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FOSTER WHEELER
ENVIRONMENTAL
CORPORATION

Southwest Division
Naval Facilities Engineering Command
Contracts Department
1220 Pacific Highway, Building 127, Room 112
San Diego, California 92132-5190

FIVE-YEAR REVIEW REPORT
OPERABLE UNITS 1 - 6
Revision 0
December 2002

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

April 9, 2003

Captain C. Schanze
CEC,U.S. Navy
Commander
Southwest Division
Naval Facilities Engineering Command
1220 Pacific Highway
San Diego, CA 92132-5190

Subject: FIVE YEAR REVIEW REPORT, OPERABLE UNITS 1-6 AT MARINE CORP LOGISTICS BASE, BARSTOW, CA

Dear Captain Schanze:

The United States Environmental Protection Agency (EPA) has reviewed the Five-Year Review Report dated December, 2002. Based upon this review, the EPA agrees with the overall conclusions, findings, and recommendations and concurs with the overall protectiveness determination. The Agency has provided comments on this document and the majority of these comments have been incorporated in the Final Report. Our suggestions on organization have been addressed with a promise to incorporate structural changes in the next Five Year Review. The Agency feels that incorporation of our comments on the document format would improve both the structure and readability of the document. Additionally, the Agency does not agree with the Navy's decision to exclude the 5-Year Review from the Administrative Record for the Barstow facility. We strongly urge you to reconsider this decision.

We appreciate the opportunity to work with you on this project and look forward to continued success at the Marine Corp Logistics Base, Barstow. If you have questions regarding this letter please feel free to contact Martin Hausladen (415) 972-3007 of this office at any time.

Sincerely,

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CONTRACT NO. N68711-98-D-5713
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FIVE-YEAR REVIEW REPORT
OPERABLE UNITS 1 - 6
Revision 0
December 2002

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

DCN: FWSD-RAC-03-0116

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Vitthal Hosangadi, P.E.
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ABBREVIATIONS AND ACRONYMS

1,1 -DCE	1,1-dichloroethene
1,2-DCA	1,2-dichloroethane
1,1,1-TCA	1,1,1-trichloroethane
µg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
acfm	actual cubic feet per minute
AGRA	AGRA Earth and Environmental, Inc.
ARAR	applicable or relevant and appropriate requirement
AS/SVE	air sparging/soil vapor extraction
bgs	below ground surface
BMP	Base Master Plan
BNI	Bechtel National, Inc.
CALNEV	CALNEV Pipeline Company, L.L.C.
CAOC	CERCLA Area of Concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
COC	constituent of concern
DD	Decision Document
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane.
DoD	Department of Defense
DON	Department of the Navy
DRMO	Defense Reutilization Materials Office
DTSC	Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
ERFA	Extended RCRA Facility Assessment
ESD	Explanation of Significant Differences
FFA	Federal Facility Agreement
FS	Feasibility Study
ft/ft	feet per foot
FWENC	Foster Wheeler Environmental Corporation
GAC	granular activated carbon
GETS	Groundwater Extraction and Treatment System
GEW	ground extraction well
gpm	gallons per minute
GWQO	groundwater quality objective
IC	institutional control
ILCR	Incremental Lifetime Cancer Risk
IRP	Installation Restoration Program
IWTP	Industrial Wastewater Treatment Plant

ABBREVIATIONS AND ACRONYMS (Continued)

JEG	Jacobs Engineering Group
JVIM	Johnson and Ettinger Vapor Intrusion Model
LTGWMP	Long-term Groundwater Monitoring Plan
McGhee	McGhee Construction, Inc.
MCL	maximum contaminant level
MCLB	Marine Corps Logistics Base
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
MTBE	methyl tert-butyl ether
N/A	not applicable
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	no further action
NPL	National Priorities List
O&M	Operation and Maintenance
OCP	organochlorine pesticide
OHM	OHM Remediation Services Corporation
OU	Operable Unit
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	perchloroethene
psig	pounds per square inch
RA	remedial action
RAO	Remedial Action Objective
RAR	Remedial Action Report
RBC	risk-based criteria
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
ROD	Record of Decision
ROI	radius of influence
ROSI	radius of sparging influence
RPM	Remedial Project Manager
RWQCB	Regional Water Quality Control Board
SAP	Sampling and Analysis Plan
SOTA	SOTA Environmental Technologies, Inc.
SOV	soil organic vapor
SVOC	semivolatile organic compound
SWDIV	Southwest Division Naval Facilities Engineering Command
TBC	to be considered
TCE	trichloroethene
TCRA	time-critical removal action
TEF	technical and economic feasibility

ABBREVIATIONS AND ACRONYMS (Continued)

TM0018	Technical Memorandum 0018
TPH	total petroleum hydrocarbons
TPH-d	total petroleum hydrocarbons as diesel
TPH-g	total petroleum hydrocarbons as gasoline
TRPH	total recoverable petroleum hydrocarbons
USC	United States Code
UST	underground storage tank
VOC	volatile organic compound
VPB	vertical profile boring
Y/N	yes/no

DECLARATION OF ACCEPTANCE FOR OUs 1 to 6 FIVE-YEAR REVIEW REPORT -2002 MARINE CORPS LOGISTICS BASE, BARSTOW, CALIFORNIA

Pursuant to the delegation of the authority in Sections 2(d) and ll(g) of the Executive Order 12580, and U.S. Department of Defense Instruction 4715.7 of 22 April 1996, the U.S. Department of the Navy is the approval authority for Comprehensive Environmental Response, Compensation, and Liability Act five-year reviews conducted at sites under its jurisdiction, custody, or control.

C. Schanze
for Captain, CEC, U.S. Navy
Commander

12/30/02
Date

EXECUTIVE SUMMARY

This Five-Year Review Report has been prepared by the United States Department of the Navy (DON) in support of the Installation Restoration Program (IRP) being conducted at the Marine Corps Logistics Base (MCLB) Barstow, California (MCLB Barstow or Base). The IRP was developed by the Department of Defense (DoD) to clean up contamination at military facilities (such as MCLB Barstow) caused by past use, storage, handling, and disposal of hazardous and other potentially toxic substances. Soil and groundwater at MCLB Barstow have been impacted by such substances and are currently being cleaned up under the IRP. The MCLB Barstow IRP follows federal and state regulations in its investigation and cleanup of Base contamination. The DON is the lead DoD authority responsible for conducting the site investigation and cleanup at MCLB Barstow. The DON's investigation and cleanup efforts are being conducted in conjunction with the U.S. Environmental Protection Agency (EPA), the Regional Water Quality Control Board (RWQCB) -Lahontan Region, and the State of California EPA's Department of Toxic Substances Control (DTSC).

The Base includes two separate facilities -Yermo Annex and Nebo Main Base. For the purposes of the IRP, the Base has been divided into a total of seven Operable Units (OUs). Each OU is divided into a number of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Areas of Concern (CAOCs). OUs 1 and 2 pertain to groundwater contamination beneath the Yermo Annex and Nebo Main Base, respectively. Groundwater contamination is primarily due to dissolved volatile organic compounds (VOCs). OUs 3 and 5 pertain to soil contamination at the Yermo Annex, and OUs 4 and 6 pertain to soil contamination at Nebo Main Base. Soil contamination is primarily due to VOCs, metals, pesticides, polychlorinated biphenyls, and polynuclear aromatic hydrocarbons. Records of Decision (RODs) were signed in 1997 for OU 3 and OU 4 (as a pair), and in 1998 for OU 1 and OU 2 (as a pair) and OU 5 and OU 6 (as a pair). A seventh OU, OU 7 covers sites that were not covered under OUs 1 through 6. The ROD for OU 7 has not yet been signed, and it is therefore not subject to this five-year review. Remedial actions (RAs) have been implemented at CAOCs within OUs 1 through 6 (none at OU 7).

This five-year review evaluates the remedies implemented at each of the CAOCs at OUs 1 through 6 by answering the following questions:

Question A: Is the remedy functioning as intended by the ROD(s)?

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and Remedial Action Objectives (RAOs) used at the time of the remedy selection still valid?

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

OU 1 is the groundwater at Yermo Annex and includes three dissolved VOC plumes [CAOC 26, Yermo North (CAOC 16), and Yermo South]. Portions of the Yermo North and Yermo South extend off Base. These plumes are being remediated by the CAOC 16 and CAOC 26 air sparging/soil vapor extraction (AS/SVE) systems, and the Yermo Annex Groundwater Extraction and Treatment System (GETS). Treatment systems are in place at one on-Base drinking water well and two off-Base drinking water wells. OU 1 includes groundwater monitoring for CAOCs from other OUs, specifically CAOCs 15, 16, 17, 20, 23, 26, and 35. The CAOC 26 AS/SVE system has met its ROD objective of reducing VOC contamination in soil and groundwater at CAOC 26 to acceptable levels, and has been shut down. The CAOC 16 AS/SVE system and the Yermo Annex GETS are in operation, and are meeting their objectives -VOC mass in groundwater and soil are being reduced, and VOC levels are decreasing. All of the remedies at OU 1 are protective of human health and the environment. Issues identified at OU 1 include the effect of declining water levels on the GETS, need for additional AS wells at CAOC 16, and evaluation of dissolved VOCs at depths below the GETS wells outside the Base. Background levels of metals in groundwater require evaluation. Four proposed off-Base extraction wells have not been installed due to the decreasing levels and extent of off-Base VOCs. A Technical Memorandum will be submitted in support of this strategy. Upon approval of the Technical Memorandum, an Explanation of Significant Differences (ESD) will be submitted. The exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy selection will be evaluated to determine if they are still valid. New information that could call into question the effectiveness of the remedy includes temporary increase in dissolved VOCs in groundwater beneath the Yermo Annex in December 2001 (these reduced to historic levels based on subsequent sampling). Methyl tert-butyl ether (MTBE) has been detected in groundwater beneath the southwest portion of the Yermo Annex. This has a potential impact on the GETS, which has been modified to address MTBE. There are no formal Operation and Maintenance (O&M) manuals for the off-Base residential well and on-Base drinking water well treatment systems. These will be prepared.

OU 2 is the groundwater at Nebo Main Base, and includes two dissolved VOC plumes (Nebo North and Nebo South). A portion of the Nebo South plume extends off Base. It also includes groundwater monitoring associated with CAOC 7 (in the southern portion of Nebo Main Base) and for evaluation of pesticides (dieldrin) at Nebo North, specifically at CAOCs 1, 2, 3, and 14 (dieldrin was not detected). An interim GETS is in place at Nebo North (on standby status). The VOC plume at Nebo North remains stable, with concentrations showing a decrease over time. An AS/SVE treatability study is planned for Nebo North based on the results of the Extended Resource Conservation and Recovery Act (RCRA) Facility Assessment (which indicated elevated levels of VOCs in soil gas). The treatability study will be followed by full-scale implementation, if found to be necessary and feasible. For Nebo South, an interim remedy consisting of a GETS was proposed in the ROD, but not implemented, as it may promote off-Base migration of VOC contamination that is currently on Base -a Technical Memorandum will be submitted in support of this strategy. Upon approval of the Technical Memorandum, an ESD will be submitted. An AS/SVE pilot test is under way, which indicates that AS/SVE is a feasible technology for Nebo South. Dissolved VOC contamination was detected in the southwest portion of Nebo Main Base (several thousand feet away from the Nebo South plume).

Additional wells are planned for the ongoing AS/SVE pilot test at Nebo South, which will allow evaluation of the relation between the Nebo South plume and the VOCs at NPZ-14. The exposure assumptions, toxicity data, cleanup levels, and RAOs used for this OU at the time of the remedy selection are still valid. There is no new information that could call into question the effectiveness of the remedies at this OU.

OU 3 is the shallow soils at Yermo Annex for which data existed prior to the Remedial Investigation (RI) and includes CAOCs 18, 20, 23, and 34. Institutional controls (ICs) were implemented for CAOCs 18, 20, 23, and 34, and continue to be protective of human health and the environment. Caps were constructed at CAOCs 20 and 23, and continue to be protective of human health and environment. RAs at OU 3 have been completed and have been deemed to be "operating properly and successfully" by the EPA, DTSC, and RWQCB. The exposure assumptions, toxicity data, cleanup levels, and RAOs used for this OU at the time of the remedy selection are still valid. There is no new information that could call into question the effectiveness of the remedies at this OU.

OU 4 is the shallow soils at Nebo Main Base (for which data existed prior to the RI) and consists of CAOCs 2, 5, 9, 10, and 11. Of these, CAOC 10 is now being evaluated under OU 7. CAOC 10 was originally eliminated (in 1994) as not requiring any action, but was subsequently found to require further investigation. No further action (NFA) was selected at the remaining CAOCs, although Base Master Plan (BMP) modifications were required (and completed) for CAOCs 2, 5, and 11. The remedies continue to be protective of human health and the environment. RAs at OU 4 have been completed and have been deemed to be operating properly and successfully by the EPA, DTSC, and RWQCB. The exposure assumptions, toxicity data, cleanup levels, and RAOs used for this OU at the time of the remedy selection are still valid. There is no new information that could call into question the effectiveness of the remedies at this OU.

OU 5 is the shallow soils at Yermo Annex (for which data did not exist prior to the RI) and consists of CAOCs 15/17, 16, 19, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 35, and 36. Of these, CAOC 25 was eliminated from the RI as not requiring additional investigation/remediation. NFA was selected at CAOCs 19, 22, 24, 25, 27, 28, 29, 30, 31, and 32. ICs were selected and implemented for CAOCs, 15, 16, 17, 18, 21, and 26. A cap and ICs were selected and installed for CAOC 35. The selected remedies at the CAOCs at OU 5 continue to be protective of human health and the environment. RAs at OU 5 have been completed and have been deemed to be "operating properly and successfully" by the EPA, DTSC, and RWQCB. The exposure assumptions, toxicity data, cleanup levels, and RAOs used for this at the time of the remedy selection are still valid. There is no new information that could call into question the effectiveness of the remedies at this OU.

OU 6 is the shallow soils at Nebo Main Base (for which data did not exist prior to the RI) and includes CAOCs 1, 3, 4, 6, 7, 8, 12, 13, 14, and 33. Of these, CAOC 33 was eliminated from the RI as not requiring further investigation. NFA was selected at CAOCs 4, 6, 8, 12, 13, and 14. ICs were required at CAOCs 1 and 3. A native soil cap and ICs were selected and implemented at CAOC 7. Groundwater at CAOC 6 is covered under OU 2. The selected remedies at OU 6

continue to be protective of human health and the environment. RAs at OU 6 have been completed and have been deemed to be "operating properly and successfully" by the EPA, DTSC, and RWQCB. The exposure assumptions, toxicity data, cleanup levels, and RAOs used for this OU at the time of the remedy selection are still valid. There is no new information that could call into question the effectiveness of the remedies at this OU.

In summary, the remedies at all of the CAOCs were found to be protective of human health and the environment. Issues were identified for some CAOCs. Recommendations and identified milestones to address these have been provided as part of this five-year review.

FIVE-YEAR REVIEW SUMMARY FORM – OU 1

SITE IDENTIFICATION		
Site name ***(from WasteLAN)*** *Marine Corps Logistics Base*		
EPA ID ***(from WasteLAN)*** *CA8170024261*		
Region: 09	**State:** CA	**City/County:** Barstow / San Bernardino County

SITE STATUS	
NPL status: ☒ Final ☐ Deleted ☐ Other (specify) _____	
Remediation status (choose all that apply): ☐ Under Construction ☒ Operating ☐ Complete	
Multiple OUs? ☒ YES ☐ NO	**Construction completion date:** 12 / 08 / 98
Has site been put into reuse? ☒ YES ☐ NO	

REVIEW STATUS	
Reviewing agency: ☐ EPA ☐ State ☐ Tribe ☒ Other Federal Agency Department of the Navy	
Author name: Kimberly Jacobsen, PE	
Author Title: Remedial Project Manager	**Author affiliation:** Southwest Division Naval Facilities Engineering Command
Review period: January/1997 to September/2002	
Date(s) of inspection: October / 14 / 2002 to October / 19 / 2002	
Type of review: ☐ Statutory ☒ Policy (☐ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only ☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead ☐ Regional Discretion)	
Review number: ☒ 1 (first) ☐ 2 (second) ☐ 3 (third) ☐ Other (specify) _____	
Triggering action: ☐ Actual RA Onsite Construction at OU __ ☐ Actual RA Start at OU # _____ ☐ Construction Completion ☐ Previous Five-Year Review Report ☒ Other (specify) ROD signing date	
Triggering action date: 4 / 22 / 1998	
Due date (five years after triggering action date): 4 / 22 / 2003	

FIVE-YEAR REVIEW SUMMARY FORM – OU 1
(Continued)

Issues:

- VOCs in soil gas at CAOC 26 show a slight increase in 2001 compared to 1999 (the CAOC 26 AS/SVE was shut down in December 1998), from approximately 15,000 $\mu g/m^3$ to 16,000 $\mu g/m^3$ (average).
- CAOC 16 AS/SVE system has not caused decrease in dissolved VOCs in groundwater at CAOC 16 in the immediate vicinity of the AS/SVE wells.
- Background levels of metals in groundwater are not available for comparison with metals in groundwater at CAOC 16.
- Declining water levels are reducing the effectiveness of the groundwater extraction wells associated with the Yermo Annex GETS.
- Off-Base extraction wells have not been installed.
- Off-Base drinking water wells (Younts and Hodges) are showing sporadic low levels of VOCs in the influent, additional assessment is required to determine vertical extent of dissolved VOCs upgradient of these wells (downgradient of the Base).

Recommendations and Follow-up Actions:

- Continue annual monitoring of soil gas at CAOC 26, consider shallow gas survey if soil gas VOCs increase by a factor of 5 to re-evaluate impact to above ground receptors, restart SVE if necessary.
- Evaluate background metals in groundwater at Yermo Annex.
- Evaluate optimization of CAOC 16 AS/SVE system.
- Evaluate hydraulic capture of Yermo Annex GETS annually to ensure ongoing capture at the MCL plume boundary.
- Submit Technical Memorandum to explain the rationale for not installing off-Base extraction wells at Yermo Annex, followed by ESD (if Technical Memorandum is approved).
- Evaluate vertical extent of dissolved VOC contamination downgradient of Base boundary (upgradient of Younts and Hodges wells).

Protectiveness Statement(s):

The remedy at OU 1 is protective of human health and the environment.

Other Comments:

- MTBE has been detected in groundwater in a number of groundwater monitoring wells in the southwest portion of Yermo Annex and is suspected to be from off-Base activities. There is known off-Base MTBE contamination upgradient of the southwest portion of Yermo Annex.
- There was a temporary increase in dissolved VOCs in groundwater in December 2001. Results from first quarter 2002 monitoring event indicate that these have decreased to pre-December 2001 levels. The increase is believed to be associated with a brief high-intensity storm event in September 2001.

- The GAC in the treatment system at the two off-Base drinking water wells (Younts and Hodges) has been changed once in the past 7 years. More frequent changeout should be considered (every 5 years). This should (and will) be documented in a formal O&M Manual.
- A formal O&M Manual should (and will) also be prepared for the YDW-5 GAC treatment system.

Notes:

$\mu g/m^3$ – micrograms per cubic meter
AS/SVE – air sparging/soil vapor extraction
CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern
ESD – Explanation of Significant Differences
GAC – granular activated carbon
GETS – Groundwater Extraction and Treatment System
MTBE – methyl tert-butyl ether
NPL – National Priorities List
OU – Operable Unit
O&M – Operation and Maintenance
VOC – volatile organic compound

FIVE-YEAR REVIEW SUMMARY FORM – OU 2

SITE IDENTIFICATION

Site name ***(from WasteLAN)*** *Marine Corps Logistics Base*

EPA ID ***(from WasteLAN)*** *CA8170024261*

Region: 09	**State:** CA	**City/County:** Barstow / San Bernardino County

SITE STATUS

NPL status: ☒ Final ☐ Deleted ☐ Other (specify) _____

Remediation status (choose all that apply): ☐ Under Construction ☒ Operating ☐ Complete

Multiple OUs? ☒ YES ☐ NO | **Construction completion date:** 12 / 08 / 98

Has site been put into reuse? ☒ YES ☐ NO

REVIEW STATUS

Reviewing agency: ☐ EPA ☐ State ☐ Tribe ☒ Other Federal Agency Department of the Navy

Author name: Kimberly Jacobsen, PE

Author Title: Remedial Project Manager | **Author affiliation:** Southwest Division Naval Facilities Engineering Command

Review period: January/1997 to September/2002

Date(s) of inspection: October / 14 / 2002 TO October / 19 / 2002

Type of review: ☐ Statutory
☒ Policy (☐ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only
☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead
☐ Regional Discretion)

Review number: ☒ 1 (first) ☐ 2 (second) ☐ 3 (third) ☐ Other (specify) _____

Triggering action:
☐ Actual RA Onsite Construction at OU __ ☐ Actual RA Start at OU # _____
☐ Construction Completion ☐ Previous Five-Year Review Report
☒ Other (specify) ROD signing date

Triggering action date: 4 / 22 / 1998

Due date (five years after triggering action date): 4 / 22 / 2003

FIVE-YEAR REVIEW SUMMARY FORM – OU 2
(Continued)

Issues:

- Nebo North – AS/SVE has not yet been implemented for the Nebo North plume.
- Nebo South – deviation from ROD –off-Base GEWs were not installed.
- NPZ-14 - VOCs detected several thousand feet away from the Nebo South plume.

Recommendations and Follow-up Actions:

- Implement AS/SVE at Nebo North (if found to be necessary and feasible).
- If AS/SVE is deemed feasible at Nebo South, submit Technical Memorandum to explain the rationale for not installing off-Base extraction wells followed by ESD (if Technical Memorandum is approved).
- Monitor NPZ-14 annually and evaluate the relation between VOCs at NPZ-14 and the Nebo South plume.

Protectiveness Statement(s):

The remedy at OU 2 is protective of human health and the environment.

Other Comments:

- None

Notes:

AS/SVE – air sparging/soil vapor extraction

ESD – Explanation of Significant Differences

GEW – groundwater extraction well

NPL – National Priorities List

OU – Operable Unit

ROD – Record of Decision

VOC – volatile organic compound

FIVE-YEAR REVIEW SUMMARY FORM – OU 3

SITE IDENTIFICATION

Site name ***(from WasteLAN)*** *Marine Corps Logistics Base, Barstow*

EPA ID ***(from WasteLAN)*** *CA8170024261*

Region: 09	**State:** CA	**City/County:** Barstow / San Bernardino County

SITE STATUS

NPL status: ☒ Final ☐ Deleted ☐ Other (specify) _____

Remediation status (choose all that apply): ☐ Under Construction ☐ Operating ☒ Complete

Multiple OUs? ☒ YES ☐ NO | **Construction completion date:** 01 / 29 / 1999

Has site been put into reuse? ☒ YES ☐ NO

REVIEW STATUS

Reviewing agency: ☐ EPA ☐ State ☐ Tribe ☒ Other Federal Agency Department of the Navy

Author name: Kimberly Jacobsen, PE

Author Title: Remedial Project Manager | **Author affiliation:** Southwest Division Naval Facilities Engineering Command

Review period: January/1997 to September/2002

Date(s) of inspection: October / 14 / 2002 to October / 19 / 2002

Type of review: ☒ Statutory
☐ Policy (☐ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only
☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead
☐ Regional Discretion)

Review number: ☒ 1 (first) ☐ 2 (second) ☐ 3 (third) ☐ Other (specify) _____

Triggering action:
☐ Actual RA Onsite Construction at OU __ ☒ Actual RA Start at OU #3 9/9/1998
☐ Construction Completion ☐ Previous Five-Year Review Report
☐ Other (specify) _____

Triggering action date: 9 / 9 / 1998

Due date (five years after triggering action date): 9 / 9 / 2003

FIVE-YEAR REVIEW SUMMARY FORM – OU 3
(Continued)

Issues:

- None

Recommendations and Follow-up Actions:

- None

Protectiveness Statement(s):

The remedies at OU 3 are protective of human health and the environment.

Other Comments:

- None

Notes:

NPL – National Priorities List

OU – Operable Unit

FIVE-YEAR REVIEW SUMMARY FORM – OU 4

SITE IDENTIFICATION		
Site name ***(from WasteLAN)*** *Marine Corps Logistics Base, Barstow*		
EPA ID ***(from WasteLAN)*** *CA8170024261*		
Region: 09	**State:** CA	**City/County:** Barstow / San Bernardino County

SITE STATUS	
NPL status: ☒ Final ☐ Deleted ☐ Other (specify) _____	
Remediation status (choose all that apply): ☐ Under Construction ☐ Operating ☒ Complete	
Multiple OUs? ☒ YES ☐ NO	**Construction completion date:** 01 / 29 / 1999
Has site been put into reuse? ☒ YES ☐ NO	

REVIEW STATUS	
Reviewing agency: ☐ EPA ☐ State ☐ Tribe ☒ Other Federal Agency Department of the Navy	
Author name: Kimberly Jacobsen, PE	
Author Title: Remedial Project Manager	**Author affiliation:** Southwest Division Naval Facilities Engineering Command
Review period: January/1997 to September/2002	
Date(s) of inspection: October / 14 / 2002 to October / 19 / 2002	
Type of review: ☒ Statutory ☐ Policy (☐ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only ☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead ☐ Regional Discretion)	
Review number: ☒ 1 (first) ☐ 2 (second) ☐ 3 (third) ☐ Other (specify) _____	
Triggering action: ☐ Actual RA Onsite Construction at OU __ ☒ Actual RA Start at OU #4 9/9/1998 ☐ Construction Completion ☐ Previous Five-Year Review Report ☐ Other (specify) _____	
Triggering action date: 9 / 9 / 1998	
Due date (five years after triggering action date): 9 / 9 / 2003	

FIVE-YEAR REVIEW SUMMARY FORM – OU 4
(Continued)

Issues:

- None

Recommendations and Follow-up Actions:

- None

Protectiveness Statement(s):

The remedies at OU 4 are protective of human health and the environment.

Other Comments:

- None

Notes:

NPL – National Priorities List

OU – Operable Unit

FIVE-YEAR REVIEW SUMMARY FORM – OU 5

SITE IDENTIFICATION		
Site name ***(from WasteLAN)*** *Marine Corps Logistics Base, Barstow*		
EPA ID ***(from WasteLAN)*** *CA8170024261*		
Region: 09	**State:** CA	**City/County:** Barstow / San Bernardino County

SITE STATUS	
NPL status: ☒ Final ☐ Deleted ☐ Other (specify) _____	
Remediation status (choose all that apply): ☐ Under Construction ☐ Operating ☒ Complete	
Multiple OUs? ☒ YES ☐ NO	**Construction completion date:** 01 / 31 / 2001
Has site been put into reuse? ☒ YES ☐ NO	

REVIEW STATUS	
Reviewing agency: ☐ EPA ☐ State ☐ Tribe ☒ Other Federal Agency Department of the Navy	
Author name: Kimberly Jacobsen, PE	
Author Title: Remedial Project Manager	**Author affiliation:** Southwest Division Naval Facilities Engineering Command
Review period: January/1997 to September/2002	
Date(s) of inspection: October / 14 / 2002 to October / 19 / 2002	
Type of review: ☒ Statutory ☐ Policy (☐ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only ☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead ☐ Regional Discretion)	
Review number: ☒ 1 (first) ☐ 2 (second) ☐ 3 (third) ☐ Other (specify) _____	
Triggering action: ☐ Actual RA Onsite Construction at OU __ ☐ Actual RA Start at OU # _____ ☐ Construction Completion ☐ Previous Five-Year Review Report ☒ Other (specify) ROD signing date	
Triggering action date: 1 / 23 / 1998	
Due date (five years after triggering action date): 1 / 23 / 2003	

FIVE-YEAR REVIEW SUMMARY FORM – OU 5
(Continued)

Issues:

- None

Recommendations and Follow-up Actions:

- None

Protectiveness Statement(s):

The remedies at OU 5 are protective of human health and the environment.

Other Comments:

- None

Notes:

NPL – National Priorities List

OU – Operable Unit

FIVE-YEAR REVIEW SUMMARY FORM – OU 6

SITE IDENTIFICATION		
Site name ***(from WasteLAN)*** *Marine Corps Logistics Base, Barstow*		
EPA ID ***(from WasteLAN)*** *CA8170024261*		
Region: 09	**State:** CA	**City/County:** Barstow / San Bernardino County

SITE STATUS	
NPL status: ☒ Final ☐ Deleted ☐ Other (specify) _____	
Remediation status (choose all that apply): ☐ Under Construction ☐ Operating ☒ Complete	
Multiple OUs? ☒ YES ☐ NO	**Construction completion date:** 12 / 10 / 1999
Has site been put into reuse? ☒ YES ☐ NO	

REVIEW STATUS	
Reviewing agency: ☐ EPA ☐ State ☐ Tribe ☒ Other Federal Agency Department of the Navy	
Author name: Kimberly Jacobsen, PE	
Author Title: Remedial Project Manager	**Author affiliation:** Southwest Division Naval Facilities Engineering Command
Review period: January/1997 to September/2002	
Date(s) of inspection: October / 14 / 2002 to October / 19 / 2002	
Type of review: ☒ Statutory ☐ Policy (☐ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only ☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead ☐ Regional Discretion)	
Review number: ☒ 1 (first) ☐ 2 (second) ☐ 3 (third) ☐ Other (specify) _____	
Triggering action: ☐ Actual RA Onsite Construction at OU __ ☐ Actual RA Start at OU # _____ ☐ Construction Completion ☐ Previous Five-Year Review Report ☒ Other (specify) ROD signing date	
Triggering action date: 1 / 23 / 1998	
Due date (five years after triggering action date): 1 / 23 / 2003	

FIVE-YEAR REVIEW SUMMARY FORM
(Continued)

Issues:

- None

Recommendations and Follow-up Actions:

- None

Protectiveness Statement(s):

The remedies at OU 6 are protective of human health and the environment.

