IR Site 27. This mechanism is not significant at this time because of surface cover. If the pavement were removed from the site during and after redevelopment, this could become a significant pathway. Based on human-health risk assessment (HHRA) results, inhalation of indoor air from this pathway represents a total cancer risk of 3×10^{-5} (U.S. EPA) or 4×10^{-6} (Cal/EPA), i.e., within the risk management range. U.S. EPA cancer risk based on modeling vapor migration to indoor air was calculated both by using concentrations of VOCs in groundwater and by using concentrations of VOCs in soil gas samples, and the results were compared and detailed in Appendix K of the RI Report (BEI 2005). The U. S. EPA residential indoor air cancer risks based on soil gas (3×10^{-5}) are slightly higher than those calculated using groundwater data (2×10^{-5}). Site-specific soil physical parameters collected as input for the Johnson and Ettinger model were found to be virtually the same as model default values. However, the model-calculated vapor permeability of 1.10×10^{-7} square centimeters (cm^2) is substantially more protective than the field-measured permeability of 3.3×10^{-9} cm^2. Because the indoor air concentration was higher (and therefore represents a greater risk) using the model default calculations, model default values were used rather than site-specific values.

- Tidal fluctuation at the shoreline and seasonal fluctuations of the groundwater table may be significant mechanisms to promote migration of chemicals of interest between vadose zone soil and groundwater. However, migration of chemicals of interest in the subsurface caused by infiltrating groundwater is not a primary transport mechanism because of surface cover and minimal presence of VOCs in vadose zone soil. Most of IR Site 27 is paved, including the locations of railroad spurs.

- Particulate dispersion is not a primary transport mechanism at this time because of surface cover; however, even if the site is not paved when it is redeveloped, this would not be a primary transport mechanism due to the general absence of chemicals of interest in soil. Based on HHRA results, this pathway does not present a significant risk.

2.7 RISK ASSESSMENT

A conceptual site model (CSM) was used to identify ways in which human or ecological receptors might come into contact with chemicals of interest in soil, soil gas or groundwater at IR Site 27 now or in the future. This CSM identified the physical characteristics, distribution, and migration pathways of chemicals of interest at IR Site 27.

The FWBZ is in direct contact with the salt water of Seaplane Lagoon. The water in the shoreline wells is under tidal influence and has TDS and common ion concentrations consistent with saltwater mixing. In water from the inland wells, TDS and common ion concentrations are consistent with freshwater. The location of the sheet pile bulkhead is the dividing point between shoreline and inland wells.

The primary chemicals of interest at IR Site 27 are chlorinated VOCs, which are present in groundwater and soil gas throughout the site. Additional chemicals of interest include PAHs and arsenic, which were reported in a limited number of groundwater samples, and PAHs and two metals (iron and thallium), which are present in soil. Arsenic, iron, and thallium were reported in soil at concentrations exceeding their respective PRGs. Arsenic concentrations in groundwater exceeded the Alameda Point background 95th quantile and the California MCL in a limited area encompassing wells 15-MW3, 27MW01, and 27MW02. These arsenic concentrations appear to be related to the VOC plume in this area. Specifically, geochemical changes in the saturated zone resulting from biodegradation of VOCs in groundwater may be mobilizing the transfer of background concentrations of arsenic from soil to groundwater.

Potential migration pathways to air include migration of VOCs from groundwater, soil gas, and soil to indoor and outdoor air. Potential migration pathways to off-site receptors include the discharge of groundwater to Seaplane Lagoon.

Groundwater is not used for drinking water at the site, and is not anticipated to be used in the future, primarily because of the likelihood of saltwater intrusion with sustained pumping.

2.7.1 Human-Health Risk Assessment

Routes of potential exposure associated with residential, occupational, and construction scenarios at IR Site 27 that are considered complete include the following.

- **Residential**. Residential exposure routes include incidental soil ingestion, dermal contact with soil, inhalation of particulates and vapors from soil in outdoor air, inhalation of vapors from soil and groundwater in indoor air, ingestion of groundwater, inhalation and dermal contact with groundwater while showering, and ingestion of produce grown in local soil.
- **Occupational.** Occupational exposure routes (for office workers) include incidental soil ingestion, dermal contact with soil, inhalation of particulates and vapors from soil in outdoor air, and inhalation of vapors in indoor air.

- **Construction.** Construction exposure routes (for construction workers) include incidental soil ingestion, dermal contact with soil, and inhalation of particulates from soil and vapors in outdoor air.

Future site use as a marina could also include recreational activities by children and adults. The exposure pathways for recreational users include direct contact (ingestion, inhalation, dermal contact) with chemicals in soil. The residential exposure scenario for direct contact with soil is considered protective of recreational users because exposure by potential recreational users is expected to be less than that for residents.

U.S. EPA has established a cancer risk management range from 10^{-4} to 10^{-6} for making decisions on whether remediation is warranted. Risks below 10^{-6} are considered acceptable. Risks within the risk management range may be acceptable, depending on decisions made by risk managers. Risks above 10^{-4} typically warrant additional investigation or remediation. The noncancer health risk associated with exposure to a chemical is called the hazard quotient (HQ) or a hazard index (HI) for cumulative noncancer risk. The target risk level for HQ and HI values is 1.

The results of the HHRA are presented in Table 2-6, which provides a summary of the total reasonable maximum exposure (RME) risk assessment results and HIs for future residential, occupational, construction receptors for exposure to sitewide COPCs in soil and groundwater. For hypothetical future residents, U.S. EPA and Cal/EPA RME cancer risks are above the risk management range for two exposure pathways: ingestion of groundwater and dermal contact with groundwater while showering.

The U.S. EPA incremental cancer risks associated with direct contact with soil are at or below the minimal risk management level of 10^{-6} when the risk for arsenic, which is reported at concentrations comparable to background concentrations in soil, is subtracted from the total risk. The Cal/EPA incremental cancer risk is 2×10^{-6}. The HI for ingestion of soil is 3 (Table 2-6), associated with several metals with individual HQ values of less than 1. The exposure point concentration (EPC) for lead (11.4 mg/kg) is well below the site-specific residential PRG (184 mg/kg).

The RME residential risk for direct contact with soil (ingestion, inhalation and dermal contact) is considered protective of a recreational user in the future. A recreational user could be exposed through these pathways but at a lower rate than assumed for a resident. The incremental RME risk for these pathways for a resident is 10^{-6} and the risk to a recreational user would be lower. For occupational and construction scenarios, the cancer risks and noncancer hazard values are within the risk management range.

The primary chemicals contributing to cancer risk in groundwater are arsenic, vinyl chloride, and PAHs. The majority of the risk in soil is associated with arsenic. However, arsenic concentrations in soil were comparable to the Alameda Point background concentrations. The primary chemical contributing to risk in soil gas is TCE. The primary chemicals contributing to noncancer risk (hazard index) are arsenic in groundwater and iron in soil.

2.7.2 Ecological Risk Assessment

Chemicals of potential ecological concern (COPECs) for aquatic receptors at San Francisco Bay were identified using analytical data collected from groundwater monitoring wells, and included all chemicals that were reported at least once. As a conservative measure, concentrations of COPECs for aquatic receptors were estimated using maximum concentrations of COPECs in groundwater; these maximum concentrations were compared to CTR surface water criteria continuing concentrations (CCCs). Therefore, the ERA provides a protective overestimate of the actual risk of adverse ecological effects at IR Site 27.

Based on sitewide groundwater concentrations, there is low-to-negligible potential ecological risk from reported COPECs for aquatic receptors, even if groundwater were to enter Seaplane Lagoon at the maximum reported concentrations. The ERA identified a potential for VOCs to exceed the CTR screening values for human-health consumption of organisms if aquatic life organisms were to consume chemicals present in groundwater that reaches Seaplane Lagoon. The VOCs at IR Site 27 likely represent a low potential ecological risk due to low HQs, infrequent occurrence, concentrations below CTR surface water criteria for human-health consumption of organisms in shoreline wells, and nonpersistence in aquatic environments. Therefore, the ERA concluded that, due to the low or negligible risk for aquatic life from reported COPECs, no further investigation or assessment of ecological risk for groundwater reaching surface water at IR Site 27 is recommended.

Due to the absence of substantial terrestrial habitat at the site, the conceptual model overestimates the use of the site by potential ecological receptors. Future use plans do not include substantial terrestrial habitat; therefore, the potential ecological risk from future site conditions is also likely overestimated. Due to the overestimation of the potential ecological risk at the site presented in the screening-level ERA, and the unlikelihood of future development of terrestrial habitat at the site, no further investigation or assessment of ecological risk for soil at IR Site 27 was recommended (BEI 2005).

2.8 REMEDIAL INVESTIGATION SUMMARY AND CONCLUSIONS

The data developed during the RI were used to conduct a site-specific baseline HHRA and a screening-level ERA (BEI 2005). These risk assessments characterized the current and potential threats that may be posed by contaminants that could migrate to groundwater or surface water, be released to air, leach through soil, remain in soil, or bioaccumulate in the food chain.

The analyses of contaminants during the RI and the risk assessments were designed to help establish acceptable exposure levels for use in developing appropriate remedial alternatives in the FS.

The results from previous Navy investigations and from the RI identified the following areas of potential concern at IR Site 27:

- groundwater containing VOCs and dissolved arsenic at concentrations exceeding drinking water criteria; VOCs and dissolved arsenic represent the majority of risk associated with the site
- soil containing low concentrations of chemicals that can migrate by particulate dispersion from unpaved surfaces via airborne dust, surface water transport (runoff), direct human contact, and other mechanisms (not significant unless pavement is removed in the future); these low concentrations of chemicals in soil do not represent a significant risk at the site

Potential sources of the COPCs in soil and groundwater at IR Site 27 include historical and current operations conducted within the boundaries of the site. A less likely potential source is the migration of a hypothetical slug of VOCs released to groundwater upgradient of IR Site 27. VOCs have been reported in groundwater samples from IR Sites 19 and 22. However, reported VOC concentrations at these sites do not appear likely to indicate an off-site source. Historical operations included ship docking, repair, and painting; equipment and materials staging and storage; vehicle washdown; and chemical storage and handling in Building 168. Current operations are generally similar to historical operations.

The planned future use of IR Site 27 is mixed use, including marina and inner harbor areas that will allow residential, recreational, commercial, and light industrial use. For the occupational and construction scenarios, the cancer risk and noncancer hazard values are within or below the NCP risk management range. For hypothetical future residents, U.S. EPA and Cal/EPA RME cancer risk values are above the risk management range of 10^{-6} to 10^{-4} or have a noncancer HI value of greater than 1 for the following exposure pathways (listed in order of decreasing risk):

- dermal contact with groundwater while showering
- ingestion of groundwater
- ingestion of soil (only for noncancer HI values)

Recreational risks would be even lower for all pathways because exposure under the recreational scenario would also be lower. In addition, the EPC for lead is well below the site-specific residential PRG.

Most of the risk in groundwater (greater than 90 percent) is associated with ingestion of arsenic and vinyl chloride, and dermal contact with two PAHs. PAHs are limited in extent and only reported in 1 of 14 groundwater samples. Arsenic concentrations exceeding the Alameda Point background 95th percentile (20.4 μg/L) are limited to groundwater samples collected from one monitoring well (15-MW3). In soil, most of the risk for direct contact with soil (ingestion, inhalation and dermal contact) is associated with arsenic. Arsenic concentrations in soil are comparable to background concentrations and the incremental risk associated with arsenic in soil is at or below the risk level of 10^{-6}.

The screening-level ERA assessed ecological terrestrial receptors and aquatic receptors. The results of the screening-level ERA indicated negligible ecological risk to terrestrial wildlife receptors from soil and negligible risk to benthic fish and invertebrates from groundwater.

The RI Report recommended progressing to an FS to address the presence of chlorinated VOCs in groundwater that exceed drinking water criteria at IR Site 27.

No further action was recommended for PAHs and arsenic in groundwater due to limited distribution of elevated concentrations of these chemicals. Although PAHs were the primary risk drivers in groundwater (based solely on the groundwater ingestion pathway), the distribution of these chemicals is limited to three wells with TDS values ranging from 11,000 to 27,000 mg/L. These three wells are located in the western portion of IR Site 27 where groundwater does not meet the regulatory requirements for a drinking water source. Arsenic, another risk driver in groundwater, was present at an elevated concentration in a limited area and is likely an artifact of geochemical conditions resulting from dechlorination of VOCs.

No further action was recommended for metals in soil. Arsenic was reported at concentrations comparable to Alameda Point background concentrations and the distribution of iron in soil was limited.

No further investigation or assessment of ecological risk for soil at IR Site 27 was recommended. The absence of planned current or future substantial terrestrial habitat at the site indicates little current or potential likelihood of use of the site by ecological receptors. Additionally, for aquatic life in Seaplane Lagoon, the ERA identified only low or negligible risk associated with COPECs in soil and groundwater at IR Site 27.

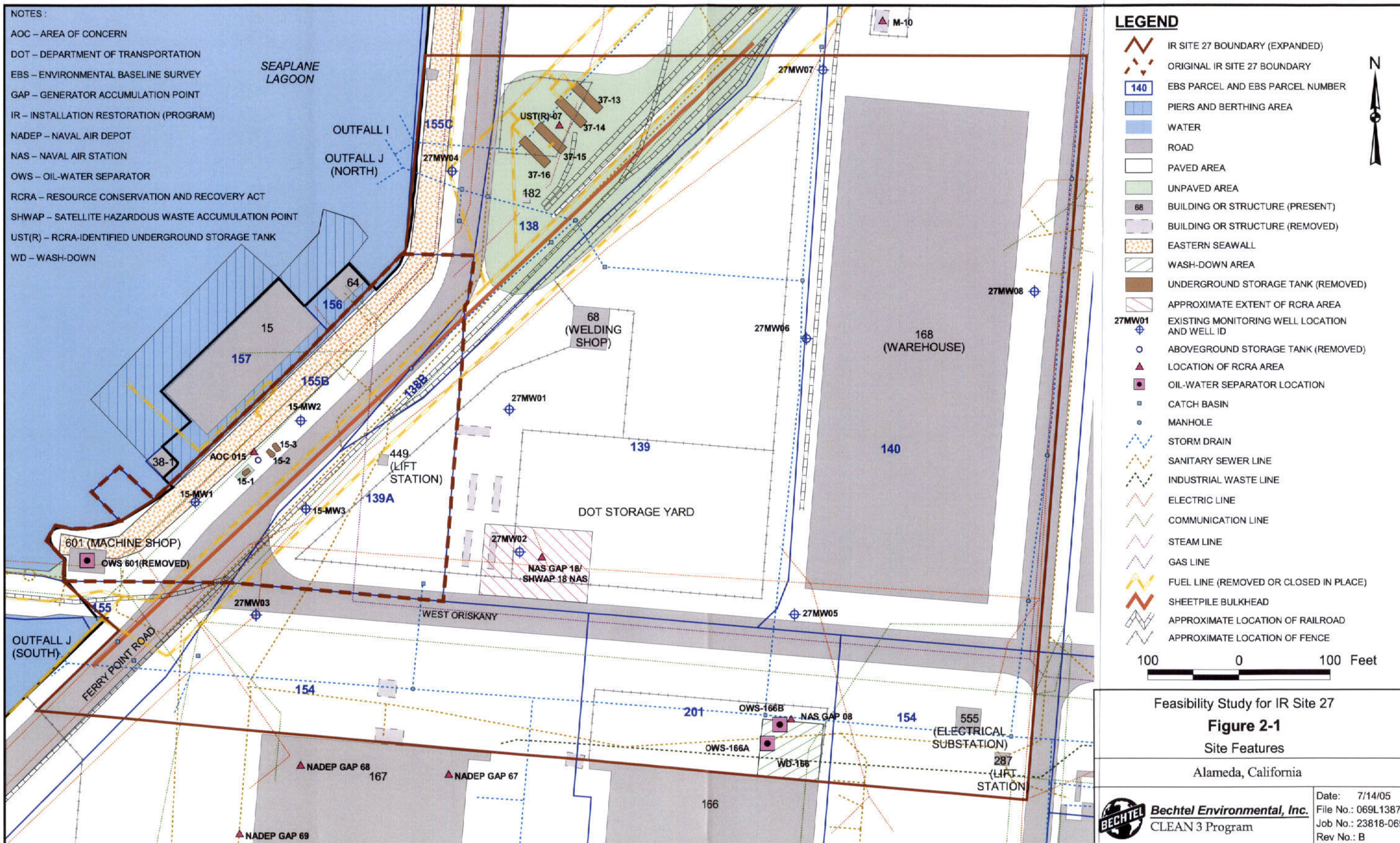
The Navy recommended that an FS be undertaken to evaluate options to address the contamination at IR Site 27 representing a risk to human health under the residential future-use scenario. The FS considers the future land use in evaluating these options. The Navy's preliminary RAO for this area is to remediate or manage the site in order to reduce risks to levels within the risk management range, i.e., to levels between 10^{-6} and 10^{-4} for cancer risk, and to levels representing an HI of less than 1 for noncancer adverse health effects.

The Navy also deferred the sampling and analysis required to fill two data gaps (groundwater in the vicinity of a washdown area, which includes two OWSs, and PCBs in the vicinity of the electrical substation) until the remedial design/remedial action phase of the project (BEI 2005).

FIGURES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006

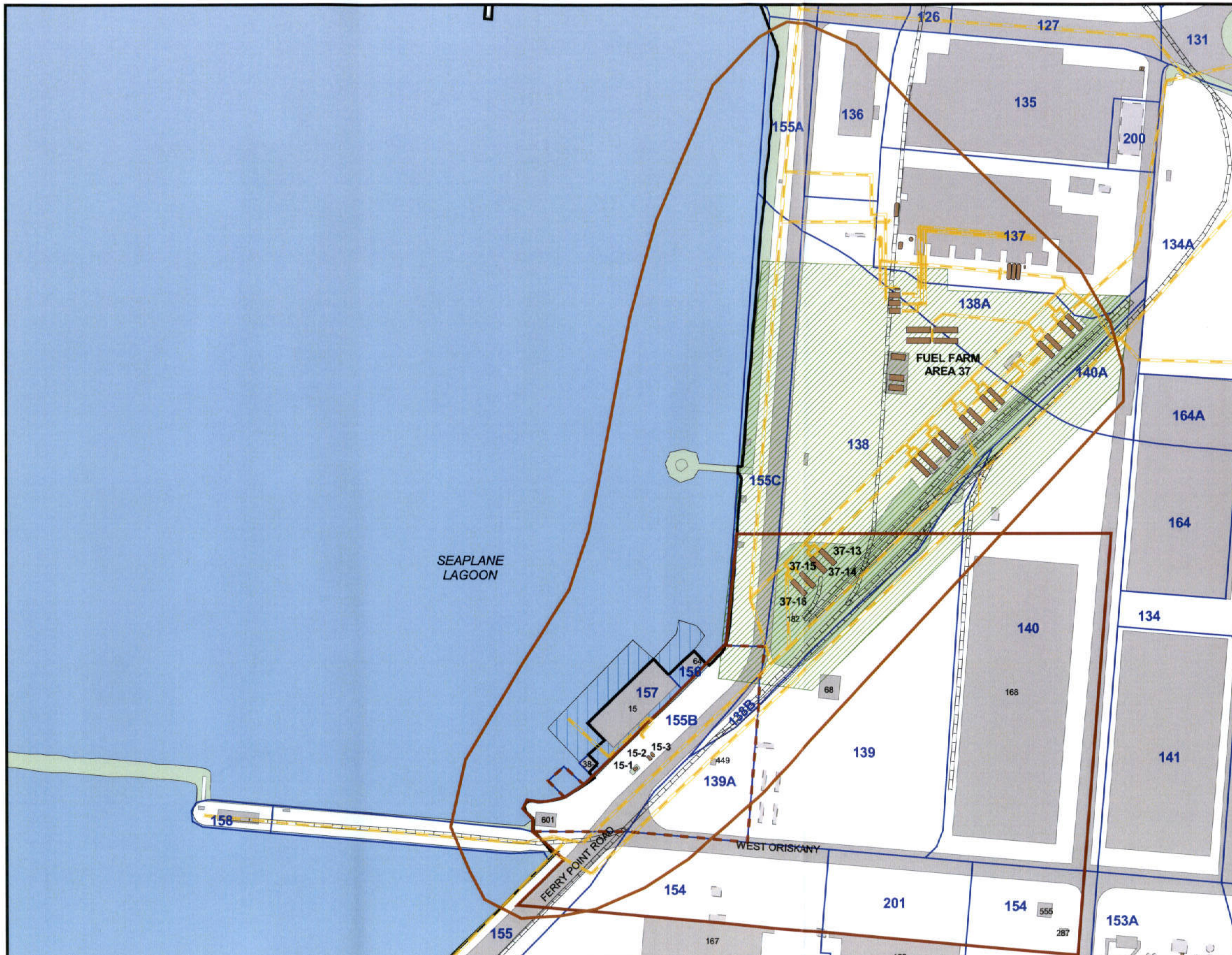


Feasibility Study for IR Site 27

Figure 2-1

Site Features

Alameda, California



LEGEND

- IR SITE 27 BOUNDARY (EXPANDED)
- ORIGINAL IR SITE 27 BOUNDARY
- 140 EBS PARCEL AND EBS PARCEL NUMBER
- PIERS AND BERTHING AREA
- WATER
- ROAD
- PAVED AREA
- UNPAVED AREA
- 68 BUILDING OR STRUCTURE (PRESENT)
- BUILDING OR STRUCTURE (REMOVED)
- CORRECTIVE ACTION AREA 11B
- UNDERGROUND STORAGE TANK (REMOVED)
- APPROXIMATE LOCATION OF RAILROAD
- FUEL LINE (REMOVED OR CLOSED IN PLACE)
- APPROXIMATE BOUNDARY OF FUEL PIPELINE REMOVAL AREA 4

NOTES :

EBS – ENVIRONMENTAL BASELINE SURVEY

IR – INSTALLATION RESTORATION (PROGRAM)

UST – UNDERGROUND STORAGE TANK

N

200 0 200 Feet

Feasibility Study for IR Site 27

Figure 2-2

Locations of USTs and Fuel Lines Removed or Closed in Place

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 7/14/05
File No.: 069L13878
Job No.: 23818-069
Rev No.: B

TOP OF UNIT (IN FEET BELOW GROUND SURFACE)	STRATIGRAPHIC UNITS			HYDROGEOLOGIC UNITS
0	FILL (UNDERLAIN BY MARSH CRUST AT SOME LOCATIONS)			WATER TABLE AQUIFER - NOT A PRIMARY AQUIFER (FWBZ)
5-15	BAY SEDIMENT UNIT (BSU)			AQUITARD
20-50	MERRITT SAND FORMATION			MERRITT SAND AQUIFER - A PRIMARY AQUIFER (SWBZ)
60-80	SAN ANTONIO FORMATION	UPPER UNIT	ALLUVIAL DEPOSITS	
90-120		LOWER UNIT	YERBA BUENA MUD	AQUITARD
			OTHER ESTUARINE DEPOSITS	
100-200	ALAMEDA FORMATION	UPPER CLAY-RICH PORTION		
180-220		ALLUVIAL DEPOSITS		ALAMEDA AQUIFER - PRINCIPAL REGIONAL AQUIFER
400-800	FRANCISCAN FORMATION			

NOTES:

FWBZ - FIRST WATER-BEARING ZONE
SWBZ - SECOND WATER-BEARING ZONE

SOURCE:

TETRA TECH EM INC. 1999. OU-2 RI REPORT DRAFT, ALAMEDA POINT, ALAMEDA, CALIFORNIA. PREPARED FOR THE UNITED STATES DEPARTMENT OF THE NAVY, ENGINEERING FIELD ACTIVITY WEST, NAVAL FACILITIES ENGINEERING COMMAND, SAN BRUNO, CALIFORNIA. JUNE 29.

Feasibility Study for IR Site 27

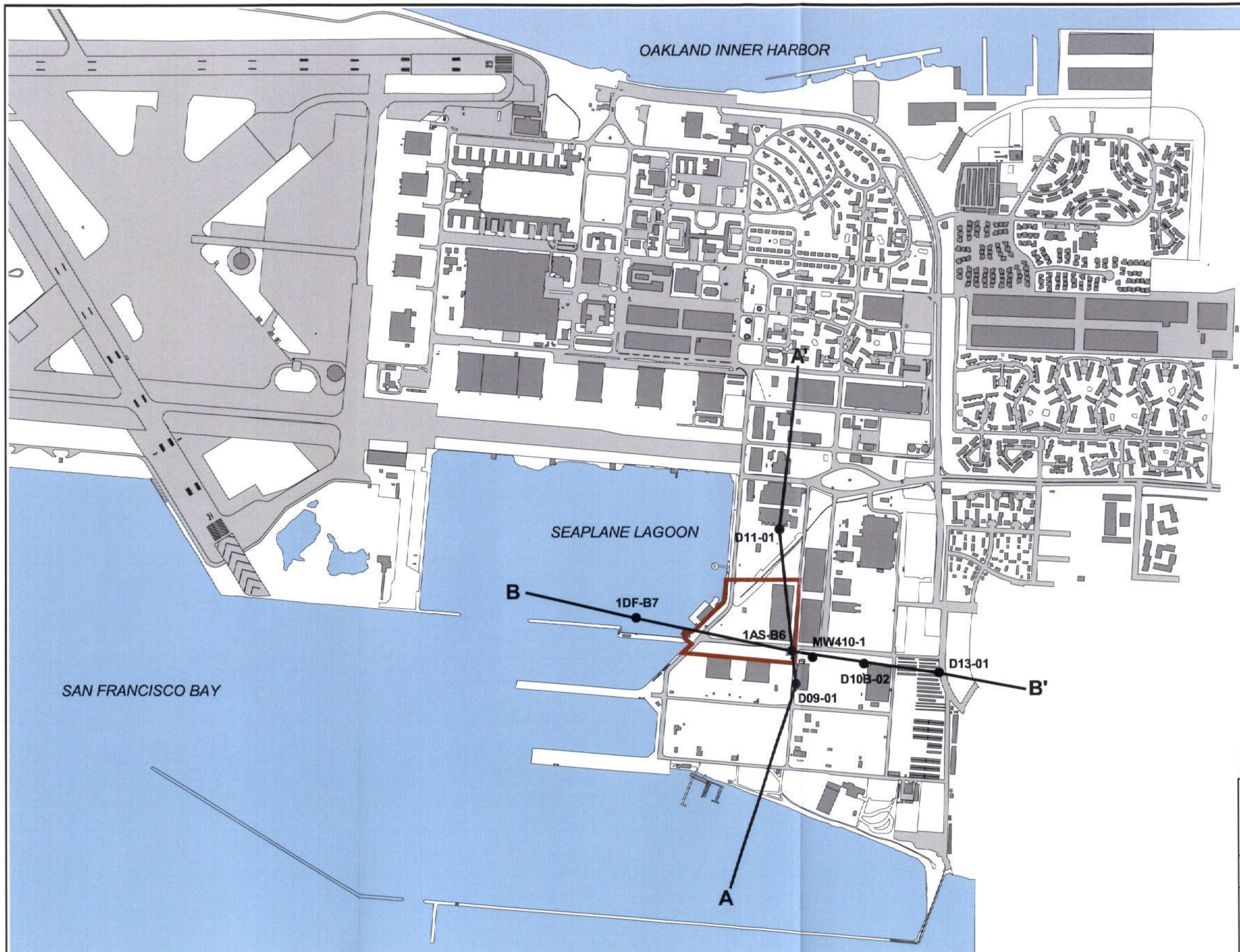
Figure 2-3

Generalized Stratigraphic and Hydrologic Units at Alameda Point

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 7/14/05
File No: 069C13881
Job No: 23818-069
Rev No: B



LEGEND

- BORINGS
- BUILDING OR STRUCTURE
- ROAD OR RUNWAY
- WATER
- IR SITE 27 BOUNDARY (EXPANDED)
- A —— A' CROSS SECTION

SOURCES :
PRC ENVIRONMENTAL MANAGEMENT, INC. 1997. TIDAL INFLUENCE STUDY LETTER REPORT, NAVAL AIR STATION ALAMEDA, CALIFORNIA. PREPARED FOR UNITED STATES DEPARTMENT OF THE NAVY, ENGINEERING FIELD ACTIVITY WEST, NAVAL FACILITIES ENGINEERING COMMAND, SAN BRUNO, CALIFORNIA. JUNE 23.