Other Comments:

- None

Notes:

NPL – National Priorities List

OU – Operable Unit

1.0 INTRODUCTION

The Department of the Navy (DON) is conducting environmental restoration activities at the Marine Corps Logistics Base, Barstow, California (MCLB Barstow or Base), as part of the Installation Restoration Program (IRP). The IRP was established by the Department of Defense (DoD) to identify, evaluate, and control the spread of contaminants from historical hazardous waste sites at military installations. The DON is the lead federal agency responsible for conducting the site investigation and cleanup at MCLB Barstow. The DON's investigation and cleanup efforts are being conducted in conjunction with the U.S. Environmental Protection Agency (EPA), Region IX, Regional Water Quality Control Board (RWQCB) -Lahontan Region (referred to hereafter as the Water Board), and the State of California Environmental Protection Agency's Department of Toxic Substances Control (DTSC) through a Federal Facility Agreement (FFA). All of these entities are collectively referred to as FFA Parties, and their representatives as FFA Remedial Project Managers (RPMs).

MCLB Barstow consists of two separate facilities, the Yermo Annex and the Nebo Main Base, which are approximately 7 miles apart (see Figure 1-1). Soil and groundwater at both locations have been impacted by contaminants and are being cleaned up under the IRP. Contaminants include volatile organic compounds (VOCs), metals, and other contaminants in soil and groundwater. Figures 1-2 and 1-3 show the Yermo Annex and Nebo Main Base, respectively.

1.1 PURPOSE

The purpose of this five-year review is to evaluate the implementation and performance of the selected remedies at MCLB Barstow and to confirm whether the selected remedy remains protective of human health and the environment. The methods, findings, and conclusions of the five-year review are documented in this report. In addition, issues found during the review are identified and recommendations to address them are presented in this Five-Year Review Report.

Consistent with Executive Order 12580, the Secretary of Defense is responsible for ensuring that five-year reviews are conducted at all qualifying DoD cleanup sites. *According to the Navy/Marine Corps Policy for Conducting Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Statutory Five-Year Reviews* (DON, 2001), a statutory five-year review is required when both of the following conditions are met:

- Upon completion of the remedial actions (RAs) at a site, hazardous substances, pollutants, or contaminants will remain above levels that allow for unlimited use and unrestricted exposure.

- The Record of Decision (ROD) or Decision Document (DD) for the site was signed on or after October 17, 1986.

The DON is preparing this Five-Year Review Report pursuant to CERCLA, Section 121 and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). CERCLA Section 121 states:

> *If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgment of the President that action is appropriate at such site in accordance with Sections [104] or [106], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.*

The NCP, 42 United States Code (USC), Section 962l(c), implementing regulations, 40 Code of Federal Regulations (CFR) 300.430(f)(4)(ii), provide:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after initiation of the selected remedial action.*

The DON is responsible for the five-year review of the remedies implemented at MCLB Barstow. Foster Wheeler Environmental Corporation (FWENC) assisted the DON and MCLB Barstow in conducting the five-year review of Operable Units (OUs) 1 through 6. This is the first five-year review for MCLB Barstow. The five-year review is required due to the fact that hazardous substances, pollutants, or contaminants remain on Base above levels that allow for unlimited use and unrestricted exposure.

1.2 ORGANIZATION OF OPERABLE UNITS

To streamline the cleanup process the Base has been divided into seven OUs, as follows:

1. OU 1 and OU 2 -address groundwater contamination at Yermo Annex and Nebo Main Base, respectively.

2. OU 3 and OU 4 -address soil contamination at Yermo Annex and Nebo Main Base, respectively, for which analytical data existed prior to the Remedial Investigation (RI).

3. OU 5 and OU 6 -address soil contamination at Yermo Annex and Nebo Main Base, respectively, for which analytical data did not exist prior to the RI.

4. OU 7 -addresses contamination not covered by OUs 1 through 6.

RODs have been signed for OUs 1 through 6, as follows:

1. OUs 1 and 2: *Operable Units 1 and 2, Final Record of Decision*, Marine Corps Logistics Base, Barstow, California [OUs 1 and 2 ROD; Jacobs Engineering Group (JEG), 1998a].

2. OUs 3 and 4: *Operable Units 3 and 4, Final Record of Decision*, Marine Corps Logistics Base, Barstow, California. [OUs 3 and 4 ROD, (JEG, 1997)].

3. OUs 5 and 6: *Operable Units 5 and 6, Final Record of Decision*, Marine Corps Logistics Base, Barstow, California. [OUs 5 and 6 ROD; (JEG, 1998b)].

Within each OU, there are several hazardous waste areas termed CERCLA Areas of Concern (CAOCs). Figures 1-4 and 1-5 show the CAOCs (1 through 38) and OUs 1 through 6 at the Yermo Annex and Nebo Main Base, respectively. Cleanup actions are ongoing or have been completed at OUs 1 through 6, while OU 7 is under investigation. Cleanup actions at the CAOCs can be broadly classified into the following three categories:

1. Requiring no further action (NFA)
2. Requiring institutional controls (ICs) to protect health and environment
3. Requiring cleanup, or RA

Those CAOCs that are identified as NFA in their respective RODs do not require five-year reviews. It should be noted that a number of CAOCs identified as NFA required modifications of the Base Master Plan (BMP) for MCLB Barstow. Modifications in general, consisted of including site history and the requirement that the MCLB Barstow Environmental Department be contacted prior to construction activities at these CAOCs. CAOCs with these modifications were subjected to this five-year review. Figure 1-6 shows the organization of CAOCs and OUs at MCLB Barstow.

Some of the CAOCs are further divided into strata (discrete lateral areas of contamination) and zone (vertical depths of contamination in soil). At a number of CAOCs in OUs 3, 4, 5, and 6, where groundwater contamination is suspected, the groundwater is remediated or monitored under OU 1 or OU 2.

The CAOCs, OUs to which they belong, and five-year review requirements are summarized in Table 1-1. Five-year reviews are required for the following CAOCs: 1, 2, 3, 5, 6, 7, 11, 14, 15, 16, 17, 18, 20, 21, 23, 26, 34, 35, 37, and 38 (Table 1-1).

In addition to the above list of CAOCs, the five-year review addresses the following additional issues (associated with OUs 1 and 2):

- On-Base drinking water wells at the Yermo Annex
- Off-Base (residential) drinking water wells adjacent to the Yermo Annex and Nebo Main Base

- Potential presence of metals in groundwater in the northern portion of Yermo Annex

- Potential presence of pesticides in groundwater in the northern portion of Nebo Main Base

- Potential limited VOC contamination in groundwater in the southwestern portion of Nebo Main Base (NPZ-14)

Groundwater monitoring at the Yermo Annex and Nebo Main Base is conducted in general accordance with the *Draft Final OUs 1-6 Long-term Groundwater Monitoring Plan* (LTGWMP) (JEG, 1998c), and the *Final Sampling and Analysis Plan* (SAP) (FWENC, 2002a). The remediation systems at CAOC 37 are operated and maintained in general accordance with the *Draft Operation and Maintenance (O&M) Manual, Groundwater Extraction, Treatment, and Recharge System and Air Sparging (AS) and Soil Vapor Extraction Systems (SVE), Yermo Annex* (CAOC 37 O&M Manual) [OHM Remediation Services Corporation (OHM), 1999]. The remediation system at Nebo North is operated and maintained in general accordance with the *Final Optimization Manual, NRF-1 Groundwater Extraction and Treatment System (GETS), Nebo Main Base* (Nebo North GETS O&M Manual) (OHM, 1997).

The caps at CAOCs 7 and 35 are operated and maintained in general accordance with the *Final Operations and Maintenance Manual, Closed Landfills at CAOCs 7 and 35* (CAOC 7 and 35 O&M Manual) [Bechtel National, Inc. (BNI), 1999]. The cap at CAOC 20 is operated in accordance with Appendix B of the *Remedial Action Report (RAR), CAOC 20 and 23, OUs 3 and 4* (OUs 3 and 4 RAR) [Southwest Division Naval Facilities Engineering Command (SWDIV), 2000)]. The cap at CAOC 23 is operated in general accordance with the *Maintenance Manual, Concrete Landfill Cap, CAOC 23, Yermo Annex, Marine Corp Logistics Base, Barstow, California* (CAOC 23 O& M Manual) [AGRA Earth and Environmental, Inc. (AGRA), 1998].

1.3 FIVE-YEAR REVIEW TRIGGER DATE

According to the NCP and five-year review, reports are to be completed and signed within five years of the trigger date for a site when, upon the completion of the RAs at a site, hazardous substances, pollutants, or contaminants will remain above levels that allow for unlimited use and unrestricted exposure. The *OUs 1 and 2 ROD* (JEG, 1998a), signed 22 April 1998, requires the review of OUs 1 and 2 to be completed by 22 April 2003. According to DON policy, the trigger date for the statutory five-year review of OUs 3 and 4 is the RA mobilization date for CAOCs 20 and 23, or 9 September 1998. The trigger date for the statutory five-year review of OUs 5 and 6 is the date of signing of the OUs 5 and 6 ROD, 23 January 1998, driven by CAOC 16. The due date for this combined five-year review is therefore 23 January 2003.

1.4 DOCUMENT ORGANIZATION

This Five-Year Review Report is organized as follows:

- **Section 1.0** provides the purpose and authority for conducting the five-year review, lead agency for conducting the five-year review, review number, trigger date, identification of OUs at MCLB Barstow, and organization for the five-year review document.
- **Section 2.0** describes site chronology.
- **Section 3.0** describes the background of the sites (grouped by ROD), and general site description and history (grouped by location at Yermo Annex and Nebo Main Base).
- **Section 4.0** describes the remedial action objectives (RAOs) (grouped by ROD) and description of remedies conducted at the ICs and RA sites (grouped by location at Yermo Annex and Nebo Main Base).
- **Section 5.0** describes the five-year review process, including administrative components, community involvement, document and data review, site inspection, and interviews.
- **Section 6.0** presents the technical assessments of the sites, grouped by CAOCs, with summaries for each of the six OUs.
- **Section 7.0** presents any issues identified during the technical assessment, potential affects of issues, and discussion of any unresolved issues raised by other parties, grouped by CAOCs.
- **Section 8.0** includes recommendations and follow-up actions for the CAOCs.
- **Section 9.0** includes the protectiveness statement.
- **Section 10.0** proposes the date for the next review.
- **Section 11.0** provides the referenced documents used for this report.
- **Appendix A** provides a summary of analytical data for Yermo Annex groundwater.
- **Appendix B** provides a summary of remediation system performance at CAOC 37 at Yermo Annex.
- **Appendix C** provides a summary of analytical data for Nebo Main Base.
- **Appendix D** provides an assessment of exposure assumptions, toxicity data, cleanup levels, RAOs for OU 1 through OU 6.
- **Appendix E** provides an assessment of CAOC 26.
- **Appendix F** provides an assessment of the Yermo Annex GETS.

Appendices A, B, and C are included in electronic format only. Attachments to Appendix E are also in included in electronic format only.

2.0 OPERABLE UNIT CHRONOLOGIES

The chronology presented in Table 2-1 identifies significant events pertaining to OUs 1 through 6. The history of the IRP prior to the designation of OUs is also included. Additional Base history is available in the RODs or other available documents within the Administrative Record File.

3.0 BACKGROUND

The following sections discuss the RODs for MCLB Barstow, and site description and history of the CAOCs at Yermo Annex and Nebo Main Base. Each ROD is discussed separately, while site description and history are discussed for each CAOC. The CAOCs at Yermo Annex are described first, followed by the CAOCs at Nebo Main Base.

3.1 RECORDS OF DECISION FOR MCLB BARSTOW

3.1.1 OUs 1 and 2 ROD

The *OUs 1 and 2 ROD* (JEG, 1998a) covers groundwater at Yermo Annex and Nebo Main Base, respectively.

At Yermo Annex (OU 1), there are three dissolved VOC plumes (see Figure 1-4): CAOC 26 plume, Yermo North plume (or CAOC 16), and Yermo South plume, all of which are undergoing RA. The dissolved VOCs primarily include trichloroethene (TCE) and perchloroethene (PCE). Groundwater monitoring for soil at CAOCs 15, 16, 17, 20, 23, 26, and 35 (under OU 3 and OUS) is also included in OU 1, as is monitoring for potential metals contamination in groundwater beneath CAOC 16.

The Yermo Annex of MCLB Barstow lies within the west/northwest-trending Barstow Basin, which is approximately bounded by the Blackwater/Calico Faults to the northeast and by the Lenwood Fault to the southwest. The Barstow Basin dips sharply to the southeast and is filled with a sequence of late Tertiary to early Quaternary alluvial deposits. Surface sediments throughout the basin typically consist of windblown sand and recent alluvial deposits derived from the Mojave River or shed from adjacent highlands.

The sediments underlying the Yermo Annex are essentially composed of a thick sequence (up to 600 feet) of alluvial fan deposits of gravel, sand, silt, and clay. Beneath these deposits lies a sequence of low permeability Tertiary volcanic and sedimentary rocks. These rocks likely constitute bedrock in this area. Geophysical survey data and lithologic logging of deep exploratory boreholes performed during the RI identified the top of bedrock at approximately 600 feet below ground surface (bgs), as noted in the *Remedial Investigation/Feasibility Study Remedial Investigation Report for Operable Units 1 and 2* (JEG, 1995a).

Two separate aquifers have been identified in the area surrounding the Yermo Annex, the regional aquifer, and the more localized Mojave River aquifer (Densmore, Cox, and Crawford, 1997). Beneath the Yermo Annex, the Mojave River aquifer is generally composed of the saturated sediments that extend from the surface to a depth of approximately 200 feet bgs. This aquifer is underlain by a regional aquifer, which consists of the saturated sediments between approximately 200 feet bgs and bedrock at about 600 feet bgs beneath the eastern boundary of the Yermo Annex.

Figure 3-1 shows groundwater contours based on groundwater elevation data collected in October 2002. Based on the groundwater elevation contours provided in Figure 3-1, the general direction of groundwater flow was from the west to the east, across a major portion of the site. In the northwest portion of the site, groundwater flow to the southeast was observed, as a result of the influence of the infiltration galleries in that portion of the site. The calculated hydraulic gradient ranged from 0.0009 feet per foot (ft/ft) to 0.0046 ft/ft. The steepest hydraulic gradients were observed in the vicinity of the groundwater extraction wells (GEWs). At Nebo Main Base (OU 2), there are two dissolved VOC plumes (see Figure 1-5): Nebo North and Nebo South, both of which are undergoing RA. It should be noted that the ROD for the Nebo South plume is an "interim" ROD. Groundwater monitoring for soil CAOC 7 (OU 6) is also included in OU 2, as is monitoring for potential pesticide contamination in groundwater at Nebo North (CAOC 14).

MCLB Nebo Main Base is underlain by sandy Quaternary-age deposits of the Mojave River alluvium in the north, and by gravelly alluvial fans in the south. These materials appear to be interlayered colluvium and stream alluvium progressing from Pleistocene-age material at depth to recent material at the surface.

The trace of the northwest-southeast trending Harper Lake-Camp Rock Fault cuts across the eastern quarter of the Main Base. The fault and the related structural features mark the eastern margin of the Barstow sub-basin with the Yermo sub-basin. Data from Nebo-South indicated that the material appears to be predominantly mid-alluvial fan colluvial materials, with some thin beds of possible alluvium. These alluvial materials, albeit possibly discontinuous, may form preferential pathways for contaminant and fluid migration (OHM, 1995). Groundwater flow is generally sub-parallel to the Mojave River, which is the main feature within this unit. The eastern margin of the Barstow sub-basin is marked by the Harper Lake-Camp Rock Fault.

Figure 3-2 shows groundwater contours based on groundwater elevation data collected in July/August 2002. The contours in Figure 3-2 indicate significant influence from the Harper Lake-Camp Rock Fault. East of the fault, the groundwater flow was generally to the southeast with a relatively uniform hydraulic gradient of 0.004 ft/ft. West of the Harper Lake-Camp Rock Fault, a relatively complex groundwater flow pattern was observed. Flow west of the fault was generally to the east-northeast, with a hydraulic gradient ranging from 0.001 ft/ft to 0.02 ft/ft and averaging approximately 0.012 ft/ft overall. The hydraulic gradient is relatively steep in the southwest comer of the site and flattens out toward the Harper Lake-Camp Rock Fault.

3.1.2 OUs 3 and 4 ROD

The *OUs 3 and 4 ROD* (JEG, 1997) covers shallow soil contamination at Yermo Annex (OU 3: CAOCs 18, 20, 23, 34) and at Nebo Main Base (OU 4: CAOCs 2, 5, 9, 11) for which analytical data existed prior to the RI (see Figures 1-4 and 1-5). Landfill caps were installed at CAOCs 20 and 23. Groundwater monitoring for these caps is covered under OU 1. Groundwater monitoring for CAOC 2 is covered under OU 2.

3.1.3 OUs 5 and 6 ROD

The *OUs 5 and 6 ROD* (JEG, 1998b) covers shallow soil contamination at the Yermo Annex (OU 5: CAOCs 15/17, 16, 19, 21, 22, 24 to 32, 35, 36) and at the Nebo Main Base (OU 6: CAOCs 1, 3, 4, 6, 7, 8, 10, 12, 13, 14, 33) for which analytical data did not exist prior to the RI (see Figures 1-4 and 1-5). A landfill cap was installed at CAOC 35, and associated groundwater monitoring is conducted under OU 1. Remediation of groundwater beneath CAOCs 15/17, 16, 26, and 35 is conducted under OU 1. A cap was installed at CAOC 7, and associated groundwater monitoring is conducted under OU 2. Groundwater monitoring for potential pesticides under CAOCs 1, 3, and 14 is conducted under OU 2. Groundwater monitoring for CAOC 6 (Nebo South) is conducted under OU 2.

3.2 DESCRIPTION AND HISTORY -YERMO ANNEX CAOCS

A total of 22 CAOCs were identified at Yermo Annex (Figure 1-4). Following is a brief summary of site description, impacts to vadose zone and groundwater (if any), and RAs at each CAOC within Yermo Annex.

3.2.1 CAOC 15/17 (OU 5)

CAOC 15/17 is the Oil Storage/Spillage Area and Industrial Wastewater Treatment Plant (IWTP). Soils at these CAOCs were impacted by low levels of metals, TCE, polychlorinated biphenyls (PCBs), total petroleum hydrocarbons (TPH), total petroleum hydrocarbons as diesel (TPH-d), and various pesticides. A time-critical removal action (TCRA) was conducted in 1993 to remove residual sludges. Mathematical modeling indicated that soil contamination would have very limited potential impacts to groundwater. A NFA remedy was chosen for the CAOC, as documented in the *OUs 5 and 6 ROD* (JEG, 1998a). However, there was some uncertainty with respect to groundwater impact, as soil samples were limited to 12 feet bgs. To address this uncertainty, further vadose zone evaluation was conducted in conjunction with CAOC 16.

3.2.2 CAOC 16 (OU 5)

CAOC 16 is the Building 573 and perimeter area, located in the northeast portion of Yermo Annex. Soils at this CAOC were impacted by VOCs. A concrete cap, ranging in thickness from 10 to 14 inches covers the entire area. This greatly limits the potential for worker exposure to VOCs in soil gas (at shallow depths). It also minimizes the potential for impact to groundwater (from soil/soil gas VOCs) due to infiltration. An ICs remedy was chosen for soils as documented in the *OUs 5 and 6 ROD* (JEG, 1998b). Groundwater beneath the CAOC is impacted by VOCs and potentially metals, and is covered under the OU 1. Also, the vadose zone under CAOC 16 (and CAOC 15/17) is being remediated under OU 1, via the CAOC 16 AS/SVE system.

3.2.3 CAOC 18 (OU 3)

CAOC 18 is the former Sludge Waste Disposal Area. Soils at this CAOC are impacted by low levels of VOCs, semivolatile organic compounds (SVOCs), chlorinated pesticides, PCBs, petroleum hydrocarbons, metals, and polynuclear aromatic hydrocarbons (PAHs). Mathematical modeling indicated that soil contamination would have no potential impacts to groundwater. A NFA remedy with BMP modifications was chosen for this CAOC, as documented in the *OUs 3 and 4 ROD* (JEG, 1997).

3.2.4 CAOC 19 (OU 5)

CAOC 19, the First Hazardous and Low-Level Radiological Area, is located near the center of the Yermo Annex, southeast of Building 598. Sampling indicated that SVOCs, pesticides, metals, and radioactivity were present at very low levels. Mathematical modeling indicated that soil contamination would have very limited, if any, potential impacts to groundwater. A NFA remedy was chosen for the CAOC, as documented in the *OUs 5 and 6 ROD* (JEG, 1998b).

3.2.5 CAOC 20 (OU 3)

CAOC 20, the Second Hazardous and Low-Level Radiological Area, is located on the eastern side of the Yermo Annex. Soil contaminants included VOCs, SVOCs, metals, and pesticides. Mathematical modeling indicated that soil contamination would have limited potential impacts to groundwater. RAs selected at CAOC 20 include a combination of ICs, NFA, and concrete cap, as documented in the OUs 3 and 4 ROD (JEG, 1997).

3.2.6 CAOC 21 (OU 5)

CAOC 21, the Industrial Waste Disposal Area, is located on a flat, open, unpaved area near Gate 5 at the eastern perimeter of the Yermo Annex. This CAOC was originally under OU 3. Sampling indicated that low levels of chlorinated pesticides, VOCs, SVOCs, PCBs, metals, and petroleum hydrocarbons were present. A TCRA was conducted in 1997 to remove PCB-impacted soils [greater than 1 milligrams per kilogram (mg/kg)]. Mathematical modeling indicated that soil contamination would have very limited, if any, potential impacts to groundwater. A NFA remedy with BMP modifications was chosen for CAOC 21, as documented in the *OUs 3 and 4 ROD* (JEG, 1997).

3.2.7 CAOC 22 (OU 5)

CAOC 22, the Domestic Wastewater Disposal Area, is located in the southeastern portion of the Yermo Annex, adjacent to the eastern property boundary. Sampling indicated that low levels of pesticides, TPH-d, VOCs, and metals were present in the soils. Mathematical modeling indicated that soil contamination would have very limited, if any, potential impacts to groundwater. A NFA remedy was selected for CAOC 22 as documented in the *OUs 5 and 6 ROD* (JEG, 1998b).

3.2.8 CAOC 23 (OU 3)

CAOC 23, the Landfill Area, is located in the south/southeast comer of the Yermo Annex. Soils in the CAOC (outside the landfill) are impacted by low levels of VOCs. The landfill itself was not sampled. The selected remedy for CAOC 23 consisted of ICs for some portions, and a single layer cap or concrete pavement as documented in the *OUs 3 and 4 ROD* (JEG, 1997). Groundwater at CAOC 23 is believed to have been impacted by VOCs and is monitored under OU1.

3.2.9 CAOC 24 (OU 5)

CAOC 24, the Tracked Vehicle Test Area, is located in the southwestern portion of the Yermo Annex. Sample results indicate that VOCs were not present; two SVOCs were detected at low levels; only one pesticide was detected; TPH was detected at 4,400 mg/kg; and all metals were present at background concentrations except boron, chromium, and nickel. A soil organic vapor (SOV) survey was conducted to aid in locating VOCs in the subsurface soils. Toluene, ethylbenzene, xylenes, and 1,1,1-trichloroethane (1,1,1-TCA) were detected. The laterally limited and sporadic detections of fuel-related hydrocarbons in the vapor phase suggest minor surface spillage of fuel that would be expected at a test track area. Mathematical modeling indicated that soil contamination would have no potential impacts to groundwater. A NFA remedy was selected for CAOC 24, as documented by the *OUs 5 and 6 ROD* (JEG, 1998b).

3.2.10 CAOC25 (OU 5)

CAOC 25, the Wastewater Treatment and Sludge Disposal Area, is located in the southwestern portion of the Yermo Annex. This CAOC was proposed for elimination from investigation and remediation, as noted in *Draft Elimination Rationale for Sampling Requirements for Specific Strata, Operable Units 5 and 6, Technical Memorandum 0018* (TM0018) (JEG, 1994). This proposal was accepted by the FFA Parties, and is therefore not considered for the five-year review.

3.2.11 CAOC 26 (OU 5)

CAOC 26, the Building 533 Waste Disposal Area, is located in the west-central portion of the Yermo Annex. Sampling indicates low levels of VOCs, SVOCs, pesticides, and metals above background levels. No PCBs were detected in any of the soil samples collected. A NFA remedy with BMP modifications was selected for this CAOC, as documented in the *OUs 5 and 6 ROD* (JEG, 1998b). In addition to the soil samples, SOV surveys indicated that PCE concentrations in soil would impact groundwater. To address this residual vadose zone contamination, the OU 1 groundwater RA includes AS/SVE, in combination with downgradient groundwater extraction wells.

3.2.12 CAOC 27 (OU 5)

CAOC 27, the Fuel Storage Area, is located in the north-central portion of the Yermo Annex and includes the former location of Building 436, the boiler plant, which has been decommissioned. Soil sampling indicated the presence of high levels of TPH-d, along with low levels of SVOCs, pesticides, and metals. A human health evaluation was not performed for TPH, because no health-based criteria exist for petroleum hydrocarbons. Through modeling, it was concluded that the concentration of TPH could potentially affect the groundwater. No groundwater impacts were predicted as a result of contaminant detections, except for residual petroleum hydrocarbon contamination associated with the underground storage tanks (USTs). Because releases from these USTs involved only petroleum product, they are exempt under CERCLA Section 101. However, further evaluation will be conducted under the MCLB Barstow UST program. Mathematical modeling indicated that soil contamination would have very limited, if any, potential impacts to groundwater. A NFA remedy was selected for CAOC 27, as documented by the *OUs5 and 6 ROD* (JEG, 1998b).

3.2.13 CAOC 28 (OU 5)

CAOC 28, the West Lot Dust Control Area, is located in the northwestern portion of the Yermo Annex, which is west of the main industrial facilities. Analytical results indicate that low levels of SVOCs and pesticides are present. Metals were present; however, they are believed to be naturally occurring or are present at concentrations of minor concern from a human health perspective and from a groundwater impact perspective. No petroleum hydrocarbons were detected in any of the samples. Mathematical modeling indicated that soil contamination would have very limited, if any, potential impacts to groundwater. A NFA remedy was selected for CAOC 28, as documented by the *OUs 5 and 6 ROD* (JEG, 1998b).

3.2.14 CAOC29 (OU 5)

CAOC 29, the Sludge Storage Area, is located in the northwestern comer of the Yermo Annex adjacent to CAOC 28. Analytical results indicated that no VOCs, PCBs, or pesticides were detected in any of the soil samples. Only one SVOC was detected. Metal concentrations were consistent with background levels. Mathematical modeling indicated that soil contamination would have very limited, if any, potential impacts to groundwater. A NFA remedy was selected for CAOC 29, as documented by the *OUs 5 and 6 ROD* (JEG, 1998b).

3.2.15 CAOC 30 (OU 5)

CAOC 30, the Locomotive Repair Shop Disposal Area, is in the northwest portion of the Yermo Annex. The CAOC contains the present location of the Locomotive Repair Shop (Building 628) and also contained the former Repair Shop (now defunct Building 479). A small woodshed (formerly Building 532) was located south of Building 628 prior to being dismantled. Soil sampling results indicated low levels of organochlorine pesticides (OCPs), VOCs, TPH-d, and metals. No PCBs or SVOCs were detected. Mathematical modeling indicated that soil

contamination would have very limited, if any, potential impacts to groundwater. A NFA remedy was selected for CAOC 30, as documented by the *OUs 5 and 6 ROD* (JEG, 1998b).

3.2.16 CAOC 31 (OU 5)

CAOC 31, the North Vehicle Test Track Road, is located within Lot 486 in the north-central portion of the Yermo Annex. Analytical results indicated low levels of pesticides and TPH-d. Mathematical modeling indicated that soil contamination would have no potential impacts to groundwater. A NFA remedy was selected for CAOC 31, as documented by the *OUs 5 and 6 ROD* (JEG, 1998b).

3.2.17 CAOC 32 (OU 5)

CAOC 32, the Preservation and Packaging Storage Area, is located in the north-central portion of the Yermo Annex. Analytical results indicated low levels of OCPs except for one pesticide that exceeded risk-based criteria (RBCs). One SVOC was reported at a very low concentration. Metals were detected, but are believed to be naturally occurring or were present at concentrations of minor concern from a human health perspective. Additional sampling indicated that there is no widespread PCB contamination. Mathematical modeling indicated that soil contamination would have no potential impacts to groundwater. A NFA remedy was selected for CAOC 32, as documented by the *OUs 5 and 6 ROD* (JEG, 1998b).

3.2.18 CAOC 34 (OU 3)

CAOC 34, the PCB Storage Area (former Building S-345) is located on the eastern side of the Yermo Annex adjacent to the western side of the MCLB Effluent Disposal Pond (Building 426). The PCB Storage Area consisted of two separate concrete basins labeled Basin A (western basin) and Basin B (eastern basin). The basins were demolished and removed as a part of a TCRA in 1994. Sampling conducted prior to the RA indicated high levels of PAHs, phenol, OCPs, PCBs, and metals. TPH was present at low concentrations. The entire CAOC has been covered by concrete evaporation ponds. Mathematical modeling indicated that soil contamination would have very limited, if any, potential impacts to groundwater. A NFA remedy was selected for CAOC 34, as documented by the *OUs 3 and 4 ROD* (JEG, 1997). The low levels of benzo[a] pyrene detected in the surface soils at Stratum 1 were to be noted in the BMP.

3.2.19 CAOC35 (OU5)

CAOC 35, the (currently inactive) Class III Landfill, is located in the northeastern portion of the Yermo Annex. VOCs, SVOCs, and pesticides were minimal at the surface. Subsurface samples indicated the presence of VOCs and SVOCs, including PAHs. TPH was present at high levels and PCB concentrations were high as well. These contaminants were all believed to be site-related. All metals present were at or below background level. Two modeling techniques were used to evaluate if groundwater would be affected. Results from the first model indicated that groundwater would be impacted by the contaminants within the landfill. A more refined

evaluation was conducted which indicated that groundwater would not be affected. The remedy for the landfill is a single-layer native soil cap with NFA for remaining portions of the CAOC. Groundwater monitoring is covered under OU 1.

3.2.20 CAOC 36 (OU 6)

CAOC 36, the Paint Combat Vehicle Maintenance Shop, is located in the eastern portion of the Yermo Annex, approximately 200 feet northeast of Building 573 and southeast of the IWTP. Soils at this CAOC are impacted by low levels of TPH and other organic compounds. The entire CAOC is covered with a 10-inch-thick concrete pad. A NFA remedy was selected for CAOC 36, as documented by the *OUs 5 and 6 ROD* (JEG, 1998b)

3.2.21 CAOC 37 (OU 1 Groundwater)

CAOC 37 is the groundwater beneath the Yermo Annex. It is impacted by dissolved VOCs and to some extent, dissolved metals. Figure 1-4 shows the extent of VOC contamination and area of potential metals contamination. The VOC contamination is being addressed via the Yermo Annex GETS and the CAOC 16 and CAOC 26 AS/SVE systems.

3.3 DESCRIPTION AND HISTORY -NEBO MAIN BASE CAOCS

A total of 16 CAOCs requiring RA were identified at Nebo Main Base, as shown on Figure 1-5. Following is a brief summary of site description, impacts to vadose zone and groundwater (if any), and RAs at each CAOC within Nebo Main Base.

3.3.1 CAOC 1 (OU 6)

CAOC 1, the landfill north of the golf course, is located in the northern portion of the Nebo Main Base. Non-detectable or low concentrations were present within the samples, which were analyzed for VOCs, SVOCs, OCPs, PCBs, metals, cyanide, and TPH-d. Mathematical modeling indicated that residual dieldrin could migrate to the groundwater at concentrations that would contaminate or degrade the aquifer. To address this uncertainty, groundwater is monitored as a part of the OU 2 RA. A NFA remedy with BMP modifications was selected for CAOC 1, as documented by the *OUs 5 and 6 ROD* (JEG, 1998b).

3.3.2 CAOC 2 (OU 4)

CAOC 2, the Pesticide Storage and Washout Area, is located on the north side of the Nebo Main Base. Soil samples indicated dichlorodiphenyltrichloroethane (DDT) and its breakdown products dichlorodiphenyldichloroethene (DDE) and dichlorodiphenyldichloroethane (DDD), in addition to various other pesticide and herbicide compounds with relatively low potential for vertical migration or subsurface transport of contaminants due to the silty and clayey soil at the washout area. Dieldrin concentrations were the only ones to exceed the residential soil RBCs. Fourteen

metals exhibited concentrations that were statistically above background concentrations. All metals, except thallium and lead, were considered to be naturally occurring. Thallium and lead were considered potential site-related contamination because they were commercially used in insecticides prior to 1965.

A TCRA was conducted at CAOC 2 from August to September 1994 during which 318 tons of soil were excavated. Mathematical modeling performed at CAOC 2 indicated that the contaminants remaining in the soils, specifically dieldrin, could possibly migrate to the groundwater at concentrations that would contaminate or degrade the aquifer. To address this uncertainty, groundwater is monitored under OU 2. A NFA remedy with BMP modifications was selected for CAOC 2, as documented in the *OUs 3 and 4 ROD* (JEG, 1997).

3.3.3 CAOC 3 (OU 6)

CAOC 3, the Wastewater Disposal Area, is located in the northern portion of the Nebo Main Base, adjacent to the southern boundary of CAOC 1. Analytical results from sampling indicated non-detectable or low concentrations of VOCs, SVOCs, several pesticides, and extractable petroleum hydrocarbons. All detected metals present were believed to be naturally occurring, or present at concentrations of minor concern from a human health perspective. Mathematical modeling performed at CAOC 3 indicated that residual dieldrin in the soil could migrate to the groundwater at concentrations that would contaminate or degrade the aquifer. To address this uncertainty, the groundwater is monitored as a part of the OU 2 RA. A NFA remedy with BMP modifications was selected for CAOC 3, as documented by the *OUs 5 and 6 ROD* (JEG, 1998b).

3.3.4 CAOC 4 (OU 6)

CAOC 4, the Old Trap and Skeet Range Areas, is located in the northeastern quadrant of the Nebo Main Base. The CAOC was further expanded to include an aerial infrared anomaly.

No VOCs were identified in any of the samples. PAHs were detected in some samples and are thought to have arisen from waste oil. Low levels of pesticides were detected, as well as metals, which are believed to be naturally occurring. Mathematical modeling indicated that soil contamination would have very limited, if any, potential impacts to groundwater. A NFA remedy was selected for CAOC 4, as documented in the *OUs 5 and 6 ROD* (JEG, 1998b). Additional assessment of soil and groundwater contamination was conducted at the IWTP (in CAOC 4) as a part of the Extended Resource Conservation and Recovery Act (RCRA) Facility Assessment (ERFA). Results of this assessment are included in the *ERFA Report* [SOTA Environmental Technologies, Inc. (SOTA), 2001]. Residual contamination at this CAOC will be addressed under OU 7.

3.3.5 CAOC 5 (OU 4)

CAOC 5, the Chemicals Storage Area, is located in the southeastern portion of the Nebo Main Base, north of the Drum Storage Area and Landfill (CAOC 7), and south of Joseph Boll Avenue.

A variety of lower-level detections were present throughout the site including VOCs, SVOCs, OCPs, phenol, PCBs, TPH, PAHs, and metals. Mathematical modeling indicated that soil contamination would have no potential impacts to groundwater. A NFA remedy with BMP modifications was selected for CAOC 5, as documented in the *OUs 3 and 4 ROD* (JEG, 1997).

3.3.6 CAOC 6 (OU 6)

CAOC 6, the original Trash Landfill, is located in the eastern portion of the Nebo Main Base north of Interstate 40. VOCs were non-detectable or believed to be analytical artifacts. Strata 2 and 3 indicated detections of numerous SVOCs including PAHs, the majority of which were at low levels. In addition to the soil samples collected within CAOC 6, a number of vertical profile borings (VPBs) and other borings have been advanced within CAOC 6 in support of the AS/SVE pilot study, which indicate the presence of VOCs in soil gas at CAOC 6. Although VOCs were not detected in the soil samples from CAOC 6, there is known VOC contamination of downgradient groundwater. Groundwater contamination by VOCs has been confirmed to exist beneath this CAOC. An AS/SVE pilot study was to be conducted at this site. Because RAs have been recommended for the VOC contaminants in groundwater at CAOC 6 under the *OUs 1 and 2 ROD* (JEG, 1998a), no further site characterization for VOCs in soils is recommended under the *OUs 5 and 6 ROD* (JEG, 1998b).

3.3.7 CAOC 7 (OU 6)

CAOC 7, the Drum Storage and Landfill Areas, is located in the southwest comer of the Nebo Main Base. The site consists of two separate landfill areas (western and eastern) with a former drum storage area located adjacent to the eastern landfill area. VOCs and SVOCs, OCPs, metals, and TPH-d were detected at low levels. Impacts to groundwater were evaluated using mathematical modeling. Modeling indicated that lead and dieldrin detected at Stratum 1 may affect groundwater and that the projected concentrations of lead compounds in groundwater would be less than the projected concentration from background soils. Therefore, lead is not considered to have the potential to degrade water quality. Groundwater in the vicinity of CAOC 7 is monitored under OU 2.

Because there was the potential for minor surficial soil contamination to be present at Strata 3 and 4, as required in the *OUs 5 and 6 ROD* (JEG, 1998b) the BMP was amended to include a description of the history of CAOC 7, Strata 3 and 4, including the low levels of PCBs detected and language indicating that any actions planned in the area should be coordinated and reviewed by the MCLB Barstow Environmental Department.

Because of the uncertainties regarding Strata 1 and 2, a single layer native soil cap was the selected remedy along with above-mentioned restrictions in the BMP, as documented in the *OUs 5 and 6 ROD* (JEG, 1998b).

3.3.8 CAOC 8 (OU 6)

CAOC 8, the Building 197 Wastewater Disposal Area, is located in the northeast corner of Building 197 (the Machine Shop). Very low levels of organic compounds were detected. Mathematical modeling indicated that the contaminants remaining in soils would not migrate at concentrations that would contaminate or degrade the aquifer. A NFA remedy was selected for CAOC 8, as documented in the *OUs 5 and 6 ROD* (JEG, 1998b).

3.3.9 CAOC 9 (OU 4)

CAOC 9, the Fuel Disposal Area, is located in the southwest corner of the Nebo Main Base and is located just west of the Drum Storage and Landfill (CAOC 7). Sampling indicated the presence of pesticides, VOCs, carbon disulfide, PCBs, total petroleum hydrocarbons as gasoline (TPH-g), total recoverable petroleum hydrocarbons (TRPH), and metals. Mathematical modeling indicated that soil contamination would have no potential impacts to groundwater. A NFA remedy was selected for CAOC 9, as documented in the *OUs 3 and 4 ROD* (JEG, 1997).

3.3.10 CAOC 10 (OU 4)

CAOC 10, the Sodium Valve Buried Area, is located at the southwest comer of the Nebo Main Base. It was originally grouped under OU 4, but was subsequently eliminated from requiring further investigation as noted in TM0018 (JEG, 1994). However, during construction activities at CAOC 35, it was noted that the location of the Sodium Valve Buried Area might have been incorrectly identified during the RI. This CAOC is now being evaluated under OU 7.

3.3.11 CAOC11 (OU4)

CAOC 11, the Fuel Burn Area, is located in the southwest corner of the Nebo Main Base between the tank farm area to the north and the aboveground water storage tank to the south. Soil sample analysis indicated the presence of SVOCs, pesticides, TPH, and TRPH. Mathematical modeling indicated that soil contamination would have no potential impacts to groundwater and that CAOC 11 is not likely a past, present, or future source of contamination to the groundwater. A NFA remedy with BMP modifications was selected for CAOC 11 as documented in the *OUs 3 and 4 ROD* (JEG, 1997).

3.3.12 CAOC 12 (OU 6)

CAOC 12, the Radiator Cleaning Chemical Disposal Area, is in the southern portion of the Nebo Main Base. Soil sampling identified SVOCs, pesticides, and metals. Mathematical modeling indicated that soil contamination would have no potential impacts to groundwater. A NFA remedy was selected for CAOC 12, as documented in the *OUs 5 and 6 ROD* (JEG, 1998b).

3.3.13 CAOC 13 (OU 6)

CAOC 13, the Preservation and Packaging Storage Area, is located in the southern portion of the Nebo Main Base, south of I-40 and east of the main housing area. Soil samples were collected and analyzed for SVOCs, OCPs, PCBs, TPH-d, metals, and cyanide. The results were within specified risk standards. Mathematical modeling was used to evaluate the leaching potential of any site-related contaminants. Mathematical modeling indicated that soil contamination would have no potential impacts to groundwater. A NFA remedy was selected for CAOC 13 as documented in the *OUs 5 and 6 ROD* (JEG, 1998b).

3.3.14 CAOC 14 (OU 6)

CAOC 14 consists of the three major stormwater drainage channels that constitute the Nebo Main Base surface drainage system and four outfalls that discharge into the Mojave River.

During sampling, each channel and outfall was inspected. No obvious sources such as drums, stains, or oily liquids were found. Other than greases and oils associated with runoff from vehicle traffic areas, no ongoing releases would impact these areas. All samples were analyzed for VOCs, SVOCs, OCPs, PCBs, metals, cyanide, and TPH-d. VOCs were not present in the samples with the exception of a single detection, which was assumed to be the result of laboratory contamination. SVOCs were present; however, they were present at levels below residential RBC values. Pesticides were detected at varying levels throughout each of the samples. PCBs were detected in isolated samples. Metals detected in all samples were believed to be naturally occurring or present at concentrations of minor concern from a human health perspective. Impacts to groundwater at CAOC 14 were evaluated using mathematical modeling. Results from modeling indicated that PAHs, PCBs, and pesticides could affect groundwater quality. All of these contaminants are nonvolatile, insoluble, and adsorb easily to soil particles. They are expected to be immobile in vadose zone spills. Results from additional mathematical modeling analysis indicated that groundwater concentration of each of the contaminants would be below their respective RBCs and maximum contaminant levels (MCLs), except for dieldrin and gamma-chlordane. In order to address this uncertainty, groundwater is being monitored under OU 2. A NFA remedy with BMP modifications was selected for CAOC 14 as documented in the *OUs 5 and 6 ROD* (JEG, 1998b).

3.3.15 CAOC 33 (OU 6)

CAOC 33, the Rifle Range Disposal Area, was proposed for elimination from the RI/Feasibility Study (FS), as noted in *TM0018* (JEG, 1994). This was accepted by the FFA Parties, and is therefore, not subject to the five-year review process.

3.3.16 CAOC 38 (OU 2 Groundwater)

CAOC 38 is the groundwater beneath the Nebo Main Base. It is impacted by dissolved VOCs. Figure 1-5 shows the extent of VOC contamination at the Nebo Main Base. The VOC

contamination is being addressed via the Nebo North GETS and the Nebo South AS/SVE systems. The Nebo South AS/SVE system is on a pilot-scale basis, and may be expanded to full scale in the future. The Nebo North GETS is on standby, and an AS/SVE treatability study is currently planned.

4.0 REMEDIAL ACTIONS

The following sections discuss the remedy selected, implementation, and system O& M for various OUs.

4.1 REMEDIAL ACTION OBJECTIVES

RAOs for OUs 1 through 6 are summarized in the following sections.

4.1.1 OUs 1 and 2 ROD

For OUs 1 and 2, the RAO is cleanup of groundwater to MCLs via containment of groundwater contamination at the MCL plume boundary (except directly beneath waste management areas/ waste management units).

The RAO for vadose zone cleanup at OUs 1 and 2 is to remove contaminant mass in the subsurface soils to the degree necessary to:

1. Prevent further degradation of groundwater above groundwater cleanup standards.
2. Reduce the aquifer cleanup time.

4.1.2 OUs 3 and 4 ROD

The RAO for CAOCs 20 and 23 is to limit the potential exposure to the wastes remaining on site and minimize water infiltration and groundwater impacts.

NFA or ICs remedies were selected for the remaining CAOCs under OUs 3 and 4.

4.1.3 OUs 5 and 6 ROD

The RAO for CAOC 35 Zone 1 (OU 5) remedy is to minimize water infiltration and potential future impact to groundwater, and limit potential human exposure to buried waste. The RAO for the selected remedy at CAOC 16 (OU 5) is to minimize the potential for human exposure to contaminated soils via containment. The RAO for CAOC 7 (Strata 1 and 2) under OU 6 is to minimize water infiltration and potential future impact to groundwater and limit potential human exposure to buried wastes via containment.

NFA or ICs remedies were selected for the remaining CAOCs under OUs 5 and 6.

4.2 DESCRIPTION OF REMEDIES -YERMO ANNEX

The following sections describe the RAs at the Yermo Annex. Only those CAOCs where either ICs, RAs, or BMP modifications are implemented are discussed. These include CAOCs 15/17, 16, 18, 20, 21, 23, 26, 34, 35 (Figure 4-1); and the OU 1 groundwater remediation systems -CAOC 37 (Figure 4-2).

4.2.1 CAOC 15/17 (OU 5)

At CAOC 15/17 (OU 5), a NFA remedy was selected and was determined to be protective of human health and the environment. Sections 12.1 through 12.6 of the BMP include a description of the history of this CAOC; the low levels of PCBs, hexavalent chromium, and PAHs; and language to the effect of any actions planned in these areas or changes in site use should be coordinated and reviewed by the MCLB Barstow Environmental Department.

4.2.2 CAOC 16 (OU 5)

The selected remedy for CAOC 16 is ICs. The remedy involves maintaining the existing concrete hardstand, monitoring the physical and structural integrity of the concrete hardstand, and controlling and monitoring exposure pathways at CAOC 16. A regular maintenance program is implemented to maintain a stable surface environment, which will prevent organic vapors from escaping to the atmosphere and will prevent direct contact with any soil contamination. It will also minimize infiltration of water to the subsurface.

The BMP has been amended (Sections 11.1 through 11.6) to reflect that the physical and structural integrity of the concrete hardstand shall be maintained, that any excavation, damage, or removal of the concrete hardstand will be reported to the MCLB Barstow Environmental Department, and that any actions taken that could compromise the long-term effectiveness of the concrete hardstand will be reported to the FFA signatories along with an evaluation of what measures are necessary to protect human health and the environment. The BMP amendments also include language that describes the risk to human health and the environment that exists at CAOC 16; references to the MCLB Barstow OU 5 RI, FS, and ROD; and provide a legal description (metes and bounds) of the boundaries of CAOC 16. The language in the BMP amendment also includes the title and dates of the related documents and their storage location.

If a change in land use is proposed that is inconsistent with the selected remedy for CAOC 16 or the land use recorded in the BMP for CAOC 16, the DTSC, the RWQCB, and the EPA will be notified of such a change, and concurrence will be obtained before such a change is made.

It should be noted that an AS/SVE system was installed along the perimeter of CAOC 16 under OU 1. The *OUs 1 and 2 ROD* (JEG, 1998a) requires an evaluation of the vadose zone at CAOC 16 (and CAOC 15/17) as a part of the five-year review. This evaluation is discussed in Section 6.7.

4.2.3 CAOC 18 (OU 3)

At CAOC 18, a NFA remedy (which does not involve institutional or engineering controls) was selected and was determined to be protective of human health and the environment. However, because the Incremental Lifetime Cancer Risk (ILCR) exceeded 1 x 10^{-6} in Strata 2 and 3, the *OUs 3 and 4 ROD* (JEG, 1997) required that a brief description of these two strata be provided in the BMP, low-level PCBs and pesticides detected in the soils be documented in the BMP, and that any planned activities in these areas or changes in site use should be coordinated through and reviewed by the MCLB Environmental Department. Sections 4.1 through 4.6 of the BMP address these items.

4.2.4 CAOC 20 (OU 3)

The objectives for the RA at Strata 1 and 2 at CAOC 20 were to limit the potential for exposure to and disturbance of buried wastes and to minimize the potential for future releases to groundwater.

RAs at CAOC 20 (see Figure 4-3) consist of:

1. Replacement of an existing concrete cap to minimize rainwater infiltration
2. Grading and berming to reduce rainwater infiltration over the concrete cap, thereby, further minimizing rainwater infiltration
3. Groundwater monitoring and vadose zone infiltration monitoring

These were completed in 2000 and are discussed in detail in the *OUs 3 and 4 RAR* (SWDIV, 2000). As noted therein, the remedy was determined to be "operating properly and successfully" by the DON and all FFA Parties. It should be noted that the neutron access probe for vadose zone infiltration monitoring at CAOC 20 was installed during a subsequent RA at CAOC 35, as noted in the *OUs 5 and 6 RAR* (SWDIV, 2002).

Monitoring data to be collected for CAOC 20 include soil moisture readings and groundwater monitoring. Groundwater monitoring is conducted annually under OU 1.

4.2.5 CAOC 21 (OU 5)

The selected remedy for CAOC 21 is a NFA remedy. However, because the ILCR at the CAOC exceeded 1 x 10^{-6}, for information and future planning purposes, a description of the history of the CAOC, the low levels of chlorinated pesticides, VOCs, SVOCs, PCBs, metals, and petroleum hydrocarbons, and language to the effect of any actions planned within CAOC 21 or any changes in site use were required to be coordinated and reviewed by the MCLB Barstow Environmental Department. These are addressed in Sections 13.1 through 13.6 of the BMP. A TCRA was conducted in 1997 to remove PCB-contaminated soils (greater than 1 mg/kg).

A deep vertical soil profile boring was advanced within CAOC 21 [per the *OUs 5 and 6 ROD* (JEG, 1998b)] as part of the ERFA. VOCs were detected in soil gas at this boring. Additional actions are planned under OU 7 (CAOC 9.60).

4.2.6 CAOC 23 (OU 3)

The NFA remedy was selected for Strata 3, 5, and 5a. However, because of the carcinogenic risk, a brief description of the history of CAOC 23, Strata 5 and 5a, low levels of PCBs and pesticides detected in the soils, and the language to the effect of any actions planned in this area or changes in site use were required to be coordinated and reviewed by the MCLB Barstow Environmental Department. These are included in Sections 3.1 through 3.6 of the BMP.

RAs at CAOC 23 consist of:

1. In-place abandonment of a water line
2. Deep dynamic compaction of soil
3. Installation of a concrete cap at Zone 1, which is defined as Stratum 2 and the southern portion of Stratum 1 (see Figure 4-3)
4. Groundwater monitoring and vadose zone infiltration monitoring

These were completed in 2000 and are discussed in detail in the *OUs 3 and 4 RAR* (SWDIV, 2000). As noted therein, the remedy was determined to be "operating properly and successfully" by the DON and all FFA Parties.

In addition to the above, four of the five geophysical anomalies at CAOC 23 (four at Stratum 1 and one at Stratum 4) were excavated and consolidated at the CAOC 35 Landfill, prior to installation of a cap at that CAOC. The fifth anomaly could not be found when resurveyed by geophysical methods. It may have been a surface interference that was moved when the Defense Reutilization Materials Office (DRMO) moved from the area.

Groundwater monitoring is conducted annually under OU 1.

4.2.7 CAOC 26 (OU 5)

The NFA remedy was selected for CAOC 26 soils and does not involve institutional or engineering controls. Because of concerns over the potential for vapor-phase contaminants to escape from the subsurface and impact future on-site receptors, Sections 14.1 through 14.6 of the BMP provide a description of this CAOC, and language to the effect of any actions planned in this area or changes in site use, will be coordinated through and reviewed by the MCLB Barstow Environmental Department.

System performance monitoring and ambient air sampling were performed under OU 1 to conclusively verify that an on-site inhalation threat does not exist.

4.2.8 CAOC 34 (OU 3)

In July 1994, in a TCRA, the basins were demolished and removed, along with the soils within the basins. Contaminated surface soil near the basins was also excavated. A new wastewater treatment plant was constructed on this CAOC.

The NFA remedy selected for CAOC 34 does not involve institutional or engineering controls. Although the current wastewater treatment plant eliminates potential exposures at Stratum 1, Sections 5.1 through 5.6 of the BMP address information regarding contaminants in the soils, the low levels of benzo[a] pyrene detected in the surface soils at Stratum 1, and language indicating that any changes in site use must be coordinated through and reviewed by the MCLB Barstow Environmental Department.

4.2.9 CAOC 35 (OU 5)

The major components of the selected remedy at CAOC 35 (see Figure 4-4) include:

- Installation of a 3-foot native soil cover
- Installation of a 6-inch rock cover over the native soil cover and a 6-foot fence (with finer mesh at the bottom to prevent desert tortoises from entering)
- Installation of soil moisture monitors
- Restriction of land use activities in the area (sign postage and institutional controls)

These are discussed in detail in the *OUs 5 and 6 RAR* (SWDIV, 2002). As noted therein, the remedy was determined to be "operating properly and successfully" by the DON and all FFA Parties.

Also, four of the five geophysical anomalies from CAOC 23 (OU 3) were consolidated at CAOC 35 prior to installation of the cap.

4.2.10 OU 1 Groundwater Remediation Systems (CAOC 37)

The following is a description of the remedy as stated in the *OUs 1 and 2 ROD* (JEG, 1998a). The selected remedy involves groundwater extraction, ex situ treatment and recharge of treated groundwater back into the aquifer, and AS/SVE systems for groundwater and vadose zone VOC mass removal. Groundwater cleanup standards are based on removing constituents to levels at secondary and primary MCLs as measured by groundwater monitoring wells. Vadose zone cleanup standards are based on removal of VOCs from soils to levels that will not cause groundwater to exceed the groundwater cleanup standards, and on interpretation of soil gas data using appropriate vadose zone fate and transport and groundwater mixing zone models. Monitoring is conducted to verify adherence to groundwater cleanup standards. The major components of the selected remedy, described in the ROD include the following:

- Remedy all the contaminant plumes that exceed the MCLs, except directly beneath waste management areas/waste management units, by extracting groundwater at three locations: 1) four on-Base wells at the CAOC 26 plume downgradient boundary[1]; 2) eight wells at the Base eastern boundary[2]; and 3) four off-Base wells at the MCL boundary[3].

- Treat extracted groundwater aboveground by activated carbon units.

- Operate existing AS/SVE systems for groundwater/vadose zone source removal at CAOC 26 and for groundwater VOC mass removal downgradient of CAOCs 16, 15/17, and 35.

- Recharge treated groundwater back into the aquifer via two infiltration galleries located at the upgradient edge of the plume.

- Monitor the vadose zone at CAOCs 16, 15/17, and 26 for the effectiveness of the AS/SVE systems.

- Monitor groundwater throughout the duration of the remedial action, which is estimated to take approximately 30 years, subject to evaluations of treatment effectiveness at 5-year intervals.

- Monitor groundwater at CAOCs 23 and 35 subject to landfill closure requirements.

- Sample groundwater quarterly for 1 year for five dissolved metals (nickel, chromium, antimony, thallium, and aluminum) at selected wells in the area of CAOC 16 to ascertain if these metals are naturally occurring or the result of Base activities.

- Implement ICs including access restrictions to prevent the use of untreated groundwater for drinking water in the area of the plume above MCLs and wellhead treatment of potentially impacted water supply wells.

Figures 4-2, 4-5, and 4-6 show the Yermo Annex GETS, CAOC 16 AS/SVE system, and CAOC 26 AS/SVE system, respectively. A description of the remediation systems is provided in the following subsections.

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1 These wells were installed.
2 These wells were installed, along with a ninth well downgradient of CAOC 16.
3 The four off-Base wells have not been installed as of 2002, as the extent of the off-Base portions of the plumes has reduced since 1996.

4.2.10.1 Yermo Annex GETS

The Yermo Annex GETS was designed primarily to provide hydraulic containment of the dissolved groundwater plumes at the Yermo Annex. The GETS has an operating capacity of 1,600 gallons per minute (gpm). The system is currently operating at approximately 500 gpm. During GETS operation, groundwater is withdrawn from eight extraction wells (GEW-1 through GEW-8) located along the eastern boundary of the Yermo Annex, four extraction wells located in Lot 487 (GEW-9 through GEW-12), and one extraction well located near Building 573 (GEW-13). The locations of these wells are shown on Figure 4-2. The extracted groundwater is conveyed to the treatment compound where the water is treated for VOCs with granular activated carbon (GAC) after which it is discharged into infiltration galleries near the main gate of the Yermo Annex.

The need for the four off-Base extraction wells is being evaluated, due to the reduction in dissolved VOC levels and extent of plume boundaries off Base. This strategy will be discussed in an Explanation of Significant Differences (ESD).

4.2.10.2 CAOC 16 AS/SVE System

The CAOC 16 AS/SVE system was installed in 1996 to reduce contaminant mass in the vadose and saturated zones near and downgradient of Building 573 (see Figure 4-5) and was in operation from 1999 (it is currently in operation). The CAOC 16 AS/SVE system injects air into the saturated zone through a network of AS wells that are screened below the water table. The injected air forms micro-channels in the saturated zone, volatilizing VOCs, and transferring them to the unsaturated zone (vadose zone). The VOC-laden vapors are then extracted from the vadose zone by a system of SVE wells and treated with GAC to remove VOCs prior to discharge to the atmosphere.