TETRA TECH EM INC. 1999. OU-2 REMEDIAL INVESTIGATION REPORT DRAFT, ALAMEDA POINT, ALAMEDA, CALIFORNIA. PREPARED FOR UNITED STATES DEPARTMENT OF THE NAVY, ENGINEERING FIELD ACTIVITY WEST, NAVAL FACILITIES ENGINEERING COMMAND, SAN BRUNO, CALIFORNIA. JUNE 23.

Feasibility Study for IR Site 27

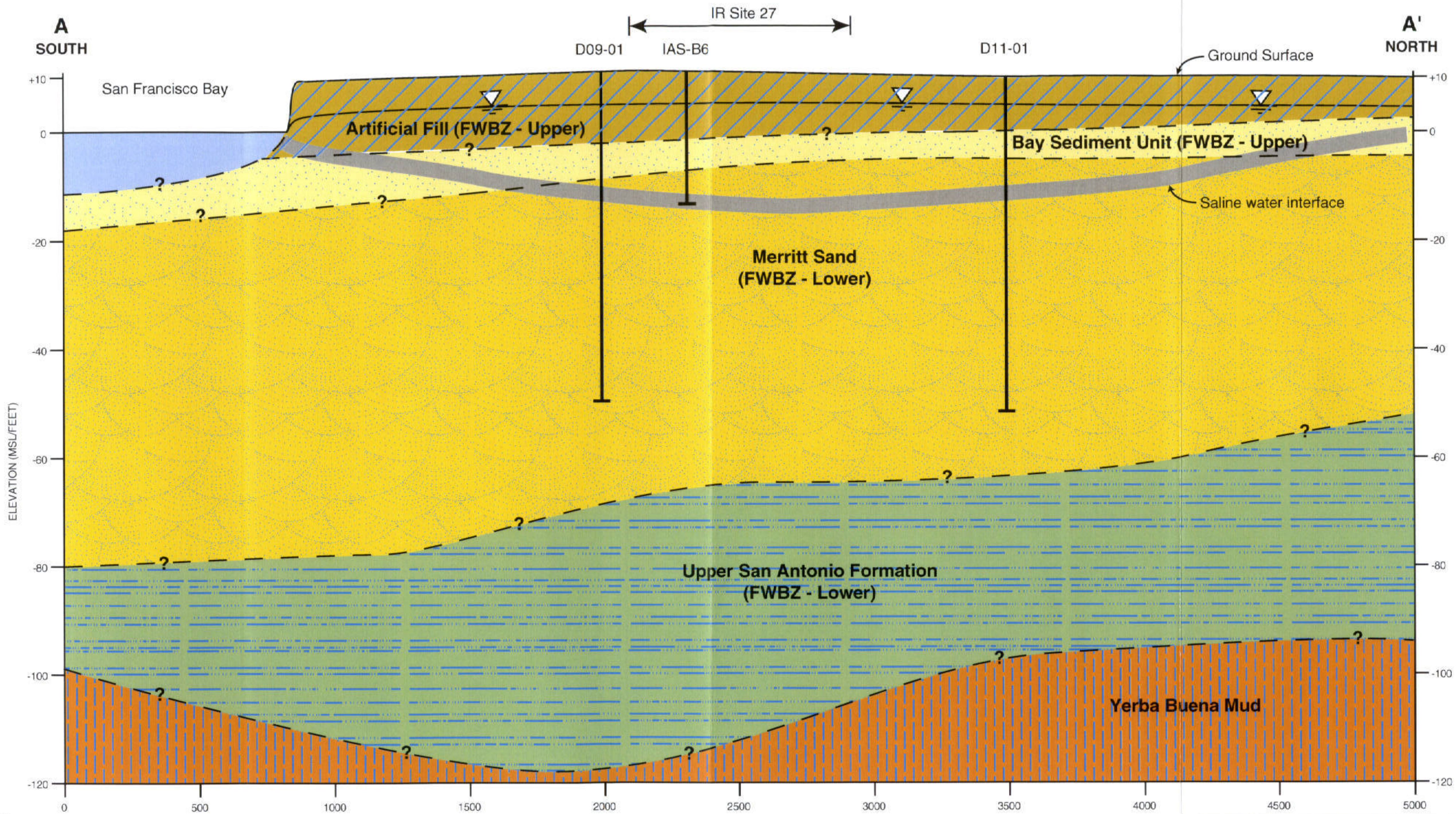
Figure 2-4

Cross Section Locations (A-A' and B-B')

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 7/14/05
File No.: 069L13882
Job No.: 23818-021
Rev No.: B



LEGEND

- WATER
- ARTIFICIAL FILL
- BAY SEDIMENT UNIT
- MERRITT SAND
- UPPER SAN ANTONIO FORMATION
- YERBA BUENA MUD

- BORING WITH IDENTIFICATION NUMBER
- WATER TABLE
- — ? — CONTACT BETWEEN UNITS, QUERIED WHERE APPROXIMATED

NOTES:

FWBZ - FIRST WATER BEARING ZONE
IR - INSTALLATION RESTORATION (PROGRAM)
MSL - MEAN SEA LEVEL

SOURCES:

PRC ENVIRONMENTAL MANAGEMENT, INC. 1997. TIDAL INFLUENCE STUDY LETTER REPORT, NAVAL AIR STATION ALAMEDA, CALIFORNIA. PREPARED FOR THE UNITED STATES DEPARTMENT OF THE NAVY, ENGINEERING FIELD ACTIVITY WEST, NAVAL FACILITIES ENGINEERING COMMAND, SAN BRUNO, CALIFORNIA. JUNE 23.

TETRA TECH EM INC. 1999. OU-2 REMEDIAL INVESTIGATION REPORT DRAFT, ALAMEDA POINT, ALAMEDA, CALIFORNIA. PREPARED FOR THE UNITED STATES DEPARTMENT OF THE NAVY, ENGINEERING FIELD ACTIVITY WEST, NAVAL FACILITIES ENGINEERING COMMAND, SAN BRUNO, CALIFORNIA. JUNE 23.

0 400 800
HORIZONTAL SCALE IN FEET

0 20 40
VERTICAL SCALE IN FEET

Feasibility Study for IR Site 27

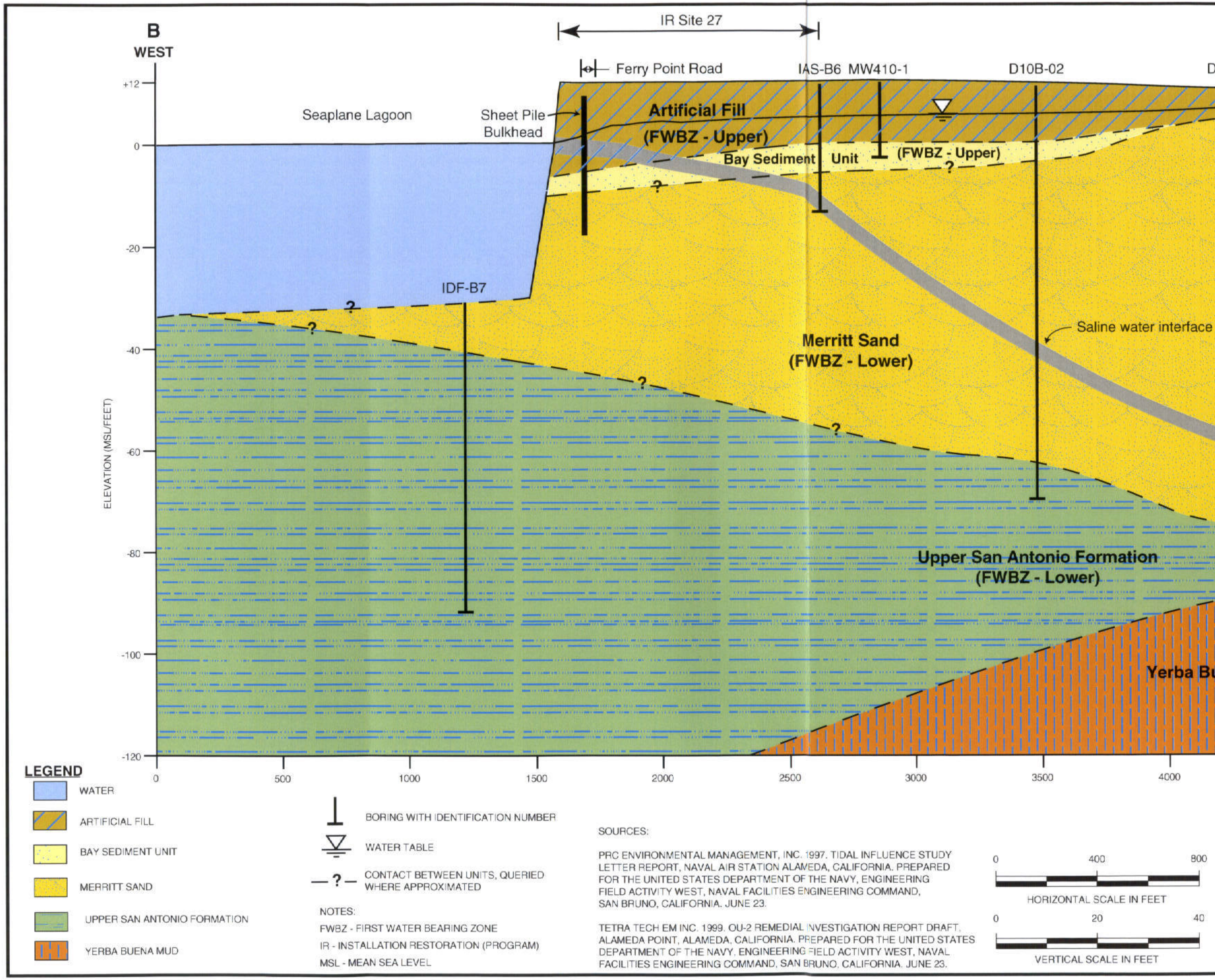
Figure 2-5

Conceptual Hydrogeologic Cross Section A-A'

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 10/6/05
File No. 069X14157
Job No: 23818-069
Rev No. C



Feasibility Study for IR Site 27

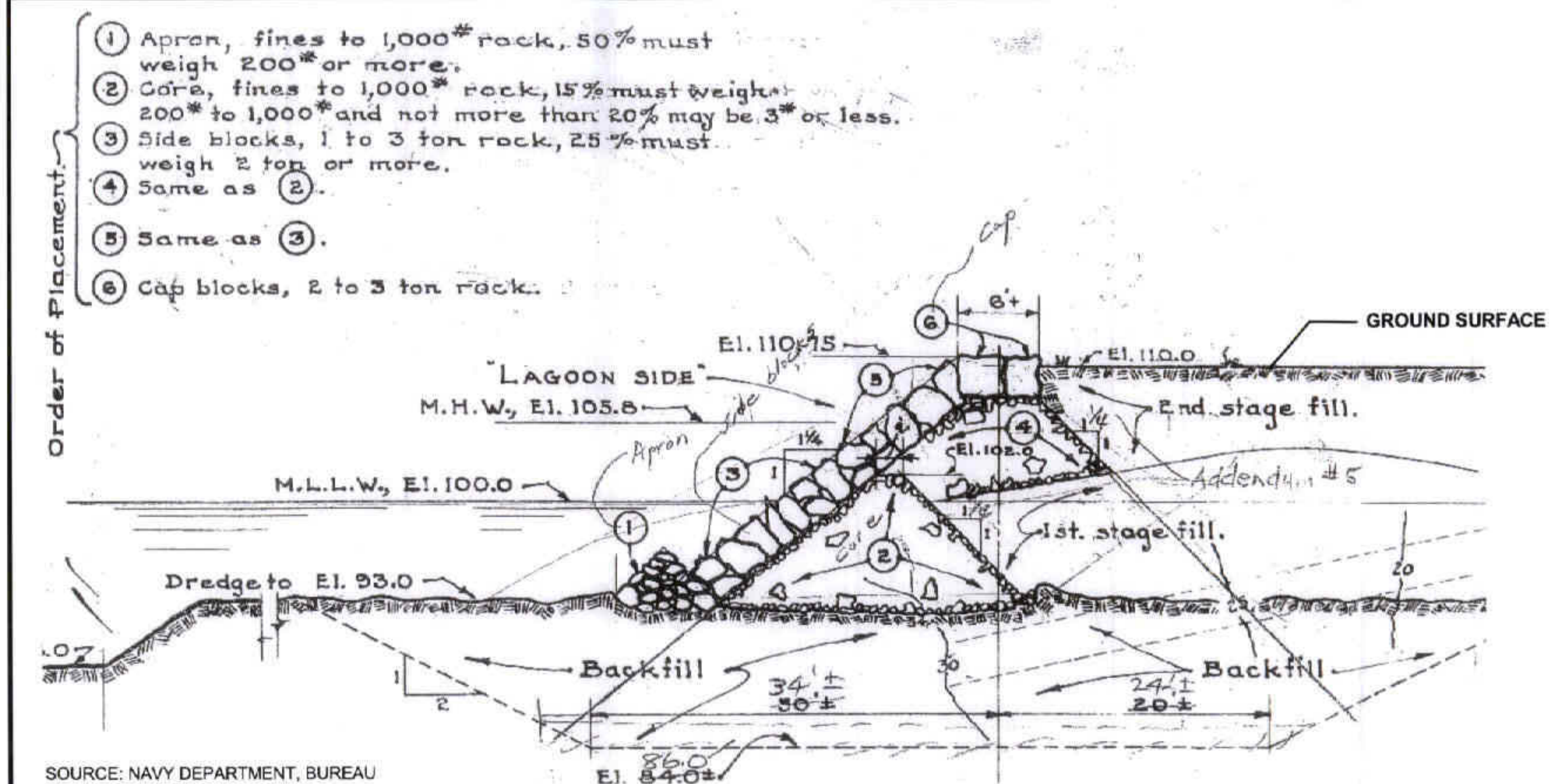
Figure 2-6

Conceptual Hydrogeologic Cross Section B-B'

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

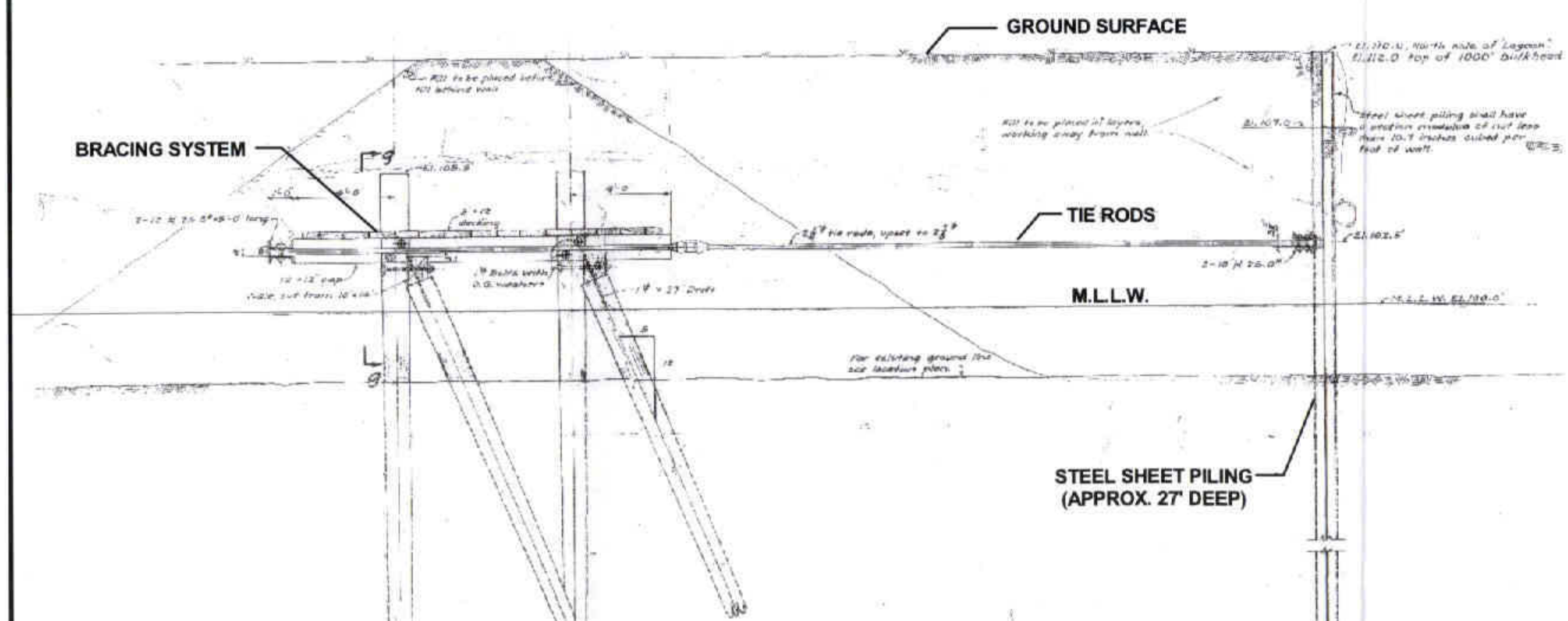
Date: 10/6/05
File No.: 069X14158
Job No.: 23818-069
Rev No.: D



SOURCE: NAVY DEPARTMENT, BUREAU OF YARDS AND DOCKS. DRAWING NUMBER 125969. DECEMBER 29, 1937.

SEAWALL SECTION

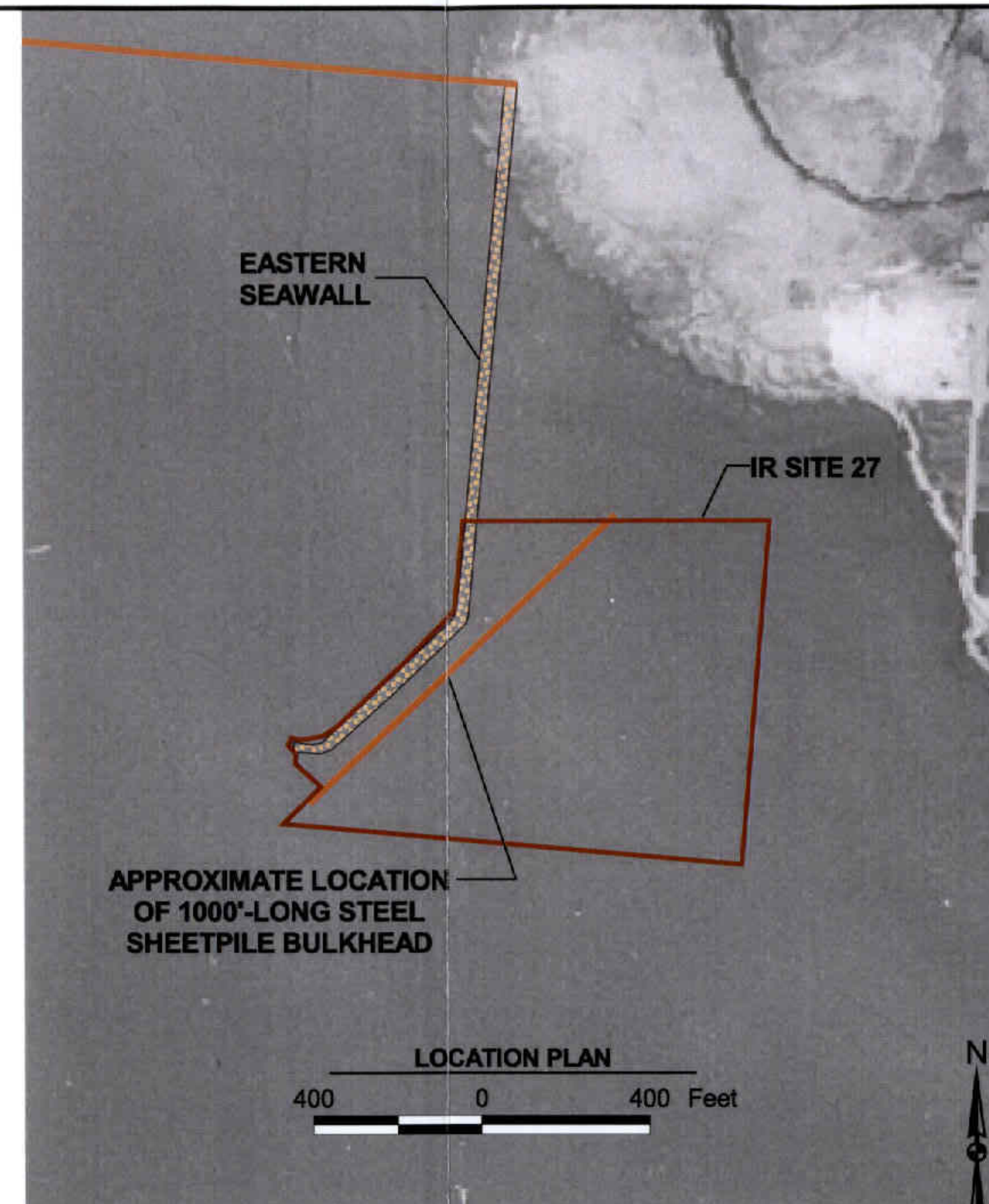
NOT TO SCALE



SOURCE: NAVY DEPARTMENT, BUREAU OF YARDS AND DOCKS. DRAWING NUMBER 125970. DECEMBER 29, 1937.

BULKHEAD SECTION

NOT TO SCALE



SOURCE: UNITED STATES NAVAL RESERVE. 1937. PROPOSED NAVAL AIR STATION AND SUPPLY DEPOT SITE, SOUTH WESTERN HARBOR AREA, ALAMEDA AND OAKLAND. SCALE 1:12,000. SEPTEMBER.

LEGEND

- IR SITE 27 BOUNDARY
- SHEETPILE BULKHEAD
- EASTERN SEAWALL

NOTES:

M.H.W. – MEAN HIGH WATER

M.L.L.W – MEAN LOWER LOW WATER

Feasibility Study for IR Site 27

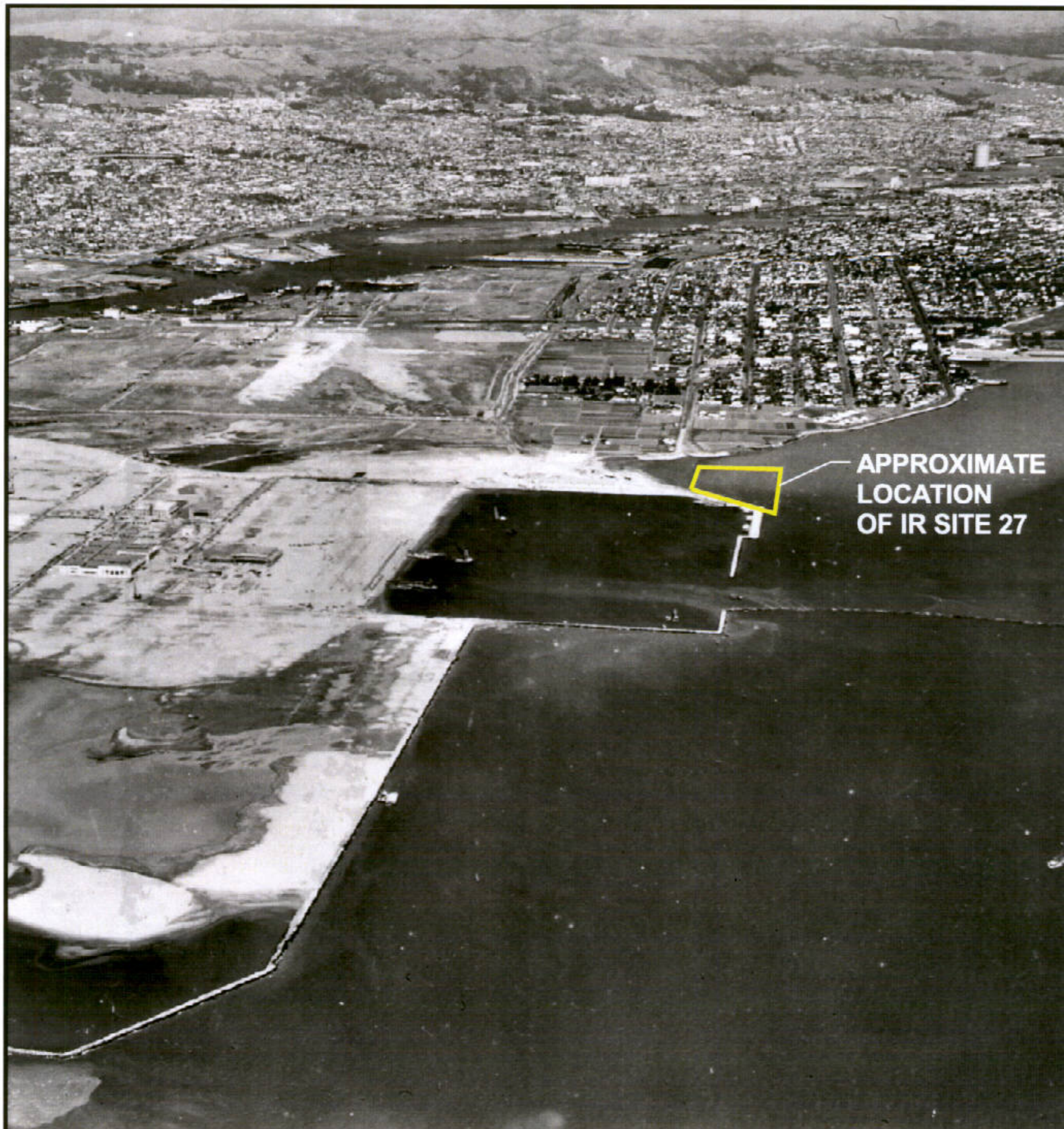
Figure 2-7

Bulkhead and Seawall Location Plan and Sections

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 7/14/05
File No.: 069L13879
Job No.: 23818-069
Rev No.: E



N APPROXIMATE

NOTE : IR SITE 27 WAS FILLED AFTER THE CONSTRUCTION OF THE SEAPLANE LAGOON

SOURCE : PACIFIC AERIAL SURVEYS, 1940.
NOT TO SCALE

Feasibility Study for IR Site 27

Figure 2-8

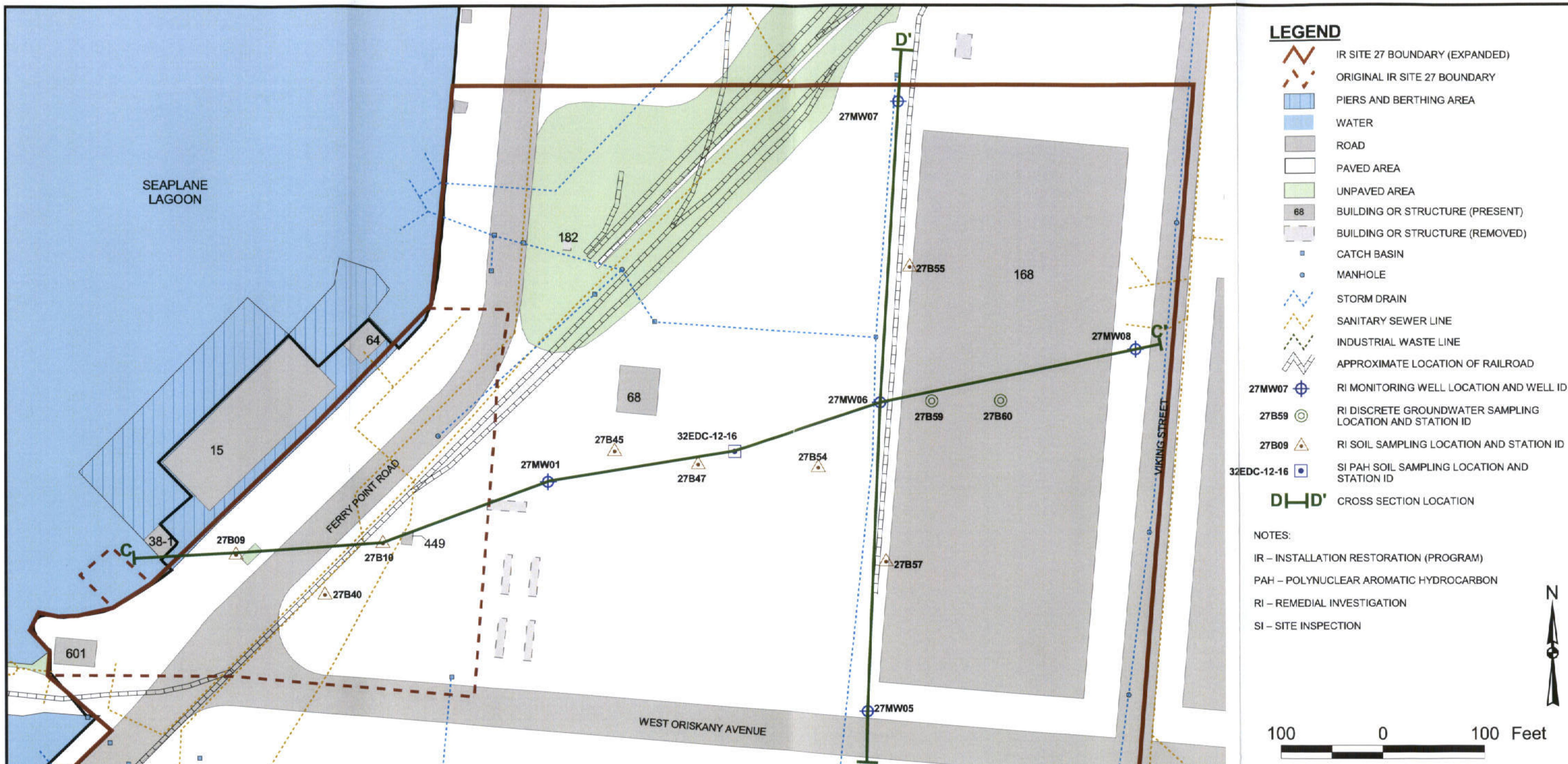
Construction of Seaplane Lagoon
Aerial View, 1940

Alameda, California

Bechtel Environmental, Inc.