4.2.10.3 CAOC 26 AS/SVE System

The CAOC 26 AS/SVE system is similar to the CAOC 16 AS/SVE system, and was installed near Building 533 (see Figure 4-6) in 1996, and was operation from 1996 through 1998.

4.2.10.4 On-Base Drinking Water System

A GAC system was installed at YDW-5 in 1989 consisting of two 20,000-pound GAC vessels in series. The GAC system treats the extracted groundwater for VOCs, should any be present.

4.2.10.5 Off-Base Drinking Water Systems

GAC systems were installed at drinking water wells at Younts and Hodges (off Base) in 1995 as a TCRA, as documented in *Time-Critical Removal Action at Private Residences Domestic Water Supply Wells Located East of the Yermo Annex* (Yermo Private Residences TCRA) (OHM, 1996).

Each system contains two 200-pound GAC vessels in series. The GAC systems treat the extracted groundwater for VOCs, should any be present.

4.3 DESCRIPTION OF REMEDIES -NEBO MAIN BASE

The following sections describe the remedies for various CAOCs at Nebo Main Base. Only those CAOCs where either ICs, RAs, or BMP modifications are implemented are discussed. These include CAOC 1, 2, 3, 5, 7, 11, and 14 (see Figure 4-7); and the OU 2 groundwater remediation systems -CAOC 38 (Figures 4-8 and 4-9).

4.3.1 CAOC 1 (OU 6)

The NFA remedy was selected for CAOC 1. Because the BLCR at Strata 2 and 3 exceed 1×10^{-6}, for information and future planning purposes, a description and history of these two strata, a description of the activities that occurred for flood control purposes, a legal description (metes and bounds) of the boundary of CAOC 1, the low levels of pesticides and PAHs detected in the surface soils at these two strata are addressed in Sections 15.1 through 15.6 in the BMP. Language in the BMP indicates that any changes in site use must be coordinated through and reviewed by the MCLB Barstow Environmental Department.

4.3.2 CAOC 2 (OU 4)

A NFA remedy was selected for CAOC 2, as documented by the ROD for OUs 3 and 4. Because the ILCR at Strata 1 and 3 exceeds 1×10^{-6}, for information and future planning purposes, the BMP was updated (Sections 6.1 through 6.6 of the BMP) to include: a description of the history of this stratum, the low levels of pesticides detected in the surface soils at these two strata, and language to the effect of any changes in site use must be coordinated through and reviewed by the MCLB Barstow Environmental Department. A TCRA was conducted from August to September 1994 during which, 318 tons of impacted soils were removed.

4.3.3 CAOC 3 (OU 6)

The NFA remedy was selected for CAOC 3 soils under OUs 5 and 6. The selected NFA remedy does not involve institutional or engineering controls. Because the ILCR at Stratum 1 exceeds 1×10^{-6}, for information and future planning purposes, Sections 16.1 through 16.6 of the BMP have been modified to include: a description of the history of this stratum, the low levels of pesticides detected in the surface soils at this stratum, and language to the effect that any changes in site use must be coordinated through and reviewed by the MCLB Barstow Environmental Department.

4.3.4 CAOC 5 (OU 4)

A NFA remedy was selected for CAOC 5 soils. Because the ILCR at Strata 1 and 2 exceeds 1 x 10^{-6}, for information and future planning purposes, Section 7.0 of the BMP has been updated to include: a description of the history of these strata, the low levels of pesticide and PCB detections in Stratum 1 soils, the presence of dust suppression material in this stratum (dust suppression is discussed in the summary section of the BMP), and language to indicate that any changes in site use must be coordinated through and reviewed by the MCLB Barstow Environmental Department.

4.3.5 CAOC 7 (OU 6)

As stated in Section 3.3.7, a NFA remedy was selected for Strata 3 and 4. However, because there was the potential for minor surficial soil contamination to be present at Strata 3 and 4, Sections 10.1 through 10.6 of the BMP were amended to include a description of the history of CAOC 7 Strata 3 and 4, the low levels of PCBs detected, and language to the effect of any actions planned in the area should be coordinated and reviewed by the MCLB Barstow Environmental Department.

Monolithic native soil caps were installed at Strata 1 and 2, as discussed in the *OUs 5 and 6 RAR* (SWDIV, 2002). These are shown on Figure 4-10. The cap is maintained, and groundwater is monitored at three monitoring wells on an annual basis. Results of groundwater analysis are summarized in Appendix C.

4.3.6 CAOC11 (OU4)

A NFA remedy was selected for CAOC 11. Because low levels of pesticides were detected in the soils that were within the risk range for carcinogenic site-related risks, a description of site history for information and planning purposes, the levels of pesticides, and language to the effect that any activities planned in this area or changes in site use should be coordinated through and reviewed by the MCLB Barstow Environmental Department are amended in Section 8.0 of the BMP.

4.3.7 CAOC 14 (OU 6)

A NFA remedy was selected for CAOC 14 under OU 6. Because low levels of pesticides, PCBs, and PAHs were detected in the soils that were within the risk range for carcinogenic site-related risks, Section 17.0 of the BMP includes: a description of the site history, the levels of pesticides detected, and language to the effect that any activities planned in this area or changes in site use should be coordinated and reviewed by the MCLB Barstow Environmental Department.

4.3.8 OU 2 Groundwater Remediation Systems (CAOC 38)

The major components of the selected remedy at Nebo North include the following:

- Use AS/SVE system for groundwater/vadose zone source removal at Warehouse 2.

- Implement ICs including access restrictions to prevent the use of untreated groundwater for drinking water in the area of the plume above MCLs, and wellhead treatment of potentially impacted water supply wells.

- Design and implement sampling protocol to monitor and evaluate the progress of natural processes in achieving remediation goals.

- Activate an existing groundwater extraction and treatment pilot study system on a contingency basis to provide containment backup if natural processes fail to contain the plume.

- Monitor vadose zone at Warehouse 2 for the effectiveness of the AS/SVE system.

- Monitor groundwater throughout the duration of the RA, which is estimated to take approximately 15 years, subject to evaluations of treatment and cost effectiveness at 5-year intervals.

The major components of the selected interim remedy at Nebo South include the following:

- Capture the contaminant plume above MCLs through five groundwater extraction wells at the leading edge of the plume.

- Treat extracted groundwater by activated carbon units aboveground.

- Recharge treated groundwater back into the aquifer via percolation ponds located on the northeast comer of the Nebo Main Base, downgradient of the plume.

- Implement ICs.

- Select the final remedy at a later date with an accompanying Proposed Plan and ROD.

A major component of the selected interim remedy at Nebo South will also include conducting an AS/SVE pilot study to further investigate the extent of vadose zone and groundwater contamination underlying CAOC 6, and evaluating the technical feasibility and effectiveness of AS/SVE at this CAOC.

The AS/SVE system for Nebo North has not yet been installed. Pilot testing is planned for 2003, to be followed by full-scale implementation (if AS/SVE is necessary/feasible) at a later date. This is based on the elevated levels of VOCs in soil gas at Nebo North, as documented in the

ERFA Report (SOTA, 2001). The GETS at Nebo North remains on standby. Natural attenuation was evaluated, but it was determined that biological degradation is not occurring (although physical dispersion may be), as noted in the *Draft Evaluation of Monitored Natural Attenuation for Groundwater Contamination at Nebo Main Base North* (Parsons Engineering Science, Inc., 1999). No additional natural attenuation monitoring was deemed necessary (groundwater is monitored quarterly/annually for VOCs under OU 2).

At Nebo South, the off-Base extraction system has not been installed, as this would cause on-Base contamination to be drawn off Base. This strategy has been agreed to by the EPA, DTSC, and RWQCB, and will be documented via an ESD. A long-term AS/SVE pilot test is ongoing at Nebo South.

No new drinking water wells have been installed within the plume areas at Nebo North and Nebo South.

A discussion of the status of the Nebo North GETS and Nebo South AS/SVE system is provided in the following subsections.

4.3.8.1 Nebo North GETS

The Nebo North GETS was designed to provide hydraulic containment for the Nebo North Plume in the event that VOC concentrations in selected wells were to increase above MCLs. These wells are monitored on a quarterly basis. The GETS has not been in operation since 1996 as the plume has been stable (in terms of extent and concentrations) and concentrations have not increased in the selected wells. Figure 4-8 shows the Nebo North GETS.

4.3.8.2 Nebo South

AS/SVE A pilot scale AS/SVE system is in place at Nebo South and testing is ongoing in accordance with the *Draft Final Pilot Test Work Plan, Phase 2 AS/SVE Pilot Test, CAOC 6, Nebo Main Base, MCLB, Barstow, California* (FWENC, 2001a). Initial results from the testing indicate that AS/SVE is a feasible technology for remediation of VOC-impacted groundwater at CAOC 6. Figure 4-9 shows the Nebo South AS/SVE system.

4.3.8.3 Off-Base Drinking Water Well

An off-Base residential well adjacent to the Nebo Main Base was taken out of service in June 1989 and the residence supplied with drinking water from the Base.

4.4 REMEDY PERFORMANCE -YERMO ANNEX

The following RAs have been implemented at the Yermo Annex:

- CAOC 20 -Landfill Cap
- CAOC 23 -Landfill Cap
- CAOC 35 -Landfill Cap
- CAOC 37 -Yermo Annex GETS
- CAOC 37 -CAOC 16 AS/SVE system
- CAOC 37 -CAOC 26 AS/SVE system

The performance of the RAs at these CAOCs is discussed below. Appendix A includes groundwater analytical results for Yermo Annex monitoring wells. Performance data for the three CAOC 37 systems are included in the O&M Plan in Appendix B.

4.4.1 CAOC 20 (OU 3)

The remedy at CAOC 20 consists of a concrete cap in combination with NFA. The concrete cap is maintained in accordance with the O&M Plan in Appendix B of the *OUs 3 and 4 RAR* (SWDIV, 2000) and is in good condition. Groundwater is monitored under OU 1. Historical groundwater monitoring data collected from CAOC 20 monitoring wells (YS20-1 and YS20-2) are presented in Appendix A (Table A-8), and are summarized on Figure 4-11. These data indicate that the constituents of concern (COCs) were less than the respective MCLs. The radiological analyses results in Appendix A (Table A-9) indicate in general that the analytes are less than the respective MCL. The slight exceedance of gross alpha value over its MCL in YS20-1 during third quarter 2001 is within the laboratory-specified error range.

The cap and fence at CAOC 20 are in good working condition. Inspections were conducted to check for the presence of concrete cracks in the joint sealer. No cracks were observed, as noted in the *Annual Monitoring and Maintenance Report, CAOCs 20, 23, 7, and 35* [McGhee Construction, Inc. (McGhee), 2002]. Debris and sediment were removed from the entrance of the 12-inch-diameter drain pipe and the discharge end of the drainpipe on an as-needed basis (McGhee, 2002). Inspection and maintenance of chain-link fence were performed. In addition, weed control activities were performed.

Soil moisture data is monitored on a regular basis (daily) using a soil moisture monitoring system. In addition, a rainfall gauge measures rainfall at regular intervals. The measured soil moisture does not vary significantly with depth (McGhee, 2002). This indicates that the cap is functioning effectively.

4.4.2 CAOC 23 (OU 3)

The remedy at CAOC 23 consists of a concrete cap in combination with ICs. The cap is maintained in accordance with the *CAOC 23 O&M Manual* (AGRA, 1998) and is in good condition. Monitoring consists of groundwater (under OU 1) and vadose zone moisture (precipitation) monitoring. It should be noted that Section 2.3.8 of the *OUs 3 and 4 ROD* (JEG, 1997) calls for vadose zone monitoring, but none is required for the option, as noted in Section 2.3.6.3 of the same ROD.

Appendix A (Table A-10) summarizes the historical groundwater monitoring data for the CAOC 23 groundwater monitoring wells. These are also summarized on Figure 4-11, which indicates that VOC concentrations are below MCLs.

Results of groundwater monitoring indicate that:

1. VOCs in the upgradient wells are stable and below MCLs.
2. VOCs in downgradient wells are stable and also below MCLs.

Based on the absence of an increase in VOC levels in groundwater, the remedy for CAOC 23 is performing effectively.

No cracks were observed in the joint sealer during inspections (McGhee, 2002). Weed control activities and inspection and maintenance of chain-link fence were performed (McGhee, 2002).

4.4.3 CAOC 35 (OU 5)

The remedy at CAOC 35 consists of a native soil cap with vadose zone moisture and groundwater monitoring. The soil cap is maintained in accordance with the *CAOC 7 and 35 O&M Manual* (BNI, 1999), and is in good condition.

Appendix A (Table A-12) summarizes historical groundwater monitoring data for the CAOC 35. These are also summarized on Figure 4-12. As can be seen from Figure 4-12, VOCs in groundwater in the immediate vicinity of CAOC 35 have generally remained stable with time, but (downgradient) wells, YS35-3, YS35-4, and YS17-8, show an increasing trend.

The cap and fence at CAOC 35 are in good working condition. Inspection and maintenance of chain-link fence and weed control activities were performed, as noted in the *Annual Monitoring and Maintenance Report, CAOCs 20, 23, 7, and 35* (McGhee, 2002).

Soil moisture data is monitored on a regular basis (daily) using a soil moisture monitoring system. In addition, a rainfall gauge measures rainfall at regular intervals. Soil moisture data for CAOC 35, McGhee (2002) indicate in general that the measured soil moisture does not vary significantly with depth. This indicates that the cap is functioning effectively. The monument survey revealed no movement with respect to the landfill monuments (McGhee, 2002) indicating that there was no measurable differential settlement.

4.4.4 CAOC 37 -Yermo Annex GETS (OU 1)

The Yermo Annex GETS is operated in accordance with the *CAOC 37 O&M Manual* (OHM, 1999) and *SAP* (FWENC, 2002a). Following is a description of the performance of the Yermo Annex GETS.

4.4.4.1 Containment at MCL Boundaries

The primary objective of the Yermo Annex GETS is to achieve MCLs in groundwater by hydraulic containment at the MCL plume boundaries. This is monitored on a quarterly basis by measuring groundwater levels and plotting groundwater level contour maps. Figure 4-13 shows the capture zones for August 2002 based on groundwater modeling (Appendix F) along with MCL plume boundaries for March/April 2002. As can be seen from this figure, there is hydraulic containment for the majority of each of the three plumes.

4.4.4.2 Reduction of VOC Mass

As of August 2002, approximately 1.43 billion gallons of contaminated groundwater have been extracted and treated by the GETS, removing approximately 100 pounds of total VOCs since the initial startup in 1996.

Figure B-l in Appendix B shows a plot of the historical average annual flow rates and average annual VOC influent concentrations [TCE, PCE, and 1,1-dichloroethene (1,1-DCE)] versus time. As can be seen in Figure B-l, average annual flow rates have decreased since initial startup (December 1996), while influent VOC concentrations have increased slightly. Figure B-2 in Appendix B shows the cumulative removals of TCE, PCE, and 1,1-DCE by the GETS. Removals appear to be gradually approaching asymptotic levels.

The levels of VOCs in the treated groundwater have remained below detection limits, indicating that the system is operating properly.

4.4.4.3 Reduction in VOC Concentrations

Concentrations of VOCs in groundwater at OU1 have generally decreased since 1996. Figure 4-14 shows decreases in dissolved VOCs at selected locations of OU 1. A cumulative listing of VOC data for OU 1 is presented in Appendix A. As discussed in the *Annual Groundwater Monitoring Report for 2001, Marine Corps Logistics Base* (FWENC, 2002b), a number of groundwater monitoring wells at OU 1 have become dry due to the falling groundwater levels in the Yermo area (1 to 3 feet per year). As a result, the locations in Figure 4-14 include, in some cases, more than one well.

As can be seen from Figure 4-14, with the exception of YS17-8, all the monitoring wells show a general decreasing trend in dissolved VOCs for all three plumes at the Yermo Annex. However, it is somewhat premature to determine if VOCs will reach MCLs within the remediation time frame (30 years).

4.4.4.4 Extraction Well Performance

Extraction well performance has generally declined since 1996. This is due to the ongoing drop in water levels at the Yermo Annex (and in the Yermo area as a whole). This is shown on Figure

B-3 in Appendix B. The decrease in water levels has made a significant portion of the extraction well screen ineffective for a number of extraction wells, resulting in reduced extraction flow rates.

4.4.5 CAOC 37 -CAOC 16 AS/SVE System

The CAOC 16 AS/SVE system is operated in accordance with the *CAOC 37 O&M Manual* (OHM, 1999). The following sections discuss the performance of the CAOC 16 AS/SVE system.

4.4.5.1 VOC Removal Rates and Concentrations

Operation of the CAOC 16 AS/SVE system began in June 1999. System performance is summarized in Appendix B. Figure B-4 shows the influent concentrations of total VOCs and freon over time. Figure B-5 shows the VOC/freon removal rates over time, while Figure B-6 shows the cumulative mass removed by the CAOC 16 AS/SVE system. As can be seen from Table B-6, a total of approximately 6,300 pounds of VOCs and 500 pounds of freon have been extracted from soil (and groundwater) by the CAOC 16 AS/SVE system.

The following observations and trends are noted from Appendix B:

1. The concentrations of freon in extracted soil vapor have decreased to negligible levels, confirming that freon was localized and limited in the subsurface.

2. Concentrations of VOCs in extracted soil vapor have also generally decreased since 1999.

3. VOC removal rates have generally declined since 1999 (due to the decrease in concentrations, since the flow rates have remained generally consistent).

The levels of VOCs in the treated soil vapor have remained well below acceptable levels, indicating that the treatment system is effective.

4.4.5.2 Soil Vapor Monitoring -Effectiveness Wells

The CAOC 16 soil vapor monitoring and extraction wells were sampled quarterly throughout 2001. The soil vapor samples were collected under static conditions (AS/SVE system not in operation) in January 2001, April 2001, June 2001, October 2001, and January 2002. Analytical data are presented in Figures B-7, B-8, and B-9 and are summarized on Figure 4-15. The following trends can be noted from these figures:

1. VOC concentrations in soil vapor in the extraction wells have generally decreased with time.
2. VOC concentrations in soil vapor in the monitoring wells have also generally decreased, with a few exceptions.

3. Also, VOC concentrations in soil vapor in the three combination wells (YCW16-1, YCW16-2, and YCW16-3) show a significant decrease in spite of their distance from the SVE wells.

The three combination wells have soil vapor probes at five different depths across the vadose zone. Figure B-10 in Appendix B shows VOC concentrations with depth for October 1999 through January 2002. As can be seen from this figure, the highest VOC concentrations continue to occur between about 80 and 120 feet bgs for all three combination wells. This indicates that the VOCs in soil gas beneath the CAOC are not migrating downwards. Also, it is obvious that the magnitude of VOC concentrations is also decreasing with time (most likely due to the continued operation of the CAOC 16 AS/SVE system).

4.4.5.3 Groundwater Monitoring -Effectiveness Wells

Samples were collected from wells (YS18-2, YS17-7, YS17-8, YWA-1, and YWB-1) to assess the effectiveness of the CAOC 16 AS/SVE system in reducing VOC concentrations in groundwater. Figure 4-16 shows the VOC concentration trends in these and other selected wells in the CAOC 16 area. As can be seen from Figure 4-16, VOCs in the wells in the CAOC 16 area have remained fairly consistent.

4.4.6 CAOC 37 -CAOC 26 AS/SVE System

The CAOC 26 AS/SVE system was installed to reduce contaminant mass in the vadose and saturated zones at CAOC 26. The CAOC 26 AS/SVE system process is identical to the CAOC 16 AS/SVE system process. The CAOC 26 AS/SVE system was started in December 1996 and operated through December 1998. It has not been in operation since then, as it has met its objectives, as discussed in the *CAOC 26 Technical and Economic Feasibility (TEF) Report* (CAOC 26 TEF Report) (FWENC, 200Ib).

4.4.6.1 VOC Removals

The system extracted an estimated 1,449 pounds of VOCs from the subsurface. Figure B-11 in Appendix B shows cumulative mass removals.

4.4.6.2 VOC Reduction in Groundwater

VOCs in groundwater at CAOC 26 have remained below MCLs since the CAOC 26 AS/SVE system shut down in 1998. This is shown on Figure 4-17.

4.4.6.3 VOCs in Soil Gas at CAOC 26

Since shutdown, the CAOC 26 soil vapor monitoring network has been sampled on a regular basis. It is now sampled annually in accordance with the CAOC 26 TEF Report (FWENC, 2001b). Figure B-12 in Appendix B shows plots of the analytical data results. These are also

summarized on Figure 4-17. These plots in general indicate a slight increasing trend in soil vapor concentrations at some locations, as of December 2001. Average concentrations have increased from approximately 15,000 micrograms per cubic meter (µg/m^3) in 1999 to approximately 16,000 µg/m^3 in 2001. However, the soil vapor concentrations are significantly lower than the October 1996 levels.

4.4.7 On-Base Drinking Water Wells

Samples of influent, intermediate, and effluent at YDW-5 are collected on a monthly basis, results of which are summarized in Appendix A. Samples of the influent showed sporadic detections for VOCs, at relatively low levels (below MCLs). The GAC in the lead vessel has been replaced once since installation.

4.4.8 Off-Base Drinking Water Wells

The off-Base residential drinking water wells (Younts and Hodges) each have two 200-pound GAC vessels in service. Samples of influent, intermediate, and effluent are collected on a semiannual basis at both the Younts and Hodges wells. The results of these analyses are summarized in Appendix B, Table B-12. VOCs have been sporadically detected in the Younts and Hodges influent at levels below 2 micrograms per liter (µg/L). The GAC in the vessels was changed in August 2002 due to these relatively low detections of VOCs in the effluent (less than 0.5 µg/L).

4.5 REMEDY PERFORMANCE -NEBO MAIN BASE

The following RAs have been implemented at the Nebo Main Base:

- CAOC 7 -Landfill Cap
- CAOC 38 -Nebo North GETS
- CAOC 38 -Nebo South AS/SVE (pilot test)

The performance of the RAs at these CAOCs is discussed below. Appendix C includes groundwater analytical results for the Nebo Main Base.

4.5.1 CAOC 7 (OU 6)

The cap at CAOC 7 is maintained in accordance with the *CAOC 7 and 35 O&M Manual* (BNI, 1999). Appendix C (Table C-7) provides historical groundwater monitoring data for CAOC 7 wells. CAOC 7 monitoring wells sampled to date included Wells NS7-1, NSP-2 and NSP-3. None of the COCs were detected at or above MCLs during 2001 in these wells.

Samples from these wells were also analyzed for 21 different OCPs during the second quarterly monitoring event of 2001 in accordance with the *LTGWMP* (JEG, 1998c). With the exception of

endosulphan sulfate (reported at an estimated concentration of 0.022 µg/L), none of the 21 OCPs were detected above their respective reporting limits (Table C-7, Appendix C) in the samples collected. These data are also summarized on Figure 4-18.

The fence at CAOC 7 was noted for requiring minor repairs. These repairs are covered under the regular inspection and maintenance program for the chain-link fence. The cap at CAOC 7 is in good working condition as noted in the *Annual Monitoring and Maintenance Report, CAOCs 20, 23, 7, and 35* (McGhee, 2002). Weed control activities were performed (McGhee, 2002).

Soil moisture data is monitored on a regular basis (daily) using a soil moisture monitoring system. In addition, a rainfall gauge measures rainfall at regular intervals. Summarized soil moisture data presented in Table 1 of the *Annual Monitoring and Maintenance Report, CAOCs 20, 23, 7, and 35* (McGhee, 2002) indicate that in general, the measured soil moisture does not vary significantly with depth. This indicates that the cap is functioning effectively. The monument survey revealed no movement with respect to the landfill monuments (McGhee, 2002) indicating that there was no measurable differential settlement.

4.5.2 CAOC 38 -Nebo North (OU 2)

The GETS at Nebo North is operated in accordance with the *Nebo North GETS O&M Manual* (OHM, 1997). Appendix C (Table C-l) summarizes the historical analytical results for VOCs at Nebo North. Concentrations of TCE in wells associated with the Nebo North plume remained relatively stable. TCE was not detected in concentrations above its MCL (5.0 µg/L) in any of the Nebo North wells during 2001, except in T22A/B-MW-1 during the first quarter [11 µg/L (estimated value)] and fourth quarter (11 µg/L).

PCE was detected above its MCL during one or more events in five Nebo North plume wells, MW-B, MW-D, T22A/B-MW1, NRF-1, and NS2-2, during 2001. In Well MW-B, PCE concentrations, ranged from 2 µg/L to 14 µg/L. PCE was consistently detected between 3 and 6 µg/L in Well MW-D. PCE concentrations in Well T22A/B-MW-1 analyzed during 2001 sampling events range from 6 µg/L to 8 µg/L (estimated value). PCE was detected at 11 µg/L (estimated concentration) in Well NRF-1 during the fourth quarterly 2001 sampling event. During the first quarterly 2001 sampling event, PCE was detected in Well NS2-2 at 18 µg/L, but was reported from 0.4 µg/L (estimated concentration) to 1 µg/L (estimated concentration) during the subsequent quarters during 2001.

Figure 4-19 shows the concentrations versus time plots for COCs, which show in general, a decrease in concentrations. Well NS2-2 showed a temporary spike in April 2001, but subsequently decreased to historic levels.

4.5.3 CAOC 38 -Nebo South (OU 2)

The Phase 2 AS/SVE pilot test at Nebo South was started in October 2001 and is ongoing (as of September 2002). The test has proven to be successful and demonstrates the feasibility of AS/SVE at the site. Following is a summary of results to date:

1. Extractions were performed at a vacuum of approximately 60 inches of water and 120 inches of water at five extraction wells individually. Maximum flow rates for each well ranged from 39 to 71 cubic feet per minute (cfm), with the exception of one well (NS6-V5) at 9 cfm. This well likely has a portion of the extraction screen submerged.

2. Flow versus vacuum followed expected trends, with no flow increase beyond 120 inches of vacuum.

3. The effective SVE radius of influence (ROI) at most wells (except NS6-V5) was in the 150-foot range.

4. Maximum injection pressures for sparging at each sparge well ranged from 31 to 37 pounds per square inch (psig) at flow rates ranging from 12 to 25 actual cubic feet per minute (acfm).

5. The effective radius of sparge influence is at least 40 feet and potentially as high as 80 feet and greater, based on dissolved oxygen measurements.

Figure 4-20 shows COC concentrations versus time trend plots for selected wells at Nebo South. These plots indicate in general, a decrease in dissolved concentrations in the vicinity of the pilot test (in particular, after the start of the pilot test in December 2001).

4.5.4 Off-Base Drinking Water Well

The off-Base residence (Johnston) continues to be supplied with drinking water by the Base.

4.6 METALS AT YERMO ANNEX

In addition to the active remediation systems at Yermo Annex, the *OUs 1 and 2 ROD* (JEG, 1998a) required an evaluation of metals in groundwater beneath CAOC 16. The results of historical analyses are included in Appendix A (Table A-5). As can be seen from Table A-5, only nickel and chromium concentrations exceed MCLs. These are summarized on Figure 4-21. The following observations can be made regarding chromium and nickel based on Figure 4-21:

- Chromium concentrations exceeded MCLs only in Well YCW16-1 (on two occasions between October 1999 and April 2002, out of eight sampling events).
- Nickel concentrations exceeded MCLs in Well YCW16-1, once in Well YCW16-3, and once in Well YS34-2.

The *LTGWMP* (JEG, 1998c) required monitoring of four background wells for metals, in order to establish background metals levels for Yermo Annex. However, these wells have been dry.

4.7 PESTICIDES AT NEBO MAIN BASE

As discussed in the *OUs 3 and 4 ROD* (JEG, 1997) annual monitoring is required for pesticides at Nebo North.

At Nebo North, samples from three monitoring wells (MW-D, NS1-6, and NS2-2) located along the eastern margin of the golf course have been analyzed annually for dieldrin in accordance with the *LTGWMP* (JEG, 1998c). Dieldrin has not been detected in the samples collected from these monitoring wells (Appendix C, Table C-3) since 1998.

4.8 VOCS AT NPZ-14

Groundwater samples collected from NPZ-14 indicate the presence of PCE at levels ranging from 10 µg/L to 31 µg/L. This well is a piezometer and is located several thousand feet away from the Nebo North and Nebo South plumes. Figure 4-22 shows a summary of VOC data for NPZ-14, which indicates a decreasing trend for PCE concentrations.

4.9 OPERATION AND MAINTENANCE COSTS

The O&M costs associated with RAs are an indicator of remedy performance in that a wide variation in actual costs from projected costs may indicate poor performance. The projected costs (based on the respective RODs) and actual estimated costs of O&M associated with the OUs are summarized in Table 4-1.

Based on Table 4-1, actual costs are in the same range as projected costs (where available), and are typically lower.

5.0 FIVE-YEAR REVIEW PROCESS

The EPA's *Comprehensive Five-Year Review Guidance* (EPA, 2001) and DON *Policy for Conducting CERCLA Statutory Five-Year Reviews* (DON, 2001) outline the five-year review process and the elements required. This section of the document describes the process and presents the data reviewed.

5.1 ADMINISTRATIVE COMPONENTS

The required administration components include the notification of potentially interested parties of the initiation of process, identification of the five-year review team, and schedule for the five-year review.

5.1.1 Notification of Potentially Interested Parties of Initiation of Review Process

A public meeting/open house was conducted on November 6, 2002, as part of the ongoing IRP activities at MCLB Barstow. Public notices were placed in local newspapers during the week of September 6, 2002. The FFA signatories were notified prior to placing the public notices.

Attendees at the public meeting/open house were advised that the five-year review process for OU 1 through OU 6 was ongoing and that the review document would be placed in the information repository.

Upon completion of the five-year review process, fact sheets will be mailed to parties on the Base's IRP community mailing list.

5.1.2 Identification of Five-Year Review Team

The five-year review team consisted of the following:

1. Mr. Bret Raines (MCLB Barstow Environmental Department)
2. Ms. Kimberly Jacobsen, P.E. (SWDIV)
3. Mr. Vitthal Hosangadi, P.E. (FWENC: SWDIV Contractor)

Ms. Jacobsen was supported by SWDIV technical, legal, and managerial staff. Mr. Hosangadi was supported by technical staff, including engineers, geologists, hydrogeologists, and regulatory specialists.

The FFA signatories were provided with a draft of the Five-Year Review Report for information.

5.1.3 Outline of Components and Schedule of Five-Year Review

The five-year review consists of the following tasks:

- Community involvement via the public meeting
- Document review
- Data review
- Site inspection
- Five-year Review Report development and review

These tasks were accomplished during the June through December 2002 time period.

5.2 COMMUNITY INVOLVEMENT

As mentioned in Section 5.1.1, a public meeting/open house was held on November 6, 2002, at the Ramada Inn in Barstow. Attendees were informed of the ongoing five-year review process, and were invited to provide input to MCLB Barstow.

5.3 DOCUMENT REVIEW

This five-year review consists of a review of relevant documents noted in Section 11.0.

5.4 DATA REVIEW

Data reviewed for the five-year review consisted of the following:

1. Groundwater monitoring data for OUs 1 and 2
2. Soil vapor monitoring data for OUs 1 and 2
3. Operating data for active remediation systems
4. BMP amendments

5.5 SITE INSPECTION

Site inspection of all CAOCs were conducted between September 9, and October 5, 2002.

6.0 TECHNICAL ASSESSMENT

This technical assessment of the protectiveness of remedies implemented at the CAOCs is based on answering the following three questions:

Question A: Is the remedy functioning as intended by the ROD(s)?

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy selection still valid?

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

6.1 TECHNICAL APPROACH

The technical assessment requires evaluation of the above-mentioned three questions. These questions can include a number of considerations, as discussed below.

6.1.1 Technical Assessment Questions

6.1.1.1 *Question A*: Is the Remedy Functioning as Intended by the ROD(s)?

The EPA's guidance document for five-year reviews identifies several areas that need to be considered when evaluating whether the remedy selected in the decision documents is functioning as designed. Areas of consideration include:

- Remedial Action Performance -Is the remedy operating as designed?
- System O& M -Will the system and current O&M activities maintain the effectiveness of the response actions?
- Cost of System O&M -How do planned costs compare to actual costs?
- Institutional Controls and Other Measures Implementation -Are these functioning as planned?
- Monitoring Activities -Do the current monitoring activities provide adequate information to determine the protectiveness and effectiveness of the remedy implemented?
- Optimization Opportunities -Are there areas for improvement?
- Early Indications of Potential Issues -Are there problems that could lead to the remedy being not protective or suggest protectiveness is at risk unless changes are made?

6.1.1.2 *Question B:* Are the Exposure Assumptions, Toxicity Data, Cleanup Levels, and RAOs Used at the Time of the Remedy Selection Still Valid?

When evaluating the validity of the selected remedy, it is important to consider changes in standards, newly promulgated standards or "to be considered" (TBC) standards, changes in exposure pathways, changes in land use, or if any new contaminants and/or contaminant sources and/or remedy by-products have been identified.

6.1.1.3 *Question C*: Has Any Other Information Come to Light that Could Call into Question the Protectiveness of the Remedy?

The final question in conducting a technical assessment of the selected remedy includes the evaluation of any new information that may have become available that could call into question the protectiveness of the remedy selected. Situations include ecological risks, unidentified risks from natural disasters (for example, flooding), or land use changes.

6.1.2 Organizational Approach

The considerations noted above for each of the three questions are discussed for CAOCs with ICs, RAs, and NFAs with BMP modifications in the following sections. All CAOCs with BMP modifications are discussed as a group for both the Yermo Annex and the Nebo Main Base. Since Question B is appropriate for evaluation on a ROD-wise basis, Appendix D includes its evaluation for each of the three RODs. The other questions are addressed below.

6.2 TECHNICAL ASSESSMENT FOR CAOCS WITH BMP MODIFICATIONS AND INSTITUTIONAL CONTROLS

The NFA remedy with BMP modifications was selected for a number of CAOCs under OUs 3,4, 5, and 6 at the Yermo Annex (CAOCs 15/17, 16, 18, 21, 26, and 34) and Nebo Main Base (CAOCs 1, 2, 3, 5, 6, 11, 14). Groundwater monitoring at CAOCs 16 and 26 (VOCs) is covered under OU 1, while groundwater monitoring at CAOCs 1, 2, 3 (dieldrin), 6 (VOCs), and 14 (dieldrin) is covered under OU 2. The ICs remedy was selected at CAOCs 16, 20, 23, and 35 at the Yermo Annex, and at CAOC 7 at the Nebo Main Base.

All of the CAOCs with BMP modifications and ICs had a requirement that the CAOC history and contaminants be included in the BMP, and that planned activities within the CAOC be reviewed by the MCLB Barstow Environmental Department. As discussed in Sections 4.2 and 4.3, the BMP has been updated as required for all of these CAOCs. With the exception of CAOC 16, there have been no activities within these CAOCs. Activities at CAOC 16 were coordinated with the MCLB Barstow Environmental Department. There are no indicators of potential problems associated with the remedy selected and implemented for these CAOCs.

A review of the *OUs 3 and 4 ROD* (JEG, 1997) and *OUs 5 and 6 ROD* (JEG, 1998b) indicates that there have been no changes to toxicity data or cleanup levels for the contaminants in soils at any of these CAOCs. The RAOs also remain unchanged (see Appendix E).

No new information has come to light that might call into question the protectiveness of the selected remedy at these CAOCs. There have been no activities at this CAOC requiring Base environmental review, and none appear to be planned at this time.

6.2.1 Implementation of BMP Modification and ICs Remedies

As discussed in Sections 4.2 and 4.3, BMP modifications have been made for those CAOCs requiring BMP modifications. ICs (fences, signs, and/or restrictions on activities) are in place at CAOCs 7, 16, 20, 23, and 35. Based on discussions with Base personnel, the MCLB Barstow Environmental Department is notified of construction activities on Base. This allows the MCLB Barstow Environmental Department to determine if these activities fall within a CAOC, and if additional actions are required. The BMP and the RODs contain specific requirements for notification of and approval by FFA signatories if construction activities impact the restrictions on activities at these CAOCs.

6.3 TECHNICAL ASSESSMENT FOR CAOC 16 (OU 5)

6.3.1 Remedial Action Performance

As discussed in Section 4.2.2, the IC remedy was selected for CAOC 16 (per the *OUs 5 and 6 ROD*, JEG, 1998b), with a requirement that CAOC 16 history be included in the BMP, and that planned activities within the CAOC be reviewed by the MCLB Barstow Environmental Department. The *OUs 1 and 2 ROD* (JEG, 1998a) required evaluation of the CAOC 16 AS/SVE system and GETS in reducing groundwater and vadose zone contamination at CAOC 16.

As discussed in Section 4.2.2, the BMP has been updated as required. The performance of the AS/SVE and GETS are discussed in Section 6.7 and 6.9, respectively.

6.3.2 System O&M

The AS/SVE system at CAOC 16 is discussed in Section 6.7.

6.3.3 Institutional Controls

The ICs for CAOC 16 are functioning properly. There has been construction at CAOC 16, associated with a Paint and Undercoat Facility (ongoing as of September 2002). The MCLB Barstow Environmental Department was contacted in the planning stage and provided guidance/ requirements as part of the execution of the project. Sampling was performed at several locations to ensure that worker exposure and site safety were addressed.

6.3.4 Monitoring Activities

Monitoring activities at CAOC 16 are associated with the AS/SVE system and are discussed in Section 6.10.

6.3.5 Optimization

Optimization of the remedy at CAOC 16 is associated with the AS/SVE system and is discussed in Section 6.10.

6.3.6 Early Indicators of Potential Problems

There are no indicators of potential problems associated with the remedy selected and implemented for CAOC 16.

6.3.7 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC. Soils at this CAOC were impacted by VOCs with predicted impacts to groundwater. A review of the *OUs 5 and 6 ROD* (JEG, 1998b) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in soil. The RAOs also remain unchanged (see Appendix D).

6.3.8 Other Information

No new information has come to light that might call into question the protectiveness of the selected remedy at this CAOC.

6.4 TECHNICAL ASSESSMENT FOR CAOC 20 (OU 3)

6.4.1 Remedial Action Performance

The remedy selected at CAOC 20 (landfill cap) under the *OUs 3 and 4 ROD* (JEG, 1997) has been implemented successfully, as discussed in Section 4.2.4. It is protective of human health and the environment.

Actions at CAOC 20 included the modification of an existing concrete cap to provide further protection from precipitation infiltration and monitoring/maintenance of the surface of the remaining strata which contained buried wastes. RAOs focused on preventing exposure to contaminants in excess of an ILCR of 1×10^{-6} and a Hazard Index of 1.0. While the calculated human health risk results for the soils in the area to be capped were below the acceptable risk range of 10^{-4} to 10^{-6}, uncertainties existed because of the lack of analysis of the buried waste itself. ICs were enacted to prevent disturbance of the soils and to prevent future land use.

Maintenance of the concrete cap and soil cap were RAOs used to establish the protectiveness of the remedy. In addition, groundwater monitoring has been conducted for detection monitoring.

As part of the five-year review process, the *OUs 3 and 4 ROD* (JEG, 1997) requires that the RA be re-evaluated following the fourth year of monitoring for decisions on the effectiveness of the RAO and the potential need for additional actions. If the monitoring indicates a statistically significant release at CAOC 20, any appropriate action is to be proposed after consultation with the EPA, DTSC, and RWQCB. This evaluation will be done in the next five-year review (in 2007), as the fourth year of monitoring is 2003. However, based on data collected to date (since 1999), levels of COCs in the groundwater monitoring wells at CAOC 20 have remained below MCLs, as discussed in Section 4.4.1, indicating that the remedy is effective

6.4.2 System O&M

There are no operating systems associated with CAOC 20. The O&M costs are minimal, primarily associated with removal of debris in the channel and moisture monitoring. The remedy is cost effective and utilizes a permanent solution. The fence around the site is intact and in good repair.

6.4.3 Institutional Controls

The IC that is in place at Stratum 1 of CAOC 20 is restricted use of the site. No activities were observed that would have violated the IC. No new uses of groundwater were reported and/or observed.

6.4.4 Monitoring Activities

Monitoring activities at CAOC 20 consist of cap inspection, moisture monitoring, and annual groundwater monitoring (to determine if there is any impact to groundwater from CAOC 20). The number of moisture monitoring points, wells, and sampling frequency are adequate to monitor remedy effectiveness.

6.4.5 Optimization

Given the nature of the remedy implemented at CAOC 20, there is no scope for optimization. The frequency of monitoring is annual, which is considered adequate.

6.4.6 Early Indicators of Potential Problems

There are no indicators of potential problems associated with the remedy selected and implemented for CAOC 20.

6.4.7 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC. Soils at this CAOC were impacted by low levels of VOCs, SVOCs, metals, and pesticides, with relatively limited (predicted) impacts to groundwater. A review of the *OUs 3 and 4 ROD* (JEG, 1997) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in soil. The RAOs also remain unchanged (see Appendix D).

6.4.8 Other Information

No new information has come to light that might call into question the protectiveness of the selected remedy at this CAOC. There have been no activities at this CAOC requiring MCLB Barstow Environmental Department review, and none appear to be planned at this time.

6.5 TECHNICAL ASSESSMENT FOR CAOC 23 (OU 3)

6.5.1 Remedial Action Performance

As discussed in Section 4.2.6, a combination of NFA remedy and concrete cap was selected for CAOC 23, with a requirement that CAOC 23 history be included in the BMP and that planned activities within the CAOC be reviewed by the MCLB Barstow Environmental Department. As discussed in Section 4.2.6, the BMP has been updated as required.

The following RAOs were developed: minimize the potential for disturbance of wastes, minimize potential future releases to groundwater, attain landfill closure applicable or relevant and appropriate requirements (ARARs), and provide a final remedy that minimizes impacts to existing DRMO facilities. The installation of the concrete cap has allowed each of the RAOs to be met. The concrete cap functions as a barrier against contact with the buried waste and restrictions against breaching the cap will verify that this function is maintained in the future. The cap also functions to prevent precipitation from percolating into the buried solid wastes. The concrete cap has provided a better working surface for the existing salvage yard. Levels of COCs in groundwater are below MCLs, as discussed in Section 4.4.2. The remedy is therefore performing effectively.

6.5.2 Institutional Controls

The ICs for CAOC 23 are functioning properly. There have been activities within the area consistent with the use of the cap as a laydown area for DRMO.

6.5.3 Monitoring Activities

Monitoring activities at CAOC 23 consist of cap inspection, weed control, and annual groundwater monitoring (to determine if there is any impact to groundwater from CAOC 23). The cap is surveyed annually for settling. The number of wells and sampling frequency are adequate to monitor remedy effectiveness.

6.5.4 Optimization

Given the nature of the remedy implemented at CAOC 23, there is no scope for optimization. The frequency of monitoring is annual, which is considered adequate.

6.5.5 Early Indicators of Potential Problems

There are no indicators of potential problems associated with the remedy selected and implemented for CAOC 23.

6.5.6 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC (see Appendix. D). Soils at this CAOC were impacted by low levels of VOCs, with very limited (predicted) impacts to groundwater. A review of the *OUs 3 and 4 ROD* (JEG, 1997) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in soil. The RAOs also remain unchanged.

6.5.7 Other Information

No new information has come to light that might call into question the protectiveness of the selected remedy at this CAOC. There have been no activities at this CAOC requiring MCLB Barstow Environmental Department review, and none appear to be planned at this time.

6.6 TECHNICAL ASSESSMENT FOR CAOC 35 (OU 5)

6.6.1 Remedial Action Performance

As discussed in Section 4.2.8, the remedy selected at CAOC 35 is a monolithic native soil cap. It has been implemented successfully, as discussed in Section 4.4.3. The RAOs developed for CAOC 35 include: minimize the potential for the disturbance of the wastes, minimize the potential of future releases to groundwater, and attain landfill closure ARARs. Through the installation of a cap, the remedy has met each of the RAOs. Groundwater monitoring for the CAOC has been conducted under OUs 1 and 2, and indicates that VOC levels in some downgradient wells show an increasing trend (see Section 4.4.3). These wells (YS35-3, YS35-4, and YS17-8) are within the hydraulic capture zone of GEW-13 and GEW-15, as can be seen from Figure 4-13.

This remedy is protective of human health and the environment.

6.6.2 System O&M

There are no operating systems associated with CAOC 35. The cap is surveyed annually for settlement. The O&M costs are minimal, primarily associated with moisture monitoring. The remedy is cost effective and utilizes a permanent solution. The fence around the site is intact and in good repair.

6.6.3 Institutional Controls

The IC that is in place at the site is restricted use of the site. No activities were observed that would have violated the IC. No new uses of groundwater were reported and/or observed.

6.6.4 Monitoring Activities

Monitoring activities at CAOC 35 consist of:

1. Cap inspection
2. Moisture content monitoring beneath the soil
3. Groundwater monitoring in the vicinity of the cap

These are considered adequate to verify the effectiveness of the remedy. Also, as discussed in Section 4.4.3, levels of VOCs in the groundwater monitoring wells have remained stable.

6.6.5 Optimization

Given the nature of the remedy implemented at CAOC 35, there is no scope for optimization. The frequency of groundwater monitoring is annual, which is considered adequate.

6.6.6 Early Indicators of Potential Problems

There are no indicators of potential problems associated with the remedy selected and implemented for CAOC 35.

6.6.7 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC (see Appendix D). Soils at this CAOC were impacted by VOCs, SVOCs, PAHs, TPH, and PCBs, with relatively limited (predicted) impacts to groundwater. A review of the *OUs 5 and 6 ROD* (JEG, 1998b) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in soil. The RAOs also remain unchanged.

6.6.8 Other Information

No new information has come to light that might call into question the protectiveness of the selected remedy at this CAOC. There have been no activities at this CAOC requiring MCLB Barstow Environmental Department review, and none appear to be planned at this time.

6.7 TECHNICAL ASSESSMENT FOR OU 1 (CAOC 37): CAOC 16 AS/SVE SYSTEM

It should be noted that the *OUs 1 and 2 ROD* (JEG, 1998a) provides some specific requirements for CAOC 16 groundwater with respect to the five-year review, as follows:

1. It specifically excludes vadose zone cleanup at CAOC 16, due to the logistics of installing wells on the Building 573 hardstand. However, it requires an evaluation of overall technical and economic feasibility of vadose zone cleanup at this CAOC.

2. It also requires demonstration (by evaluation of soil vapor and groundwater monitoring data) that adequate progress is being made toward cleanup of groundwater at CAOC 16 (due to both groundwater extraction and AS/SVE).

Hence, the following discussions address remediation progress at CAOC 16 from groundwater and vadose zone due to the CAOC 16 AS/SVE system, as well as due to those groundwater extraction wells that are directly impacting the CAOC 16 plume.

6.7.1 Remedial Action Performance

The RAO for the CAOC 16 AS/SVE system is the reduction of VOCs in groundwater at the CAOC 16 area. The VOC levels in groundwater monitoring wells in the immediate vicinity of the sparge wells do not show a noticeable decrease in the last 2 years (see Figure 4-16). System optimization should be considered, as discussed later. However, in general, VOC levels in the groundwater at CAOC 16 have remained stable or decreased slightly, as can be seen in Figure 4-16.

As discussed in Section 4.4.5, there has been a reduction of VOCs in the vadose zone, as evidenced by the removal of approximately 6,300 pounds of VOCs (as of August 2002). There has also been a reduction in VOC levels in soil gas in the vicinity of the SVE wells. It is observed that levels of VOCs in the soil vapor probes of the combination wells, which are as far as 1,000 feet away from the SVE wells, appear to have decreased over the last 2 years. This decrease in VOCs at the combination wells may be due to the ongoing SVE. While the distance of the combination wells from the extraction wells is higher than the normal range of ROI expected at CAOC 16 (approximately 300 feet), the hardstand may be acting as an impermeable barrier, thereby extending the ROI.

The decrease in VOC levels in soil gas beneath the hardstand, and the general decrease in VOC levels in groundwater indicates that there is progress at CAOC 16 toward: 1) meeting groundwater cleanup and 2) reduction in VOCs in the vadose zone.

6.7.2 System O&M

The continued operation of the system (with optimization) will verify the effectiveness of this remedy.

6.7.3 Monitoring Activities

Monitoring activities for the CAOC 16 AS/SVE system consist of the following:

1. VOC levels in soil gas from extraction wells -while the system is in operation

2. VOC levels in soil gas from monitoring wells and extraction wells -after a 1-week shutdown -representing static conditions

3. VOC levels in groundwater from groundwater monitoring wells in the vicinity of AS wells

These activities are adequate for monitoring the performance of the system.

6.7.4 Optimization

As mentioned above (Section 6.7.1), the levels of VOCs in groundwater monitoring wells in the vicinity of the AS wells do not show a noticeable decrease over the last 2 years. This may be due to the presence of relatively higher VOC levels in groundwater upgradient of the CAOC 16 AS wells (such as in the Yermo combination wells), or, deficiencies in the AS/SVE system. Possible optimizations include the use of pulsed operations and addition of AS wells as discussed below.

6.7.4.1 Pulsed Operations

The AS/SVE system is currently operated in a constant mode. Research indicates that pulsed operation of sparge systems often results in enhanced performance, particularly when removal rates reach asymptotic levels. An optimization study in which wells are pulsed in a predetermined pattern over a long term is recommended when removal rates reach asymptotic levels. Impacts of pulsing or sparge systems on VOC levels in extracted vapors, and more importantly, VOC levels in groundwater should be evaluated.

6.7.4.2 Additional Sparging Wells

The results of the pilot study at CAOC 16 presented in the *Engineering Evaluation/Cost Analysis, Operable Unit 1* (JEG, 1995b) indicates that a radius of sparging influence (ROSI) of

approximately 75 feet would be appropriate for the sparging system. This corresponds approximately to the depth of the sparge screen below the water table). However, at CAOC 16, the sparging system spacing ranges from 300 to 400 feet.

It is evident from the results of sparging at CAOC 26 that AS/SVE can be an effective technology for reducing VOC levels in groundwater at the Yermo Annex. Well spacing at CAOC 26 ranges from 60 to 90 feet. Installation of additional AS wells at CAOC 16 to reduce the spacing to 90 feet or less is expected to have a significant effect (at CAOC 26, this spacing reduced VOC concentrations in groundwater from over 50 µg/L to less than 1 µg/L in a year).

6.7.5 Early Indicators of Potential Problems

There are no early indicators of potential problems for the CAOC 16 AS/SVE system.

6.7.6 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC (see Appendix D). Soils at this CAOC were impacted by VOCs, with (predicted) impacts to groundwater. A review of the *OUs 1 and 2 ROD* (JEG, 1998a) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in groundwater. The RAOs also remain unchanged.

6.7.7 Other Information

No new information has come to light that might call into question the protectiveness of the selected remedy at this CAOC.

6.8 TECHNICAL ASSESSMENT FOR OU 1: CAOC 26 AS/SVE SYSTEM

6.8.1 Remedial Action Performance

The RAO for the CAOC 26 AS/SVE system is the reduction of VOCs in groundwater and vadose zone in the CAOC 26 area. As discussed in Section 4.4.6, there has been a reduction of VOCs in the vadose zone, as evidenced by the removal of approximately 1,140 pounds of VOCs by the system. The levels of VOCs in groundwater near the CAOC 26 AS/SVE system have also generally remained below MCLs since 1998. Based on this, the CAOC 26 TEF Report (FWENC, 2001b) was submitted and approved. The CAOC 26 AS/SVE system remains inactive.

The VOC levels in the groundwater monitoring well in the vicinity of CAOC 26 remain below MCLs. In addition to VOCs in groundwater, VOCs in soil gas in the soil gas probes were also monitored annually. The VOCs in soil gas in these probes are increasing slightly, as of 2001 (see Section 4.4.6.3).

6.8.2 System O&M

The system is not in operation.

6.8.3 Monitoring Activities

Monitoring activities for the CAOC 26 AS/SVE system consist of the following:

1. Annual monitoring of VOCs in groundwater at Wells YS26-2 and 3.
2. Annual monitoring of VOCs in soil gas probes.

These activities are considered adequate for monitoring the performance of the system.

6.8.4 Optimization

As the system is not in operation, optimization is not required.

6.8.5 Early Indicators of Potential Problems

As noted in the *OUs 1 and 2 ROD* (JEG, 1998a), soil gas VOCs in the shallow subsurface have been identified as a potential risk, due to migration to the surface. Soil gas VOCs at depth may impact groundwater. VOCs in soil gas have shown a slight increase between 1999 and 2001.

The *OUs 1 and 2 ROD* (JEG, 1998a) also required an evaluation of the effectiveness of the CAOC 26 SVE wells in extracting soil gas from the shallow subsurface (as there was a concern that they may not be). To address this concern and the potential impact of increase in soil gas VOCs, a detailed evaluation was performed (see Appendix E), which includes the following:

1. Impact of soil gas VOCs in the shallow subsurface on aboveground receptors, based on modeling using the Johnson and Ettinger Vapor Intrusion Model (JVIM)
2. Ability of existing AS/SVE system to extract soil gas from shallow subsurface
3. Impact of soil gas VOCs at depth on groundwater, based on SESOIL modeling

As can be seen from Section 2.0 in Appendix E, the VOCs in soil gas in the shallow subsurface do not have an impact on aboveground receptors, based on JVIM calculations. The concentrations would have to increase by a factor of 10 in order to have an impact. However, as noted in Appendix E, if soil gas VOCs increase by a factor of 5, shallow soil-gas surveys should be considered, followed by re-evaluation of potential impacts using the JVIM.

If there were to be an increase in VOCs in soil gas at shallow depths that warranted restart of the SVE, the existing SVE wells would be capable of removing VOCs from these depths notwithstanding the depth of the extraction wells (150 to 160 feet bgs), as discussed in Section 3.0 of Appendix E.

Similarly, an increase in VOCs would have limited impact to groundwater based on SESOIL modeling, as discussed in Section 4.0 of Appendix E. Assuming a worst-case scenario where VOCs increase by a factor of 20 and stay at that level, SESOIL modeling results indicate that PCE concentrations in groundwater would not reach the MCL even at 100 years.

6.8.6 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC (see Appendix D). Soils at this CAOC were impacted by low levels of VOCs, with VOC impacts to groundwater. A review of the *OUs 1 and 2 ROD* (JEG, 1998a) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in soil or groundwater. The RAOs also remain unchanged.

6.8.7 Other Information

No new information has come to light that might call into question the protectiveness of the selected remedy at this CAOC. There have been no activities at this CAOC requiring MCLB Barstow Environmental Department review, and none appear to be planned at this time.

6.9 TECHNICAL ASSESSMENT FOR OU 1: GETS

6.9.1 Remedial Action Performance

The remedy selected in the *OUs 1 and 2 ROD* (JEG, 1998a) has been implemented successfully. The remedy is protective of human health and the environment, while meeting the objective of attaining hydraulic containment at the MCL boundaries.

As discussed in Section 4.4.4, the GETS is performing adequately, as evidenced by the following observations:

1. Containment at the MCL plume boundary
2. VOC mass reduction
3. Reduction in VOC concentrations

However, the ongoing decline in groundwater levels poses a serious threat to the continued effectiveness of the GETS. A detailed evaluation of the GETS performance is included in Appendix F.

As can be seen from Appendix F, the ROI of the extraction wells is in the same range as that predicted by the aquifer testing conducted during the RI/FS. Since the spacing of extraction wells was based on the ROI, the ROI evaluation in Appendix F verifies that the existing extraction well spacing is adequate.

6.9.2 System O&M

The operation of the system will allow meeting the RAOs. However, with the ongoing drop in water levels, four wells (GEW-5, GEW-10, GEW-11, GEW-12) are extracting water at less than 20 gpm. Elimination of the wells from active functioning at their current flow rate will likely have minimal impact on hydraulic containment. Also, fortuitously, these wells are located in areas of minimal or no contamination. Appendix F includes modeling results, which confirm this hypothesis.

6.9.3 Institutional Controls

No new groundwater supply wells have been installed in the plumes areas, on or off Base. Installation of such wells would require notification of the MCLB Barstow Environmental Department.

6.9.4 Monitoring Activities

Monitoring wells in the vicinity of the extraction wells are sampled quarterly to assess system effectiveness in accordance with the *SAP* (FWENC, 2002a). The existing number of monitoring wells is considered adequate for effectiveness monitoring.

6.9.5 Optimization

As discussed earlier, shutting down Wells GEW-5, -10, -11, and -12 is recommended due to their low pumping rates. Given their location with respect to the plume, this measure serves to optimize the GETS performance.

In an overall sense, additional optimization is not necessary for the Yermo North plume, particularly if the optimization measures suggested for the CAOC 16 AS/SVE system are implemented and in light of the recent installation of the new well, GEW-15. Similarly, for the Yermo South plume, the recent installation of the new well, GEW-14, will improve hydraulic containment of this plume.

For the CAOC 26 plume, elimination of Wells GEW-10, -11, and -12 results in extraction from a single well (GEW-9). However, as can be seen from Figure F.4-2 in Appendix F, the portions of the CAOC 26 plume that are not captured by GEW-9 are captured by GEW-13. Hence, no additional wells are required for the CAOC 26 plume at this time.

One of the requirements of the *OUs 1 and 2 ROD* (JEG, 1998a) was to install four additional groundwater extraction wells off Base to provide containment of the off-Base portions of the Yermo North plume and Yermo South plume. However, based on the monitoring of the off-Base plumes since 1996, it appears that concentrations of VOCs off-Base are decreasing, as is the lateral extent of contamination. This is shown in Figure 4-14, which shows a decreasing trend in VOC concentrations in the off-Base monitoring wells since 1999. Installation of off-Base

extraction wells would also have a competing effect and possibly jeopardize the performance of the existing on-Base wells, which currently perform at reduced capacity (due to falling water levels). A Technical Memorandum will be submitted to the FFA Parties in support of this strategy. Upon approval of the Technical Memorandum, an ESD will be submitted.