CLEAN 3 Program

Date: 7/25/05
File No.: 069E13885
Job No.: 23818-069
Rev No.: B



Feasibility Study for IR Site 27

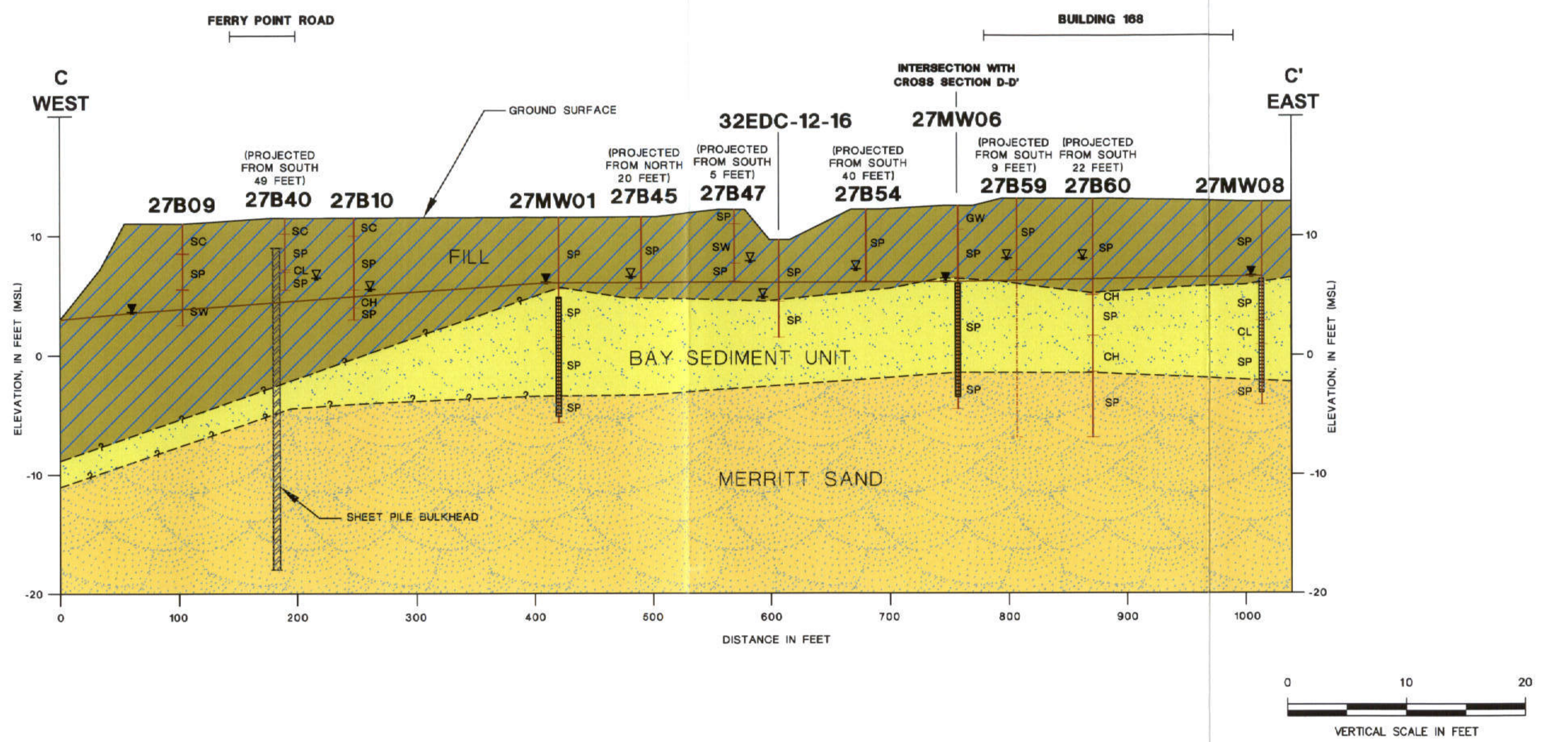
Figure 2-9

Geologic Cross Section Locations (C-C' and D-D')

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 7/6/05
File No.: 069L13886
Job No.: 23818-069
Rev No.: A



LEGEND

- ARTIFICIAL FILL
- BAY SEDIMENT UNIT
- MERRITT SAND
- WATER TABLE ELEVATION
- CONTACT BETWEEN UNITS, QUERIED WHERE APPROXIMATED
- MEASURED WATER LEVEL ELEVATION (MONITORING WELL)
- ESTIMATED WATER LEVEL ELEVATION (SOIL BORING)
- SCREENED INTERVAL
- LOG NOT RECORDED

NOTES:

CH – HIGH-PLASTICITY CLAY
CL – LOW-TO-MEDIUM-PLASTICITY CLAY
GW – GRAVEL, WELL GRADED
IR – INSTALLATION RESTORATION (PROGRAM)
MSL – MEAN SEA LEVEL
SC – CLAYEY SAND
SP – POORLY GRADED SAND
SW – WELL GRADED SAND

Feasibility Study for IR Site 27

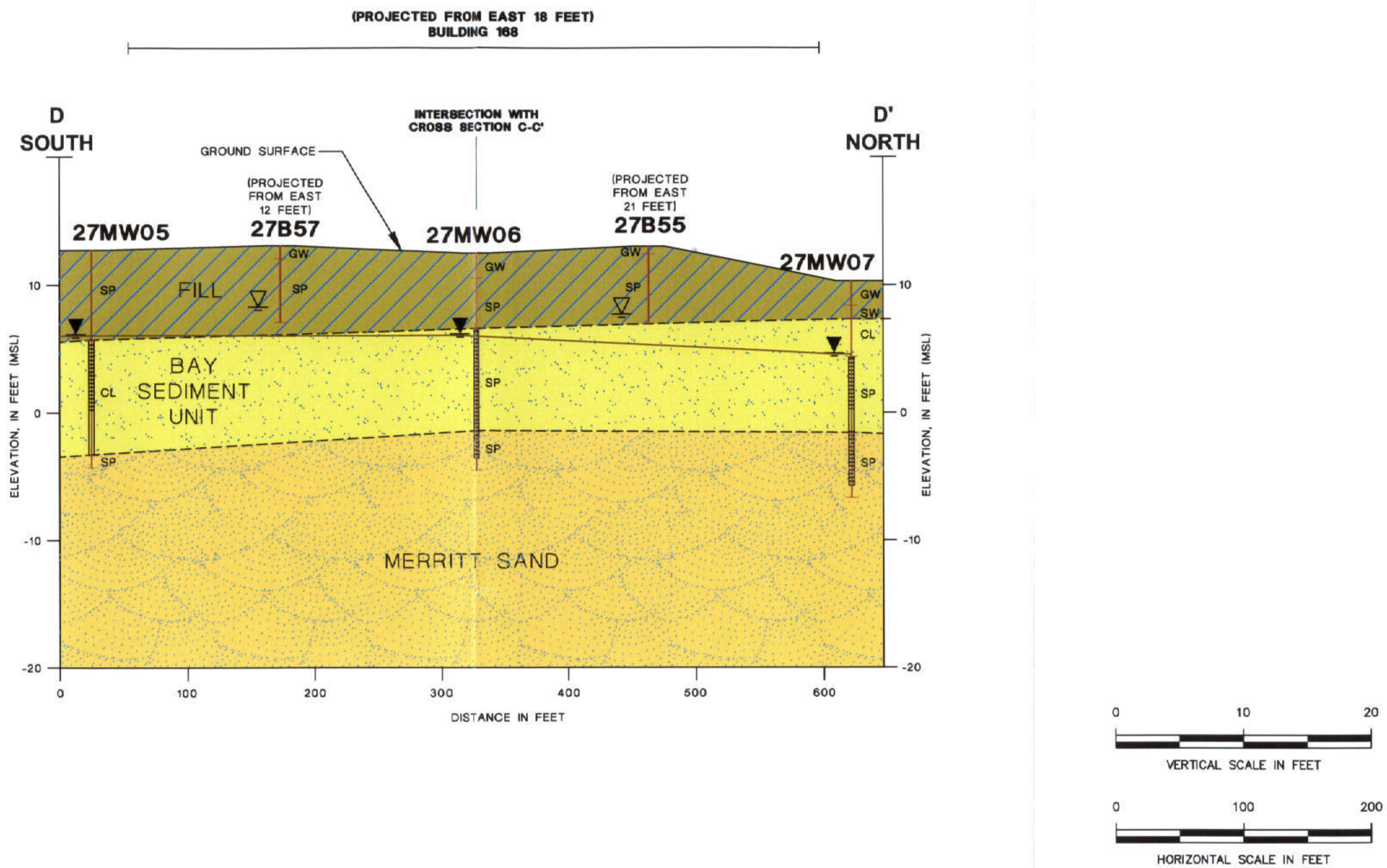
Figure 2-10

Geologic Cross Section C-C'

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 10/6/05
File No: 069X13887
Job No: 23818-069
Rev No: C



LEGEND

- ARTIFICIAL FILL
- BAY SEDIMENT UNIT
- MERRITT SAND
- WATER TABLE ELEVATION
- CONTACT BETWEEN UNITS, QUERIED WHERE APPROXIMATED
- MEASURED WATER LEVEL ELEVATION (MONITORING WELL)
- ESTIMATED WATER LEVEL ELEVATION (SOIL BORING)
- SCREENED INTERVAL

NOTES:

CL – LOW-TO-MEDIUM-PLASTICITY CLAY
GW – GRAVEL, WELL GRADED
IR – INSTALLATION RESTORATION (PROGRAM)
MSL – MEAN SEA LEVEL
SP – POORLY GRADED SAND
SW – WELL GRADED SAND

Feasibility Study for IR Site 27

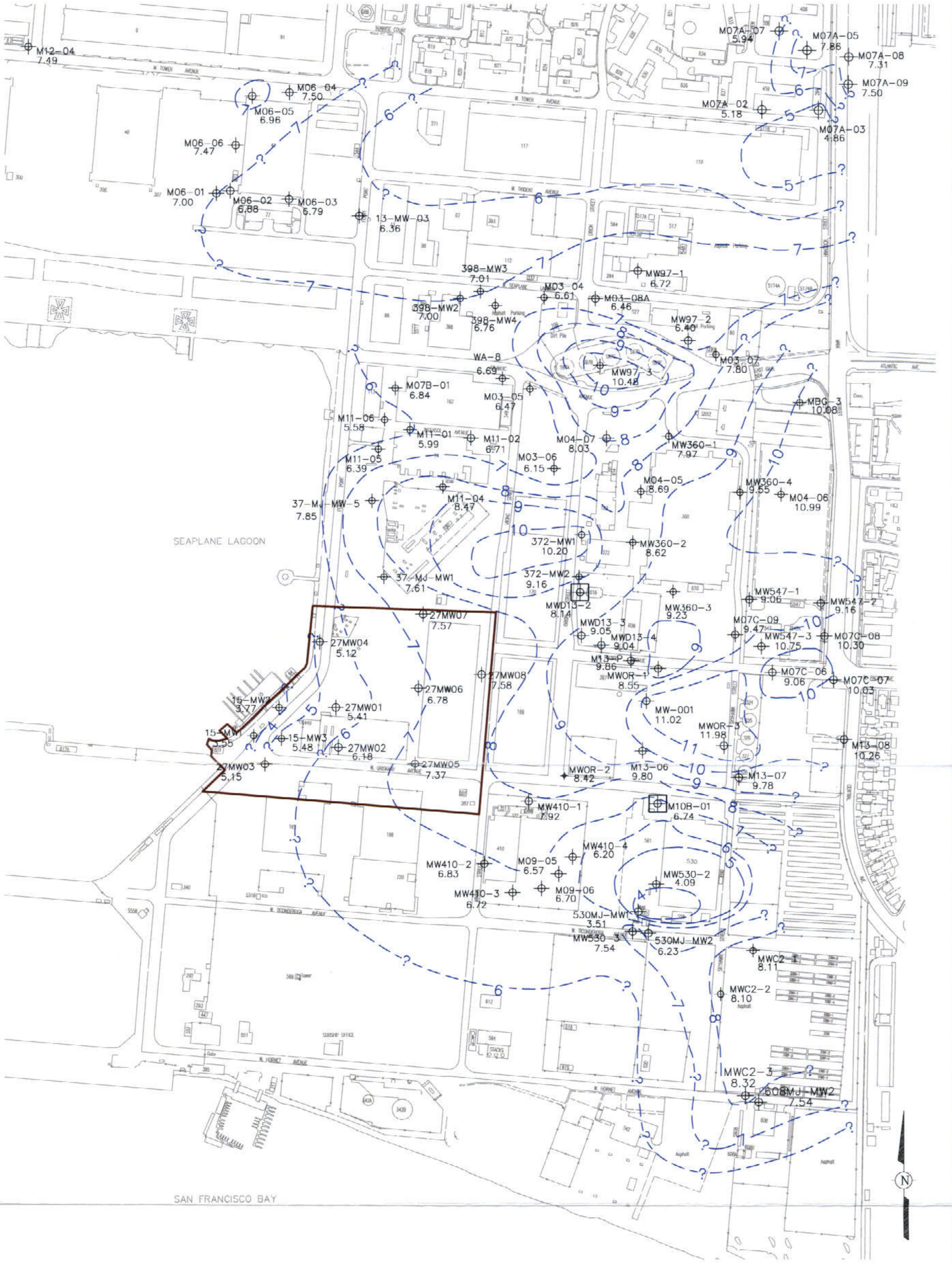
Figure 2-11

Geologic Cross Section D-D'

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 10/6/05
File No: 069X13888
Job No: 23818-069
Rev No: C



LEGEND

IR SITE 27 BOUNDARY (EXPANDED)

— 7 — GROUNDWATER ELEVATION CONTOUR IN FEET MSL

—?— APPROXIMATED GROUNDWATER ELEVATION CONTOUR IN FEET MSL

MONITORING WELL LOCATION

LOCATION OF MONITORING WELL PAIR USED FOR VERTICAL GRADIENT

NOTES :

IR – INSTALLATION RESTORATION (PROGRAM)

MSL – MEAN SEA LEVEL

SOURCE: SHAW ENVIRONMENTAL, 2004. POTENTIOMETRIC SURFACE MAP FIRST WATER-BEARING ZONE SPRING 2004. DRAWING NO. 843780-D633. JUNE 25.

Feasibility Study for IR Site 27

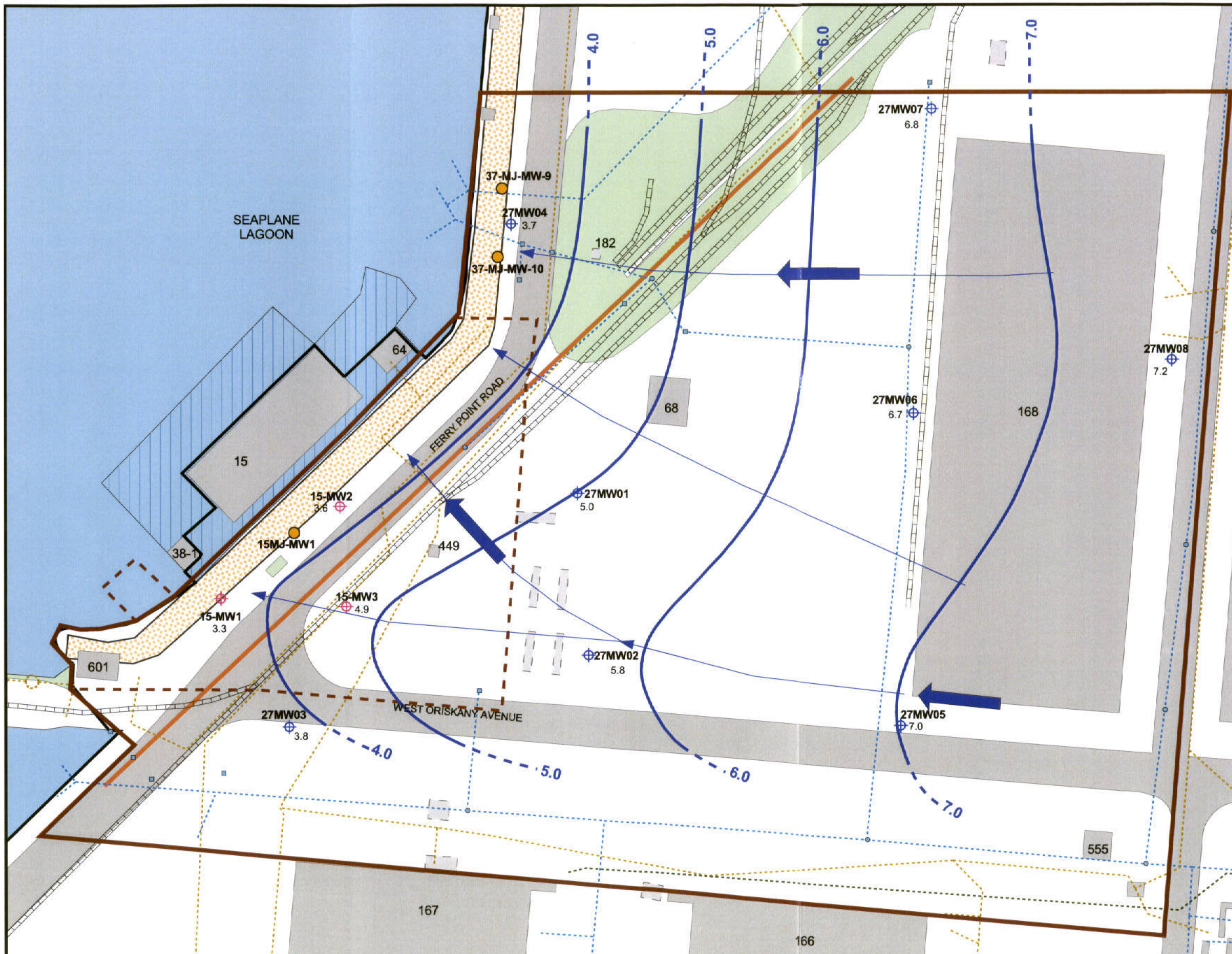
Figure 2-12

Southeast Alameda Point Groundwater Elevation Map, First Water-Bearing Zone, Spring 2004

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 6/30/05
File No: 069Q13889
Job No: 23818-069
Rev No: A



Feasibility Study for IR Site 27

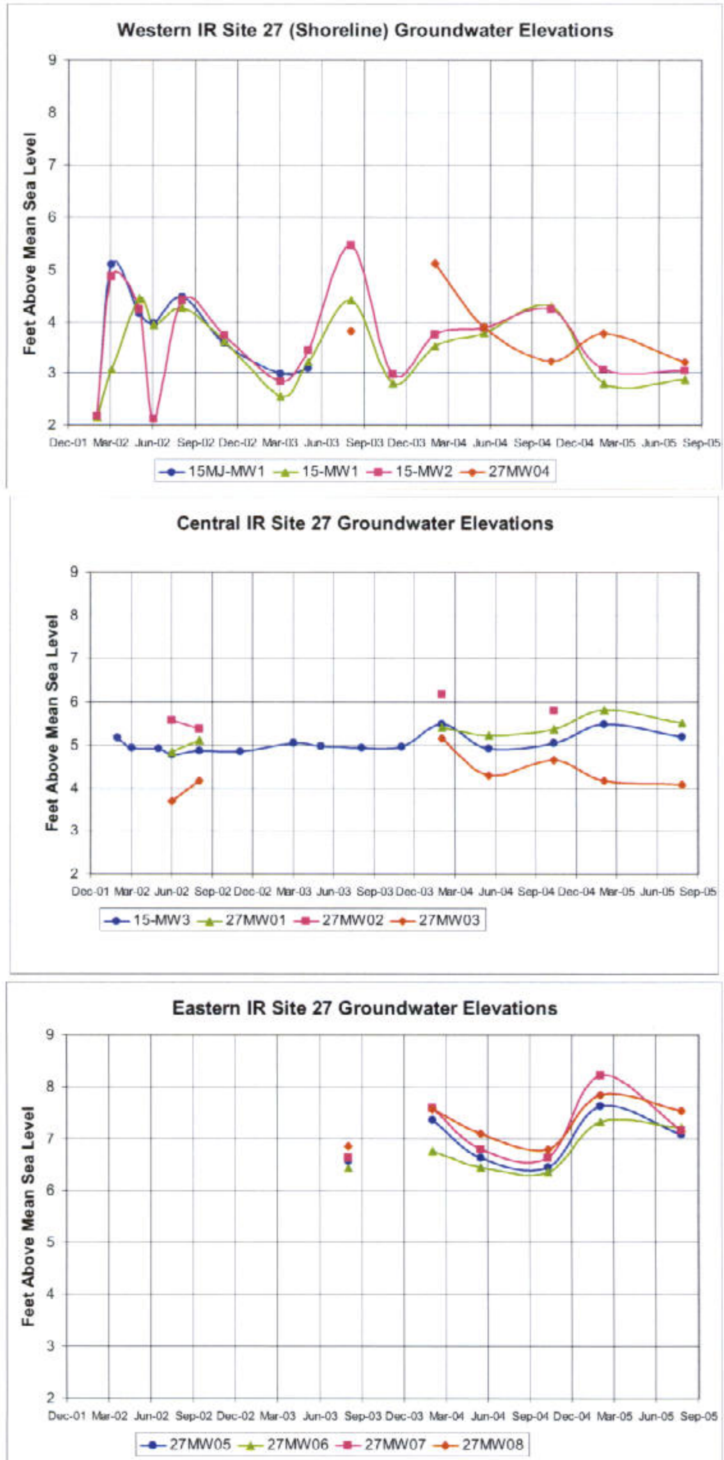
Figure 2-13

Groundwater Elevation Map, June 2004

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 7/14/05
File No.: 069Q13890
Job No.: 23818-069
Rev No.: B



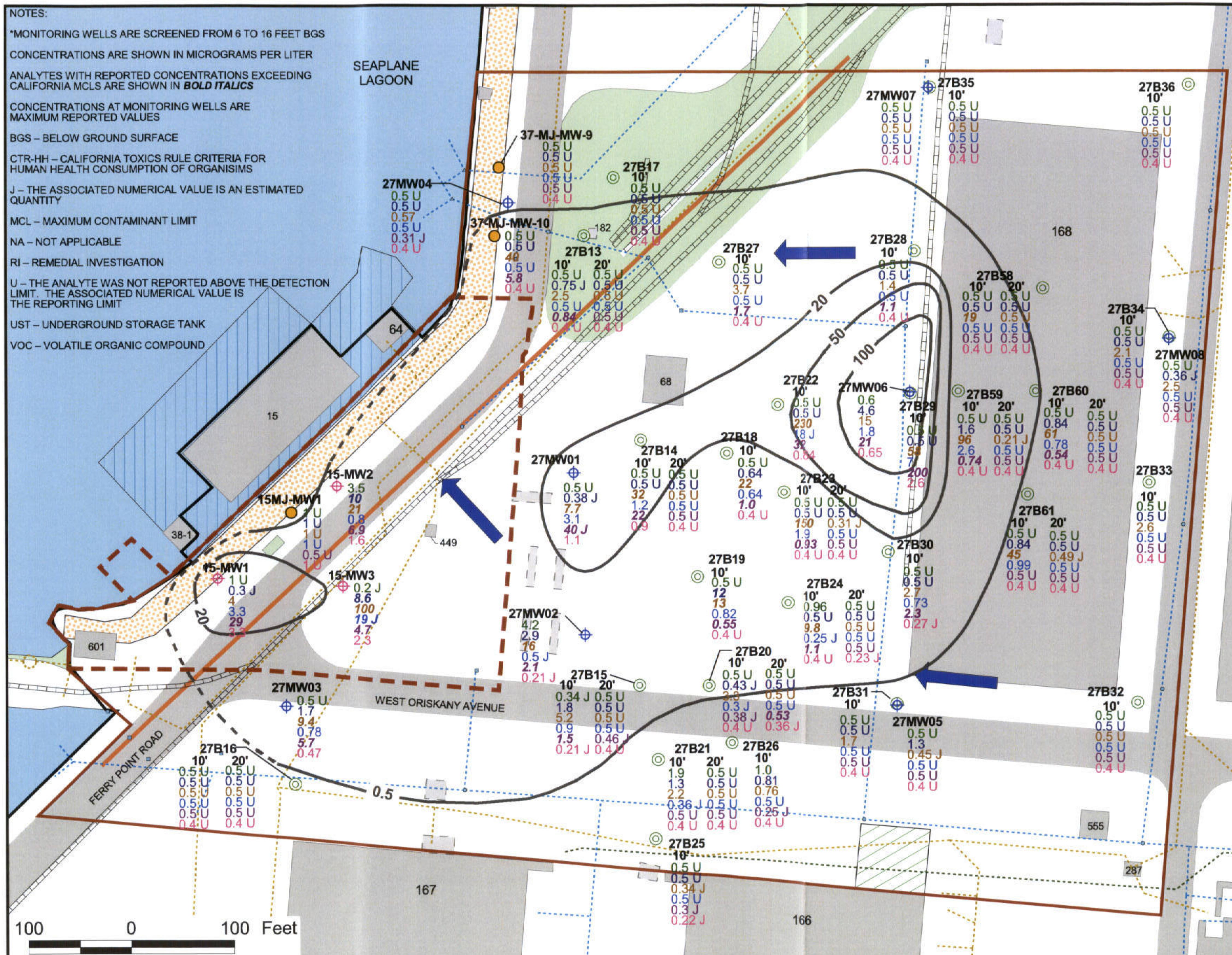
Feasibility Study for IR Site 27

Figure 2-14
Hydrographs

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 3/6/06
File No.fig2-14.doc
Job No.23818-069



LEGEND

- IR SITE 27 BOUNDARY (EXPANDED)
- ORIGINAL IR SITE 27 BOUNDARY
- 68 BUILDING OR STRUCTURE (PRESENT)
- BUILDING OR STRUCTURE (REMOVED)
- APPROXIMATE LOCATION OF RAILROAD
- PIERS AND BERTHING AREA
- WATER
- ROAD
- PAVED AREA
- UNPAVED AREA
- EASTERN SEAWALL
- WASHDOWN AREA 166 (WD-166)
- CATCH BASIN
- MANHOLE
- STORM DRAIN
- SANITARY SEWER
- INDUSTRIAL WASTE
- SHEETPILE BULKHEAD
- APPROXIMATE GROUNDWATER FLOW DIRECTION
- 27MW01 RI MONITORING WELL LOCATION AND WELL ID
- 27B34 RI DISCRETE GROUNDWATER SAMPLING LOCATION AND STATION ID
- 15-MW1 UST REMOVAL MONITORING WELL LOCATION
- 15MJ-MW1 UST REMOVAL MONITORING WELL LOCATION (ABANDONED 2003) AND WELL ID
- 0.5 VINYL CHLORIDE CONCENTRATION ISOCONTOUR IN MICROGRAMS PER LITER (DASHED WHERE APPROXIMATED)

DISCRETE GROUNDWATER SAMPLING LOCATION ID → 27B33 10' (DEPTH IN FEET BGS*)

CONCENTRATION IN MICROGRAMS PER LITER / ANALYTE / REVIEW QUALIFIER:

- 0.5 U TETRACHLOROETHENE
- 0.5 U TRICHLOROETHENE
- 2.6 U CIS-1,2-DICHLOROETHENE
- 0.5 U TRANS-1,2-DICHLOROETHENE
- 0.5 U VINYL CHLORIDE
- 0.4 U 1,1-DICHLOROETHANE

COMPARISON CRITERIA (MICROGRAMS PER LITER)

	SHORELINE GROUNDWATER	INLAND GROUNDWATER	
	CTR-HH	FEDERAL MCL	CALIFORNIA MCL
TETRACHLOROETHENE	8.85	5	5
TRICHLOROETHENE	81	5	5
CIS-1,2-DICHLOROETHENE	NA	70	6
TRANS-1,2-DICHLOROETHENE	140,000	100	10
VINYL CHLORIDE	525	2	0.5
1,1-DICHLOROETHANE	NA	NA	5

Feasibility Study for IR Site 27

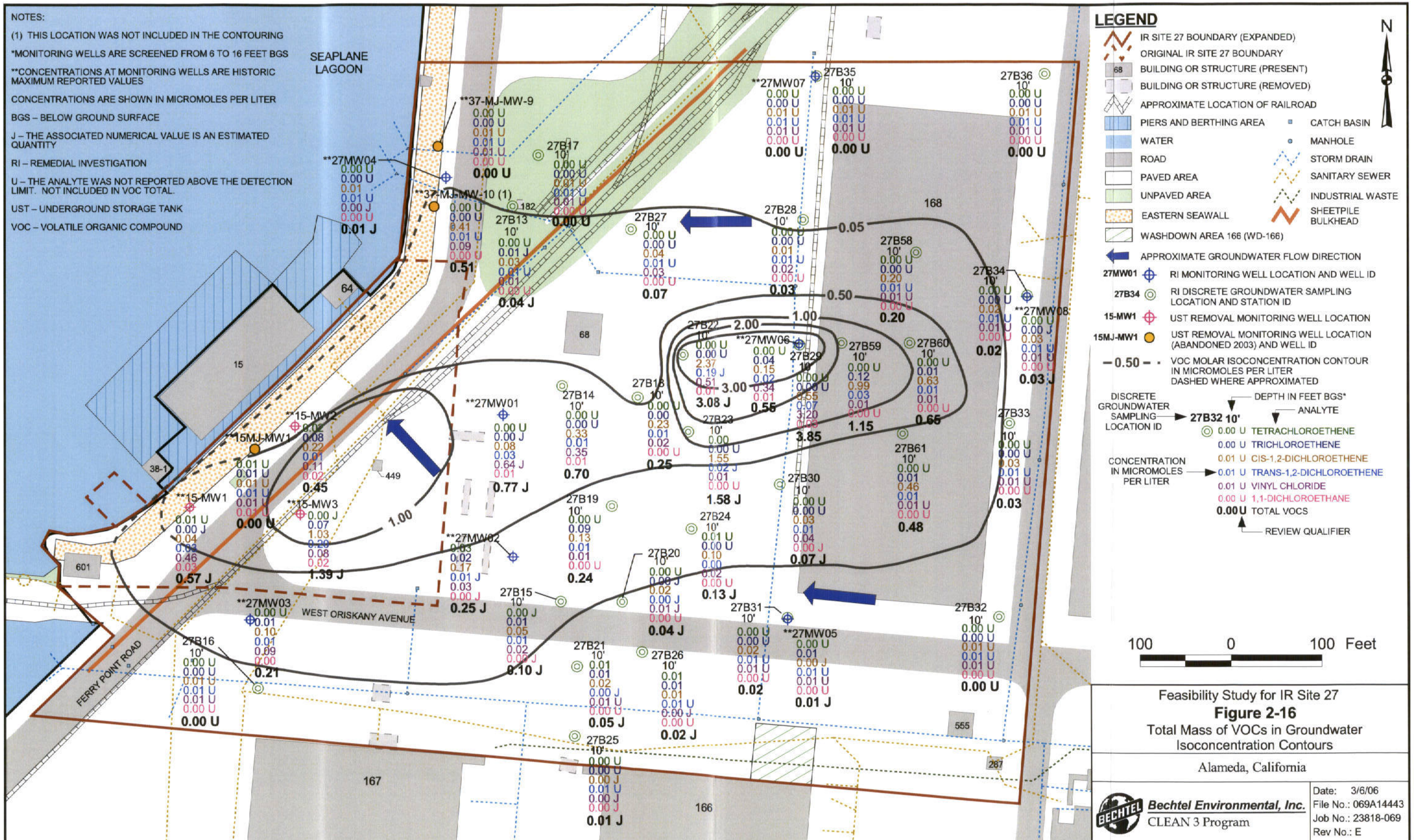
Figure 2-15

Vinyl Chloride in Groundwater Isoconcentration Contours

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

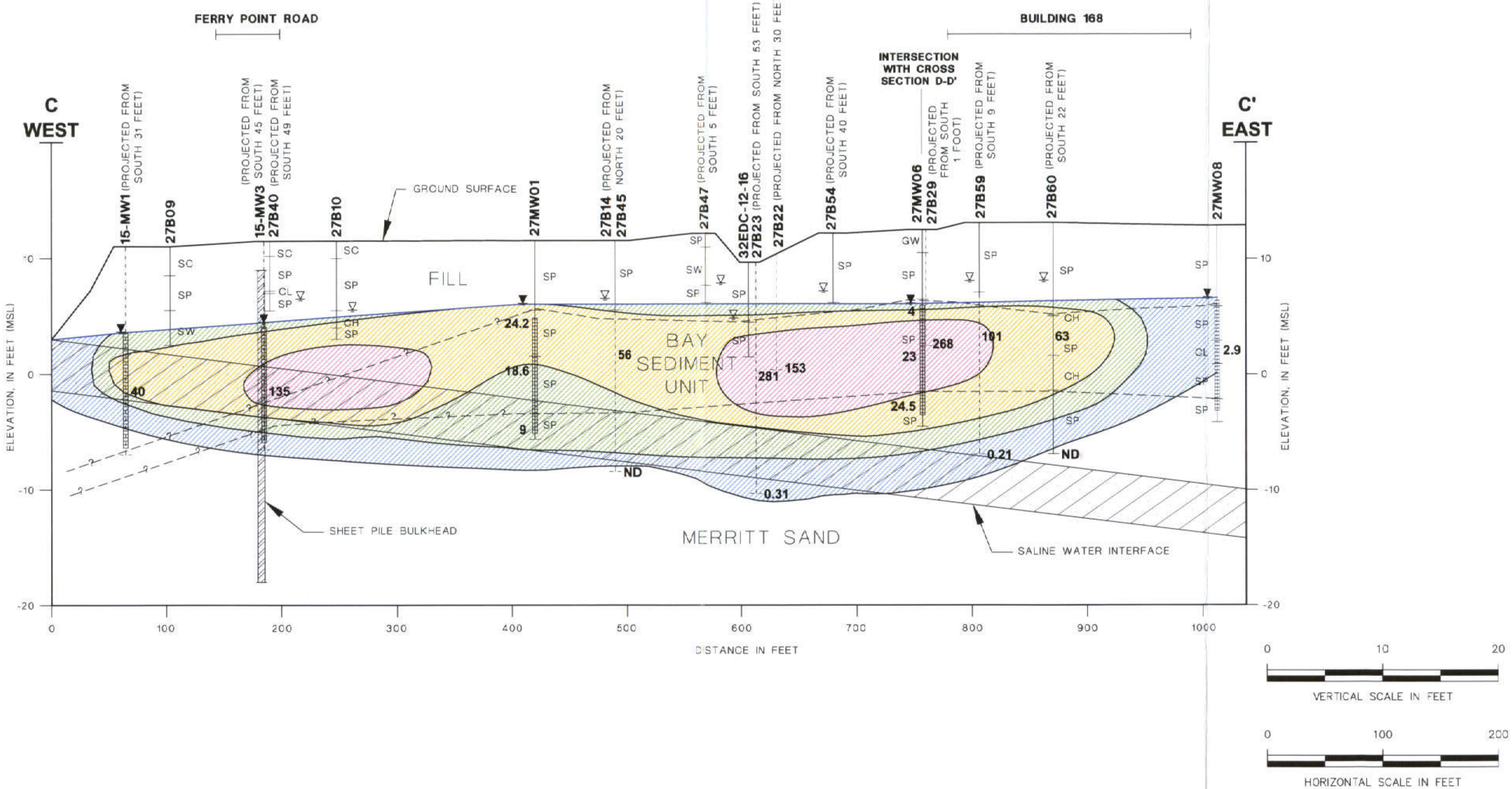
Date: 3/6/06
File No.: 069A13891
Job No.: 23818-069
Rev No.: D



Feasibility Study for IR Site 27
Figure 2-16
Total Mass of VOCs in Groundwater Isoconcentration Contours
Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 3/6/06
File No.: 069A14443
Job No.: 23818-069
Rev No.: E



LEGEND

WATER TABLE ELEVATION

CONTACT BETWEEN UNITS, QUERIED WHERE APPROXIMATED

MEASURED WATER LEVEL ELEVATION (MONITORING WELL)

ESTIMATED WATER LEVEL ELEVATION (SOIL BORING)

SCREENED INTERVAL

BORING NOT LOGGED/LOG NOT AVAILABLE

SALINE WATER INTERFACE

40 SUM OF HISTORICAL MAXIMUM VALUES (µg/L): (TETRACHLOROETHENE + TRICHLOROETHENE + CIS-1,2-DICHLOROETHENE + TRANS-1,2-DICHLOROETHENE + VINYL CHLORIDE + 1,1-DICHLOROETHANE)

APPROXIMATE EXTENT OF SELECTED CHLORINATED VOCs DETECTED IN GROUNDWATER:

- 0–5 µg/L
- 5–20 µg/L
- 20–100 µg/L
- >100 µg/L

NOTES:

CH – HIGH-PLASTICITY CLAY
CL – LOW-TO-MEDIUM-PLASTICITY CLAY
GW – GRAVEL, WELL GRADED
IR – INSTALLATION RESTORATION (PROGRAM)
MSL – MEAN SEA LEVEL
µg/L – MICROGRAMS PER LITER
ND – NOT DETECTED
SC – CLAYEY SAND
SP – POORLY GRADED SAND
SW – WELL GRADED SAND
VOC – VOLATILE ORGANIC COMPOUND

Feasibility Study for IR Site 27

Figure 2-17

Vertical Profile for Selected Chlorinated VOCs in Groundwater

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 3/6/06
File No: 069X13883
Job No: 23818-069
Rev No: D

N00236.002255
ALAMEDA POINT
SSIC NO. 5090.3

TABLES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006

Table 2-1
Monthly Temperature and Rainfall Summary

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average maximum temperature (°F)	57.3	61.6	63.3	66.5	69.0	71.7	72.6	73.6	74.6	72.0	63.9	57.4	66.9
Average minimum temperature (°F)	44.5	47.9	49.1	50.6	53.5	55.7	57.0	58.3	58.3	55.3	49.6	44.5	52.0
Average total precipitation (inches)	4.85	4.40	3.56	1.35	0.56	0.12	0.07	0.10	0.32	1.31	3.45	3.33	23.43

Source: Oakland Museum data from October 1, 1970, to July 31, 2000

Acronym/Abbreviation:
°F – degrees Fahrenheit

Table 2-2
Hydrogeologic Setting[a], IR Site 27 and Vicinity

Hydrogeologic Unit[b]	Unit Composition	REMEDIAL INVESTIGATION DATA[c]								HISTORIC DATA[d]					
		Top of Unit (feet)	Estimated Thickness (feet bgs)	Aquifer Type	Potentiometric Head (feet MSL[e])	Estimated Groundwater Flow Direction	Tidal Efficiency	Tidal Time Lag (hours)	Horizontal Gradient (unitless)	Top of Unit (feet)	Estimated Thickness (feet bgs)	Aquifer Type	Potentiometric Head (feet MSL[e])	Estimated Groundwater Flow Direction	Horizontal Gradient (unitless)
Upper FWBZ	Artificial fill	0	5.5–12	unconfined	2.14 to 7.18	west-to-northwest	2 to 50%	7	0.007–0.01	0	11–14	unconfined	-3.47 to +2.62	north	0.03
	Sandy member of BSU	6–12	0–8	unconfined						—[f]	—	unconfined	—	—	—
Aquitard[g]	Clayey member of BSU	6–12	0–9	thin-to-discontinuous semipermeable aquitard	NA	NA	NA	NA	NA	11–14	5–6	thin-to-discontinuous semipermeable aquitard	NA	NA	NA
Lower FWBZ	Merritt Sand Formation	5.5–16	—	unconfined-to-semiconfined	2.14 to 7.18	west-to-northwest	2 to 50%	7	0.007–0.01	17–18	36–46	semiconfined	—	north	—
	Upper San Antonio Formation	—	—	semiconfined		below study boundary				55–63	60–80	semiconfined	—	north	—
Regional aquitard	Yerba Buena Mud	—	—	aquitard		below study boundary				105–115	55–90	aquitard		below study boundary	
Regional aquifer	Alameda Formation	—	—	confined		below study boundary				180–220	—	confined		below study boundary	

Notes:
- [a] source material from TtEMI 1999 and ERM 1996
- [b] hydrogeologic units presented in order from shallow to deep
- [c] data obtained from wells at IR Site 27 installed during the RI, and for shoreline wells 15-MW1 and 15-MW2 at IR Site 27 installed prior to the RI
- [d] historic data obtained from EBS from wells in vicinity of IR Site 27 and data from paired FWBZ-SWBZ wells at IR Sites 9, 19, and 23
- [e] based on measured depths to water not adjusted for saline water density
- [f] dash indicates no information available
- [g] not present in most IR Site 27 borings

Acronyms/Abbreviations:
- bgs – below ground surface
- BSU – Bay Sediment Unit
- EBS – environmental baseline survey
- FWBZ – first water-bearing zone
- IR – Installation Restoration (Program)
- MSL – mean sea level
- NA – not applicable
- SWBZ – second water-bearing zone

Table 2-3
Estimated Values of Aquifer Hydraulic Parameters

Site	Lithologic Material	Test Method	Method of Analysis	Transmissivity ($feet^2/min$)	Hydraulic Conductivity (feet/min)	Hydraulic Conductivity (feet/day)	Storage Coefficient (dimensionless)	Specific Yield (dimensionless)	Source
First Water-Bearing Zone – Artificial Fill/BSU/Merritt Sand									
IR Site 27									
	Artificial fill	soil (lab)	ASTM D5084	—*	6.7E-04	9.6E-01	—	—	IR Site 27 RI
	BSU	soil (lab)	ASTM D5084	—	2.5E-04	3.6E-01	—	—	IR Site 27 RI
	BSU/Merritt Sand	slug test	Bouwer-Rice	—	2.11E-03	3.04	—	—	IR Site 27 RI
	Merritt Sand	soil (lab)	ASTM D5084	—	1.3E-06	1.9E-03	—	—	IR Site 27 RI
OU-2A Sites:									
IR Site 9	NS	soil (lab)	Unknown	—	0.0019	2.74	—	—	TtEMI 2004
		slug test	Bouwer and Rice	—	—	1.70	—	—	Shaw 2003b
IR Site 13	NS	pumping test	Theis	0.1170	0.0037	5.265	0.0009	—	TtEMI 2004
			Neuman	0.0763	0.0024	3.431	0.0007	0.12	TtEMI 2004
			Cooper-Jacob	0.1418	0.0035	5.103	0.0033	—	TtEMI 2004
			Hantush	0.1100	0.0034	4.950	—	—	TtEMI 2004
Second Water-Bearing Zone – Merritt Sand									
OU-2A Site:									
IR Site 9	NS	pumping test	Hantush-Jacob	0.036	0.0016	2.3	0.0023	—	Shaw 2003b

Note:
* dash indicates no information available

Acronyms/Abbreviations:
- ASTM – American Society for Testing and Materials
- BSU – Bay Sediment Unit
- IR – Installation Restoration (Program)
- min – minute
- NS – not supplied
- OU – operable unit
- RI – remedial investigation

Table 2-4
Comparison of Analytes in Groundwater Between Shoreline and Inland Wells, 1995–2004

Analytes	NUMBER OF ANALYTES			
	Shoreline		Inland	
	Within VOC Plume[a]	Outside VOC Plume[a]	Within VOC Plume[a]	Outside VOC Plume[a]
Organic compounds at concentrations above detection limits				
Chlorinated VOCs	11 (41/54)[a]	2 (2/7)	17 (39/39)	2 (6/8)
Fuel-related VOCs	7 (30/72)	8 (11/17)	5 (28/39)	0 (0/8)
SVOCs – PAHs	7 (4/5)	9 (2/2)	2 (3/5)	1 (2/4)
Organic compounds at concentrations exceeding MCLs				
Chlorinated VOCs	5[b] (33/54)	0 (0/7)	4[c] (38/39)	0 (0/8)
Fuel-related VOCs	1[d] (3/72)	1[d] (1/17)	1[e] (2/39)	0 (0/8)
Organic compounds at concentrations exceeding CTR Human Health Consumption of Organisms				
Chlorinated VOCs	1[f] (1/54)	0 (0/7)	0 (0/39)	0 (0/8)
SVOCs – PAHs	3[g] (1/5)	1[h] (1/2)	1[i] (1/5)	0 (0/4)
Metals at concentrations exceeding comparison criteria				
Metals statistically different from Alameda Point background (number of samples with concentrations exceeding 95 percent UCL)	5[j] (16/38)	3[k] (7/7)	3[l] (19/30)	2[m] (0/8)
Metals statistically different from Alameda Point background and exceeding MCLs	0 (0/38)	0 (0/7)	1[n] (16/30)	0 (0/8)
Metals *not* statistically different from Alameda Point background and exceeding MCLs	2[o] (3/38)	0 (0/7)	0 (0/30)	0 (0/8)
Metals statistically different from Alameda Point background and exceeding CTR CCC	0 (0/38)	0 (0/7)	0 (0/30)	0 (0/8)
Metals *not* statistically different from Alameda Point background and exceeding CTR CCC	4[p] (20/38)	3[q] (5/7)	2[r] (3/30)	1[s] (1/8)
Metals statistically different from Alameda Point background and exceeding CTR Human Health Consumption of Organisms criteria	0 (0/38)	0 (0/7)	0 (0/30)	0 (0/8)
Metals *not* statistically different from Alameda Point background and exceeding CTR Human Health Consumption of Organisms criteria	1[s] (4/38)	0 (0/7)	0 (0/30)	1[s] (1/8)

Table 2-4 (continued)

Notes:

[a] number of samples containing analytes (e.g., 41/54) shows that 41 samples out of a total of 54 contained one or more of the listed constituents at concentrations above the specified criteria as described in the RI (BEI 2005)
[b] 1,1-DCA; cis-1,2-DCE; PCE; TCE; vinyl chloride
[c] cis-1,2-DCE; trans-1,2-DCE; TCE; vinyl chloride
[d] benzene
[e] MTBE
[f] PCE
[g] benzo(a)pyrene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene
[h] benz(a)anthracene
[i] chrysene
[j] arsenic, beryllium, iron, molybdenum, selenium
[k] arsenic, beryllium, iron
[l] arsenic, iron, molybdenum
[m] arsenic, iron
[n] arsenic
[o] lead, thallium
[p] lead, copper, mercury, nickel
[q] lead, nickel, zinc
[r] copper, nickel
[s] mercury

Acronyms/Abbreviations:

CCC – criteria continuing concentration (chronic toxicity)
CTR – California Toxics Rule
DCA – dichloroethane
DCE – dichloroethene
IR – Installation Restoration (Program)
MCL – maximum contaminant limit
MTBE – methyl tert-butyl ether
PAH – polynuclear aromatic hydrocarbon
PCE – tetrachloroethene
PRG – preliminary remediation goal
SVOC – semivolatile organic compound
TCE – trichloroethene
UCL – upper confidence limit
VOC – volatile organic compound

Table 2-5
Analytes in Groundwater Reported Above Applicable Comparison Criteria in Shoreline Wells and Inland Wells
(micrograms per liter)

Analyte	MAXIMUM CONCENTRATION Prior to 2002	MAXIMUM CONCENTRATION 2002–2004	CTR Criterion
Shoreline wells – analytes exceeding CTR human-health consumption of organisms criterion			
tetrachloroethene	40	NA	8.85
mercury	—[a]	0.11	0.051
Shoreline wells – analytes exceeding CTR criteria continuing concentration			
copper	—	7.3	3.1
lead	—	81	8.1
mercury	—	0.11	0.025
nickel	—	19	8.2
zinc	—	100	81
Inland wells – analytes exceeding primary MCL			**MCL[b] Comparison Criterion**
cis-1,2-dichloroethene	44	100	6
trans-1,2-dichloroethene	NA	19	10
methyl tert-butyl ether	NA	38	13
trichloroethene	26	8.6	5
vinyl chloride	2	40	0.5
arsenic	—	23.9	10

Notes:
[a] *dash indicates no samples analyzed for metals*
[b] U.S. EPA or California criterion, whichever is lower

Acronyms/Abbreviations:
CTR – California Toxics Rule
MCL – maximum contaminant level
NA – not applicable because not above criterion
U.S. EPA – United States Environmental Protection Agency

Table 2-6
Reasonable Maximum Exposure Cancer Risks and Hazard Indices by Receptor

Receptor/Exposure Pathway	U.S. EPA Cancer Risk*	Cal/EPA Cancer Risk*	Hazard Index
Residential			
Ingestion of groundwater	5E-04	2E-03	7
Dermal contact with groundwater while showering	8E-04	8E-04	0.4
Inhalation of indoor air from soil gas (sitewide)	3E-05	4E-06	0.3
Ingestion of homegrown produce	1E-05	5E-05	0.2
Ingestion of soil	9E-06	6E-05	3
Inhalation of groundwater while showering	3E-06	9E-06	0.4
Dermal contact with soil	1E-06	5E-06	0.09
Inhalation of particulates	9E-08	1E-07	0.03
Sitewide total	**1E-03**	**3E-03**	**11**
Occupational			
Sitewide total	**6E-06**	**4E-05**	**0.3**
Building 168 total	**5E-06**	**4E-05**	**0.3**
Construction			
Sitewide total	**1E-06**	**2E-06**	**0.2**

Notes:
* *cancer risk calculated using U.S. EPA and Cal/EPA toxicity values*

Acronyms/Abbreviations:
Cal/EPA – California Environmental Protection Agency
U.S. EPA – United States Environmental Protection Agency

Section 3
REMEDIAL ACTION OBJECTIVES

U.S. EPA guidance (U.S. EPA 1988a) defines RAOs as medium-specific or OU-specific goals for protecting human health and the environment. These objectives focus the FS and define the scope of potential cleanup activities, thereby guiding the development and evaluation of remedial alternatives.

This section presents RAOs proposed for VOC-contaminated groundwater associated with IR Site 27 at Alameda Point. Issues addressed include affected media and chemicals of concern (COCs), existing and potential receptors and exposure pathways, ARARs, and site remediation (cleanup) goals. Because this report addresses contaminated groundwater, this section also discusses remediation time frames and areas of attainment in the context of RAOs.

General response objectives are used to identify RAOs. The general response objectives for IR Site 27 are as follows.

- Protect beneficial uses of groundwater underlying IR Site 27.
- Protect beneficial uses of surface water adjacent to IR Site 27.
- Protect human health by prohibiting domestic use of groundwater that has been impacted by COCs until the Navy, U.S. EPA, DTSC, and the San Francisco Bay RWQCB concur that there is no longer an unacceptable risk from such exposure.

Direct human contact with soil at IR Site 27 does not pose significant human-health or ecological risk and therefore cleanup of soil is not required and is not addressed in this FS Report.

3.1 AFFECTED MEDIA AND CHEMICALS OF CONCERN

Previous investigations at Alameda Point have shown that shallow groundwater has been impacted by VOCs at IR Site 27 (BEI 2005). HHRA results indicate that potential exposure to contaminated shallow groundwater (assuming domestic groundwater use) would present the primary risk to human health at IR Site 27. Therefore, VOC-contaminated groundwater is the primary medium of concern for this FS Report. Soil at IR Site 27 is not a medium of concern because it does not present a significant risk to human health and the environment (BEI 2005).

COCs were identified for groundwater at IR Site 27 based on groundwater sampling conducted during the RI (BEI 2005) and the BGMP (ITSI 2005). COCs for IR Site 27 were likely site-related, but no source was confirmed. COCs were reported in groundwater at concentrations exceeding their respective comparison criteria: CTR surface water criteria (for shoreline groundwater) and state and/or federal MCLs (for inland groundwater), as described in Section 2.5.3. COCs identified for groundwater at IR Site 27 include PCE; TCE; cis-1,2-DCE; trans-1,2-DCE; vinyl chloride; 1,1-DCA; and arsenic.

3.2 POTENTIAL RECEPTORS AND EXPOSURE PATHWAYS

Currently, no human populations are exposed to VOC-affected groundwater in the shallow aquifer at Alameda Point. However, because Alameda Point is being redeveloped for civilian use, potential future receptors and exposure pathways must also be considered. The planned future use of the site is mixed use, including commercial, marina, and multi-unit residential, as described in the Alameda Point Preliminary Development Concept prepared for the Alameda Reuse and Redevelopment Authority (Roma Design Group 2005). The HHRA evaluated risks under a residential scenario that assumes domestic groundwater use, specifically ingestion and showering (BEI 2005). This scenario was used because it is the most conservative and therefore provides the greatest protection for human health.

The highest cancer and noncancer risks to human health were associated with potential exposure to contaminated groundwater at IR Site 27, assuming domestic groundwater use. To calculate risk under this scenario, it was assumed that contaminated groundwater in the shallow aquifer would be extracted by residents for domestic purposes without treatment for a period of 30 years. Risk assessment results are summarized in Section 2 of this FS Report.

There is little likelihood that future residential exposures at IR Site 27 would be similar to the type of domestic groundwater use assumed in the HHRA calculations. The shallow aquifer at IR Site 27 is not expected to be a target for future water resource development due primarily to its proximity to Seaplane Lagoon, because significant pumping would result in saltwater intrusion. Furthermore, Alameda Point is located in an urban area, and an alternative high-quality municipal water supply would be available to future residents. In this situation, it is unlikely that homeowners would want to bear the expense and inconvenience of replacing municipally supplied water with potable supplies from their own private wells. ICs could be used to prohibit installation of drinking water wells within the area of the IR Site 27 groundwater plume, extraction of VOC-impacted groundwater for domestic purposes, and cross-connection between FWBZ and SWBZ groundwater until after remediation goals are achieved or the Navy and regulatory agencies agree that ICs are no longer required.

Another consideration regarding potential human receptors and exposure pathways concerns the possible volatilization of VOCs from contaminated groundwater associated with the IR Site 27 VOC plume. The upward migration of these vapors through the vadose zone to the ground surface and into indoor air could conceivably result in long-term inhalation exposures. The evaluation of this exposure pathway as part of the HHRA conducted for IR Site 27 in the RI Report (BEI 2005) suggested that upward migration of these vapors through the vadose zone does not present a significant risk to potential future residents at IR Site 27.

The HHRA did not identify adverse health risks related to VOCs in soil under any redevelopment scenario (BEI 2005). Potential human exposure to these soils was not considered a significant risk driver; therefore, this FS Report addresses only groundwater at IR Site 27.

Based on the screening-level ERA (BEI 2005), concentrations of VOCs in groundwater near the shoreline do not pose a risk to aquatic ecological receptors, and no protective measures were considered warranted for protection of terrestrial ecological receptors at the site. As such, the RI recommended no further action for aquatic and terrestrial receptors. Therefore, only human receptors are addressed in this FS Report.

3.3 POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

CERCLA Section 121(d) requires that final remedial actions attain (or the ROD must justify the waiver of) any federal or more stringent state environmental standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate. This subsection provides an overview of the methodology for identifying the site-specific potential ARARs that will govern response actions for contaminated groundwater at IR Site 27. Those potential ARARs determined to be principal drivers in the development of remediation (cleanup) goals for IR Site 27 groundwater are summarized in Section 2.4. A complete and detailed analysis of potential ARARs for IR Site 27 is included as Appendix A.

As the lead federal agency for environmental cleanup activities at Alameda Point, the DON has primary responsibility for identification of potential federal ARARs. Identification of potential state ARARs for this FS was initiated through a DON request to DTSC in a letter dated July 7, 2005. A copy of this letter is included as Attachment A2 in Appendix A.

According to 40 C.F.R. § 300.5, "applicable requirements" are those standards of cleanup or control and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. A requirement is applicable if the prerequisites of the standard show a direct correspondence to site conditions. An applicable requirement is an ARAR.

If a requirement is not specifically applicable, it must then be determined whether the requirement is "relevant and appropriate" to the site. Relevant and appropriate requirements are those standards, criteria, or limitations promulgated under federal or state environmental or facility citing law that, while not applicable, nevertheless address problems or situations sufficiently similar to those encountered at a CERCLA site to make their use well suited to that particular facility. A requirement must be determined to be both relevant and appropriate in order to be considered an ARAR. If a requirement satisfies both of these tests, it must be complied with in the same manner as an applicable requirement (U.S. EPA 1988a).

ARARs can be separated into three categories: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs are numerical standards that establish acceptable levels of risk for individual COCs in affected environmental media. Such ARARs may be derived from the application of health- or risk-based methodologies to site-specific conditions. Federal and state drinking water standards are examples of chemical-specific ARARs. Location-specific ARARs restrict remedial activities based on site locations or conditions. An example is development restrictions imposed in environmentally sensitive areas such as wetlands. Action-specific ARARs are technology- or activity-based requirements or limitations on remedial actions; action-specific ARARs are identified in Section 6 of this FS Report in association with the detailed analysis of alternatives.

3.3.1 Potential Chemical-Specific ARARs

Seven COCs (six chlorinated VOCs and arsenic) were identified for groundwater at IR Site 27. The general response objectives listed at the beginning of this section are aimed at mitigating unacceptable exposures to shallow groundwater and protecting existing beneficial uses of groundwater and surface water. In addition to these narrative objectives, remedial response actions at IR Site 27 are driven by potential state and federal ARARs that provide criteria establishing numerical groundwater remediation goals.

3.3.1.1 GROUNDWATER

The potential federal and state chemical-specific ARARs for remediation of IR Site 27 groundwater include the substantive provisions of the following:

- federal MCLs for PCE, TCE, vinyl chloride, and arsenic in drinking water, as promulgated by U.S. EPA under the Safe Drinking Water Act (SDWA) at 40 C.F.R. § 141.61(a) and (c)
- federal MCLGs for cis-1,2-DCE and trans-1,2-DCE at 40 C.F.R § 141.50(a)
- state primary MCLs for cis-1,2-DCE, trans-1,2-DCE, vinyl chloride, and 1,1-DCA at California *Code of Regulations* (Cal. Code Regs.) Title (tit.) 22, § 64444
- RCRA standards in Cal. Code Regs. tit. 22, § 66261.21, 66261.22(a)(1), 66261.23, 66261.24(a)(1), 66261.100
- RCRA standards in Cal. Code Regs. tit. 22 § 66264.94(a)(1), (a)(3), (c), (d), and (e)
- Porter-Cologne Water Quality Control Act (Porter-Cologne Act), California Water Code (Cal. Water Code) §§ 13241, 13243, 13263(a), 13269, and 13360
- Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan), Chapters 2 and 3 (Beneficial Uses and Water Quality Objectives)
- SWRCB Res. 88-63

One of the significant issues in identifying ARARs for groundwater under the SDWA and RCRA is whether the groundwater at the site can be classified as a source of drinking water. The U.S. EPA groundwater policy is set forth in the preamble to the NCP (55 *Federal Register* 8666, 8752–8756 [1990]). This policy uses the groundwater classification system set forth in the draft U.S. EPA Guidelines for Groundwater Classification under the U.S. EPA Groundwater Protection Strategy (U.S. EPA 1986). Under this policy, groundwater is classified in one of three categories (Class I, II, or III) based on ecological importance, replaceability, and vulnerability considerations. The U.S. EPA guidelines define Class III groundwater as groundwater with TDS concentrations above 10,000 mg/L and a yield of less than 150 gpd (U.S. EPA 1986).

Class III groundwater can also be classified based on economic or technological treatability tests as well as on quality or quantity (both sets of criteria are not needed, just one or the other).

Site-specific information indicates that a portion of the groundwater at IR Site 27 would classify as Class II and a portion would classify as Class III. The site-specific beneficial use analysis (Section 2.4.6) indicates that groundwater near the shoreline, west of the sheet pile bulkhead (which includes Ferry Point Road along the shoreline with Seaplane Lagoon) would be classified as Class III on the basis of TDS greater than 10,000 mg/L (Figure 3-1). Groundwater underlying the remainder of the site (east of the sheet pile bulkhead) would classify as Class II groundwater for the purposes of this CERCLA cleanup. Appendix A, Section A.2.2.1.1, includes a detailed discussion of groundwater classification considerations for IR Site 27.

Federal MCLs and maximum contaminant level goals (MCLGs) developed by the U.S. EPA under the SDWA are generally considered potentially relevant and appropriate requirements for aquifers with Class I and Class II characteristics, and therefore are potential federal ARARs. The point of contact for MCLs and MCLGs under the SDWA is at the tap. Therefore, the MCLs and MCLGs are not applicable ARARs for Navy sites. However, MCLs and MCLGs are generally considered relevant and appropriate as remediation goals for current or potential drinking water sources. The VOC-impacted inland groundwater at IR Site 27 exhibits Class II characteristics and, therefore, for FS purposes, MCLs and MCLGs are potential ARARs for inland groundwater. However, because shoreline groundwater at IR Site 27 is saline, this groundwater is not considered a current or potential drinking water source, and therefore MCLs and MCLGs are not potential ARARs for shoreline groundwater.

3.3.1.2 SURFACE WATER

There are no natural streams, rivers, ponds, lakes, or other surface water bodies within the boundaries of IR Site 27. Even though IR Site 27 is adjacent to the Seaplane Lagoon (which is contiguous with San Francisco Bay), surface water is not a medium of concern for the site. Sediments in Seaplane Lagoon (including the portion offshore of IR Site 27) are being investigated as part of IR Site 17. Shoreline groundwater is in contact with surface water, and groundwater generally flows toward Seaplane Lagoon. Therefore, surface-water requirements were identified to assist in developing cleanup goals for IR Site 27.

The substantive provisions of the following federal and state chemical-specific requirements were identified as potential ARARs for surface water:

- CERCLA alternative concentration limits in CERCLA Section 121(d)(2)(B)(ii) (42 U.S.C. § 9621[d][2][B][ii])
- Water quality standards in the National Toxics Rule and CTR standards at 40 C.F.R. § 131.36 and 131.38
- Porter-Cologne Act (Cal. Water Code §§ 13241, 13243, 13263[a], 13269, and 13360)

- Basin Plan, Chapters 2 and 3 (Beneficial Uses and Water Quality Objectives)
- Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California, Sections 1.3 and 1.4

3.3.2 Potential Location-Specific ARARs

For the IR Site 27 remedial action, the following categories of potential location-specific resources were evaluated: cultural resources, wetlands protection, floodplain management, hydrologic resources, biological resources, coastal resources, and geologic characteristics. The conclusions for ARARs pertaining to these resources are as follows.

- No archaeological or historic data have been identified at IR Site 27. Therefore, no potential cultural resources ARARs were identified.
- IR Site 27 is not located in a wetland or floodplain. Although a runway wetland area exists to the west of IR Site 27, it is located approximately 3,000 feet from the site, across Seaplane Lagoon. Remedial actions at IR Site 27 would not affect the wetland area. With regard to floodplains, there are no naturally occurring streams or ponds at Alameda Point. Therefore, no potential wetlands protection or floodplain management ARARs were identified.
- IR Site 27 contains no designated hydrologic resources, nor would the IR Site 27 remedial actions affect any such resource. Therefore, no potential hydrologic resources ARARs were identified.
- The Migratory Bird Treaty Act of 1972 (16 U.S.C. §§ 703–712) is the only potential biological resource ARAR for the remedial actions at IR Site 27 because there is the potential for listed birds to land on the site.
- IR Site 27 is adjacent to the Seaplane Lagoon, which is contiguous with San Francisco Bay. The Coastal Zone Management Act (16 U.S.C. §§ 1451–1464, 15 C.F.R. § 930) is a potential ARAR.
- There are no known faults directly at or in the vicinity of IR Site 27. The nearest active fault is the Hayward Fault, which is approximately 6.5 miles east of Alameda Point. Therefore, no potential geologic characteristics ARARs were identified.

3.4 REMEDIAL ACTION OBJECTIVES FOR IR SITE 27 GROUNDWATER

RAOs are site-specific, qualitative goals that define the purpose of site cleanup. RAOs specify the following:

- COCs
- exposure route(s) and receptor(s)
- an acceptable contaminant level or range of levels for each exposure route (i.e., a remediation goal)

Because RAOs typically involve preserving or restoring a resource (e.g., groundwater or surface soil), they are expressed in terms of the medium of interest and target cleanup levels whenever possible. RAOs were identified as the result of the RI HHRA and ERA (BEI 2005), the potential beneficial uses of groundwater (Section 2.4.6), and the ARARs analysis (Section 3.3 and Appendix A). RAOs for shoreline and inland groundwater at IR Site 27 are identified in Table 3-1.

3.4.1 RAOs for Shoreline Groundwater

MCL- and/or MCLG-based RAOs were not considered for shoreline groundwater due to its Class III characteristics. The CTR surface water criterion was used for development of the RAOs for shoreline groundwater. Because shoreline groundwater already meets these CTR criteria, no consideration of an attenuation factor or mixing zone is needed. No surface water RAOs for aquatic receptors are selected for IR Site 27 because of the lack of significant ecological risk to aquatic life organisms, as established by the ERA conducted at IR Site 27.

RAOs derived from numerical water quality criteria for priority pollutants promulgated in the CTR (40 C.F.R. § 131.38) and implemented in the Enclosed Bays and Estuaries Plan (SWRCB 2000) as a part of the Basin Plan apply in the receiving water (Seaplane Lagoon and San Francisco Bay), following initial dilution.

3.4.2 RAOs for Inland Groundwater

The RAOs selected for inland groundwater were based on the most stringent of the following:

- the federal primary MCL
- the nonzero federal MCLG
- the state primary MCL

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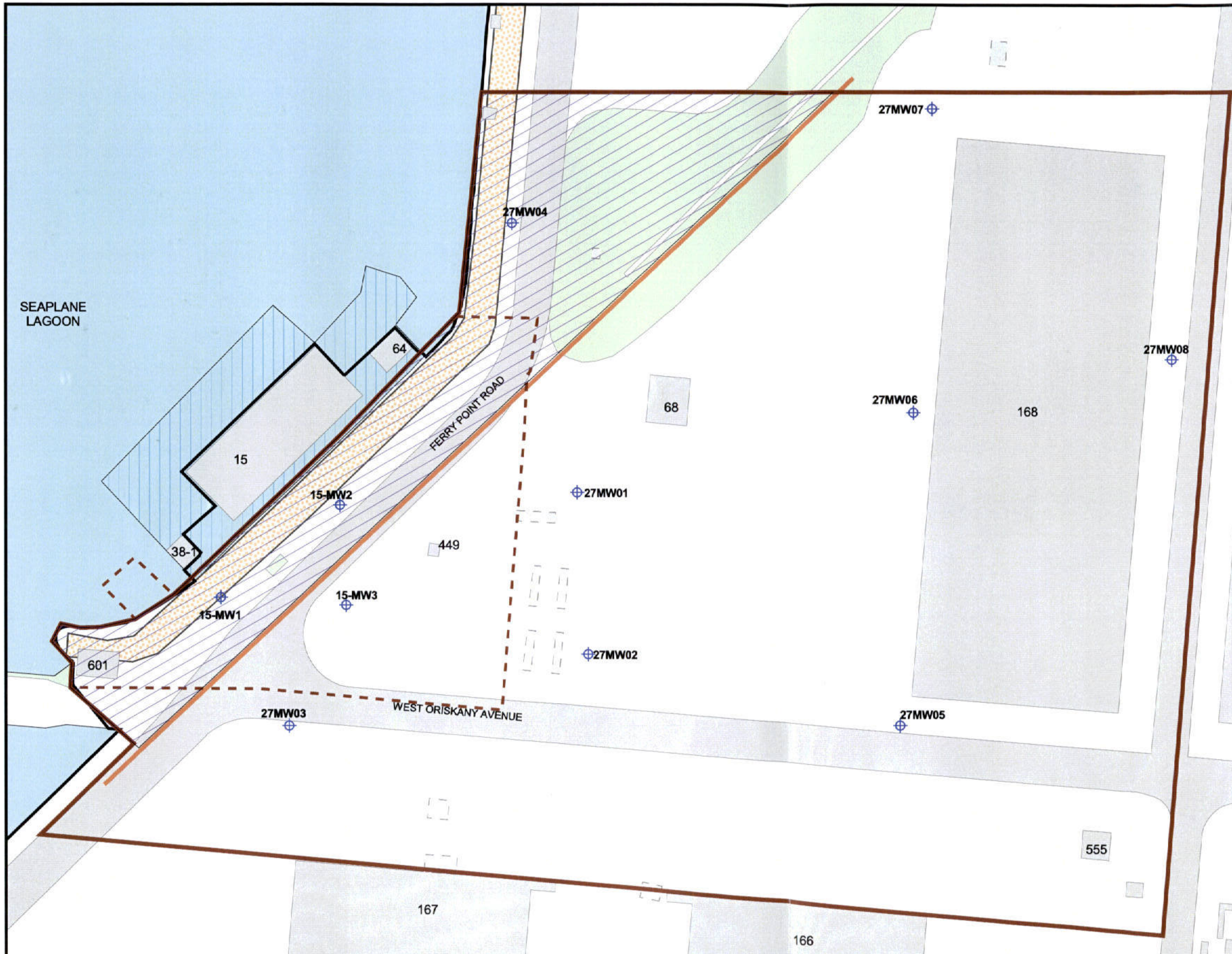
FIGURES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006



Feasibility Study for IR Site 27

Figure 3-1

Class III Groundwater Area

Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 7/14/05
File No.: 069L13917
Job No.: 23818-069
Rev No.: B

TABLE

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006

Table 3-1
Groundwater Remedial Action Objectives for IR Site 27

Chemical of Concern	Proposed RAO (µg/L)	Exposure Route	Potential Receptor
Shoreline groundwater			
trans-1,2-dichloroethene	140,000[a]	Ingestion	Recreational fisherman
tetrachloroethene	8.85[a]		
trichloroethene	81[a]		
vinyl chloride	525[a]		
Inland groundwater			
1,1-dichloroethane	5[b]	Ingestion, dermal contact while showering	Hypothetical future resident (as a means to evaluate the unrestricted use scenario)
cis-1,2-dichloroethene	6[b]		
trans-1,2-dichloroethene	10[b]		
tetrachloroethene	5[c]		
trichloroethene	5[c]		
vinyl chloride	0.5[b]		
arsenic	10[d]		

Notes:
[a] RAO based on CTR criterion for human health consumption of organisms (40 C.F.R. § 131.38)
[b] RAO based on California primary MCL
[c] RAO based on federal and California primary MCL of 5 µg/L
[d] RAO based on federal primary MCL of 10 µg/L

Acronyms/Abbreviations:
ARAR – applicable or relevant and appropriate requirement
C.F.R. – *Code of Federal Regulations*
CTR – California Toxics Rule
µg/L – micrograms per liter
MCL – maximum contaminant level
RAO – remedial action objective

Section 4
IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

This section discusses general response actions and associated technologies capable of addressing the VOC-contaminated groundwater at IR Site 27. The remedial technologies are screened for effectiveness, implementability, and relative cost (U.S. EPA 1988b). Technologies retained after the screening evaluation are then assembled into remedial alternatives in Section 5.

Prior to the selection of appropriate response actions and technologies, the site COCs were evaluated with respect to the remediation goals to determine the level of removal and/or treatment potentially required.

Technologies are assessed primarily on the basis of their ability to address the VOCs identified in Table 3-1. However, the impact of the technologies on other site COCs is also discussed.

4.1 GENERAL RESPONSE ACTIONS

General response actions are broad category approaches for achievement of RAOs. Some response actions may stand alone as complete remedial alternatives. However, in most cases, combinations of response actions are required to effectively address site-related contamination and meet all the RAOs.

The following general response actions are considered in this FS Report.

- **No action** entails no further response actions of any type, including no administrative controls or monitoring. The NCP and CERCLA require consideration of a no action alternative as a basis for comparison with other remedial alternatives.
- **LUCs** reduce potential hazards by limiting public exposure to site-related contaminants, primarily through administrative measures (e.g., institutional controls [ICs]) or engineering controls (ECs). Only the IC component of LUCs was considered for groundwater. Examples of ICs include permits for installation of new water supply wells or future-use restrictions placed on property deeds or titles. ICs do not reduce the volume, mobility, or toxicity of COCs in groundwater.
- **Monitoring** includes the periodic collection of groundwater samples and chemical analyses of these samples to evaluate COC extent and migration, and/or changes in site conditions over time.
- **Monitored natural attenuation (MNA)** relies on naturally occurring *in situ* processes (e.g., biodegradation, chemical transformation, volatilization, dilution, dispersion, and adsorption) to achieve remediation goals within a reasonable time frame (U.S. EPA 1999). Under certain conditions, these natural processes act to reduce the mass, toxicity, mobility, or volume of VOC-contaminated soil and groundwater. Monitoring is necessary to check cleanup progress.
- **Containment** technologies control risk by eliminating routes of VOC exposure or reducing exposures to acceptable levels through physical or hydraulic control of groundwater. Containment technologies may reduce contaminant mobility

but would not necessarily reduce the toxicity or volume of VOCs. Monitoring is necessary to check cleanup progress.

- **Extraction** methods remove contaminated groundwater affected by VOCs. Because contaminants in extracted groundwater are transferred (for final disposition) and not destroyed, extraction does not reduce the toxicity, mobility, or volume of VOCs.
- ***Ex situ* treatment** involves above-grade engineered processes to separate or destroy VOCs. Separation technologies transfer COCs from one medium to another, generally creating a more concentrated and easily treated waste stream. Destruction technologies transform site-related COCs into generally innocuous by-products, although they may produce other (nontarget) contaminants in residual streams. Destructive treatment often involves planned or inadvertent releases to the environment (e.g., air emissions).
- ***In situ* treatment** involves using in-place processes (e.g., biological, physical, thermal, or chemical processes). Thermal, physical, or chemical processes may also be used to break down contaminants and/or alter their properties so they can be easily extracted.

4.2 IDENTIFICATION OF REMEDIAL TECHNOLOGIES

Remedial technologies that have been identified for the general response actions are presented in Table 4-1. The technologies selected include those based on U.S. EPA guidance, remedial technology literature, and Alameda Point experience.

4.3 SCREENING OF REMEDIAL TECHNOLOGIES

For each remedial technology, associated process options have been identified. Remedial technologies and associated process options were screened for effectiveness, implementability, and cost. The objective of screening was to select appropriate process options for each technology and to use the selected technologies to formulate remedial alternatives. Development and evaluation of these alternatives are discussed in Section 5.

The screening criteria were applied based on their relative importance to the FS process (U.S. EPA 1988b). The criterion of effectiveness was given the most weight, followed by implementability, and then cost. When two or more process options yielded comparable results, cost was the deciding factor. Factors considered for the screening criteria are provided in Table 4-2.

The following subsections discuss the screening results. Results for process options are grouped by general response action (Section 4.1) and technology. Table 4-3 summarizes the screening results and lists process options retained for the development of alternatives (Section 5).

4.3.1 No Action

The no action alternative was included in the screening process because it is automatically retained as the baseline for comparison with other response actions.

4.3.2 Land-Use Controls

LUCs are restrictions placed on the use of land or on activities that may take place in a given area. LUCs may include engineering controls or ICs. Only ICs are included for consideration as a remedial technology for groundwater at IR Site 27. ICs for groundwater at IR Site 27 would be designed to prevent transferee exposure to groundwater that poses unacceptable risk until the Navy, U.S. EPA, DTSC, and the San Francisco Bay RWQCB concur that there is no longer an unacceptable risk from such exposure.

The following four general categories of ICs are considered for IR Site 27: governmental controls, proprietary controls, enforcement tools with LUC components, and informational tools. ICs are often more effective if they are layered or implemented in series. Layering means using several categories of ICs at the same time to enhance the protectiveness of the remedy. Implementation of ICs in series may be applied to assure both the short- and long-term effectiveness of the remedy. The following subsections describe and evaluate ICs that could be applied at IR Site 27.

4.3.2.1 GOVERNMENTAL CONTROLS

Governmental controls use the regulatory authority of a governmental entity to impose restrictions on citizens or property under its jurisdiction. Examples of government controls include zoning restrictions and groundwater-use restrictions. A discussion of potential governmental-controls-based ARARs is presented in Appendix A.

Effectiveness

At IR Site 27, zoning and groundwater-use restrictions are potentially effective.

Implementability

Governmental controls such as zoning restrictions and groundwater-use restrictions are readily implementable at IR Site 27.

Cost

The cost associated with governmental controls would be low.

Conclusion

Governmental controls were retained for further evaluation as a component of remedial alternatives.

4.3.2.2 PROPRIETARY CONTROLS

Proprietary controls involve legal instruments placed in the chain of title of the site property. Proprietary controls can be implemented without the intervention of any federal, state, or local regulatory authority. Proprietary controls include easements and covenants. Covenant-based proprietary controls are used extensively by the Navy at Alameda Point IR sites. For ICs at these sites, the Navy is following the approach outlined in the March 2000 MOA between the DON and the DTSC (Attachment A). The document presented as Attachment B entitled Principles and Procedures for Specifying, Monitoring and Enforcement of LUCs and Other Post-ROD Actions provides further details of the Navy's covenant-based IC strategy.

Effectiveness

At IR Site 27, easements and covenants are potentially effective.

Implementability

Proprietary controls are readily implementable at IR Site 27.

Cost

The cost associated with proprietary controls would be low.

Conclusion

Proprietary controls were retained for further evaluation as a component of remedial alternatives because of the possibility of property transfer in the future.

4.3.2.3 ENFORCEMENT TOOLS WITH LUC COMPONENTS

Enforcement tools are defined as tools such as administrative orders or consent decrees, available to U.S. EPA under CERCLA and RCRA, that can be used to restrict the use of land.

Effectiveness

Enforcement tools are less appropriate than other IC options as a long-term solution at IR Site 27.

Implementability

Enforcement tools would be more difficult to implement than other ICs.

Cost

The cost associated with enforcement tools would be low.

Conclusion

Enforcement tools are eliminated from further evaluation because they are more difficult to implement and less appropriate as a long-term solution than other IC options. The Navy is following a covenant-based proprietary controls approach, as outlined in the March 2000 MOA at Alameda Point (Attachment A).

4.3.2.4 INFORMATIONAL TOOLS

Informational tools provide information or notification that residual contamination may remain on-site. Common examples include state registries of contaminated properties, deed notices, and advisories.

Effectiveness

Because informational tools are nonenforceable, they are not an effective or reliable long-term solution as a stand-alone option. They are most likely to be used as a second layer to help ensure the overall reliability of ICs.

Implementability

Implementation of information tools would be relatively easy.

Cost

The cost associated with informational tools would be low.

Conclusion

Informational tools are eliminated from further evaluation as a stand-alone option because they are nonenforceable and other more effective ICs are available as remedial alternative components. They are retained for use as a secondary layer to help ensure overall reliability of ICs.

4.3.3 Monitoring

The monitoring process involves regular site inspections, groundwater sampling and analysis, and compliance reporting. One process option, groundwater sampling and analysis, was evaluated. Groundwater would be periodically sampled and analyzed to monitor aquifer hydraulics and variations in contaminants and aquifer chemistry.

4.3.3.1 EFFECTIVENESS

Groundwater monitoring as a stand-alone action is not effective at reducing the mass, volume, or toxicity of groundwater contamination. It is effective as a means of evaluating chemical concentrations and changes in site conditions over time.

4.3.3.2 IMPLEMENTABILITY

Groundwater monitoring is implementable at IR Site 27, as demonstrated by previous investigations.

4.3.3.3 COST

Groundwater monitoring can be a cost-effective process option if it is planned and executed efficiently and if it is fixed in duration.

4.3.3.4 CONCLUSION

Groundwater monitoring is a practical method of confirming the effectiveness of remediation and plume stability, and can be combined with other technologies. This process option is, therefore, retained for further evaluation in this FS Report as a component of remedial alternatives. Monitoring as a stand-alone remedy is eliminated.

4.3.4 Monitored Natural Attenuation

MNA is a process option that employs monitoring to confirm the effectiveness of naturally occurring *in situ* processes (e.g., biodegradation, chemical transformation, volatilization, dilution, dispersion, and adsorption) in achieving RAOs within a reasonable time frame. Under certain conditions, these natural processes act to reduce the mass, toxicity, mobility, or volume of COC-contaminated soil and groundwater. Monitoring is performed to check the progress of attenuation processes.

4.3.4.1 LINES OF EVIDENCE

Multiple, distinct, but diverging lines of evidence have been used in recent years to demonstrate natural attenuation mechanisms (Wiedemeier et al. 1998; U.S. EPA 1998, 1999a). The most common lines of evidence used to demonstrate natural attenuation of dissolved VOCs in groundwater include the following:

- historical trends
- mass reduction
- microbiological data
- modeling
- oxidation-reduction conditions

Historical Trends

This line of evidence involves using historical contaminant data to show that the contaminant plume is shrinking, stable, or growing at a slower rate than predicted by conservative solute transport velocity calculations. At this time, data for groundwater in the vicinity of the IR Site 27 plume are available from which to draw conclusions. Additionally, data (including MNA parameters) continue to be generated by the ongoing monitoring of the IR Site 27 plume under the BGMP.

Historical data for wells installed in the western portion of IR Site 27 (wells 15-MW1, 15-MW2, and 15-MW3) are available for the period of 1995 through 2005. Historical data for wells installed in the central and western portions of IR Site 27 (wells 27MW01 through 27MW08) are available for the period of 2003 through 2005. Figure 4-1 plots the chlorinated VOC concentration trends for three wells:

- 27MW06, located in the central portion of the Building 168 plume area
- 15-MW3, located in the central portion of the Ferry Point Road plume area

- 15-MW1, located downgradient from the central portion of the Ferry Point Road plume area

These plots demonstrate reductions in concentrations of the parent compounds PCE and/or TCE and the increases and decreases in concentrations of daughter products DCE and vinyl chloride as dechlorination progresses. A comparison of the data for wells 15-MW3 and 15-MW1 shown on Figure 4-1 indicates that the Ferry Point Road plume is stable or shrinking, based on the fact that concentrations are lower at the downgradient well for all constituents except the final breakdown product vinyl chloride, and the concentrations of vinyl chloride are decreasing. A stable or shrinking plume is direct evidence for natural attenuation (Sinke 2001).

Mass Reduction

The presence of degradation products such as DCE and vinyl chloride in the groundwater is evidence that intrinsic biodegradation of PCE and TCE is occurring at IR Site 27. Figure 4-1 demonstrates the reductive dechlorination of cis-1,2-DCE to vinyl chloride in well 15-MW1. Concentrations of cis-1,2-DCE decreased from 1995 through 2002, while concentrations of the breakdown product vinyl chloride increased. Subsequent decreases in vinyl chloride concentrations (2002 to 2005) indicate that this compound is also undergoing reductive dechlorination and that there is a reduction in the mass of parent compounds.

Indirect geochemical evidence may be used to assess whether conditions are conducive to contaminant biodegradation. The presence of VOC degradation products (e.g., DCE and vinyl chloride) at IR Site 27 suggests that mildly reducing conditions conducive to anaerobic biodegradation of these solvents exist in the aquifer. Monitoring of natural attenuation parameters was conducted during the RI and is ongoing as part of the BGMP. Table 4-4 lists natural attenuation data collected between 2002 and 2005 and uses a screening process developed by U.S. EPA to ascertain whether these data indicate that natural attenuation is occurring at IR Site 27 as a result of reductive dechlorination (U.S. EPA 1998). For the three locations monitored by wells 27MW06, 15-MW3, and 15-MW1, the results of the screening process indicate that there is at least limited evidence that reductive dechlorination is occurring.

In addition, the preponderance of daughter products (cis- and trans-1,2-DCE, and vinyl chloride) with respect to parent compounds TCE and PCE suggests that MNA has been occurring for an extended period of time and that much of the parent material has undergone biodegradation.

Microbiological Data

Microbiological data can be used as evidence that indigenous microorganisms are capable of degrading the VOC groundwater contaminants. For instance, dehalococcoides (DHE) microorganisms and several DHE-like organisms have been shown to completely dechlorinate TCE, DCE, and vinyl chloride in an anaerobic environment (Major 2002). While microcosm studies have not been performed at IR Site 27, at least one strain of DHE has been shown to be present at Alameda Point (Koenigsberg et al. 2003).