6.9.6 Early Indicators of Potential Problems

The ongoing reduction in water levels poses a potential problem. If water levels continue to drop at a rate of 3 feet per year, only Wells GEW-7, -9, -13, -14 and -15 will likely be useable beyond 2004. A detailed evaluation is provided in Appendix F.

Operation of Wells GEW-7, -9, -13, -14 and -15 provides hydraulic capture at the MCL plume boundary. This is true both at current flow rates and at future lower flow rates. The capture should be evaluated on an annual basis, and installation of additional wells should be considered if capture of the on-Base contaminant plume above MCLs is reduced.

6.9.7 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC (see Appendix D). Groundwater in the CAOC is impacted by VOCs. A review of the *OUs 1 and 2 ROD* (JEG, 1998a) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in soil. The RAOs also remain unchanged.

6.9.8 Other Information

There have been no activities at this CAOC requiring MCLB Barstow Environmental Department review, and none appear to be planned at this time. There have been a few developments pertaining to groundwater that might call into question the effectiveness of this remedy. These are discussed below.

6.9.8.1 Increase (Temporary) in Dissolved VOCs in December 2001

The annual sampling event for 2001 indicated an increase in dissolved VOCs at the Yermo Annex. This increase was noted in most wells sampled, with the notable exception of three wells located in the hardstand area at CAOC 16. This increase was presumed to be associated with an intense, but short duration rainstorm event in September 2001.

To further evaluate the increase, the first quarterly sampling event included all the wells at Yermo Annex that were sampled in December 2001. As noted in the *First Quarter 2002 Monitoring Data Summary Report* (FWENC, 2002c), most of the sampled wells showed VOC levels much lower than those observed in December 2001. It was observed that the VOC levels had reduced to those prior to December 2001.

6.9.8.2 Detection of MTBE

Methyl tert-butyl ether (MTBE) has been detected at a number of monitoring wells in the southeast portion of the Yermo Annex. The CALNEV Pipeline Company, L.L.C. (CALNEV) Barstow Terminal (referred to as the CALNEV Site) fuel-handling facility located immediately adjacent to the southern perimeter of Yermo Annex (see Figure 6-1) is hydraulically upgradient of the Base.

Based on the *Groundwater Investigation Report, CALNEV Pipeline Company, L.L.C. -Barstow Terminal Site, Daggett, California* (CALNEV Groundwater Investigation Report) (CH2M Hill, 2002), from March 1994 to present, groundwater flow beneath the CALNEV Site has been to the northeast at an average gradient of approximately 0.0066 ft/ft. The CALNEV Site has three documented hydrocarbon releases. Numerous site investigations and RAs have occurred at the CALNEV Site since 1992. The first release was discovered during 1992, while the remaining two releases were discovered during 1995, as noted in the *CALNEV Groundwater Investigation Report* (CH2M Hill, 2002). Several hydrocarbon constituents, including benzene, toluene, ethylbenzene, xylenes, MTBE, and total hydrocarbons (as TPH-g and TPH-d), have been detected beneath the CALNEV Site above the groundwater quality objectives (GWQOs) for the Mojave River Aquifer. MTBE and benzene have been detected at the highest concentrations at monitoring wells downgradient from the CALNEV Site. During the June 1995 sampling event, the maximum detected MTBE concentration in a downgradient well was 25,000 µg/L. Sustained high concentrations of MTBE were observed in two downgradient wells. Concentrations of hydrocarbons in groundwater have declined significantly over time and are now largely below detection limits in all monitoring wells. During CALNEV's June 2002 sampling event, hydrocarbons were not detected in groundwater beneath the CALNEV Site, with the exception of MTBE, which was detected in one monitoring well at a concentration below the GWQO. However, based on reviews of historic data and model predictions based on particle-tracking, it was concluded that groundwater plumes may have migrated offsite in the mid-1990s and may be present at concentrations exceeding the GWQOs beyond the extent of the CALNEV Site's downgradient monitoring well network. It was concluded that based on current water quality data for the CALNEV Site, hydrocarbons present in the soil do not appear to pose a threat to groundwater at current or declining groundwater levels. However, because significant water level increases have occurred in the past and soil contamination has been observed within this range of water level fluctuations, significant water level increases may pose a threat to groundwater.

At the Yermo Annex, MTBE was detected in nine samples during the Base's second/third quarter 2002 event. Detected concentrations ranged from 0.4 to 440 µg/L, although two of the nine detections were reported as estimated concentrations below the contract-specified reporting limit, as noted in the *Second/Third Quarter MTBE Data Summary Report* (FWENC, 2002d).

Relatively high concentrations of MTBE were detected in Wells YS20-2, YS23-12, YS23-13, and YS23-16 in the southeast portion of the site. MTBE was not detected in any wells located outside the southeastern portion of the site during the second/third quarter 2002, except for Well YCW16-2. This is shown in Figure 6-2.

The DON has installed two additional GAC vessels at the GETS treatment pad to account for possible MTBE occurrence in extracted groundwater.

6.10 TECHNICAL ASSESSMENT FOR CAOC 7 (OU 6)

6.10.1 Remedial Action Performance

As discussed in Section 4.3.5, the remedy selected at CAOC 7 (native soil cap monolithic) under the *OUs 5 and 6 ROD* (JEG, 1998b) has been implemented successfully. As discussed in Section 4.5.1, none of the COCs were detected above MCLs in CAOC 7 groundwater monitoring wells. The selected remedy is protective of human health and the environment.

The RAO for this CAOC was preventing exposure to contaminants and reducing precipitation infiltration. The cap has performed as expected and has achieved both goals. In addition, groundwater monitoring was proposed for the first 5 years on an annual basis and results were to be evaluated at the end of the fourth year (2003). According to the *OUs 5 and 6 ROD* (JEG, 1998b), if all results are below MCLs, sampling can be conducted once every 5 years (after concurrence with EPA, DTSC, and RWQCB).

Also, as discussed in Section 4.3.5, the BMP has been updated as required. There have been no activities within this CAOC.

6.10.2 System O&M

There are no operating systems associated with CAOC 7. The O&M costs are minimal, primarily associated with occasionally repairing well monuments that have become damaged. The cap is surveyed annually for settling. The remedy is cost effective and utilizes a permanent solution. The fence around the site is intact, but some repairs are required.

6.10.3 Institutional Controls

The IC in place at CAOC 7 is restricted use of the site. No activities were observed that would have violated the IC. No new uses of groundwater were reported and/or observed.

6.10.4 Monitoring Activities

Monitoring activities at CAOC 7 consist of:

1. Moisture content monitoring
2. Groundwater monitoring

These are considered adequate to verify the effectiveness of the remedy, and to date, two events of groundwater monitoring have been conducted.

6.10.5 Optimization

Given the nature of the remedy implemented at CAOC 7, there is no scope for optimization. The frequency of monitoring is annual, which is considered adequate.

6.10.6 Early Indicators of Potential Problems

There are no indicators of potential problems associated with the remedy selected and implemented for CAOC 7.

6.10.7 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC (see Appendix D). Soils at this CAOC were impacted by low levels of PCBs with relatively limited (predicted) impacts to groundwater. A review of the *OUs 5 and 6 ROD* (JEG, 1998b) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in soil. The RAOs also remain unchanged.

6.10.8 Other Information

No new information has come to light that might call into question the protectiveness of the selected remedy at this CAOC. There have been no activities at this CAOC requiring MCLB Barstow Environmental Department review, and none appear to be planned at this time.

6.11 TECHNICAL ASSESSMENT FOR OU 2 GROUNDWATER REMEDIATION SYSTEMS (CAOC 38) -NEBO NORTH

6.11.1 Remedial Action Performance

The GETS at Nebo North has been in standby status since 1995. Selected wells are monitored on a quarterly basis. If VOC levels in these wells exceed MCLs, the GETS would be restarted. An AS/SVE treatability study is currently planned for this area under OU 7.

As discussed in Section 4.5.2, levels of VOCs in these wells at Nebo North have remained relatively stable and in general, have decreased slightly.

6.11.2 Monitoring Activities

Monitoring activities for Nebo North consist of groundwater sampling on a quarterly basis in accordance with the *LTGWMP* (JEG, 1998c) and the *SAP* (FWENC, 2002a). These are considered adequate.

6.11.3 Optimization

At this time, there is no scope for optimization at Nebo North.

6.11.4 Early Indicators of Potential Problems

There are no early indicators of potential problems.

6.11.5 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC. Groundwater at this CAOC is impacted by dissolved VOCs. A review of the *OUs 1 and 2 ROD* (JEG, 1998a) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in soil. The RAOs also remain unchanged.

6.11.6 Other Information

No new information has come to light that might call into question the protectiveness of the selected remedy at this CAOC. There have been no activities at this CAOC requiring MCLB Barstow Environmental Department review, and none appear to be planned at this time.

6.12 TECHNICAL ASSESSMENT FOR OU 2 GROUNDWATER REMEDIATION SYSTEMS -NEBO SOUTH

6.12.1 Remedial Action Performance

The *OUs 1 and 2 ROD* (JEG, 1998a) specifies an interim remedy consisting of groundwater extraction, five off-Base groundwater extraction wells, on-Base treatment, and disposal at on-Base oxidation ponds. However, based on the nature/extent of contamination, implementation of this remedy would cause migration of on-Base contamination to off-Base locations. Hence, the interim remedy as specified in the *OUs 1 and 2 ROD* (JEG, 1998a) remains on hold. As of August 2002, the Phase 2 AS/SVE pilot test is ongoing). As noted in Section 4.5.3, the AS/SVE appears to be an effective technology for remediation of dissolved VOCs at Nebo South. This is evaluated in the *Draft CAOC 6 AS/SVE Phase 2 Pilot Test Report* (FWENC, 2002d). If AS/SVE is deemed feasible, it will be implemented on a full-scale basis. Enhancement of the test may be considered in the interim.

A Technical Memorandum will be prepared and submitted to FFA Parties to obtain concurrence/ approval for use of AS/SVE as opposed to a GETS for Nebo South. Upon approval of the Technical Memorandum, an BSD will be submitted. Also, the only potential receptor of VOC-impacted groundwater, the downgradient residential property, is provided with drinking water by MCLB Barstow. This is expected to continue for the foreseeable future.

6.12.2 Institutional Controls

No new groundwater supply wells have been installed (or planned for installation) on or off Base within the boundaries of the Nebo South plume. Installation of such wells would require notification of the MCLB Barstow Environmental Department.

6.12.3 Monitoring Activities

Monitoring activities for groundwater are conducted annually and are considered adequate for monitoring plume migration. Groundwater and soil gas within the pilot test study area are monitored more frequently and meet the intended requirements.

6.12.4 Early Indicators of Potential Problems

There are no early indicators of potential problems at this time.

6.12.5 Validity of Exposure Assumptions, Toxicity Data, Cleanup Levels, RAOs

There have been no changes that impact the validity of technical assumptions, toxicity data, cleanup levels, and RAOs at this CAOC (see Appendix D). Soils at this CAOC were impacted by low levels of VOCs, with limited (predicted) impacts to groundwater. A review of *OUs 1 and 2 ROD* (JEG, 1998a) indicates that there have been no changes to toxicity data or cleanup levels for these contaminants in soil. The RAOs also remain unchanged.

6.12.6 Other Information

No new information has come to light that might call into question the protectiveness of the selected remedy at this CAOC. There have been no activities at this CAOC requiring MCLB Barstow Environmental Department review, and none appear to be planned at this time.

6.13 TECHNICAL ASSESSMENT SUMMARIES

Following is a summary of technical assessment for OUs 1 through 6.

6.13.1 OU 1 Technical Assessment Summary

OU 1 is the groundwater at Yermo Annex and includes three dissolved plumes [CAOC 26, Yermo North (CAOC 16) and Yermo South]. It includes groundwater monitoring for soil CAOCs from other OUs, specifically CAOCs 20, 23, and 35. Remediation systems in place include:

- CAOC 26 AS/SVE system to reduce vadose and groundwater contamination (VOCs) at CAOC 26.
- CAOC 16 AS/SVE system to reduce groundwater contamination (VOCs) at CAOC 16.
- Yermo Annex GETS to remediate VOC-contaminated groundwater below Yermo Annex MCLs.
- Treatment systems at one on-Base and two off-Base drinking water wells.

OU 1 also has the following requirements for the five-year review:

- Evaluation of metals contamination in groundwater CAOC 16.
- Evaluation of the effectiveness of the AS/SVE and GETS in reducing groundwater and vadose zone contamination at CAOC 16 (although reduction of vadose zone contamination is not an RAO for CAOC 16) and the need for additional investigation.
- Evaluation of the effectiveness of the CAOC 26 AS/SVE system in reducing VOC levels in shallow subsurface (this was not specifically required in the five-year review, but was required as part of the ROD).

Following is a summary of the technical assessment for OU 1.

6.13.1.1 CAOC 26

The CAOC 26 AS/SVE system is protective of human health and environment. VOCs in soil gas are monitored annually, and show a slight increase since 1999. However, these concentrations would have to increase by a factor of 10 in the shallow subsurface to impact aboveground receptors (Appendix E). In terms of impact to groundwater, assuming a worst-case scenario where concentrations increase by a factor of 20 and remain at that level, SESOIL modeling results indicate that MCLs would not be exceeded even at 100 years. VOCs in groundwater in the zone of influence of the CAOC 26 AS/SVE system remain below MCLs and are expected to remain at these levels. Should there be a need to restart the SVE portion (due to increase in soil gas VOCs), the existing SVE wells can extract soil gas from the shallow subsurface.

The portion of the GETS for the CAOC 26 plume (GEW-9, GEW-10, GEW-11, GEW-12) is operating at reduced capacity, as a result of Wells GEW-10, GEW-11 and GEW-12 being shut down. VOC levels have been decreasing, and the GETS remedy continues to be protective of human health and environment. Operation of GEW-9 alone continues to provide hydraulic capture for the majority of the CAOC 26 plume. Those portions of the CAOC 26 plume that are not captured by GEW-9 will be captured by the CAOC 16 GEWs.

6.13.1.2 CAOC 16

The CAOC 16 AS/SVE system along with ICs are protective of human health and environment. While reduction of vadose zone contamination was not a RAO, the SVE portion of the system

appears to be effective in doing so. The AS portion does not appear to be effective in reducing VOCs in groundwater in the zone of influence of the CAOC 16 AS wells. Optimization by way of additional sparge wells and pulsing of AS/SVE may be warranted. The portion of the GETS associated with CAOC 16 provides adequate hydraulic capture at the MCL boundary, both at current and future (predicted) lower flow rates (GEW-13 and GEW-15).

6.13.1.3 GETS

The portion of the GETS for the CAOC 26 plume is discussed in Section 6.18.11.1, and the portion for the CAOC 16 plume is discussed in Section 6.18.11.2. The portion of the GETS for the Yermo South plume is considered generally adequate, with the recent addition of GEW-14. The treatment system for extracted groundwater has been functioning effectively and was upgraded to account for the potential presence of MTBE in extracted groundwater.

6.13.1.4 On-Base Drinking Water Wells

The GAC treatment system for YDW-5 well is protective of human health and environment. There is no formal O&M manual in place. It is recommended that this be prepared.

6.13.1.5 Off-Base Drinking Water Wells

The GAC treatment systems for the Younts and Hodges wells are protective of human health and environment. It should be noted that the *Private Residences TCRA* (OHM, 1996) recommends changeout of the GAC on an annual basis. Recent sampling (August 2002) indicates impending breakthrough, which indicates that vessels have been in operation for approximately 7 years without breakthrough. It is recommended that the GAC in these vessels be changed out at least every 5 years. Also, there is no formal O&M manual for maintenance of these systems. It is recommended that such a document be prepared (the change out requirements would be noted therein).

6.13.1.6 Metals at Yermo Annex

As discussed in Section 4.6, chromium was detected above its MCL at one location at CAOC 16 on two occasions (out of eight sampling events between 1999 and 2002). Nickel was exceeded at the same location on several occasions, with two other locations showing a single occurrence. Based on this, nickel appears to be a localized occurrence at CAOC 16. Chromium may also be a localized occurrence. Given the location of the occurrences of chromium and nickel with respect to GEW-13 (see Figure 4-21), the influent to the GETS is analyzed for metals, as impacts to receptors would be via the reinfiltration of treated water at the infiltration galleries. To date, levels of nickel and chromium in the extracted groundwater have been at or near the detection limits.

The *LTGWMP* (JEG, 1998c) identified four monitoring wells for background metals monitoring. These have not been sampled to date (as they have been dry). It should be noted that while

YW29-2 sampling did indicate low levels of chromium and nickel, additional wells would have to be sampled to obtain statistically valid background levels of metals. Hence, additional evaluation of background levels of metals is recommended.

6.13.1.7 Off-Base Extraction Wells

The *OUs 1 and 2 ROD* (JEG, 1998a) requires installation of four off-Base extraction wells. These wells have not been installed to date for the following reasons:

1. Ongoing decrease in levels and extent of dissolved VOCs at off-Base monitoring wells
2. Capture of a portion of the off-Base plumes with on-Base extraction wells
3. Possible competition by off-Base extraction wells with on-Base extraction wells will jeopardize performance of on-Base extraction wells

It is recommended that an ESD be submitted to document/support the above.

6.13.2 OU 2 Technical Assessment Summary

OU 2 is the groundwater at Nebo Main Base, and includes two dissolved VOC plumes (Nebo North and Nebo South). It also includes groundwater monitoring associated with CAOC 7 and includes an evaluation of pesticides at Nebo North.

As per the *OUs 1 and 2 ROD* (JEG, 1998a), an interim GETS is in place at Nebo North (on standby status). For Nebo South, an interim remedy consisting of a GETS was proposed in the ROD, but not implemented, as it may promote off-Base migration of VOC contamination that is currently on Base.

Dissolved VOC contamination has been detected in the southwest portion of Nebo Main Base (NPZ-14). Following is a summary of the technical assessment for OU 2.

6.13.2.1 Nebo North

VOCs

The interim remedy at Nebo North is protective of human health and the environment. The dissolved VOC plume at Nebo North remains fairly stable, and as of August 2002, the GETS has not required a restart.

Pesticides

Pesticides have not been detected in groundwater at Nebo North to date, based on three annual events since 1998. Per the *LTGWMP* (JEG, 1998c) monitoring for pesticides can be discontinued after 5 years if this trend continues.

6.13.2.2 Nebo South

The ongoing Phase 2 AS/SVE pilot test indicates that AS/SVE would be an effective technology for remediating the dissolved VOC plume at Nebo South. The plume has been stable, and concentrations (on Base) are noted to be reducing within the area of test influence.

As discussed in Section 4.8, NPZ-14 (located several thousand feet away from the Nebo South plume) indicates PCE at levels ranging from 10 to 31 µg/L. This well should be monitored annually.

6.13.3 OU 3 Technical Assessment Summary

OU 3 is the shallow soils at Yermo Annex (for which data existed prior to the RI) and includes CAOCs 18, 20, 23, and 34. Caps were constructed at CAOCs 20 and 23, and these measures are considered protective of human health and environment. NFAs (with BMP modification) were implemented at CAOCs 18 and 34 and are protective of human health and environment.

6.13.4 OU 4 Technical Assessment Summary

OU 4 is the shallow soils at Nebo Main Base (for which data existed prior to the RI) and consists of CAOCs 2, 5, 9, 10, and 11. Of these, CAOC 10 is now being evaluated under OU 7. NFA was required at the remaining CAOCs (although BMP modification was required for CAOCs 2, 5, and 11). This remedy continues to be protective of human health and the environment.

6.13.5 OU 5 Technical Assessment Summary

OU 5 is the shallow soils at Yermo Annex and consists of CAOCs 15/17, 16, 19, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 35, and 36. Of these, CAOC 25 was eliminated from the RI/FS as not requiring additional investigation/remediation. NFA was selected at CAOCs 15/17, 19, 21, 22, 24, 25, 27, 28, 29, 30, 31, and 32 (BMP modifications were required at CAOCs 15/17, 21, and 26). ICs were selected for CAOC 16. Caps and ICs were selected for CAOC 35. The selected remedies at the CAOCs at OU 5 considered are protective of human health and the environment.

6.13.6 OU 6 Technical Assessment Summary

OU 6 is the shallow soils at Nebo Main Base. It includes CAOCs 1, 3, 4, 6, 7, 8, 12, 13, 14, and 33. Of these, CAOC 33 was eliminated from the RI/FS as not requiring further investigation/ remediation. NFA was required at CAOCs 4, 6, 8, 12, 13, and 14. ICs were required at CAOCs 1 and 3. A native soil cap and ICs were implemented at CAOC 7. Groundwater at CAOC 6 is covered under OU 2. The selected remedies at OU 6 are considered protective of human health and the environment.

7.0 ISSUES

A summary of issues for the CAOCs discussed in Section 4.0, if any, are summarized in Tables 7-1 and 7-2 for Yermo Annex and Nebo Main Base, respectively.

No unresolved issues have been raised by support agencies or the community including the state, other federal agencies, local governments, citizens, and other interested parties.

8.0 RECOMMENDATIONS AND FOLLOW-UP ACTIONS AT OUs 1 THROUGH 6

Summaries of recommendations and follow-up actions at the 11 Yermo Annex CAOCs and eight Nebo Main Base CAOCs (that require ICs or RAs) are provided in Tables 8-1 and 8-2, respectively.

9.0 PROTECTIVENESS STATEMENT

The RAs at OUs 1 through 6 are protective of human health and the environment. This determination is made utilizing the information considered in the performance of this five-year review.

10.0 NEXT REVIEW

The next five-year review for OUs 1 through 6 is required by January 31, 2008, which is 5 years from the date of this review.

11.0 REFERENCES

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TABLES

TABLE 1-1

SUMMARY OF CAOCs

CAOC	OU	Selected Remedy	5-Yr Review Required?
1	6	NFA + BMP modification	Yes
2	4	NFA + BMP modification	Yes
3	6	NFA + BMP modification	Yes
4	6	NFA	No
5	4	NFA + BMP modification	Yes
6	6	NFA – groundwater under OU 2	Yes
7	6	Native soil cap, restriction on activities, groundwater monitoring (OU 2), precipitation infiltration monitoring at Strata 1 and 2, BMP modification at Strata 3 and 4.	Yes
8	6	NFA	No
9	4	NFA	No
10	4	NFA, now being evaluated under OU 7	No
11	4	NFA + BMP modification	Yes
12	6	NFA	No
13	6	NFA	No
14	6	NFA + BMP modification	Yes
15	5	NFA + BMP modification	Yes
16	5	Restriction on activities, groundwater under OU 1	Yes
17	5	NFA + BMP modification	Yes
18	3	NFA + BMP modification	Yes
19	5	NFA	No
20	3	Limited Activities, groundwater monitoring (OU 1), precipitation infiltration monitoring, modification of concrete cap at Stratum 1. Limited Activities, groundwater monitoring (OU 1), precipitation, infiltration monitoring, drainage control (include Stratum 3).	Yes
21	5	NFA + BMP modification	Yes
22	5	NFA	No
23	3	IC at Stratum 1, NFA at Strata 3, 4, 5, 5a. Concrete cap, groundwater monitoring (OU 1), Restriction of activities at Zone 1.	Yes
24	5	NFA	No
25	5	NFA (determined prior to RI)	No
26	5	NFA + BMP modification, groundwater under OU 1	Yes
27	5	NFA	No
28	5	NFA	No
29	5	NFA	No
30	5	NFA	No
31	5	NFA	No

TABLE 1-1

SUMMARY OF CAOCs

CAOC	OU	Selected Remedy	5-Yr Review Required?
32	5	NFA	No
33	6	NFA (determined prior to RI)	No
34	3	NFA + BMP modification	Yes
35	5	NFA at Strata 1 and 2, native soil cap, restriction on activities, groundwater monitoring (OU 1), precipitation infiltration monitoring at Zone 1.	Yes
36	5	NFA	No
37	1	Groundwater extraction and treatment, AS/SVE systems, ICs	Yes
38	2	Groundwater extraction and treatment, AS/SVE systems, ICs	Yes

Notes:

AS/SVE - Air Sparging/Soil Vapor Extraction
BMP – Base Master Plan
CAOC – CERCLA Area of Concern
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
IC – institutional control
NFA – no further action
OU – Operable Unit
RI – Remedial Investigation

TABLE 2-1

OPERABLE UNIT HISTORY AND CHRONOLOGIES

DATE	EVENT
1942	MCLB Barstow established at Nebo Main Base.
1946	Yermo Annex acquired.
1980	CERCLA enacted, DON implements the Installation Restoration Program
Sept. 1983	Initial Assessment Study conducted
1983	TCE found in groundwater production wells at the Yermo Annex.
1984 - 1986	Confirmation Studies conducted.
1989	Groundwater production wells at Yermo Annex were connected to a GAC system.
Nov. 1989	MCLB Barstow is placed on the CERCLA National Priorities List.
Oct. 1990	MCLB Barstow enters into a FFA with the Environmental Protection Agency, Department of Toxic Substances Control, and the Regional Water Quality Control Board. The FFA identified 7 OUs throughout the Base.
Aug. 1991	Preliminary Review/Visual Site Inspection Report completed.
Feb. – Dec. 1992	Phase I RI conducted for OU 1 and OU 2.
Mar. – Oct. 1992	Phase I RI conducted for OU 3 and OU 4.
1992	TCE detected above MCL in a private residence's drinking water well adjacent to Nebo Main Base. A TCRA was conducted to remove the well from service and connect the residence to the Base water supply system.
1993	TCRA was conducted to remove residual sludge at CAOC 15/17.
Jun. – Sept. 1994	Phase II RI conducted for OU 1 and OU 2.
Aug. – Sept. 1994	TCRA to remove 318 tons of impacted soil from CAOC 2 completed.
1995	TCE detected above MCL downgradient of Yermo Annex eastern boundary. A TCRA conducted to provide residences with carbon treatment systems.
Oct. 1995	OU 1 and OU 2 RI Report completed.
1996	OU 1 and OU 2 FS Report completed.
1996	OU 1 and OU 2 Proposed Plan completed.
1996	OU 5 and OU 6 FS Report completed.
Feb. 1996	Phase I Ecological Risk Assessment conducted.
Aug. 1996	RI/FS for OU 3 and OU 4 completed.
Aug. 1996	Proposed Plan for OUs 3 and 4 completed.
Jun. 1997	OU 3 and OU 4 ROD signed.
Jul. – Aug. 1997	TCRA to remove PCB-impacted soils (>1 mg/kg) at CAOC 21.
1997	OU 5 and OU 6 Proposed Plan completed.
Jan. 1998	OU 5 and OU 6 ROD signed.
Apr. 1998	OU 1 and OU 2 ROD signed.
1997 - Present	A non-time-critical removal action for groundwater containment and cleanup is being conducted at the Yermo Annex. Its purpose is to prevent further migration of contaminants beyond the Base boundary and accelerate groundwater cleanup.
September 1998	Actual remedial action started at OUs 3 and 4
2002	Five-Year Review conducted for OUs 1 through 6.

TABLE 2-1

OPERABLE UNIT HISTORY AND CHRONOLOGIES

Notes:

CAOC – CERCLA Area of Concern
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
DON – Department of the Navy
FFA – Federal Facility Agreement
FS – Feasibility Study
GAC – granular activated carbon
MCL – Maximum Contaminant Level
MCLB – Marine Corps Logistics Base
mg/kg – milligrams per kilogram
OU – Operable Units
PCB – polychlorinated biphenyl
RI – Remedial Investigation
ROD – Record of Decision
TCE – trichloroethene
TCRA – time-critical removal action

TABLE 4-1

OPERATION AND MAINTENANCE COSTS

CAOC	OU	O&M Item	Projected Costs	Actual Costs	Comments
20	3	Cap maintenance and monitoring	$20,200 per year (for four years)	Maintenance: $20,000 per year (for four years)	Monitoring costs covered under OU 1 groundwater monitoring.
23	3	Cap maintenance and monitoring	Not estimated	Maintenance: $28,200 per year	Monitoring costs covered under OU 1 groundwater monitoring.
35	5	Cap maintenance and monitoring	Not available (were part of total cost estimate of $1,432,215 for capital and O&M)	Maintenance: $28,500 per year	Monitoring costs covered under OU 1 groundwater monitoring.
7	6	Cap maintenance and monitoring	Not available (were part of total cost estimate of $1,273,080 for capital and O&M)	Maintenance: $21,600 per year	Monitoring costs covered under OU 2 groundwater monitoring.
37	1	Operation of two AS/SVE systems and one GETS, groundwater monitoring	$1.2 Million per year	$600,000	One AS/SVE system is not in operation.
38	2	Operation of two GETS, groundwater monitoring	$371,000 per year	$200,000	The Nebo North GETS is on standby status, there is no GETS at Nebo South. If these were in operation, costs would increase by approximately $200,000 per year. Costs would also increase if a full scale AS/SVE system were to be in place at Nebo South.