Modeling

The analytical model BIOCHLOR Natural Attenuation Decision Support System (BIOCHLOR) was used to simulate the reduction of concentrations of dissolved-phase VOCs (e.g., TCE, DCE, and vinyl chloride) in IR Site 27 groundwater. BIOCHLOR is a U.S. EPA-accepted software package that provides an analytical solution to modeling natural attenuation of dissolved-phase organic compounds. Two areas of higher VOC concentrations were identified in the RI: the Ferry Point Road plume and the Building 168 plume. The two plumes were modeled to predict the amount of time that may be required to reduce chlorinated VOC concentrations to meet RAOs. The model simulation results presented in Appendix B are used in this FS Report to predict the rates of decay and the required duration for MNA to reduce chlorinated VOC concentrations to reach RAOs.

Oxidation-Reduction Conditions

Measurement of oxidation-reduction (redox) conditions in groundwater can be used to evaluate the potential for conditions that are conducive to anaerobic bioremediation of chlorinated solvents in groundwater. Redox conditions at the site can be understood by evaluating the distribution of redox-sensitive parameters. Microorganisms obtain energy for new and existing cells through the mediation of redox reactions involving the transfer of electrons from an electron donor to an electron acceptor (Zehnder and Stumm 1988, Pirt 1975, Bouwer 1994). In general, the electron donor is an organic compound, while the electron acceptor is inorganic (Zehnder and Stumm 1988). The free energy yielded by redox reactions varies substantially, depending on the electron acceptor (Figure 4-2). During respiration, microorganisms will preferentially use the electron acceptors yielding the greatest free energy (Bouwer 1994).

Figure 4-2 shows that the order of preference for the most common inorganic electron acceptors is: oxygen, nitrate, manganese (IV), iron (III), sulfate, and carbon dioxide. Therefore, the dominant microbial community in a groundwater system depends largely on the distribution of electron acceptors. Where oxygen is plentiful, aerobic bacteria will predominate; where oxygen is depleted but nitrate is plentiful, nitrate-reducing bacteria will predominate.

The importance of electron-acceptor use patterns to biological communities in groundwater has led to the convention of discussing redox conditions in terms of the dominant terminal electron acceptor process (TEAP). The predominant TEAP is often inferred on the basis of electron acceptor and reduced product concentrations and provides a useful indicator of the overall redox conditions. In general, the more reducing the conditions, the greater the excess of electron donors (oxidizable organic compounds) relative to electron acceptors.

For oxygen, nitrate, and sulfate, decreased concentrations relative to ambient concentrations indicate that they are being utilized as electron acceptors. Reduced products are particularly important in the case of manganese and iron reduction because manganese (IV) and iron (III) are only sparingly soluble, while manganese (II) and iron (II) have higher solubilities. Thus, elevated concentrations of the metals indicate they are being used as electron acceptors.

Methane is also an important reduced product that is generally present only under the most reducing conditions, when methanogenesis is occurring. Decreases in carbon dioxide concentrations do not provide a reliable indicator of its reduction because it is generally reduced only under conditions that also support its production through oxidation and fermentation of oxidizable organic compounds. Figure 4-3 presents the results of measurements for dissolved oxygen and oxidation-reduction potential (ORP) for IR Site 27 wells 27MW06, 15-MW3, and 15-MW1. Dissolved oxygen concentrations are variable, but are generally low (less than 5 mg/L). ORP measurements indicate that conditions vary between oxidizing (positive values) and reducing (negative values). When taken in conjunction with the presence of breakdown products of chlorinated compounds, including cis- and trans-1,2-dichloroethene, vinyl chloride, ethene, ethane, and methane, these data suggest that reductive dechlorination is possible and has been occurring at IR Site 27.

4.3.4.2 EFFECTIVENESS

Natural attenuation should be effective in reducing concentrations of VOCs in groundwater over the long term. The current presence of degradation products at IR Site 27 indicates that the biodegradation of VOCs is occurring.

4.3.4.3 IMPLEMENTABILITY

MNA appears to be technically feasible for IR Site 27. The methods of groundwater sampling and analysis are well proven and their use is ongoing at the site. The plume is accessible for monitoring purposes.

4.3.4.4 COST

MNA has a low capital cost and a moderate operation and maintenance (O&M) cost as long as the monitoring shows that degradation is taking place at a reasonable rate. Long-term monitoring costs for MNA could be high.

4.3.4.5 CONCLUSION

Natural attenuation is retained for further evaluation as a remedial alternative component.

4.3.5 Containment

Containment involves isolating contaminated groundwater from potential receptors. Contaminated groundwater can be contained using vertical barriers or hydraulic controls. Process options for vertical barriers have been screened. Use of hydraulic controls for containment is discussed in Section 4.3.6.

Vertical barriers would minimize the horizontal movement of contaminated groundwater or limit the flow of uncontaminated groundwater into the plume. These barriers could be installed on both the upgradient and downgradient margins of the plume and/or at specific areas within the plume. Vertical barrier process options include the following:

- sheet piles
- biobarrier
- grout curtains
- soil mixing
- slurry walls

Because these process options have common advantages and limitations, they are screened as one process.

4.3.5.1 EFFECTIVENESS

It is unlikely that a downgradient vertical barrier would be fully effective in containing the IR Site 27 groundwater plume. A sheet pile bulkhead was installed in 1940 near the current shoreline of IR Site 27 as part of the hydraulic filling of this portion of Alameda Point. It may be acting as a barrier that retards migration of VOCs in groundwater into the San Francisco Bay. A hydraulic head upgradient of the bulkhead appears to have built up and dissipated by lateral movement of groundwater around the bulkhead. A similar effect would likely occur with any other vertical barrier that would be installed at IR Site 27. Some type of groundwater pumping would likely be required to prevent a bypass of contaminated groundwater around the perimeter of the containment wall. This would lessen the overall effectiveness because it could not serve as a stand-alone option for containment.

4.3.5.2 IMPLEMENTABILITY

Implementability at IR Site 27 is dependent on the location of the vertical barrier. Installation of a wall could be difficult because of the presence of subsurface utilities and the width of the plume (approximately 800 feet).

4.3.5.3 COST

Installation of a vertical physical barrier at IR Site 27 could be high in cost because of the width of the plume and the possible need to relocate subsurface utilities.

4.3.5.4 CONCLUSION

Vertical subsurface barriers were eliminated from further consideration for IR Site 27 due to low implementability and high potential cost. Furthermore, no treatment of VOC contaminants would occur under this response action.

4.3.6 Extraction

Extraction methods are used to remove contaminated groundwater for *ex situ* treatment or disposal. Groundwater extraction also can be used for containment. Vertical groundwater extraction wells were evaluated for this FS Report. This process option is a component of "pump-and-treat" technology.

4.3.6.1 EFFECTIVENESS

Although the VOC contaminant mass might be reduced using extraction methods, this technology has been shown to be an inefficient and high-cost means for removing contaminants to low levels (API 1993, Bartow and Davenport 1992, Doty and Travis 1991, MacDonald and Kavanaugh 1994, Mackay and Cherry 1989, NRC 1994).

4.3.6.2 IMPLEMENTABILITY

Extraction is considered to be moderately implementable at IR Site 27. Due to the expanse of the plume, a large network of extraction wells would be required to capture the plume. Discharge of treated water may pose administrative and technical challenges. Due to the proximity to Seaplane Lagoon, groundwater extraction at significant rates for extended periods is expected to result in saltwater intrusion.

4.3.6.3 COST

Extraction of groundwater is considered to be moderate in capital cost and high in O&M cost. Other technologies producing similar results are considered to be more cost-effective.

4.3.6.4 CONCLUSION

Due to the low effectiveness and high cost, groundwater extraction has been eliminated from further consideration.

4.3.7 *Ex Situ* Treatment

With *ex situ* treatment, physical, chemical, biological, and/or thermal methods are used to treat extracted contaminated groundwater in above-grade applications. This response action category was not considered further due to the elimination of hydraulic controls and extraction methods as process options.

4.3.8 *In Situ* Treatment

In situ treatment is accomplished without removing contaminated groundwater from the aquifer. Physical, thermal, biological and chemical *in situ* treatments are further evaluated in the following subsections.

4.3.8.1 PHYSICAL TREATMENT

In situ physical treatment of groundwater contamination usually involves aeration of the contaminated area, which releases VOCs as a vapor. Two physical treatment process options are considered: air sparging and Dynamic Subsurface Circulation.

Air Sparging

Air sparging involves injecting air into the saturated zone to remove contaminants through volatilization. This injected air helps to flush (bubble) the contaminants up into the unsaturated zone, where a vapor extraction system is usually implemented to remove the vapor-phase contamination. The vapor typically requires additional treatment prior to discharge to the atmosphere. The air sparging process is most effective in reducing concentrations in the source areas.

Effectiveness. Geology in the areas of highest groundwater concentrations at IR Site 27 is fairly uniform (Merritt Sand); however, lithologic variations were encountered. Air sparging is sensitive to changes in hydraulic conductivity. Airflow through a heterogeneous saturated zone may not be uniform, and thus contaminant removal efficiency will vary. Due to the shallow groundwater at the site, the capture of these vapors may be compromised. Vinyl chloride is very volatile and relatively easy to remove via air sparging, provided that ample dispersion of sparge air can be accomplished. However, air sparging typically does not achieve low levels for VOC contamination removal unless subsurface conditions are optimal.

Implementability. Implementability of air sparging in the area would be moderate. Subsurface utilities could carry vapors outside of the area of capture, so this would need to be accounted for in the remedial design. Fill material in the FWBZ at Alameda Point is stratified, and stratification could complicate vapor collection.

Cost. Principal factors affecting cost are aquifer heterogeneity, contaminant concentration, geochemical and biological interferences/reactions, and depth of the zone to be treated. Air sparging delivery systems for the VOC plume area at IR Site 27 would be high in capital cost due to the extent of the plume. If air sparging treatment is limited to areas of higher concentrations, costs would be moderate to high. Air sparging operations would be moderate in O&M cost for a short operational time frame; however, costs would increase if extended operation became necessary.

Conclusion. This process option is retained for consideration as a component of remedial alternatives.

Dynamic Subsurface Circulation

This process option combines *in situ* air stripping, air sparging, soil vapor extraction (SVE), and Dynamic Subsurface Circulation in a proprietary well design. An in-well air sparging component installed at the bottom of the well results in lifting the water table. This lifting of water creates a reduction in head at the well locations, which results in groundwater flowing toward the well at depth. SVE is applied at the well to extract vapor from the subsurface. The negative pressure from the SVE component results in suction that further lifts the water table.

The air stripping component is implemented via a submersible pump placed at the bottom of the well to recirculate water to the top for downward discharge through a spray head. In essence, the well acts as a subsurface air-stripping tower. These air sparging and air stripping effects remove VOCs and result in oxygenated water flowing out through capillary fringe soil at the top of the water-bearing zone, back into the aquifer. The partially treated groundwater is never brought to the surface; it is forced into the capillary fringe zone and creates the dynamic subsurface circulation.

The radius of influence of the Accelerated Remediation Technologies, LLC, (ART) well has been shown to be up to 70 feet (U.S. EPA 2005). Circulating well systems are most effective at treating sites with volatile contaminants having relatively high aqueous solubility and located in homogeneous permeable soil. The circulating well technology operates most efficiently with horizontal conductivities greater than 10^{-3} centimeters per second and a ratio of horizontal to vertical conductivities between 3 and 10 (FRTR 2002). Geology in the two areas of highest groundwater concentrations at IR Site 27 consists of the Merritt Sand Formation (a fairly uniform sand), and appears amenable to this technology.

Effectiveness. This technology has proven effective at sites with similar contaminants. Because the groundwater contamination is shallow, the circulation aspect of the ART well may be impeded. If wells can be extended a few feet above grade, effectiveness will be increased. Remediation takes place in the groundwater, the saturated zone, and the vadose zone with one technology.

Implementability. The ART well has moderate implementability. Remediation wells would be installed and fitted with the proprietary well equipment. The sparging equipment is designed to accommodate a 4-inch (minimum) well design, lending itself to relatively straightforward installation.

Cost. Installation of the ART wells is considered to have moderate cost. The O&M aspect of the wells and associated sparging equipment is anticipated to have high cost. If treatment is limited to areas of higher concentrations, costs would be moderate to high. Typically, two years or less of operation is performed with this technology.

Conclusion. Dynamic Subsurface Circulation is retained for further consideration.

4.3.8.2 BIOLOGICAL TREATMENT

Biological treatment involves enhancing conditions for microbial activity in order to accelerate natural attenuation (Section 4.3.4). Two process options for biological treatment have been identified: enhanced anaerobic *in situ* bioremediation (ISB) (using Hydrogen Release Compound [HRC]) and cometabolic oxidation.

Enhanced Anaerobic In Situ *Bioremediation*

Enhanced anaerobic ISB is a process that attempts to accelerate the natural biodegradation process for VOCs by providing electron donor compounds to the aquifer to facilitate microbial conversion of contaminated organic compounds to innocuous end products. Anaerobic ISB processes have been implemented in both proprietary and nonproprietary forms. A proprietary version of the technology known as HRC is offered by Regenesis, Inc. Nonproprietary applications have involved the use of commercially available carbon donor sources such as corn syrup, molasses, butane, lactate or vegetable oil. Technology applications are becoming increasingly well documented in the literature (Koenigsberg et al. 2003, Leigh et. al. 2000, Sorenson et al. 2000, Sorenson and Ely 2001, and Watts et al. 2002).

HRC is assumed as a representative process option for enhanced anaerobic ISB. HRC is a proprietary, environmentally safe, food-quality polylactate ester specially formulated for slow release of lactic acid upon hydration. HRC is applied to the subsurface by direct-push injection or within dedicated wells. HRC is then left in place where it passively works to stimulate contaminant degradation.

The chemical reduction is shown in the following chemical half reactions:

$$C_3H_6O_3 \rightarrow C_3H_4O_3 + H_{2\,(gas)}$$

$$H_2O + C_3H_4O_3 \rightarrow C_2H_4O_2 + H_{2(gas)}$$

$$C_2HCl_3 + 3H_2 \rightarrow C_2H_4 + 3Cl^- + 3H^+$$

where

$C_3H_6O_3$	=	lactic acid
$C_3H_4O_3$	=	pyruvic acid
$C_2H_4O_2$	=	acetic acid
H_2	=	hydrogen
C_2HCl_3	=	TCE
C_2H_4	=	ethene
Cl^-	=	chloride ion

Enhanced anaerobic ISB appears appropriate for treatment of VOCs at IR Site 27 because conditions in the aquifer appear mildly reducing and evidence of natural anaerobic VOC biodegradation exists. Sulfate can act as a competing electron acceptor and inhibit the process (Yang and McCarty 2001).

The ISB process can generate undesirable by-products. An *in situ* bioremediation pilot-scale test was recently completed by the Navy at IR Site 40, Naval Weapons Station, Seal Beach, California (French et al. 2004, BEI 2004). At IR Site 40, biostimulation using sodium lactate (Phase I) as well as bioaugmentation with nonindigenous bacteria (Phase II) was implemented in a chlorinated solvent plume (predominantly PCE) underlying a paved area. Results indicated that the process was effective in reducing VOC concentrations in the groundwater; however, methane, hydrogen sulfide, and vinyl chloride gases in the vadose zone were identified during and following the pilot-scale test. Some of the observations from the Seal Beach pilot-scale test (BEI 2004) were the following.

- Hydrogen sulfide gas was produced at concentrations exceeding the odor threshold but was not reported above the detection limit in vadose zone samples.

- Methane gas concentrations exceeded the lower explosive limit in two soil gas monitoring wells and in the headspace of groundwater monitoring wells in the pilot-scale test area.
- Vinyl chloride concentrations exceeded the permissible exposure limit in soil gas samples from vapor wells.

Undesirable by-products are caused by reducing conditions lower than -200 millivolts, in which the reduction of sulfate and carbon dioxide can form hydrogen sulfide and methane (Figure 4-1). The timed-release design of the HRC product is intended to avoid these strongly reducing conditions. The Seal Beach Pilot Test Report (BEI 2004) concluded that some phase transfer of vinyl chloride from groundwater to soil gas likely took place following the conversion of DCE to vinyl chloride and ethane as part of the ISB process.

Effectiveness. The ISB process has been proven effective in transforming parent VOCs (e.g., TCE) to harmless by-products or more oxidizable degradation products (e.g., vinyl chloride).

Implementability. HRC injection is moderately implementable. This process option may require bench- and/or pilot-scale testing to verify effectiveness. The natural anaerobic reducing conditions present at IR Site 27 are amenable to the ISB process.

Cost. The initial injection of HRC is anticipated to have moderate capital and material costs. The ISB process has a low O&M cost, assuming effectiveness in a reasonable time frame (i.e., approximately 5 years or less) and additional injections are not required.

Conclusion. ISB is retained for further evaluation as a component of remedial alternatives. ISB is not being considered for application west of the sheet pile bulkhead, because VOC concentrations appear to have attenuated to concentrations near or below RAOs in that portion of the site.

Cometabolic Oxidation

Cometabolic oxidation involves amending the groundwater with a gas-phase cosubstrate (methane or butane) and oxygenated air to stimulate cometabolic destruction of VOCs in the subsurface, including compounds such as DCE and vinyl chloride. This destruction is achieved by enzyme-catalyzed reactions brought on by the methane monooxygenase enzyme of indigenous bacteria that use methane as an energy source (methanotrophs). The process can degrade VOCs into carbon dioxide, water, and chloride.

The United States Department of Energy has documented a successful full-scale cometabolic oxidation application (DOE 1993, 1995, 1996), and recently a successful cometabolic oxidation of a plume containing DCE and vinyl chloride was documented in a pilot-scale study at Point Mugu, Naval Base Ventura Complex, California (Johnson et al. 2003).

The Point Mugu cometabolic oxidation project was implemented as the second phase of a sequential anaerobic-aerobic ISB strategy (Leigh et al. 2000, Porter et al. 2003). At Point Mugu (IR Site 23) the technology was implemented in the form of a recirculating system in which groundwater was extracted, amended *ex situ* with oxygen and methane gas, and then reinjected (Johnson et al. 2003). Concentrations of vinyl chloride within the pilot-scale test cell were apparently reduced from approximately 400 to 600 µg/L outside of the test cell to values below detection levels in all wells within the test cell; however, DCE removal was not demonstrated (Leigh, pers. com. 2003).

Effectiveness. Cometabolic oxidation could be effective for remediation of VOC degradation products (i.e., DCE and vinyl chloride, although not DCA) in the IR Site 27 plume. Based on the Point Mugu experience, the technology offers the potential of significantly reducing vinyl chloride concentrations. However, the technology is less demonstrated for VOC parent products (e.g., TCE).

Implementability. Recirculation of groundwater in the FWBZ should be feasible, given the measured FWBZ hydraulic conductivity of 1×10^{-3} centimeters per second.

Cost. Cometabolic oxidation implementation is presumed to have a relatively low capital and material cost. The O&M costs would be moderate, assuming the technology is proven effective in a reasonable time frame.

Conclusion. This process was eliminated from further consideration because more effective technologies are available for the IR Site 27 plume.

4.3.8.3 THERMAL TREATMENT

Thermal treatment involves heating soil and groundwater to strip VOCs and semivolatile organic compounds from pore spaces in the aquifer. Two process options are available for this technology: electrical resistive heating (ERH) and steam stripping. ERH was selected as a representative process option for this FS Report.

ERH, also known as six-phase heating, splits conventional electricity into six electrical phases for heating soil and groundwater. An innovative technology, ERH is performed in conjunction with vacuum extraction or dual-phase extraction to strip contaminants from the aquifer and remove them via phase transfer. Pilot-scale test data are available for ERH, and the technology has been pilot-tested at Alameda Point IR Site 5.

Effectiveness. At the IR Site 27 plume, ERH should effectively remove VOCs from groundwater in areas where the heating devices can be installed.

Implementability. Implementability may be limited by:

- the large plume area,
- the need to capture and treat potentially high volumes of vapor produced,
- potential for electrical interference with operating facility instrumentation, and
- the presence of underground utilities or other conductive objects that would present safety hazards.

For the plume at IR Site 27, implementation would be difficult. This technology could require high energy to heat the aquifer formation and groundwater.

Cost. Under favorable conditions, and with higher VOC concentrations, ERH is cost-competitive with other remediation technologies; however, other more cost-effective technologies exist for the dissolved-phase contamination present at IR Site 27.

Conclusion. ERH was eliminated from further consideration due to low implementability and high cost.

4.3.8.4 CHEMICAL TREATMENT

Chemical treatment process options induce *in situ* chemical reactions to mobilize and/or chemically break down contaminants in groundwater. Four process options were screened: permeable reactive barriers (PRBs), ozone sparging, microscale iron injection, and *in situ* chemical oxidation (ISCO).

Permeable Reactive Barriers

PRBs allow the passage of water while causing the degradation or removal of contaminants. A PRB is installed across the flow path of a contaminant plume, allowing the water portion of the plume to move passively through the wall. A typical application involves installing a "funnel-and-gate" system into a basal low-permeability formation. Zero-valent iron (ZVI) is assumed as the permeable reactive medium.

The introduction of ZVI into the subsurface accelerates chemical reduction of chlorinated VOCs. One of the primary mechanisms for reducing chlorinated VOCs is sequential dechlorination, which involves direct electron transfer from the ZVI to the chlorinated VOCs. This mechanism is driven by the oxidation of iron from the ZVI state (Fe^0) to ferrous iron (Fe^{+2}). This transformation is abiotic. In sequential dechlorination, the electrons then reduce the contaminant to its daughter product and then to vinyl chloride and ethene. The overall reduction is shown in the following chemical half reactions:

$$Fe^0 \rightarrow Fe^{+2} + 2e^-$$

$$C_2HCl_3 + 3H^+ + 6e^- \rightarrow C_2H_4 + 3Cl^-$$

where

Fe^0	=	zero-valent iron
Fe^{+2}	=	ferrous iron
e^-	=	electron
C_2HCl_3	=	TCE
H^+	=	hydrogen
C_2H_4	=	ethene
Cl^-	=	chloride ion

Another mechanism for reducing chlorinated VOCs is hydrogenation, which involves the production of hydrogen gas during the corrosion of ZVI under reducing conditions. This reduction is illustrated in the following chemical equations, using TCE as an example:

$$Fe^0 + 2\,H_2O \rightarrow Fe^{+2} + 2OH^- + H_{2(gas)}$$

$$C_2HCl_3 + 3H_2 \rightarrow C_2H_4 + 3Cl^- + 3H^+$$

In either case (sequential dechlorination or hydrogenation), the end product is ethene, a nontoxic gas that does not persist in soluble form. The by-products of the reductive dechlorination process are chloride (a naturally occurring anion) and hydrogen gas.

Effectiveness. A pilot-scale ZVI PRB has been used at Alameda Point at IR Site 1 (TtEMI 2002c), where VOC concentrations in groundwater were indicative of dense nonaqueous-phase liquid (DNAPL). Based on experience at Alameda Point and other sites, the ZVI process is assumed to be effective in remediating chlorinated VOCs (e.g., PCE, TCE, DCE, and vinyl chloride) to the extent that the VOCs could be induced to migrate through a treatment wall.

Implementability. Due to the large size of the IR Site 27 plume (two areas of higher concentrations totaling approximately 1 acre in size and a total plume size of approximately 11 acres), the installation of a PRB is considered to have a low implementability. Installation of a ZVI PRB would require bench- and/or pilot-scale testing. Additional hydrogeologic testing and geotechnical investigations would be required to design the barrier.

Cost. Installation of a PRB is anticipated to be high in capital cost, with a relatively low associated O&M cost.

Conclusion. A PRB is eliminated from further consideration due to low implementability and high cost.

Ozone Sparging

For *in situ* ozonation, a properly designed air sparging system is an effective and cost-efficient way to deliver ozone to the subsurface. Ozonated compressed air is injected into the reactive zone. Ozone can oxidize organic contaminants by direct oxidation in addition to the oxidation by free hydroxyl radicals, which are produced during ozone decomposition. Ozone as a direct oxidant is the third strongest oxidant after fluorine and a hydroxyl radical (Suthersan 1997). Ozone reactions are most effective in systems with acidic (low) pH. *In situ* decomposition of the ozone can lead to beneficial oxygenation and biostimulation (FRTR 2002). The chemical oxidation (destruction) caused by ozone is shown in the following chemical reactions, with TCE as an example:

$$O_3 + C_2HCl_3 \rightarrow CHClO_2^+ + CCl_2O^-$$

$$CHClO_2^+ + CCl_2O^- + H_2O \rightarrow 2CO_2 + 3HCl$$

where

O_3	=	ozone
C_2HCl_3	=	TCE
$CHClO_2^+$	=	chlorinated aldehyde
CCl_2O^-	=	chlorinated carboxylic acid
CO_2	=	carbon dioxide
HCl	=	hydrochloric acid

An ozone sparging system generally consists of four system components: a power source or ozone generator, a gas source, an ozone delivery system, and an off-gas destruction system. The gas source may be air, high-purity oxygen, or a combination of the two. Air feed systems are more complicated than liquid oxygen feed systems because the air must be clean, dry, free of contaminants, and with a dew point as low as -60 degrees Celsius (-76 °F) to prevent damage to the generator (Oxidation Systems 2005).

The ozone delivery can be enhanced by utilizing a horizontal directional drilled (HDD) well with multiple sparge points throughout the length of the HDD well. HDD well installation would minimize the surface disturbance associated with multiple sparge points. Due to the width of the plume, this would be an effective method to deliver ozone to the full extent of the plume. Currently, the HDD technology is limited to depths of less than 50 feet (FRTR 2002), which would not be a concern given the shallow groundwater at IR Site 27. Several HDD wells could be installed in transects across the plume to deliver ozone to the width and length of the plume.

Effectiveness. Ozone sparging would be effective in oxidizing VOCs in groundwater. HDD installation and delivery of the ozone would reduce the number of wells and surface disturbance typically associated with air sparging.

Implementability. Ozone sparging has a low implementability. Ozone is a highly toxic gas that could pose a human-health risk in the event of exposure. Shallow groundwater conditions at IR Site 27 would cause difficulty in capturing sparge vapors. Sparge vapors would require treatment for ozone destruction and VOC removal prior to discharge to the atmosphere.

Cost. Ozone sparging would also involve an SVE system. It is moderately high in capital cost and O&M cost. Installation of HDD wells or sparge points is typically costly.

Conclusion. Ozone sparging is eliminated from further consideration due to low implementability.

Microscale Iron Injection

This *in situ* technology is similar to PRBs and utilizes ZVI. The ZVI powder is a "sponge" iron of high purity that exhibits a high surface area because of its small particle size (40 microns) and porosity.

The Ferox process was chosen as the representative delivery mechanism for evaluation of ZVI injection. Ferox injection is a patented technology for *in situ* subsurface remediation of chlorinated VOCs. The treatment process involves the injection (at a delivery pressure of 1,000 pounds per square inch or more) of ZVI powder in a grid pattern into a targeted contamination source area. The ZVI powder is suspended in potable water to create a slurry and injected using nitrogen gas as a carrier fluid. The success of the Ferox injection in destroying chlorinated VOCs depends on the ability of the system to disperse ZVI into the treatment zone. In low-permeability formations, pneumatic fracturing is conducted as a first step to maximize ZVI dispersal in the treatment zone. In higher permeability materials such as the Merritt Sand underlying IR Site 27, pneumatic fracturing may not be necessary; ZVI is injected under high pressure as a slurry to disperse the material. ZVI treats adsorbed contaminants bound to soil, including those in the contaminant source area. In unconsolidated sediment, a minimum overburden pressure (that can vary depending on site conditions) is required to inject the ZVI and reduce the potential for short-circuiting the iron to the surface during injection. Generally, the shallower the aquifer and the higher the permeability, the smaller the radius of influence from the injection point. The presence of structures or underground utilities could also complicate injection and influence the distribution of the ZVI.

A Ferox injection technology demonstration was conducted by the Navy at Remedial Unit C4 in Parcel C at Hunters Point Shipyard in San Francisco, California. ZVI was injected into a test area with TCE concentrations as high as 88,000 μg/L in groundwater. Based on 12 weeks of groundwater monitoring results following ZVI injection, the reduction of TCE, the predominant contaminant, to ethene and chloride was rapid and nearly complete (a reduction of 99.2 percent within the treatment zone) (TtEMI 2003c). The lifetime of the microscale iron has not been fully evaluated, but based on field applications to date, the iron would be effective for at least 2 to 3 years.

Effectiveness. The Ferox process has proven effectiveness in reducing chlorinated solvent concentrations.

Implementability. The Ferox process is implementable in the VOC plume area; however, the radius of influence at each injection point is expected to be relatively small because of the shallow depth to unconfined contaminated groundwater. Therefore, a large network of injection points would be required to address the plume area.

Cost. Ferox injection is anticipated to have a moderate capital cost. No O&M costs are anticipated unless additional injections are required.

Conclusion. Microscale iron injection was retained for further evaluation for the plume area groundwater zone.

In-Situ *Chemical Oxidation*

The ISCO process involves injection of chemical reagents into the groundwater zone where contamination is present, producing hydroxyl radicals that oxidize organic contaminants. Several variations on the process are available. A major advantage of these technologies is that contaminants are rendered innocuous. Two common oxidizing agents are potassium permanganate and agents that use Fenton chemistry (dilute hydrogen peroxide and iron).

Potassium permanganate has been used to destroy VOCs and DNAPL contamination (ITRC 2005). The potassium permanganate reacts with chlorinated solvents to oxidize the chlorinated ethenes to carbon dioxide and chloride ions. For this treatment technology, potassium permanganate typically is injected into the subsurface in the form of a dilute solution (approximately 3 percent). An automated, portable feed system is typically used to prepare the permanganate for injection. Solid potassium permanganate is fed into a heated flash mixer where it is dissolved with potable water, and the solution is injected into the aquifer.

The primary advantage of potassium permanganate oxidation is that a pH adjustment step is not necessary; however, potassium permanganate is a less powerful oxidizing agent than Fenton's reagent. Therefore, interference from competing reactants, such as total organic carbon in the soil or reductants such as iron and manganese, can reduce effectiveness. Permanganate can be injected into the subsurface using a number of methods, including use of Geoprobes, hydrofracturing, and drilling of vertical and horizontal wells.

Bench-scale testing of five oxidizing agents (hydrogen peroxide, Fenton's reagent, potassium permanganate, sodium persulfate, and ozone) was performed to support the pilot-scale tests conducted at IR Sites 9, 11/21, and 16 at Alameda Point. The bench-scale tests were performed on soil and groundwater samples collected at each of the three pilot-scale test areas. Potassium permanganate was not tested at IR Sites 9 and 16 because these sites were expected to have significant chlorobenzene and DCA contamination, and permanganate was not deemed effective in treating these compounds. Based on results of bench-scale testing, the pilot study was performed using Fenton's reagent-based oxidation chemistry. Both traditional and modified Fenton's chemistry-based reagents were considered for the pilot-scale test. A modified Fenton's reagent was used because it would not require pH adjustment of the groundwater and would result in a minimal temperature rise in the subsurface. The presence of hydrocarbons can pose a potential fire and explosion risk with traditional Fenton's reagent chemistry. At IR Site 27, hydrocarbons have been reported in soil and groundwater. The use of modified Fenton's chemistry would pose a lesser risk of fire or explosion because of the lower temperature produced in the aquifer.

Fenton chemistry is a proven technology for oxidizing organic compounds. Demonstrations of *in situ* applications of this process are becoming increasingly frequent (ITRC 2005). Contaminant mass removal has been documented in field-scale tests, but in some cases, the technology has not fully met the remediation goals, resulting in reapplication or reevaluation of the site risks. Like permanganate, the optimum dose rate for Fenton's reagent will depend on the number of competing reactions in the aquifer. ISCO is anticipated to be effective in reducing the overall mass of contamination. A dilute form of the process application (a modified Fenton process) such as offered by In-Situ Oxidation Technologies, Inc. (ISOTEC) may be effective in delivering the reagents to the plume. The ISOTEC process has recently been implemented successfully at IR Sites 9 and 16 (Eilber, pers. com. 2005a).

The following general limitations are common to the ISCO processes.

- Intrusive methods are required to introduce the reagents to the formation.
- Aquifer heterogeneity can adversely affect delivery of reagents (since reagents follow preferential flow paths).

- Chemical introduction to the aquifer formation requires acceptance from regulatory agencies.
- More than one application may be necessary to accomplish site remediation goals.
- There are safety concerns regarding handling of reagents.
- These processes may be subject to interferences from or reactions with formational materials (e.g., carbonates, total organic carbon, or TDS), resulting in higher reagent use and increased costs.
- In environments where carbonate soil minerals or hard-water conditions are prevalent, vigorous reactions may occur between the carbonate and acid species.
- These processes interrupt natural biological processes in the area being treated.

Additional potential limitations associated with concentrated reagents are as follows:

- safety hazard presented by violence of reaction
- potential for a high rate of uncontrolled vapor release, depending on VOC concentrations
- possibility of soil eruptions and sinkholes
- the need for acidification of the aquifer, which could result in hazardous conditions requiring additional remediation

Site-specific experience with ISCO at Alameda Point at IR Sites 9, 11/21, and 16 has been documented. The ISOTEC process was implemented at five locations. IR Site 16 North has similar depth intervals as IR Site 27. At IR Site 16 North, a pilot-scale test was conducted using injection wells as the delivery mechanism. The pilot-scale test indicated that the ISOTEC process was effective at reducing concentrations of target contaminants of concern; however, direct-push drilling with temporary injection points was found to be a more cost-effective alternative for injection points. Therefore, three full-scale injection events were completed using direct-push drilling to deliver the reagent to the aquifer. The three full-scale events were then followed by two injection events focusing on hot spot treatment. After the injection events at the 11-acre site, the concentrations of target COCs were reduced to below the MCL, up to a 99 percent reduction (Eilber, pers. com. 2005b). Similarly, at IR Site 9, a pilot-scale test was conducted using injection wells and full-scale injection was performed using direct-push drilling to deliver the reagent to the aquifer. The IR Site 9 COCs are similar to those at IR Site 27, and the first injection event resulted in a 20 to 80 percent reduction in COC concentrations, with a radius of influence of 15 to 20 feet at each injection point (Eilber, pers. com. 2005b). A second injection event was scheduled to be conducted at IR Site 9 in July 2005.

Based upon these full-scale injection events at IR Sites 16 and 9, the reagent injection appears to be effective; however, multiple injections were necessary to meet the project objectives. The ISOTEC process is assumed in this FS Report to be a representative process option for ISCO. It is assumed that the above-mentioned implementability concerns for concentrated reagents would not be a concern for ISCO implementation at IR Site 27.

Effectiveness. ISCO could be effective at chemically oxidizing the VOC contaminants present in the IR Site 27 plume.

Implementability. It appears feasible to inject and distribute ISCO reagents in the FWBZ, based on the experience at IR Sites 9 and 16. Depending on the ISCO injection depths and the depths of subsurface utilities, preferential migration of injected reagents adjacent to deep subsurface utilities could present some challenges. No preferential migration concerns have been reported at IR Site 9 or 16.

Cost. ISCO is anticipated to have moderate capital costs and moderate O&M costs.

Conclusion. ISCO is retained for further evaluation as a process option. Fenton chemistry is carried forward in lieu of permanganate because 1) it employs stronger oxidants and 2) it has been demonstrated to treat a broader range of organic contaminants than permanganate.

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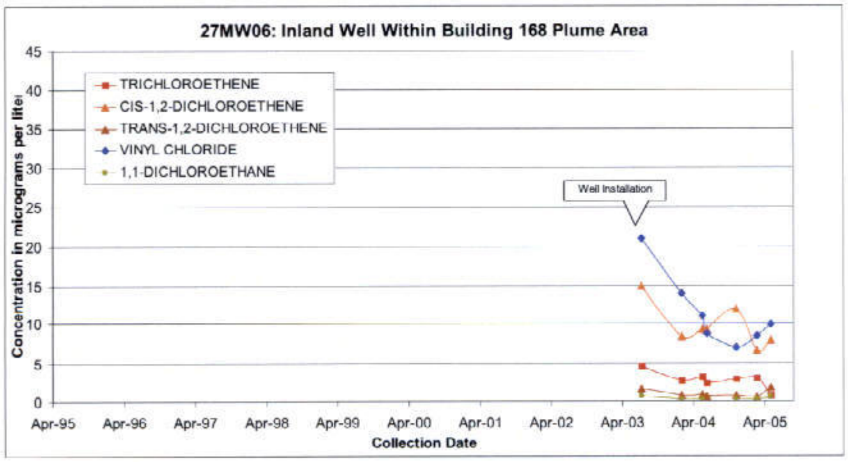
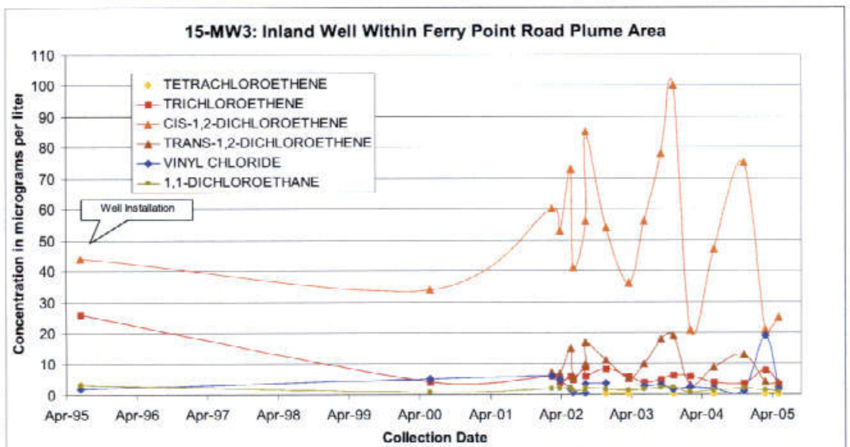
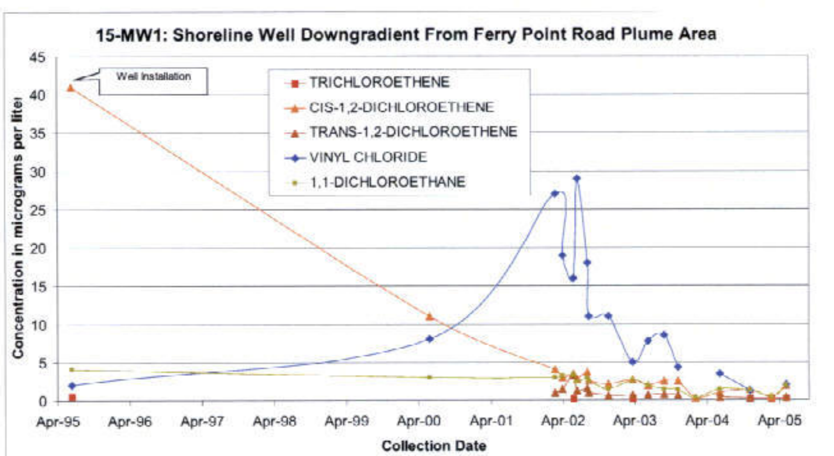
FIGURES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006







Feasibility Study Report for IR Site 27

Figure 4-1

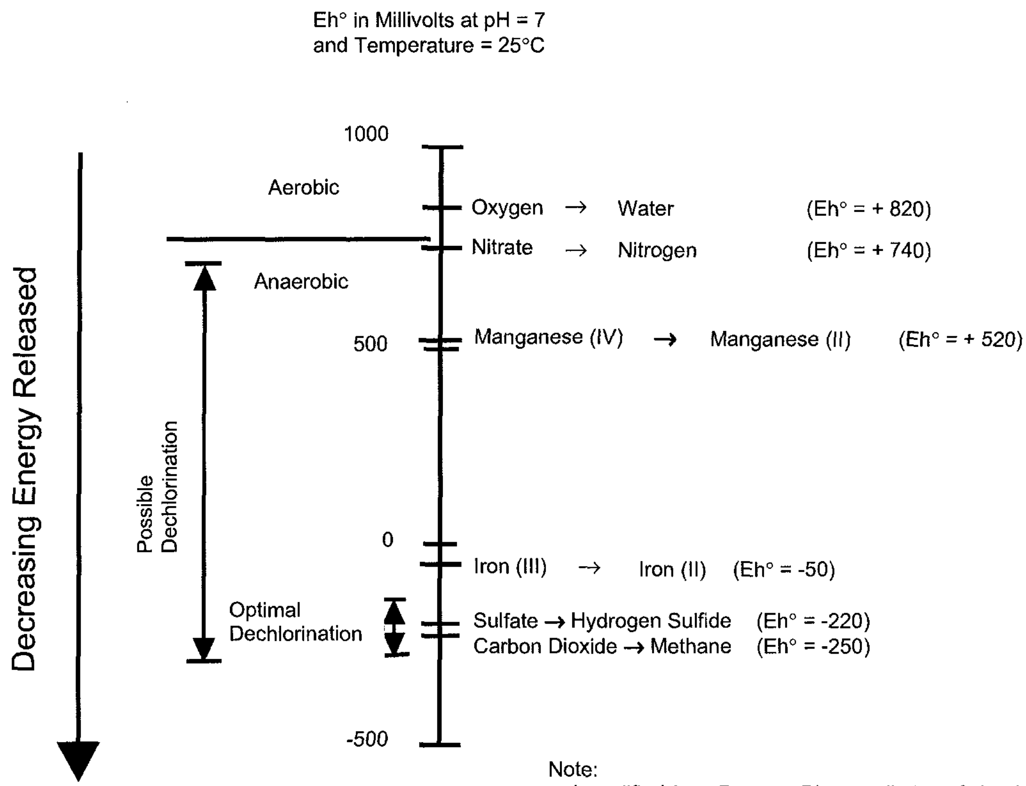
Natural Attenuation at IR Site 27

Alameda, California

Bechtel Environmental, Inc.

CLEAN 3 Program

Date: 2/27/06
File No.: fig4-1.doc
Job No.: 23818-069
Rev No.: A



Note:

* modified from Bouwer, Bioremediation of chlorinated solvents using alternate electron acceptors (*Handbook of Bioremediation*), 1994; and Wiedemeier and Pound, Guidelines for Evaluating Remediation by Natural Attenuation of Chlorinated Solvents in Groundwater, 1996

Acronyms/Abbreviations:

°C – degrees Celsius
Eh° – redox potential
redox – oxidation-reduction

Feasibility Study Report for IR Site 27

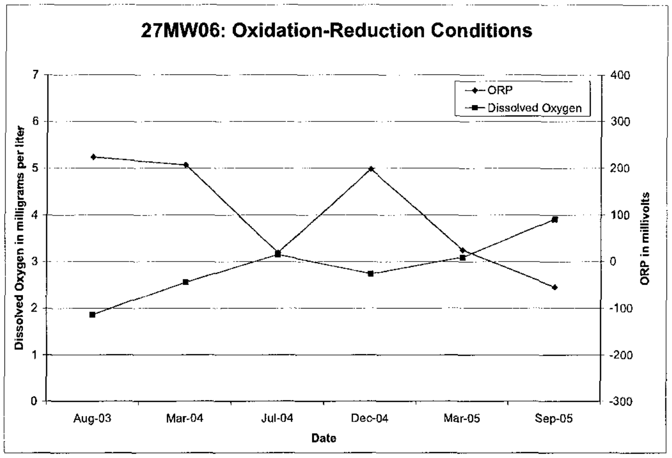
Figure 4-2

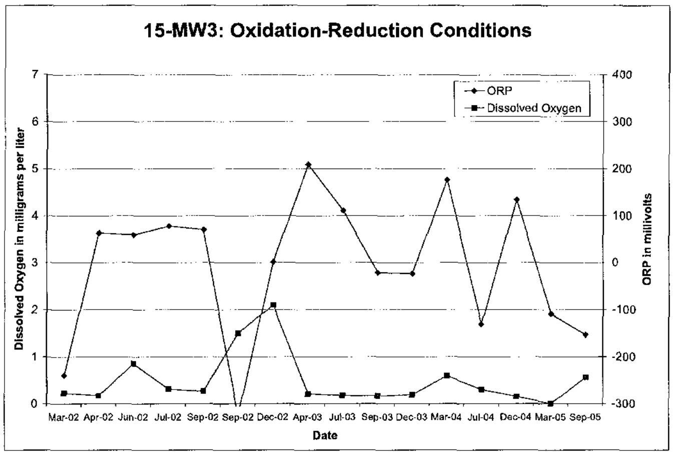
Energy Available From Typical Microbially Mediated Redox Reactions and Their Relationship to Reductive Dechlorination

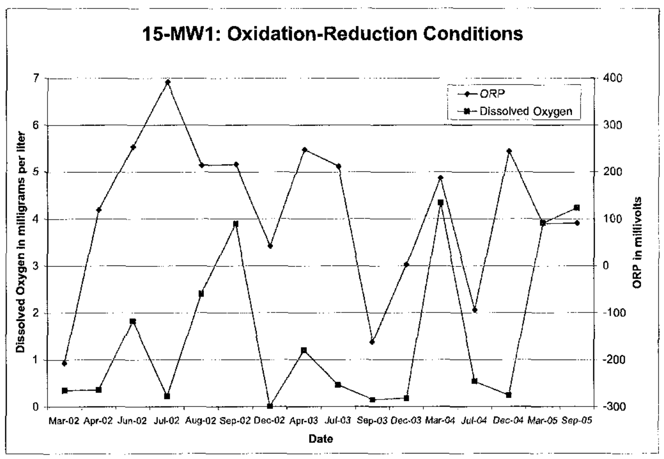
Alameda, California

Bechtel Environmental, Inc.
CLEAN 3 Program

Date: 2/27/06
File No.: fig4-2.doc
Job No.: 23818-069
Rev No.: C







Feasibility Study Report for IR Site 27

Figure 4-3

Oxidation-Reduction Conditions at IR Site 27

Alameda, California

Bechtel Environmental, Inc.

CLEAN 3 Program

Date: 2/27/06
File No.: fig4-3.doc
Job No.: 23818-069
Rev No.: A

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TABLES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006

Table 4-1
Identification of Remedial Process Options for IR Site 27

General Response Action	Remedial Technology	Process Option*
No action	None	None
LUCs	ICs	**Government controls**
		Proprietary controls
		Enforcement tools with LUC components
		Informational devices
Monitoring	Groundwater sampling and analysis	**Groundwater monitoring**
MNA	Groundwater sampling and analysis, including natural attenuation parameters	**Natural attenuation**
Containment	Vertical subsurface barriers	Sheet piles
		Biobarrier
		Grout curtains
		Deep soil mixing wall
		Slurry wall
Extraction	Groundwater extraction	Extraction wells
Ex situ treatment	Various	Various
In situ treatment	Physical treatment	**Air sparging**
		Dynamic Subsurface Circulation
	Biological treatment	**Enhanced anaerobic bioremediation (HRC)**
		Cometabolic oxidation
	Thermal treatment	Electrical resistive heating
	Chemical treatment	Permeable reactive barriers
		Ozone sparging
		Microscale iron injection
		ISCO

Note:
* bold text indicates a process option that is retained for use as a component of remedial alternatives

Acronyms/Abbreviations:
HRC – Hydrogen Release Compound (by Regenesis, Inc.)
IC – institutional control
ISCO – *in situ* chemical oxidation
LUC – land-use control
MNA – monitored natural attenuation

Table 4-2
Technology Screening Criteria

Effectiveness	Implementability	Cost
• Ability to achieve RAOs for the protection of human health and the environment • Permanent reduction in toxicity, mobility, or volume of VOCs in affected groundwater and soil • Long-term risks of treatment residuals or containment systems • Risks to the public, workers, or the environment during technology implementation	• Site characteristics limiting the construction or effective functioning of a technology • Waste or media characteristics that limit the use or effective functioning of a technology • Availability of equipment needed to implement a technology along with the capacity of any off-site treatment or disposal facilities required • Administrative feasibility of meeting substantive permit requirements	• Cost criteria used to screen remedial technologies were qualitative and based on engineering judgment unless otherwise noted. For screening purposes in a project of this magnitude, capital costs likely to approach or exceed $1 million and O&M costs likely to exceed $5 million were considered high.

Acronyms/Abbreviations:
O&M – *operation and maintenance*
RAO – remedial action objective
VOC – volatile organic compound

Table 4-3
Screening of Remedial Technologies and Process Options for Contaminated Groundwater at IR Site 27

General Response Action	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Cost	Conclusion
No action	None	None	No further response actions for groundwater.	Not evaluated at this stage of the analysis.	No action required.	No direct costs.	Retain as required by CERCLA.
LUCs	Institutional controls	Governmental controls, proprietary controls, enforcement tools with LUC components, informational devices	Nonengineering measures designed to prevent or limit exposure to hazardous substances left in place at a site, or assure the effectiveness of a selected remedy.	Should be effective in preventing or limiting access or exposure to contaminated groundwater.	Implementable. There is precedent for the use of LUCs at Alameda Point.	Low capital costs. Low to moderate O&M costs.	Retain governmental controls and proprietary controls for use as components of remedial alternatives.
Monitoring	Groundwater sampling and analysis	Groundwater monitoring	Periodic sampling and analysis is used to evaluate variations in contaminants, aquifer chemistry, and/or groundwater gradient.	Effective in evaluating chemical concentrations and changing site conditions over time. Does not reduce the mass of VOCs in groundwater.	Technically feasible and implementable. Groundwater sampling and analytical methods are well proven. The plume is accessible for monitoring purposes.	Low capital cost. Cost effective if limited in duration.	Retain as a component of alternatives. Eliminate from further consideration as a stand-alone option.
MNA	Groundwater sampling and analysis, including natural attenuation parameters	Natural attenuation	Allows natural processes to reduce contamination over time. Monitoring is typically performed to verify that these processes reduce contaminant concentrations to acceptable levels.	Natural attenuation should be effective in reducing concentrations of VOCs in groundwater over the long term; limited short-term effectiveness. There are no current receptors. Biodegradation of VOCs appears to be occurring, though slowly.	Technically feasible and implementable. Groundwater sampling and analytical methods are well proven. The plume is accessible for monitoring purposes.	Low capital cost. Moderate annual O&M cost.	Retain for use either as a stand-alone technology or as a component of remedial alternative(s).
Containment	Vertical barriers	Sheet pile, biobarrier, grout curtains, deep soil mixing wall, slurry walls	Barriers are installed to minimize the horizontal movement of contaminated groundwater or limit the flow of uncontaminated groundwater into the plume.	May be effective in limiting horizontal migration of groundwater contaminants.	Moderately implementable. Some utility relocation may be necessary. Extent of the plume would require a significantly wide barrier.	High in capital cost. Low in annual O&M cost.	Eliminate from further consideration due to low implementability and high potential cost.
Extraction	Groundwater extraction	Extraction wells	Extraction wells are used to remove contaminated groundwater for *ex situ* treatment.	Although VOC contaminant mass may be reduced, other technologies have been shown to be more effective.	Moderately implementable. Discharge of treated water may pose administrative and technical challenges. Groundwater extraction at significant rates for extended periods is expected to result in saltwater intrusion.	Moderate in capital cost, high in O&M cost relative to other technologies.	Eliminate from further consideration. More effective and cost-competitive methods exist to reduce contaminant mass.
Ex situ treatment	Various	Various	Physical, chemical, biological, and/or thermal methods are used to treat extracted contaminated groundwater *ex situ.*	Not evaluated.	Not evaluated.	Not evaluated.	Eliminate from further consideration due to elimination of hydraulic controls and extraction as remedial technologies.

Table 4-3 (continued)

General Response Action	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Cost	Conclusion
In situ treatment	Physical treatment	Air sparging	Air is injected into saturated soil matrices to remove contaminants through volatilization.	May be effective for oxidizable VOCs (e.g., vinyl chloride). Subsurface channeling of air may limit effectiveness. Aquifer conditions appear amenable.	Moderate implementability. May require bench- and/or pilot-scale testing to verify effectiveness. Vapors must be captured, extracted, and treated. Shallow groundwater may cause difficulty in capturing sparge vapors.	Moderate in capital cost. Moderate in O&M cost assuming effectiveness in a reasonable time frame (i.e., approximately 5 years or less).	Retain for further evaluation as a component of remedial alternative(s).
		Dynamic Subsurface Circulation	Utilizes a proprietary well construction that combines in-well air stripping and sparging with SVE to create dynamic circulation of groundwater and remove VOCs.	This technology has proven effective at sites with similar contaminants. Shallow groundwater may impede the circulation aspect of this technology.	Moderate implementability. Remediation wells would be installed and fitted with the proprietary well equipment.	Moderate to high in capital and O&M costs depending on plume size and duration of remediatioin.	Retain for further evaluation as a component of remedial alternative(s).
	Biological treatment	Enhanced anaerobic biodegradation	Carbon source(s) are added to the aquifer to provide electron donors to stimulate anaerobic biodegradation of solvents. HRC is assumed for evaluation purposes. Nonindigenous bacteria may optionally be added to augment the existing bacterial population.	May be effective in transforming parent VOCs (e.g., TCE) to harmless by-products or more oxidizable degradation products.	Moderate implementability. May require bench- and/or pilot-scale testing to verify effectiveness. Aquifer conditions appear amenable.	Relatively low in capital and material costs. Low O&M cost, assuming effectiveness in a reasonable time frame (i.e., approximately 5 years or less).	Retain for further evaluation as a component of remedial alternative(s).
		Cometabolic oxidation	Oxygen and methane are added to the aquifer to induce microorganisms to cometabolically oxidize solvents.	May be effective in treating oxidizable VOC degradation products. Not effective in oxidizing VOC parent products (e.g., TCE) or 1,1-DCA.	Moderate implementability. May require bench- and/or pilot-scale testing to verify effectiveness. Aquifer conditions appear amenable.	Relatively low in capital and material costs. Moderate O&M cost, assuming effectiveness in a reasonable time frame (i.e., approximately 5 years or less).	Eliminate for further evaluation based on effectiveness. Other more effective processes are available.
	Thermal treatment	Electrical resistive heating	An electrical technique to resistively heat soil and create an *in situ* source of steam to strip contaminants from the aquifer, which are then captured using SVE.	Should be effective in stripping VOC contaminants.	Low implementability. Requires installation of electrodes and specialized above-grade equipment. Heating of formational materials could take an extended period. Vapors must be extracted and treated.	High in capital cost.	Eliminate from further consideration. Difficult to implement. Not cost-competitive for dissolved-phase VOC contaminants at the levels encountered at the site.

Table 4-3 (continued)

General Response Action	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Cost	Conclusion
In situ treatment (continued)	Chemical treatment	PRBs	Barriers allow the passage of water while causing the degradation or removal of contaminants. Zero-valent iron is assumed as the treatment medium. Typically placed near the leading edge of the plume to prevent further downgradient migration.	Would likely be effective in treating TCE, PCE, DCE, and vinyl chloride contamination as it passes through the barrier. A passive strategy that would not actively treat the contaminant source area.	Low implementability. Requires bench-and/or pilot-scale testing. Additional geohydrologic testing and geotechnical investigations would be required to design the barrier.	High in capital cost. Relatively low O&M cost.	Eliminate from further consideration. Difficult to implement.
		Ozone sparging	Ozonated compressed air is injected into the reactive zone. Ozone oxidizes organic contaminants directly and through the formation of the hydroxyl radicals.	Would be effective in oxidizing VOCs in groundwater. HDD well installation and delivery of the ozone would reduce the number of wells and surface disturbance typically associated with air sparging.	Low implementability. Ozone is a highly toxic gas, which could pose a human-health risk in the event of exposure. Shallow groundwater conditions would cause difficulty in capturing sparge vapors.	Moderately high in capital cost and O&M cost.	Eliminate from further consideration. Difficult to implement.
		Microscale iron injection	Microscale zero-valent iron is injected into the source area. Causes degradation of chlorinated VOCs that come in contact with the iron.	Would likely be effective in treating TCE, PCE, DCE, and vinyl chloride contamination as it passes through the treatment zone. A passive strategy that would be used to target the contaminant source area.	Moderate implementability. May require bench- and/or pilot-scale testing to verify effectiveness. Shallow groundwater depth would require closely spaced injection points.	Moderately high in capital cost. No appreciable O&M cost unless additional iron injection is required.	Retain for further consideration as a component of remedial alternative(s).
		ISCO	Reagents are injected into the groundwater zone where contamination is present, producing hydroxyl radicals (oxidizing agents), which oxidize organic contaminants to water and carbon dioxide.	ISCO has had demonstrated success at sites with similar contaminants. The catalyst and hydrogen peroxide react to generate nonspecific oxidizing agents.	Moderate implementability. Handling reagents requires special engineering controls. Shallow groundwater would require lower injection pressure and therefore, more injection points.	Moderately high in capital cost. Moderate O&M cost.	Retain for further consideration as a component of remedial alternative(s).