Notes:

AS/SVE – air sparging/soil vapor extraction
CAOC – CERCLA Area of Concern
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
GETS – groundwater extraction and treatment system
O&M – operation and maintenance
OU – Operable Unit

TABLE 7-1

ISSUES AT YERMO ANNEX

CAOC	OU	Issue	Currently Affects Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
15/17	5	None	N/A	N/A
16	5	None (see under CAOC 37 for CAOC 16 AS/SVE)	N/A	N/A
18	3	None	N/A	N/A
20	3	None	N/A	N/A
21	3	None	N/A	N/A
23	3	None	N/A	N/A
26	5	None (see under CAOC 37 for CAOC 26 AS/SVE)	N/A	N/A
34	3	None	N/A	N/A
35	5	None	N/A	N/A
37	1	Off-Base extraction wells have not been installed	N	N
37	1	Declining water levels are decreasing the effectiveness of the existing groundwater extraction wells	N	Y
37	1	Localized nickel and chromium are present in groundwater beneath CAOC 16, adequate background information is not available to determine if this is a problem	N	N
37	1	(Temporary) increase in dissolved VOCs in groundwater in December 2001	N	N
37	1	CAOC 26 – slight increase in VOC levels in soil gas	N	N
37	1	CAOC 16 – no reduction in dissolved VOCs within the zone of AS influence at CAOC 16, likely due to inadequate number of AS wells	N	N
--	1	Younts and Hodges wells GAC changeout has occurred once in past 7 years, no formal O&M manual in place	N	N
--	1	No formal O&M manual in place for YDW-5 (on-Base drinking water well) treatment system	N	N

Notes:

AS/SVE – air sparging/soil vapor extraction
CAOC – CERCLA Area of Concern
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
GETS – groundwater extraction treatment system
MTBE – methyl tert-butyl ether
N/A – not applicable
O&M – Operation and Maintenance
OU – Operable Unit
VOC – volatile organic compound
Y/N – yes/no

TABLE 7-2

ISSUES AT NEBO MAIN BASE

CAOC	OU	Issue	Currently Affects Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
1	6	None	N/A	N/A
2	4	None	N/A	N/A
3	6	None	N/A	N/A
5	4	None	N/A	N/A
7	6	Fencing requires minor repairs	Y	N
11	4	None	N/A	N/A
14	6	None	N/A	N/A
38	2	Nebo North – AS/SVE system not yet installed	N	N
38	2	Nebo South - ROD requires installation of an off-Base GETS, which may actually have a detrimental impact, due to the potential off-site migration of dissolved VOCs	N	N
38	2	NPZ-14, which is a few thousand feet away from the identified Nebo South dissolved VOC plume, shows levels of PCE above MCLs	N	N

Notes:

AS/SVE – air sparging/soil vapor extraction
CAOC – CERCLA Area of Concern
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
GETS – groundwater extraction treatment system
MCL – Maximum Contaminant Level
N/A – not applicable
OU – Operable Unit
PCE – perchloroethene
ROD – Record of Decision
VOC – volatile organic compound
Y/N – yes/no

TABLE 8-1

RECOMMENDATIONS AND FOLLOW-UP ACTIONS AT YERMO ANNEX

CAOC	OU	Issue	Recommendations/ Follow-up Actions	Milestone Date	Affects Protectiveness? (Y/N)	
					Current	Future
15/17	5	None	None	N/A	N/A	N/A
16	5	None	None	N/A	N/A	N/A
18	3	None	None	N/A	N/A	N/A
20	3	None	None	N/A	N/A	N/A
21	3	None	None	N/A	N/A	N/A
23	3	None	None	N/A	N/A	N/A
26	5	None	None	N/A	N/A	N/A
34	3	None	None	N/A	N/A	N/A
35	5	None	None	N/A	N/A	N/A
37	1	Off-Base extraction wells have not been installed	Submit ESD for deviation from ROD	June 2003	N	N
37	1	Increase in VOC levels in soil gas at CAOC 26	Continue annual monitoring, restart SVE if necessary	N/A	N	N
37	1	Effectiveness of AS/SVE in reducing dissolved VOC concentrations at CAOC 16	1. Switch to pulsed mode 2. Evaluate the need for additional AS wells	June 2003	N	N
37	1	Declining water levels	Evaluate capture on an annual basis	December 2003	N	Y
37	1	Increase in VOCs at off-Base residential wells	Evaluate vertical extent of dissolved VOC contamination downgradient of Base boundary	March 2003	N	N
37	1	Adequate background information is not available for metals (CAOC 16)	Evaluate background metals in groundwater at Yermo Annex	December 2003	N	N
37	1	(Temporary) increase in dissolved VOCs in groundwater in December 2001	None	N/A	N/A	N/A
--	1	Younts and Hodges wells GAC change out has occurred once in past seven years, no formal O&M manual	Prepare formal O&M manual. change out GAC at least every 5 years	February 2003	N	N
--	1	YDW-5 – no formal O&M manual in place	Prepare formal O&M manual	February 2003	N	N

Notes:
AS – air sparging
CAOC – CERCLA Area of Concern
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
ESD – Explanation of Significant Differences
GAC – granular activated carbon
N/A – not applicable
OU – Operable Unit
O&M – Operation and Maintenance
ROD – Record of Decision
SVE – soil vapor extraction
VOC – volatile organic compound
Y/N – yes/no

TABLE 8-2

RECOMMENDATIONS AND FOLLOW-UP ACTIONS AT NEBO MAIN BASE

CAOC	OU	Issue	Recommendations/ Follow-up Actions	Milestone Date	Affects Protectiveness? (Y/N)	
					Current	Future
1	6	None	None	N/A	N/A	N/A
2	4	None	None	N/A	N/A	N/A
3	6	None	None	N/A	N/A	N/A
5	4	None	None	N/A	N/A	N/A
7	6	Fencing required minor repairs	Make repairs	January 2003	Y	N*
11	4	None	None	N/A	N/A	N/A
14	6	None	None	N/A	N/A	N/A
38	2	Nebo North – AS/SVE not yet installed	Implement AS/SVE pilot test, followed by full-scale, if feasible	--	N/A	N/A
38	2	Nebo South – deviation from ROD – installation of off-Base GEWs has not been done	If AS/SVE is deemed feasible, submit ESD to explain the rationale for not installing off-Base GEWs	December 2003	N	N
38	2	NPZ-14 VOC detects	Monitor annually	N/A	N	N

* after fence is repaired

Notes:

AS – air sparging
CAOC – CERCLA Area of Concern
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
ESD – Explanation of Significant Differences
GEW – groundwater extraction well
N/A – not applicable
OU – Operable Unit
SVE – soil vapor extraction
Y/N – yes/no

FIGURES

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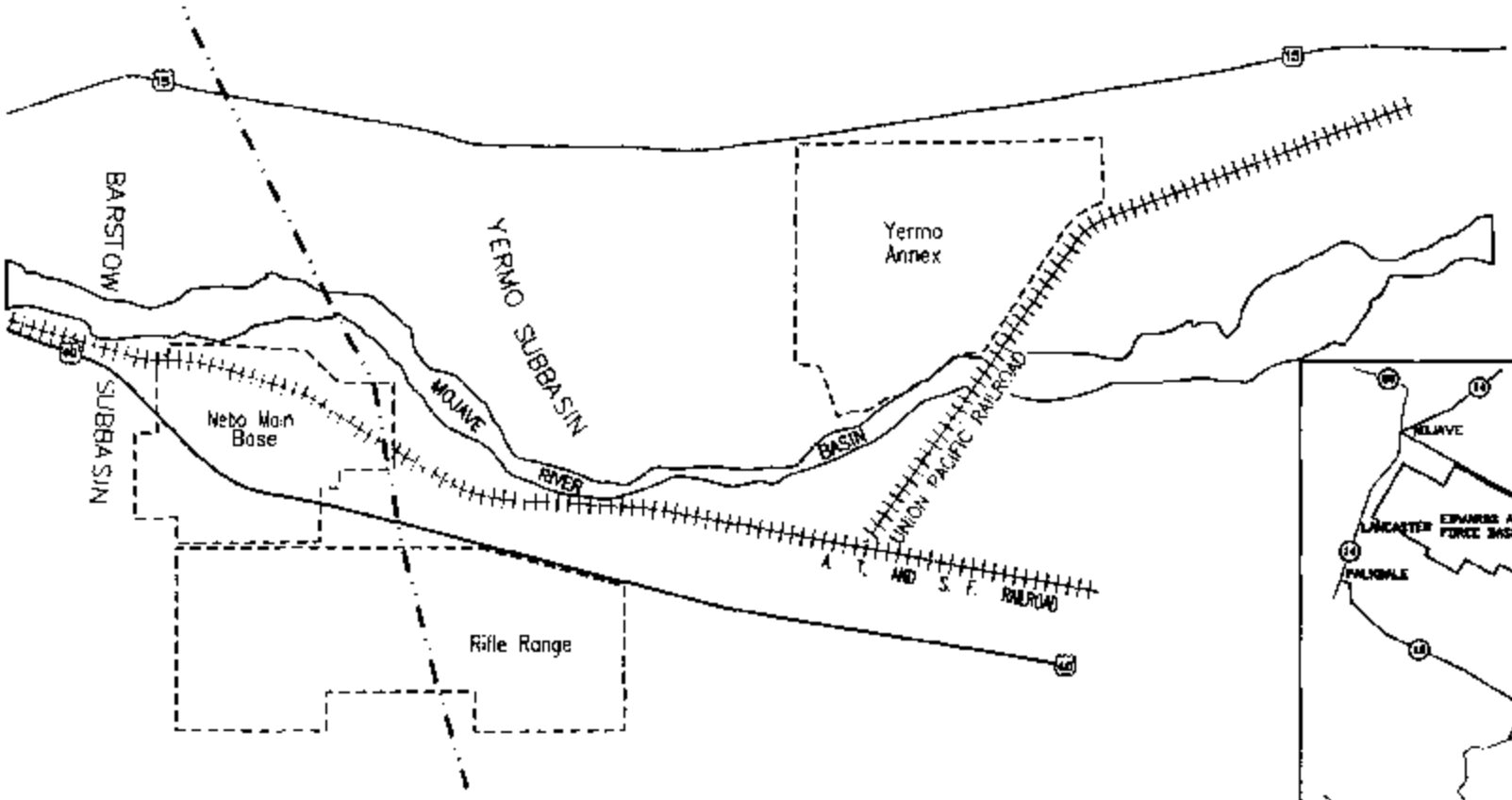

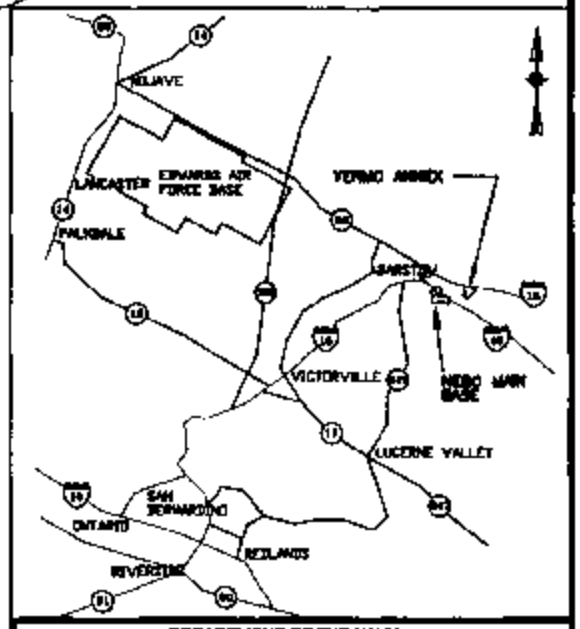

N

NTS

EXPLANATION:

- - - - - Base boundary
— · · — Harper Lake – Camp Rock Fault

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

VICINITY MAP

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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CHECKED BY:			
DATE: 12-09-02		CTO: 0049	
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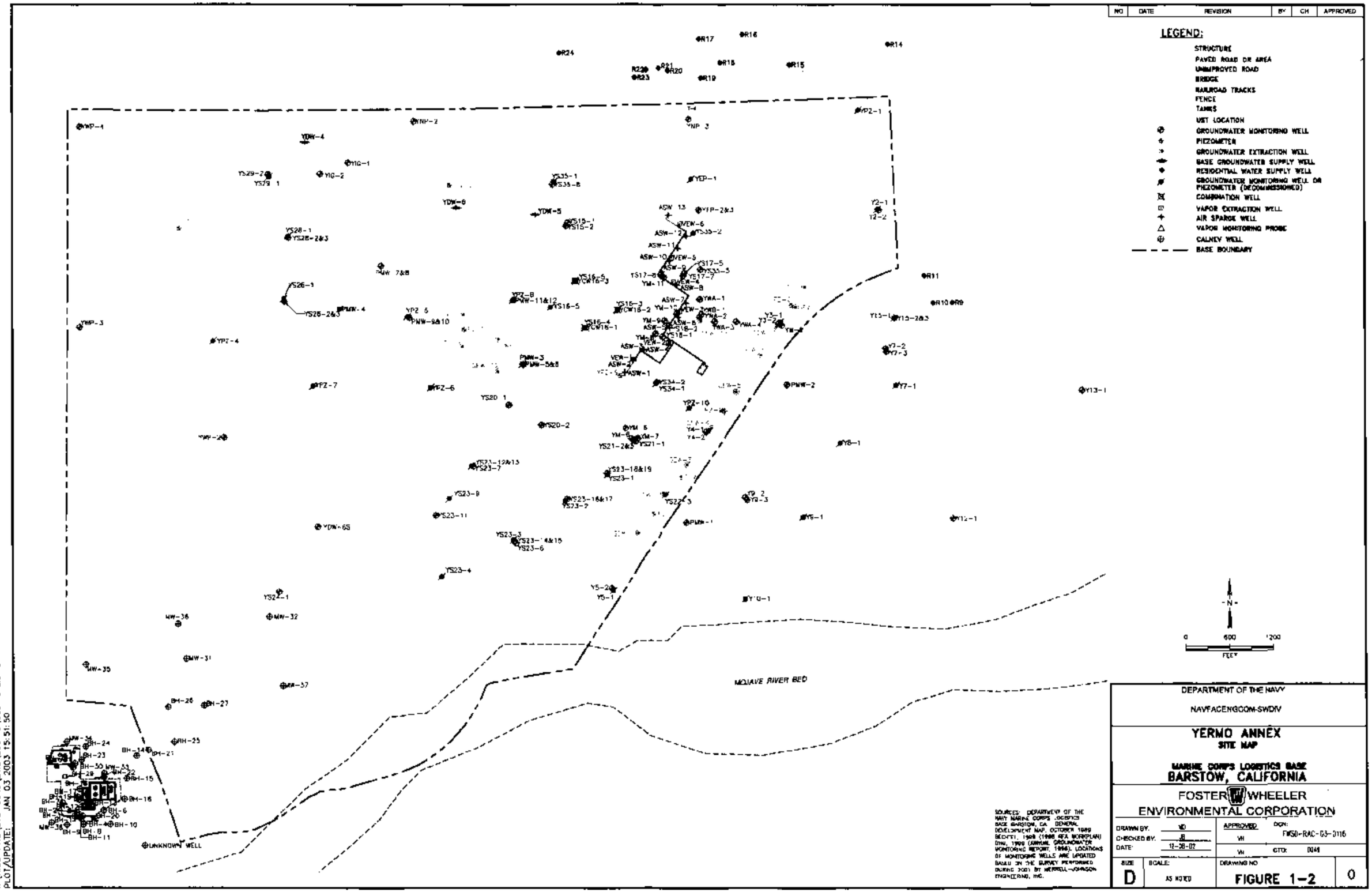
NO	DATE	REVISION	BY	CH	APPROVED



SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA GENERAL DEVELOPMENT MAP OCTOBER 1989 BECKTEL 1998 (1996 RFA WORKPLAN) DHL 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRILL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
SITE MAP

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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CHECKED BY: JB	VH	FWSD-RAC-03-0116	
DATE: 12-28-02	VH	CTO: 0049	
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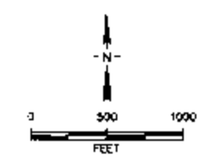
NO	DATE	REVISION	BY	CH	APPROVED

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- RESIDENTIAL WATER SUPPLY WELL
- BASE WATER SUPPLY WELL
- USGS WELLS
- BASE BOUNDARY



SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1988 BECHTEL, 1996 (1996 RFA WORKPLAN; DHM, 1992 (ANNUAL GROUNDWATER MONITORING REPORT, 1990). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM - SWDIV

NEBO MAIN BASE
SITE MAP

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER
ENVIRONMENTAL CORPORATION

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CHECKED BY: JB	VH		
DATE: 12-05-02	VH	CTO: 0043	
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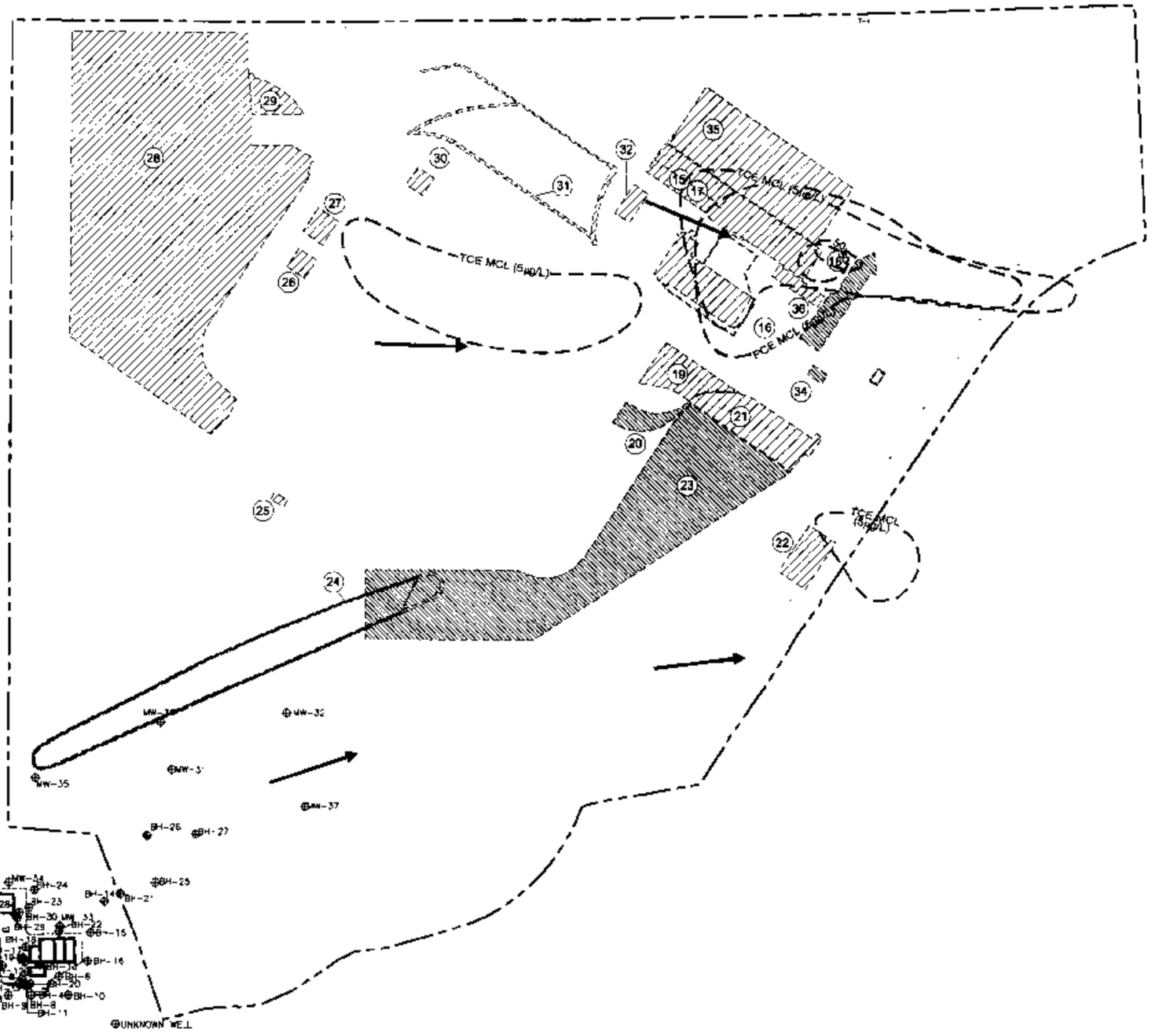

LEGEND:

- (13) (17) OIL STORAGE/SPILLAGE AND IWTP AREAS
- (18) BUILDING 573 AND PERIMETER AREA
- (18) SLUDGE WASTE DISPOSAL AREA
- (19) FIRST HAZARDOUS AND LOW-LEVEL RADIOLOGICAL AREA
- (20) SECOND HAZARDOUS AND LOW-LEVEL RADIOLOGICAL AREA
- (21) INDUSTRIAL WASTE DISPOSAL AREA
- (22) DOMESTIC WASTEWATER DISPOSAL AREA
- (23) LANDFILL AREA
- (24) TRACKED VEHICLE TEST AREA
- (25) WASTEWATER TREATMENT SLUDGE DISPOSAL AREA
- (26) BUILDING 553 WASTE DISPOSAL AREA
- (27) BUILDING 456 FUEL OIL STORAGE AREA
- (28) WEST LOT DUST CONTROL AREA
- (29) SLUDGE STORAGE AREA
- (30) LOCOMOTIVE REPAIR SHOP DISPOSAL AREA
- (31) NORTH VEHICLE TEST TRACK ROAD
- (32) PRESERVATION AND PACKAGING STORAGE AREA
- (34) PREVIOUS PCB STORAGE AREA
- (35) YERMO CLASS III LANDFILL
- (36) PAINT COMBAT VEHICLE MAINTENANCE SHOP
- (23) OPERABLE UNIT 3
- (35) OPERABLE UNIT 5
- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)
- BASE BOUNDARY
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

CAOC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER

-N-

0 600 1200
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1988 BECHTEL, 1997 (1996 RFA WORKPLAN) OHM, 1998 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRILL JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
SOIL CAOCs AND GROUNDWATER PLUMES

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED: VH	DCN: 03-0116	
CHECKED BY: VH	VH		
DATE: 12-06-02	VH	CTO: 0049	
SIZE: D	SCALE: AS NOTED	DRAWING NO: FIGURE 1-4	0

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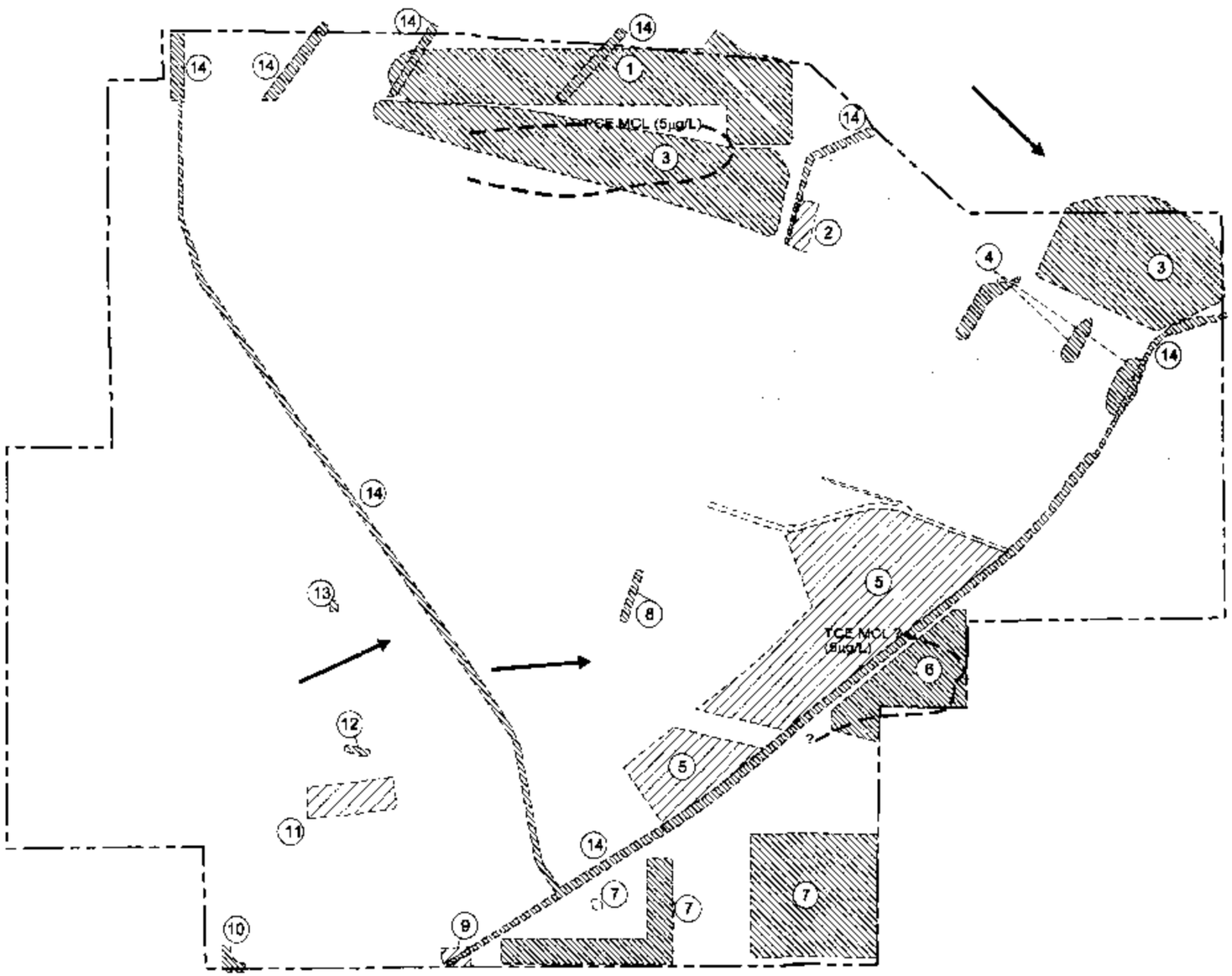

LEGEND:

1. LANDFILL NORTH OF THE GOLF COURSE
2. PESTICIDE STORAGE WASHOUT AREA
3. GOLF COURSE WASTEWATER DISPOSAL AREA
4. OLD TRAP AND SKEET RANGE
5. CHEMICAL STORAGE AREA
6. ORIGINAL TRASH LANDFILL
7. DRUM STORAGE AREA AND LANDFILL
8. BUILDING 187 WASTE DISPOSAL AREA
9. FUEL DISPOSAL AREA
10. SODIUM VALVE BURIAL AREA
11. FUEL BURN AREA
12. RADIATOR CLEANING CHEMICAL DISPOSAL AREA
13. PRESERVATION AND PACKAGING STORAGE AREA
14. DRAINAGE CHANNEL AND MOJAVE RIVERBED

- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)
- BASE BOUNDARY
- GENERALIZED GROUNDWATER FLOW DIRECTION
- 5 OPERABLE UNIT 4
- 6 OPERABLE UNIT 5

ABBREVIATIONS:

CAOC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER

N

0 500 1000
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 RED-HILL 1988 (1988 RFA WORKPLAN) CH2M 1991 (ANNUAL GROUNDWATER MONITORING REPORT, 1988). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING INC

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

NEBO MAIN BASE
SOIL CAOCs AND GROUNDWATER PLUMES

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER
ENVIRONMENTAL CORPORATION

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CHECKED BY: WH	WH		
DATE: 12-05-02	WH	CTO: 4049	
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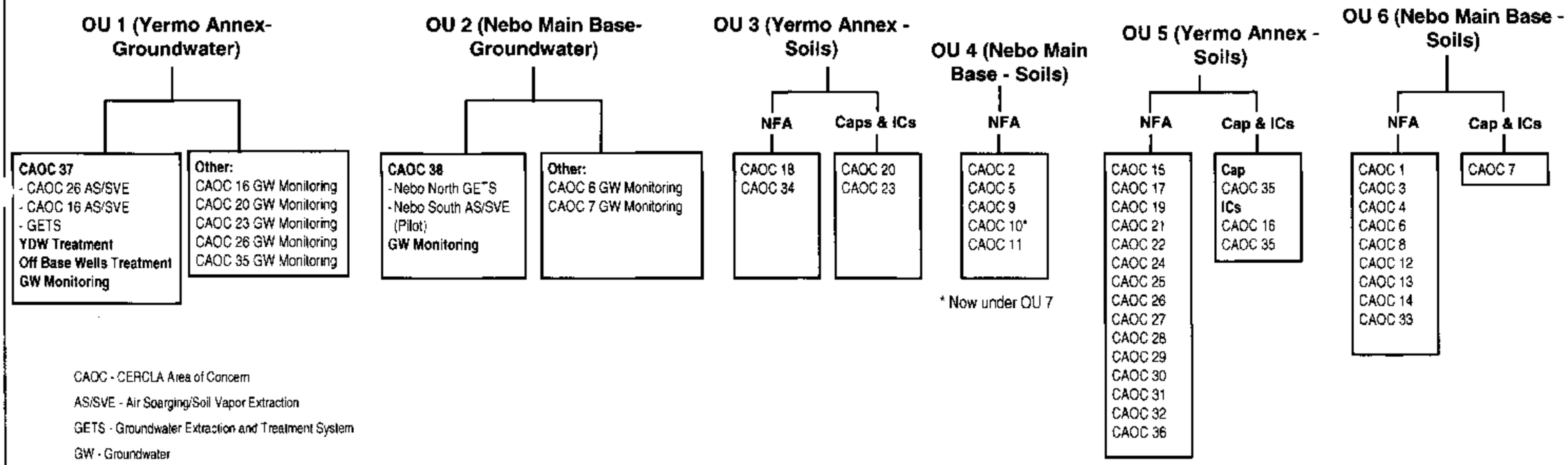
Figure 1-6