Acronyms/Abbreviations:

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
DCA – dichloroethane
DCE – dichloroethene
HDD – horizontal directional drilled
HRC – Hydrogen Release Compound, a technology produced by Regenesis, Inc.
ISCO – *in situ* chemical oxidation
LUC – land-use control
MNA – monitored natural attenuation
O&M – operation and maintenance
PCE – tetrachloroethene
PRB – permeable reactive barrier
SVE – soil vapor extraction
TCE – trichloroethene
VOC – volatile organic compound

Table 4-4
MNA Parameters and Evaluation of Evidence for Reductive Dechlorination of Chlorinated Organic Chemicals by Anaerobic Biodegradation

ANALYTICAL PARAMETERS AND WEIGHTING FOR PRELIMINARY SCREENING FOR ANAEROBIC BIODEGRADATION PROCESSES[a]					27MW06 (Center of Building 168 Plume Area)		15-MW3 (Center of Ferry Point Road Plume Area)		15-MW1 (Downgradient from Ferry Point Road Plume Area)	
Analyte	**Comparison Criteria**	**Weighting Value**	**Analyte**	**Units**	**Concentration[b]**	**Weighting Value**	**Concentration[b]**	**Weighting Value**	**Concentration[b]**	**Weighting Value**
dissolved oxygen	<0.5 mg/L	3	dissolved oxygen	mg/L	3.13	0	0.24	3	0.83	1
	>5 mg/L	-3								
ORP	<50 mV	1	ORP	mV	25	1	-21	1	42	1
	<-100 mV	2								
pH	5 <pH<9	0	pH	S.U.	7.4	0	7.3	0	7.7	0
	5>pH>9	-2								
nitrate	<1 mg/L	2	nitrate	mg/L	1.10	0	0.369	2	0.391	2
sulfate	<20 mg/L	2	sulfate	mg/L	30	0	80	0	180	0
iron (II)	>1 mg/L	3	iron, total	mg/L	0.069	0	0.19	0	0.24	0
TOC	>20 mg/L	2	organic carbon, total	mg/L	2.3	0	10.0	0	6.0	0
methane	<5 mg/L	0	methane	mg/L	0.133	0	0.168	0	0.073	0
	>0.5 mg/L	3								
ethene/ethane	>0.01 mg/L	2	total ethene/ethane	mg/L	0.007	0	0.001	0	0	0
	>0.1 mg/L	3	ethane	mg/L	0.001		0.001		0	
			ethene	mg/L	0.006		0		0	
PCE	material released	0	PCE	μg/L	0	0	0.9	0	0	0
TCE	material released	0	TCE	μg/L	3.3	0	7.1		0.3	
1,1,1-TCA	material released	0	1,1,1-TCA	μg/L	0	0	0		0	
DCE	daughter product	2	total DCE	μg/L	9.8	2	74.4	2	7.8	2
	If cis-1,2-DCE > 80% of total DCE, likely a daughter product		cis-1,2-DCE	μg/L	8.7		62		6.4	
			trans-1,3-DCE	μg/L	1.1		12		1.1	
			1,1-DCE	μg/L	0		0.4		0.3	
vinyl chloride	daughter product	2	vinyl chloride	μg/L	10	2	2.8	2	12	2
DCA	daughter product	2	1,2-DCA	μg/L	0.4	2	1.8	2	2.6	2
chloroethane	daughter product	2	chloroethane	μg/L	0	0	0	0	0	0
			Total Points Awarded[a]:			**7**		**12**		**10**

Interpretation of points awarded as evidence for anaerobic biodegradation:

Points	Interpretation
0 to 5	inadequate evidence
6 to 14	limited evidence
15 to 20	adequate evidence
> 20	strong evidence

Notes:
[a] screening procedure developed in U.S. EPA 1998
[b] field measurement and analytical data collected during RI and BGMP

Table 4-4 (continued)

Acronyms/Abbreviations:
- BGMP – basewide groundwater monitoring program
- DCA – dichloroethane
- DCE – dichloroethene
- µg/L – micrograms per liter
- mg/L – milligrams per liter
- MNA – monitored natural attenuation
- mV – millivolts
- ORP – oxidation-reduction potential
- PCE – tetrachloroethene
- RI – remedial investigation
- S.U. – standard units
- TCA – trichloroethane
- TCE – trichloroethene
- TOC – total organic carbon
- U.S. EPA – United States Environmental Protection Agency

Section 5
DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

Technologies and their associated process options retained after screening have been assembled into comprehensive remedial alternatives for IR Site 27. The alternatives represent a range of technically feasible remedial responses to address site-specific groundwater contamination.

5.1 DEVELOPMENT OF POTENTIAL REMEDIAL ACTION ALTERNATIVES

Remedial alternatives for IR Site 27 were developed based on RAOs (Section 3) and according to the requirements of CERCLA, the NCP, and, to the extent practicable, U.S. EPA technical guidance (U.S. EPA 1988b). CERCLA Section 121(b) identifies the following statutory preferences for remedial actions.

- Preferred remedial actions are those involving treatment that permanently and significantly reduces the volume, toxicity, or mobility of site-related contaminants.
- The least favorable remedial action is off-site transport and disposal of hazardous substances or contaminated materials without treatment when practical treatment technologies are available.
- Remedial actions using permanent solutions, alternative treatment technologies, or resource recovery technologies should be assessed.

The NCP states that the FS should develop a range of remedial alternatives (40 C.F.R. § 300.430[e]). These alternatives may vary in the degree of treatment employed (i.e., in the quantity of material treated or the percent reduction of contaminants) as well as in the types and quantities of residuals and untreated material remaining on-site requiring long-term management. The FS may also consider alternatives that attain remediation goals in varying lengths of time using one or more technologies.

Criteria regarding eventual selection of a preferred remedial action were also considered (U.S. EPA 1988b). According to U.S. EPA technical guidance, the preferred remedial action for IR Site 27 should:

- protect human health and the environment,
- meet contaminant-specific ARARs and be consistent with location- and action-specific ARARs,
- be cost-effective,
- use permanent solutions and alternative treatment technologies to the maximum extent practicable, and
- satisfy the preference for treatment as a principal element of the remedial action to reduce the toxicity, mobility, or volume of contaminants.

The FS may also include alternatives that do not involve treatment. In these cases, human health and the environment would be protected by using ECs to prevent or control exposure to site contaminants. As necessary, ICs (i.e., governmental controls, proprietary controls, and informational devices) would be included as part of a comprehensive remedial alternative to assure continued effectiveness of ECs and other aspects of the response action.

Naval Facilities Engineering Command (NAVFAC) experience with site remediation was considered in the development and screening of alternatives. According to NAVFAC headquarters (Mach, pers. com. 2003), the Navy has noted that multiple techniques and technologies are often required to address contaminated sites effectively. Therefore, consideration was given to applying "tool-box" combinations of technologies to address the site contaminants where appropriate.

A total of ten remedial alternatives (Table 5-1) are included in this FS Report for consideration at IR Site 27. A no action alternative (Alternative 1) is included as required by the NCP. Two alternatives (Alternatives 2 and 3) rely on unassisted natural attenuation processes and ICs to prevent exposure to groundwater. Alternatives 4A, 5, 6A, 7 and 8 have been developed to evaluate source-area treatment alternatives to achieve RAOs more quickly than MNA alone. For each of the active alternatives, ICs would be put in place until the RAOs listed in Table 3-1 are met. Two sitewide treatment alternatives, Alternatives 4B and 6B, are included to evaluate the viability of more aggressive approaches to achieving RAOs.

5.1.1 Alternative 1 – No Action

For this alternative, no further action of any type would be conducted. This alternative is included in accordance with the NCP.

5.1.2 Alternative 2 – ICs

The objective of Alternative 2 would be to prohibit activities that could result in unacceptable exposure to groundwater COCs. ICs would be put in place to prohibit extraction of groundwater for domestic purposes. Quarterly groundwater sampling has been conducted at IR Site 27 since 2002. Results have shown that VOC concentrations in groundwater are stable and declining with time. Therefore, no groundwater monitoring is included for this alternative. ICs would have an assumed duration of 70 years.

Human-health risks for the occupational and construction exposure scenarios are within the NCP risk management range. Only risk associated with domestic use of groundwater exceeds the NCP risk management range (BEI 2005).

5.1.3 Alternative 3 – MNA and ICs

For Alternative 3, MNA would be performed in association with ICs to demonstrate that contaminant levels in groundwater at IR Site 27 are being reduced over time through naturally occurring processes. A long-term groundwater monitoring program, including periodic reviews, would be implemented to track plume migration and cleanup progress.

ICs would prohibit extraction of groundwater for domestic purposes, and would prohibit actions that would interfere with MNA. ICs would remain in place until the Navy and regulatory agencies agree that risks associated with impacted groundwater are acceptable.

Groundwater monitoring would involve collecting and analyzing groundwater samples from existing on-site monitoring wells located in the probable source areas and the downgradient migration pathways of the plume. Groundwater levels in the wells would be measured to confirm groundwater flow patterns and gradients. The extent of the VOC plume was defined in the RI, so no additional monitoring wells or groundwater investigations are included under this alternative. The objective of future monitoring efforts would be to verify that natural attenuation is progressing. Based on the BIOCHLOR model simulations performed for this alternative (Appendix B), the predicted time to reach RAOs for this alternative is 70 years.

5.1.4 Alternative 4A – ISB Source Area Treatment, MNA, and ICs

Alternative 4A is included to evaluate the opportunity to accelerate the reduction of contaminant concentrations in the two probable source areas by using ISB remediation technology in association with MNA and ICs. Alternative 4A would employ anaerobic ISB technology to accelerate VOC contaminant mass removal in the two areas of highest VOC concentrations in the IR Site 27 plume. It is assumed that the proprietary HRC technology would be used to accelerate the biodegradation of VOCs. HRC would be injected by direct-push methods into the source-area aquifer zone to accelerate reductive dechlorination. An estimated 128 HRC injection points would be required. For FS cost estimating purposes, 1 year of ISB is assumed.

Groundwater sampling would be performed to document the reduction in contaminant concentrations and assess the progress of MNA after HRC injection. ICs would prohibit groundwater extraction for domestic purposes and preclude actions that would interfere with activities associated with this alternative until the Navy and regulatory agencies agree that the risks associated with impacted groundwater are acceptable. The BIOCHLOR model simulations (Appendix B) performed for this alternative indicate that VOCs within the IR Site 27 plume should attenuate to RAO concentrations in approximately 60 years. For FS cost estimating purposes, the assumed duration of ICs for Alternative 4A is 60 years.

5.1.5 Alternative 4B – Sitewide ISB Treatment, MNA, and ICs

Alternative 4B is included to evaluate the opportunity to accelerate the reduction of VOC concentrations in inland groundwater using full-scale *in situ* ISB treatment technologies that would be performed in association with MNA and ICs. For Alternative 4B, anaerobic ISB technology would be used across the entire IR Site 27 inland plume to accelerate VOC mass removal.

Alternative 4B would employ the same proprietary HRC technology described for Alternative 4A. For Alternative 4B, it is assumed for cost estimating purposes that the same source area treatments described for Alternative 4A (128 delivery points) would be conducted. In addition, rows of HRC injection points would be used to create multiple flow-through treatment barriers outside of the two treatment areas in Alternative 4A. A total of seven separate barriers would be created to treat the entire inland groundwater plume, each with two rows of HRC injection points 15 feet on center. A conceptual layout of the barriers and source area treatment zones is shown on Figure 5-1. An extended-release HRC product would be injected into the aquifer to create each of the seven barriers. Assuming a groundwater velocity of 40 feet per year and product life of 3 to 5 years *in situ*, the barriers would be spaced approximately 160 feet apart. Approximately 312 HRC injection points would be required to create the seven barriers. This alternative includes a total of 440 injection points (128 points for the two areas treated in Alternative 4A plus 312 points for the flow-through treatment barriers). For FS purposes, it is assumed that 5 years of groundwater monitoring would be required after HRC injection to achieve RAOs.

Groundwater confirmation sampling would be performed to document the reduction in contaminant concentrations and assess the progress of MNA after HRC injection. ICs would prohibit groundwater extraction for domestic purposes and prohibit actions that would interfere with activities associated with this alternative until the Navy and regulatory agencies agree that the risks associated with impacted groundwater are acceptable.

5.1.6 Alternative 5 – Air Sparging Source Area Treatment, MNA, and ICs

Like Alternative 4A, Alternative 5 is included to evaluate the opportunity to accelerate the reduction of contaminant concentrations by using *in situ* remediation technology that would be performed in association with groundwater confirmation sampling, MNA, and ICs. However, under Alternative 5, air sparging would be used as a technology for contaminant mass reduction in the two areas of higher contaminant concentrations instead of ISB. Alternative 5 would employ an on-site air compressor to inject air into the aquifer by specially designed diffusing air injection points. The sparge air would be injected into the aquifer through stainless steel diffusing tips to enhance the dispersion of air in groundwater. Because of the size of the two treatment areas, HDD technology is assumed to be used to install a row of up to ten sparge points within each HDD well. This reduces the number of wells and surface disturbance typically associated with air sparging. Concurrently, SVE would be conducted to collect the sparge air from the subsurface. One year of air sparging and SVE is assumed.

Groundwater confirmation sampling would be performed to document the reduction in contaminant concentrations during and after air sparging and assess the progress of MNA after source area treatment. The same ICs described for Alternative 4A would be applied to this alternative until the Navy and regulatory agencies agree that risks associated with impacted groundwater are acceptable. Based on the BIOCHLOR model simulations and the assumptions presented in Appendix B, VOCs present in the IR Site 27 plume should attenuate to RAO concentrations approximately 55 years after treatment for this alternative. For FS cost estimating purposes, the assumed duration of ICs for Alternative 5 is 55 years.

5.1.7 Alternative 6A – ISCO Source Area Treatment, MNA, and ICs

Alternative 6A is included to evaluate the opportunity to accelerate the reduction of contaminant concentrations in the two probable source areas by using *in situ* chemical remediation technology that would be performed in association with MNA and ICs. For Alternative 6A, ISCO would be used as a technology for contaminant mass reduction in the two areas. Alternative 6A would employ the ISOTEC chemical oxidation process, which utilizes Fenton-like chemistry to convert organic contaminants to water and carbon dioxide. Dilute 12-percent stabilized hydrogen peroxide would be injected into the two areas, followed by the injection of a chelated iron catalyst (a mixture of a surfactant [similar to soap] and dissolved ferrous sulfate). The catalyst and hydrogen peroxide react to generate hydroxyl radicals (OH•), which are powerful, nonspecific oxidizing agents. The hydroxyl radicals react with the hydrocarbon contaminants to produce carbon dioxide and water. Reagents utilized by the ISOTEC process are stabilized and at a low concentration; this results in a less vigorous, longer-duration, and safer chemical reaction than a typical chemical oxidation. It is expected that the reagent and catalyst would be applied through direct-push borings in a single injection event. Alternative 6A would require an estimated 43 injection points in the western treatment area and 57 injection points in the eastern treatment area, for an estimated total of 100 injection points. For FS cost estimating purposes, a maximum of 6 months of ISCO treatment is assumed.

Groundwater confirmation sampling would be performed to document contaminant reductions and assess the progress of MNA after ISCO. The same ICs described for Alternative 4A would be applied to this alternative until the Navy and regulatory agencies agree that risks associated with impacted groundwater are acceptable. Based on the BIOCHLOR model simulations and the assumptions presented in Appendix B, VOCs within the IR Site 27 plume should attenuate to RAO concentrations approximately 45 years after treatment for this alternative. For FS cost estimating purposes, the assumed duration of ICs for Alternative 6A is 45 years.

5.1.8 Alternative 6B – Sitewide ISCO Treatment and Groundwater Confirmation Sampling

Alternative 6B is included to evaluate the opportunity to accelerate the reduction of VOC concentrations in inland groundwater using full-scale chemical *in situ* treatment technologies that would be performed in association with confirmation sampling and ICs. For Alternative 6B, ISCO would be used to aggressively treat the entire IR Site 27 inland groundwater plume to achieve RAOs. An aggressive ISCO approach would be used across the entire 11-acre plume.

Alternative 6B would employ the same ISOTEC chemical oxidation process described for Alternative 6A. It is assumed that pilot-scale testing is not required because of extensive experience using the ISOTEC process at other Alameda Point sites (Eilber, pers. com. 2005b). For Alternative 6B, it is assumed for cost estimating purposes that a treatment radius of 20 feet would be achieved at the site and approximately 570 injection points would be required (Eilber, pers. com. 2005a). Two sequential treatment events would be performed over a 6-month period. Following completion of ISCO, post-test sampling results would be reviewed. Depending on the ISCO results, residual contaminants could require additional ISCO treatment. For FS purposes, 1 year of ISCO treatment is assumed to be adequate to achieve RAOs.

Groundwater confirmation sampling would be performed during and after each ISCO treatment to document the reduction in contaminant concentrations. ICs are assumed not to be required for this alternative. One year of quarterly groundwater sampling events and one annual event are included following ISCO treatment to document post-treatment VOC concentrations.

5.1.9 Alternative 7 – Dynamic Circulation Source Area Treatment, MNA, and ICs

Alternative 7 is included to evaluate an innovative source area treatment technology to reduce contaminant concentrations using a proprietary well technology, Dynamic Subsurface Circulation, in association with MNA and ICs. The circulation well design utilizes SVE, in-well air stripping using a circulation pump and spray system, and in-well air sparging. This combination of technologies creates circulation of treated groundwater outward from the treatment well through capillary fringe soil and returning into the well for treatment. This alternative combines in-well air sparging, in-well air stripping, SVE, and dynamic groundwater circulation to remove VOCs from soil, soil gas and groundwater. For the purposes of this FS, it is assumed that a separate pilot-scale study would not be performed, since the area of a pilot-scale study would be similar in size to the targeted treatment areas for Alternative 7.

Groundwater confirmation sampling would be performed to document the reduction in contaminant concentrations during and after treatment and to assess the progress of MNA after source area treatment. The same ICs described for Alternative 4A would be applied to this alternative until the Navy and regulatory agencies agree that risks associated with impacted groundwater are acceptable. Based on the BIOCHLOR model simulations performed for this alternative (Appendix B), VOCs within the IR Site 27 plume should attenuate to RAO concentrations approximately 55 years after treatment. For FS cost estimating purposes, the assumed duration of ICs for Alternative 7 is 55 years.

5.1.10 Alternative 8 – Zero-Valent Iron Source Area Treatment, MNA, and ICs

Alternative 8 is included to evaluate the opportunity to accelerate the reduction of contaminant concentrations by using ZVI remediation technology in association with MNA and ICs. Alternative 8 would employ injection of microscale ZVI to accelerate VOC contaminant mass removal in the two probable source areas at IR Site 27. It is assumed that the proprietary Ferox injection technology would be used to introduce ZVI into the two areas and accelerate the degradation of VOCs. A slurry of ZVI powder and potable water would be pressure-injected into the source area aquifer zone by direct-push methods to initiate rapid reductive dechlorination.

Groundwater confirmation sampling would be performed to document the reduction in contaminant concentrations during and after treatment and to assess the progress of MNA after source area treatment. The same ICs described for Alternative 4A would be applied to this alternative until the Navy and regulatory agencies agree that risks associated with impacted groundwater are acceptable. Based on the BIOCHLOR model simulations and the assumptions presented in Appendix B, VOCs present in the IR Site 27 plume should attenuate to RAO concentrations approximately 45 years after treatment for this alternative. For FS cost estimating purposes, the assumed duration of ICs for Alternative 8 is 45 years.

5.2 SCREENING OF REMEDIAL ALTERNATIVES

When numerous viable remedial alternatives exist, alternatives can be refined and screened to reduce the number of alternatives requiring detailed analysis (U.S. EPA 1988b). This screening aids in streamlining the FS process while assuring that the most promising alternatives are being considered.

In accordance with U.S. EPA criteria, information available at the time of screening will be used primarily to identify and distinguish differences among the various alternatives and to evaluate effectiveness, implementability, and cost for each alternative. Only the alternatives judged to be the best or most promising on the basis of these evaluation factors will be retained for further consideration, unless additional information becomes available that indicates that further evaluation is warranted (U.S. EPA 1988b).

Of the ten remedial alternatives considered, six were retained for detailed analysis in Section 6:

- Alternative 1 – no action
- Alternative 3 – MNA and ICs
- Alternative 4A – ISB source area treatment, MNA, and ICs
- Alternative 6A – ISCO source area treatment, MNA, and ICs
- Alternative 6B – sitewide ISCO treatment and groundwater confirmation sampling
- Alternative 7 – dynamic circulation source area treatment, MNA, and ICs

As shown in Table 5-2, Alternatives 2, 4B, 5, and 8 were eliminated from further consideration. Alternative 2 was eliminated based on low effectiveness, because no means would be provided to assess whether RAOs were achieved. Alternative 4B was eliminated, based on a comparison with other alternatives; Alternative 4B has higher costs than Alternative 6B, a longer duration (an assumed 5 years of MNA), and a need for ICs. Alternative 5 was eliminated based on low implementability because it was considered less effective than Alternative 7. Alternative 8 was eliminated because of the difficulty in injecting ZVI slurry into shallow groundwater (6 feet bgs) with coarse-grained soils (ARS 2006).

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FIGURES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006

Feasibility Study for IR Site 27

Figure 5-1

Assumed Treatment Approach for Alternative 4B

Alameda, California

TABLES

FINAL FEASIBILITY STUDY REPORT FOR IR SITE 27, DOCK ZONE

DATED 01 APRIL 2006

Table 5-1
Identification of Remedial Alternatives

Alternative*	Description
1	**no action**
2	ICs
3	**MNA and ICs**
4A	**ISB source area treatment, MNA, and ICs**
4B	sitewide ISB treatment, MNA, and ICs
5	air sparging source area treatment, MNA, and ICs
6A	**ISCO source area treatment, MNA, and ICs**
6B	**sitewide ISCO treatment and groundwater confirmation sampling**
7	**dynamic circulation source area treatment, MNA, and ICs**
8	zero-valent iron source area treatment, MNA, and ICs

Note:
* alternatives retained for detailed evaluation in Section 6 are shown in bold type

Acronyms/Abbreviations:
IC – institutional control
ISB – *in situ* bioremediation
ISCO – *in situ* chemical oxidation
MNA – monitored natural attenuation

Continue

Table 5-2
Screening Results for Remedial Alternatives

Alternative	Effectiveness	Implementability	Cost	Conclusion
1 – no action	Not evaluated.	Not evaluated.	Not evaluated.	Retained for DAA per the NCP.
2 – ICs	This alternative would rely on ICs to prevent domestic use of groundwater. No data would be collected to assess decreasing VOC concentrations in groundwater. This alternative provides no means of documenting VOC concentration reductions in groundwater or compliance with RAOs. This alternative would not meet the threshold criterion of compliance with ARARs (MCLs for inland groundwater), so it is unlikely to gain regulatory approval.	High implementability. ICs would be assumed to be in place for 70 years under this alternative.	Low in cost compared to other alternatives because groundwater sampling for MNA is not included.	Eliminated because no means are provided to assess whether RAOs were achieved and therefore this alternative has a low likelihood of gaining regulatory acceptance.
3 – MNA and ICs	This alternative would rely on natural attenuation processes to reduce VOC concentrations in groundwater. MNA would continue at the site, and groundwater monitoring data would continue to be collected to assess progress toward achieving RAOs. ICs would prohibit domestic use of groundwater until risks are considered acceptable. This alternative would be effective in meeting RAOs.	High implementability. Groundwater sampling as part of the MNA performance monitoring program is also readily implementable.	Low to moderate in cost, depending on the actual duration of MNA to achieve RAOs.	Retained for DAA. Alternative 3 is more effective than Alternative 2. Data would be collected over time to assess MNA progress toward RAOs.
4A – ISB source area treatment, MNA, and ICs	This alternative would include measures to enhance the rate of biodegradation of chlorinated VOCs in the two probable source areas. ICs would prohibit domestic use of groundwater until risks are considered acceptable. This alternative would be effective in meeting RAOs in source areas in the short term.	Moderate implementability. Following one application of enhancement through direct-push borings in the source areas, no additional maintenance or subsequent injections are included. Groundwater sampling would continue as part of the MNA performance monitoring program.	Moderate in cost.	Retained for DAA. Enhanced MNA is considered effective and implementable at moderate cost.
4B – sitewide ISB treatment, MNA, and ICs	This alternative, like Alternative 4A, would enhance the rate of biodegradation at the site. Both source area treatment and sitewide treatment would be conducted. It is considered effective in removing chlorinated VOCs although much of the treatment area has low concentrations of VOCs compared to source areas. The ISB process is expected to be effective at reducing VOC concentrations within about five years. ICs would prohibit domestic use of groundwater until risks are considered acceptable. This alternative would be effective in meeting RAOs in source areas in the short term.	Low implementability. Approximately 440 injection points would be required to implement ISB sitewide.	High in cost. Additional costs are associated with treating the lower concentrations outside of source areas. Costs would be higher than for Alternative 6B.	Eliminated, based on low implementability and higher cost than for Alternative 6B.
5 – air sparging source rea treatment, MNA, and ICs	This alternative would utilize air sparging to remove VOCs in groundwater in the two probable source areas. VOCs would be removed from the subsurface with SVE. ICs would prohibit domestic use of groundwater until risks are considered acceptable. This alternative is considered moderately effective in removing VOCs. However, introduction of air into the subsurface would temporarily reduce or halt MNA processes occurring in the source areas.	Low implementability. Capture of sparge vapors containing VOCs in shallow groundwater conditions would be difficult.	Moderate to high in cost. Duration of operation and maintenance costs not known, and could be significant.	Eliminated, based on low implementability. Considered less effective than Alternative 7.
6A – ISCO source area treatment, MNA, and ICs	This alternative would utilize ISCO to chemically destroy VOCs in groundwater in the two probable source areas. ISCO has had demonstrated success at sites with similar contaminants at Alameda Point. ICs would prohibit domestic use of groundwater until risks are considered acceptable. This alternative would be effective in meeting RAOs in source areas in the short term.	Moderate implementability. ISCO utilizes gravity injection to introduce the reagents into the groundwater zone. Shallow groundwater requires a lower injection pressure, thus additional injection points would likely be required.	Moderate to high in cost.	Retained for DAA. ISCO is considered effective and implementable in the two identified source areas at IR Site 27.
6B – sitewide ISCO treatment and groundwater confirmation sampling	This alternative would utilize ISCO to destroy VOCs across the entire 11-acre VOC plume. This process is expected to be effective, reducing VOC concentrations more quickly than other alternatives. ICs would prohibit domestic use of groundwater until risks are considered acceptable. This alternative would be effective in meeting RAOs.	Low implementability. Approximately 570 borings would be required to implement ISCO across the site.	Moderate to high in cost. Significant additional costs are associated with treating the lower concentrations outside source areas. Costs would be lower than for Alternative 4B.	Retained for DAA. Costs would be lower than for Alternative 4B.
7 – dynamic circulation source area treatment, MNA, and ICs	This alternative would utilize a proprietary well construction that combines in-well air stripping and sparging with SVE to create dynamic circulation of groundwater and remove VOCs from the two probable source areas. ICs would prohibit domestic use of groundwater until risks are considered acceptable. This alternative would be effective in meeting RAOs in source areas in the short term.	Moderate implementability. Remediation wells would be installed and fitted with sparging and groundwater recirculation equipment. Shallow groundwater conditions may require that wells be extended above grade.	Moderate in cost.	Retained for DAA. This alternative is expected to be effective in removing VOCs from groundwater.
8 – ZVI source area treatment, MNA, and ICs	This alternative would utilize ZVI to destroy VOCs. The Ferox process would be employed to inject iron powder into the aquifer to accelerate VOC reduction in the two identified source areas. This process has proven effective at sites with similar contaminants. ICs would prohibit domestic use of groundwater until risks are considered acceptable. This alternative would be effective in meeting RAOs in source areas in the short term.	Low implementability. Required injection pressure for ZVI is problematic at sites with shallow groundwater and coarse-grained soils.	Moderate to high in cost.	Eliminated, based on low implementability, due to difficulty injecting ZVI slurry into shallow groundwater with coarse-grained soils.

Acronyms/Abbreviations:
DAA – detailed analysis of alternatives
IC – institutional control
IR – Installation Restoration (Program)
ISB – *in situ* biodegradation
ISCO – *in situ* chemical oxidation
MNA – monitored natural attenuation
RAO – remedial action objective
SVE – soil vapor extraction
VOC – volatile organic compound
ZVI – zero-valent iron