Organization of OUs and CAOCs



CAOC - CERCLA Area of Concern

AS/SVE - Air Sparging/Soil Vapor Extraction

GETS - Groundwater Extraction and Treatment System

GW - Groundwater

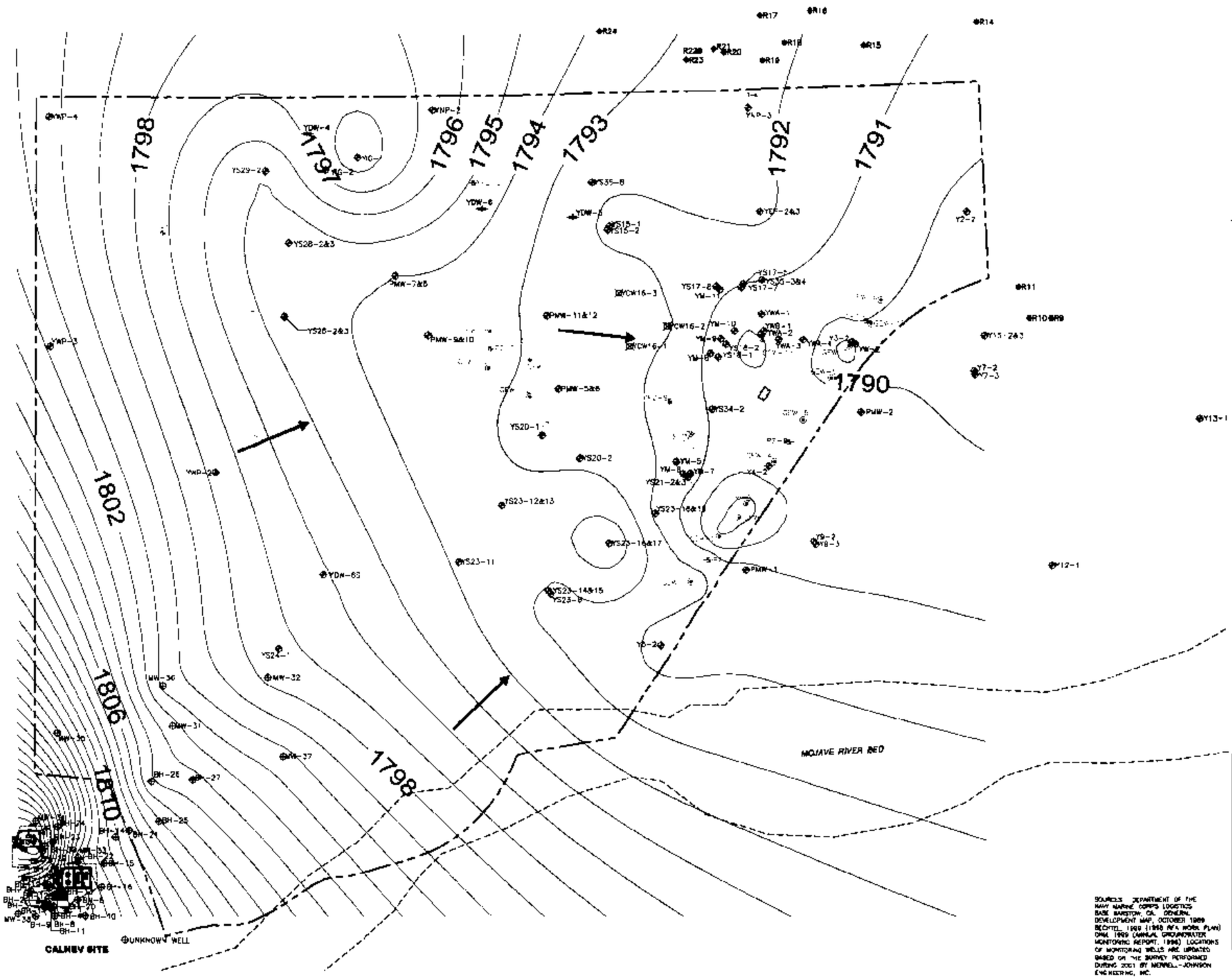
OU - Operable Unit

ICs - Institutional Controls

NFA - No Further Action

YDW - Yermo Drinking Water Well

NO	DATE	REVISION	BY	CH	APPROVED



LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- BASE BOUNDARY
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- RESIDENTIAL WATER SUPPLY WELL
- COMBINATION WELL
- CALNEV WELL
- —1796— GROUNDWATER ELEVATION CONTOUR (ELEVATION IN FEET AMSL)
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

AMSL	ABOVE MEAN SEA LEVEL
GW	GROUNDWATER
FT	FEET

YERMO

GROUNDWATER ELEVATION IN SELECTED WELLS OCTOBER 2002

WELL	GW ELEVATION (IN FT. AMSL)
YDW16-2	1792.15
YS20-1	1792.52
YS23-11	1793.86
Y2-2	1789.75
GEW-2	1788.14
PZ-D	1793.43
Y8-3	1790.55
YS26-3	1794.57
*BH-7	1817.69
*BH-15	1811.79
*BH-28	1827.79
*MW-32	1797.75
*MW-34	1824.57

NOTE:

*DATA OBTAINED FROM GROUNDWATER ELEVATION MEASUREMENT AND INTERIM CORRECTIVE ACTION MEASURES REPORT THIRD QUARTER - 2002 FOR CALNEV SITE. (CH2MHILL, 2002)

N

0 600 1200
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 (BECHTEL, 1993 (1994 RFA WORK PLAN) DNA, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1994). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY NORNELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX

YERMO ANNEX GROUNDWATER LEVEL MAP (OCTOBER 2002)

YERMO ANNEX

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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DATE: 12-12-02			
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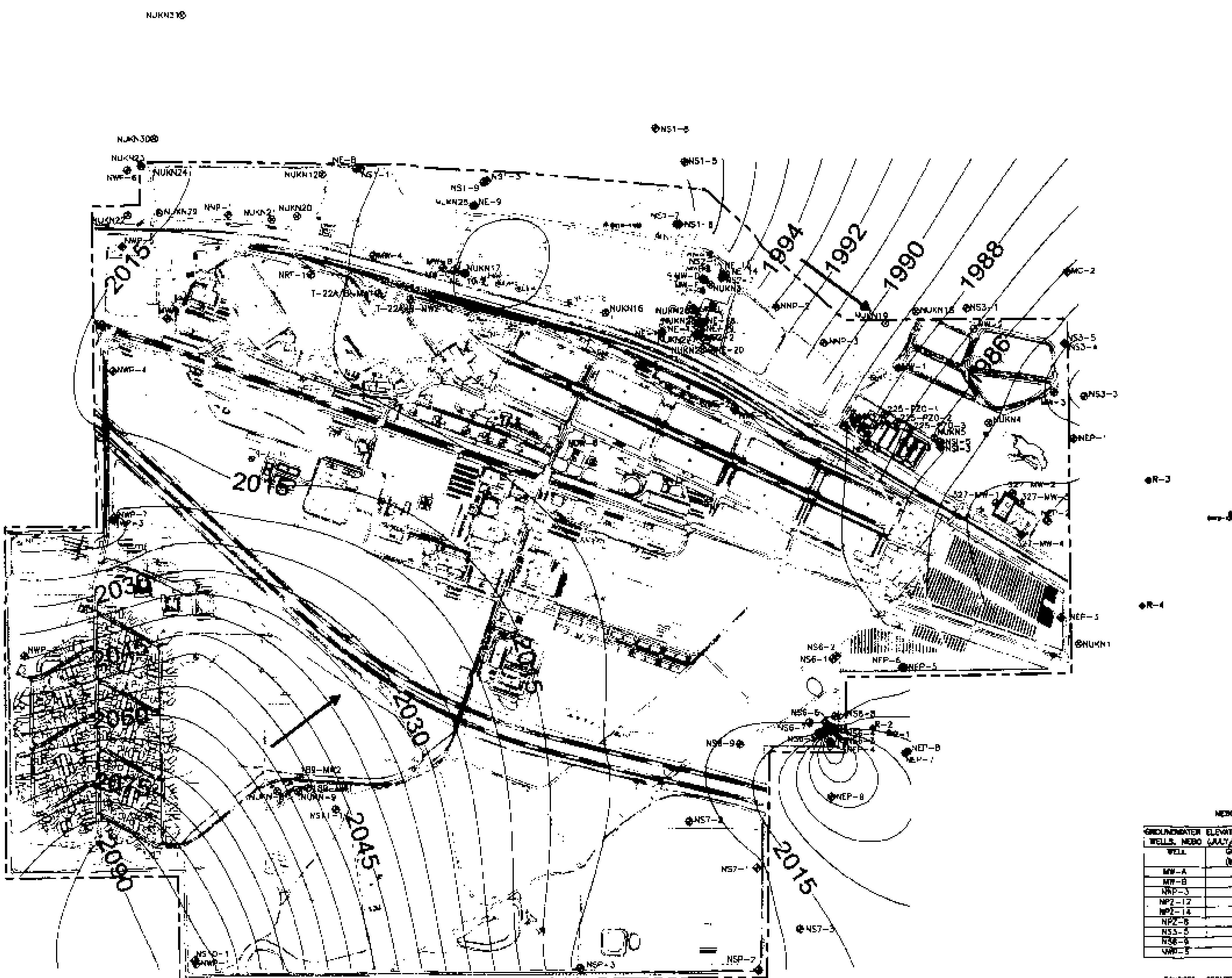

LEGEND:

STRUCTURE
PAVED ROAD OR AREA
UNIMPROVED ROAD
BRIDGE
RAILROAD TRACKS
FENCE
TANKS
UST LOCATION
GROUNDWATER MONITORING WELL
PIEZOMETER
GROUNDWATER EXTRACTION WELL
RESIDENTIAL WATER SUPPLY WELL
BASE WATER SUPPLY WELL
UNKNOWN WELL
—2010— GROUNDWATER ELEVATION CONTOUR (ELEVATION IN FEET AMSL)
GENERALIZED GROUNDWATER FLOW DIRECTION
BASE BOUNDARY

ABBREVIATIONS:

AMSL ABOVE MEAN SEA LEVEL
GW GROUNDWATER
FT. FEET

N

0 500 1000
FEET

NEBO

GROUNDWATER ELEVATION IN SELECTED WELLS, NEBO (JULY/AUGUST 2002)	
WELL	GW Elevation (in ft. amsl)
MW-A	2013.69
MW-B	2007.38
NMP-3	1984.93
NPZ-12	2051.13
NPZ-14	2032.81
NPZ-8	2008.53
NS3-5	1978.44
NS6-9	2011.57
NWP-5	2015.28

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1999 BECHTEL 1999 (1999 RFA WORKPLAN) CH2M, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX

NEBO MAIN BASE GROUNDWATER LEVEL MAP (JULY/AUGUST 2002)

NEBO MAIN BASE

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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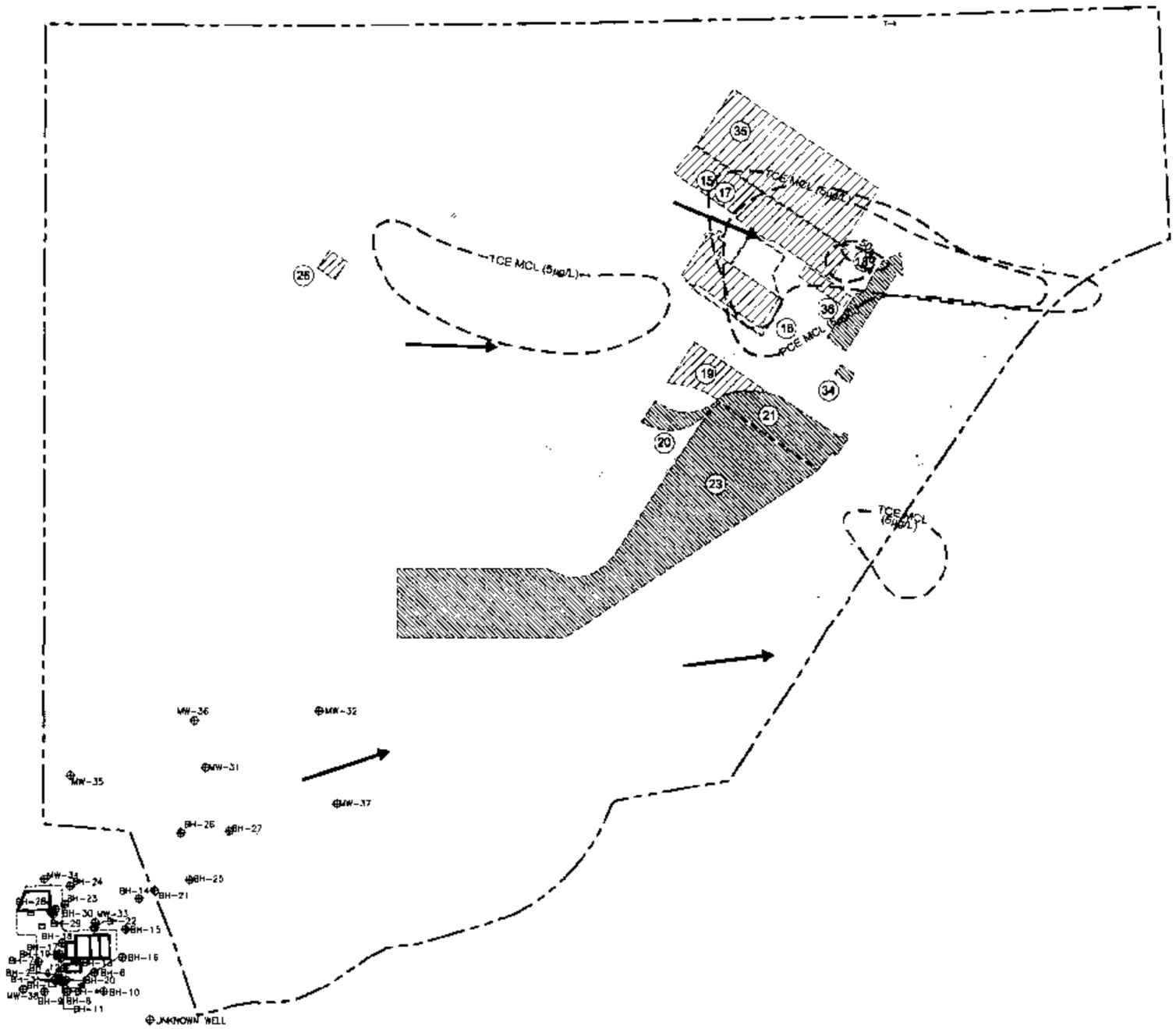

LEGEND:

- (15)(17) OIL STORAGE/SPILLAGE AND IWTP AREAS
- (16) BUILDING 573 AND PERIMETER AREA
- (18) SLUDGE WASTE DISPOSAL AREA
- (19) FIRST HAZARDOUS AND LOW-LEVEL RADIOLOGICAL AREA
- (20) SECOND HAZARDOUS AND LOW-LEVEL RADIOLOGICAL AREA
- (21) INDUSTRIAL WASTE DISPOSAL AREA
- (23) LANDFILL AREA
- (26) BUILDING 555 WASTE DISPOSAL AREA
- (34) PREVIOUS PCB STORAGE AREA
- (35) YERMO CLASS III LANDFILL
- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)
- BASE BOUNDARY
- GENERALIZED GROUNDWATER FLOW DIRECTION
- (23) OPERABLE UNIT 3
- (35) OPERABLE UNIT 5

ABBREVIATIONS:

CAOC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHYLENE
PCE	TETRACHLOROETHYLENE
µg/L	MICROGRAMS PER LITER

N

0 600 1200

FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1988 BECHTEL, 1998 (1998 RFA WORKPLAN) CH2M 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX

SOIL CAOCs AND GROUNDWATER PLUMES REQUIRING REMEDIAL ACTION

MARINE CORPS LOGISTICS BASE

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED	DCN	
CHECKED BY: VH	VH	03-0116	
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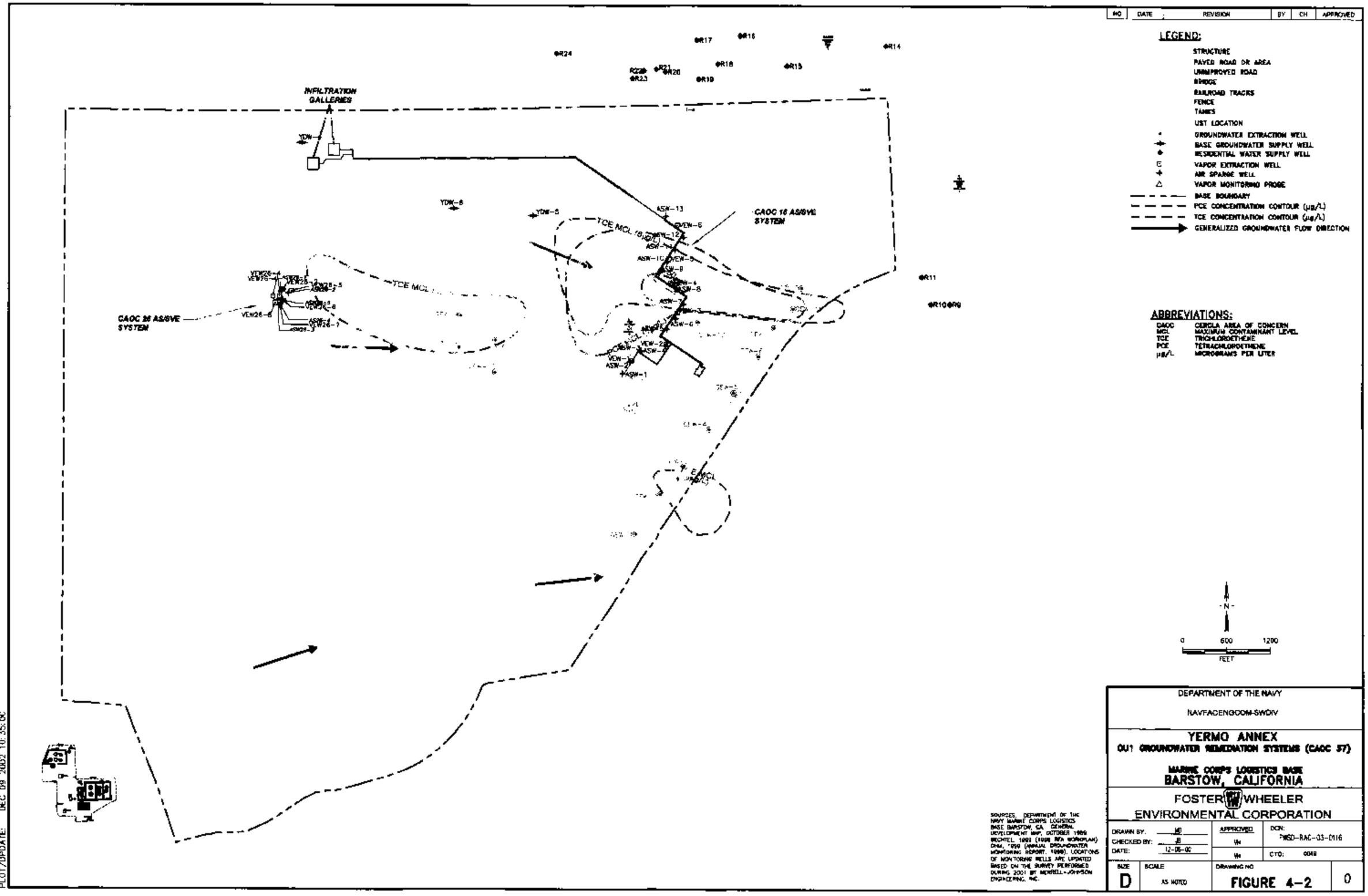

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1996 BECHTEL 1993 (1996 RFA WORKPLAN) CH2M, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX

OU1 GROUNDWATER REMEDIATION SYSTEMS (CAOC 37)

MARINE CORPS LOGISTICS BASE

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED	DCN:	
CHECKED BY: JB	VM	PWSD-RAC-03-0116	
DATE: 12-06-02	VM	CTO: 0049	
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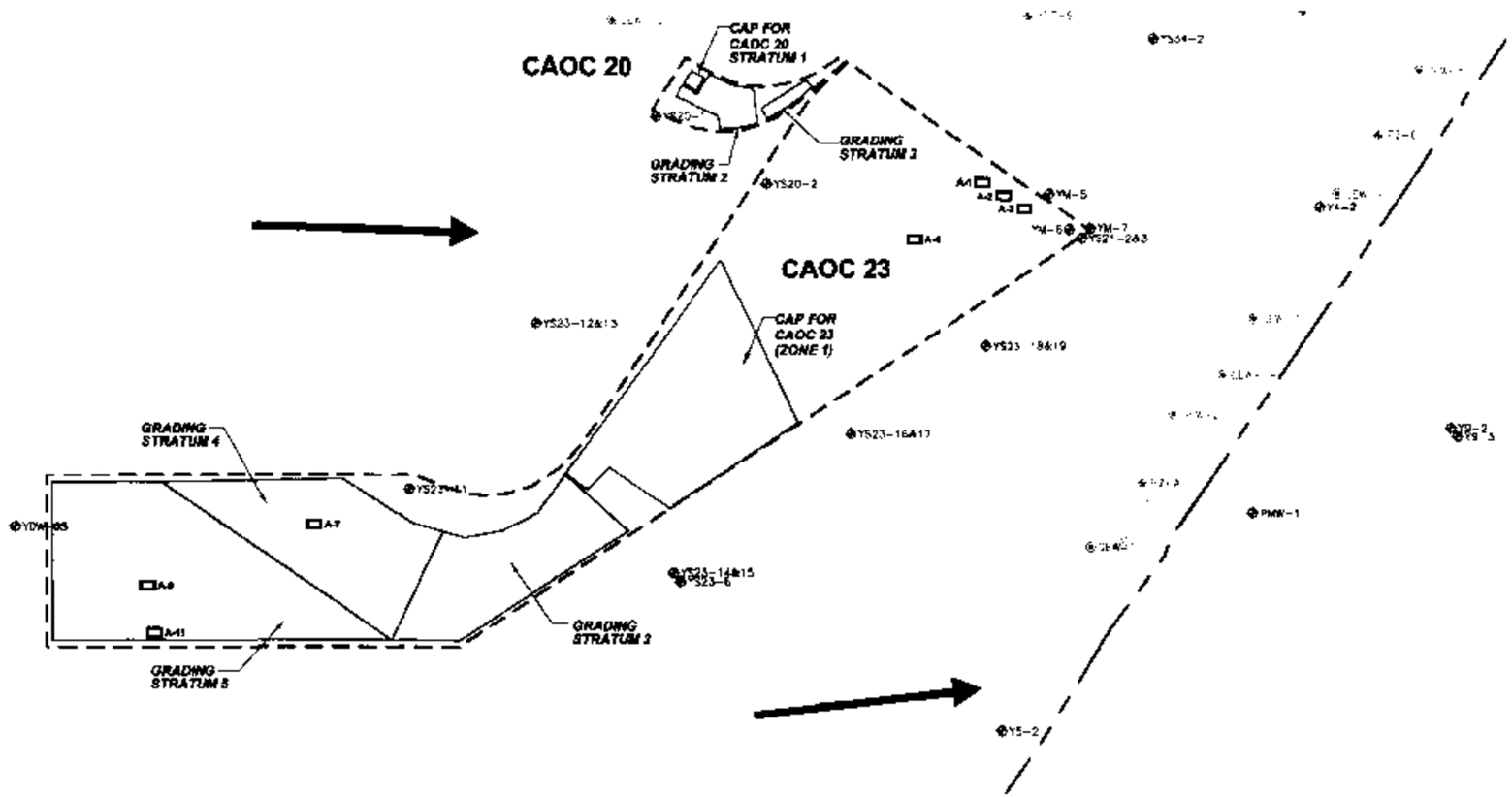

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- BASE BOUNDARY
- CAOC BOUNDARY
- GENERALIZED GROUNDWATER FLOW DIRECTION
- A-11 GEOPHYSICAL ANOMALIES

ABBREVIATIONS:

CAOC CERCLA AREA OF CONCERN

N

0 300 600
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA GENERAL DEVELOPMENT MAP, OCTOBER 1999 BECHTEL, 1994 (1993 RFA WORKPLAN) CH2M, 1994 (ANNUAL GROUNDWATER MONITORING REPORT, 1994). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MORRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
CAOC 20 AND 23 CAPS

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER
ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED:	DCN: FWSD-RAC-03-0116	
CHECKED BY: JE			
DATE: 12-06-02		CTO: 0049	
SIZE: D	SCALE: AS NOTED	DRAWING NO: FIGURE 4-3	0

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PLOT/UPDATE: DEC 09 2002 09:47:21

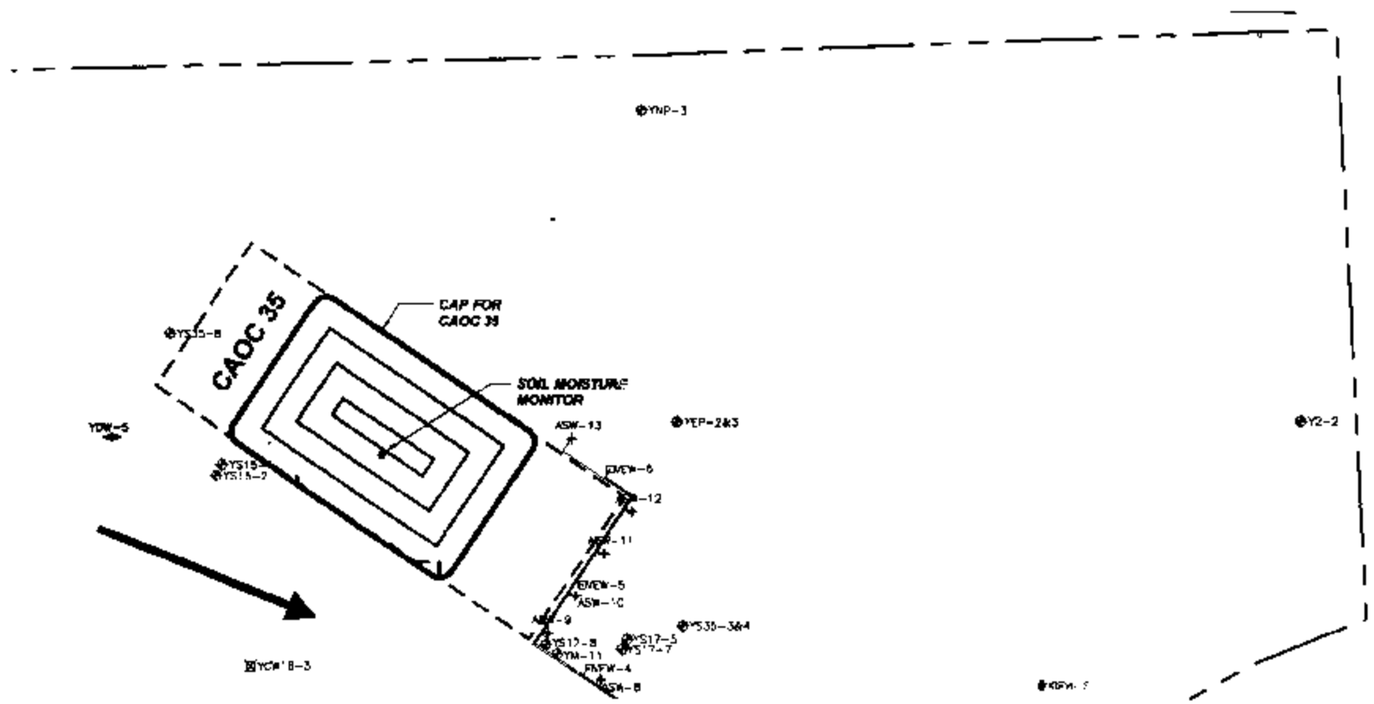
NO	DATE	REVISION	BY	CH	APPROVED

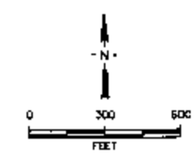
LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- COMBINATION WELL
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- BASE BOUNDARY
- CAOC BOUNDARY
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

CAOC CERCLA AREA OF CONCERN





SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 BECHTEL, 1996 (1996 RFA WORKPLAN) OHL, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
CAOC 35 CAP

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: ND	APPROVED:	DCN: FWSD-RAC-03-011E	
CHECKED BY: JH	YH		
DATE: 12-06-03	YH	CTO: 0049	
SIZE: D	SCALE: AS NOTED	DRAWING NO: FIGURE 4-4	0

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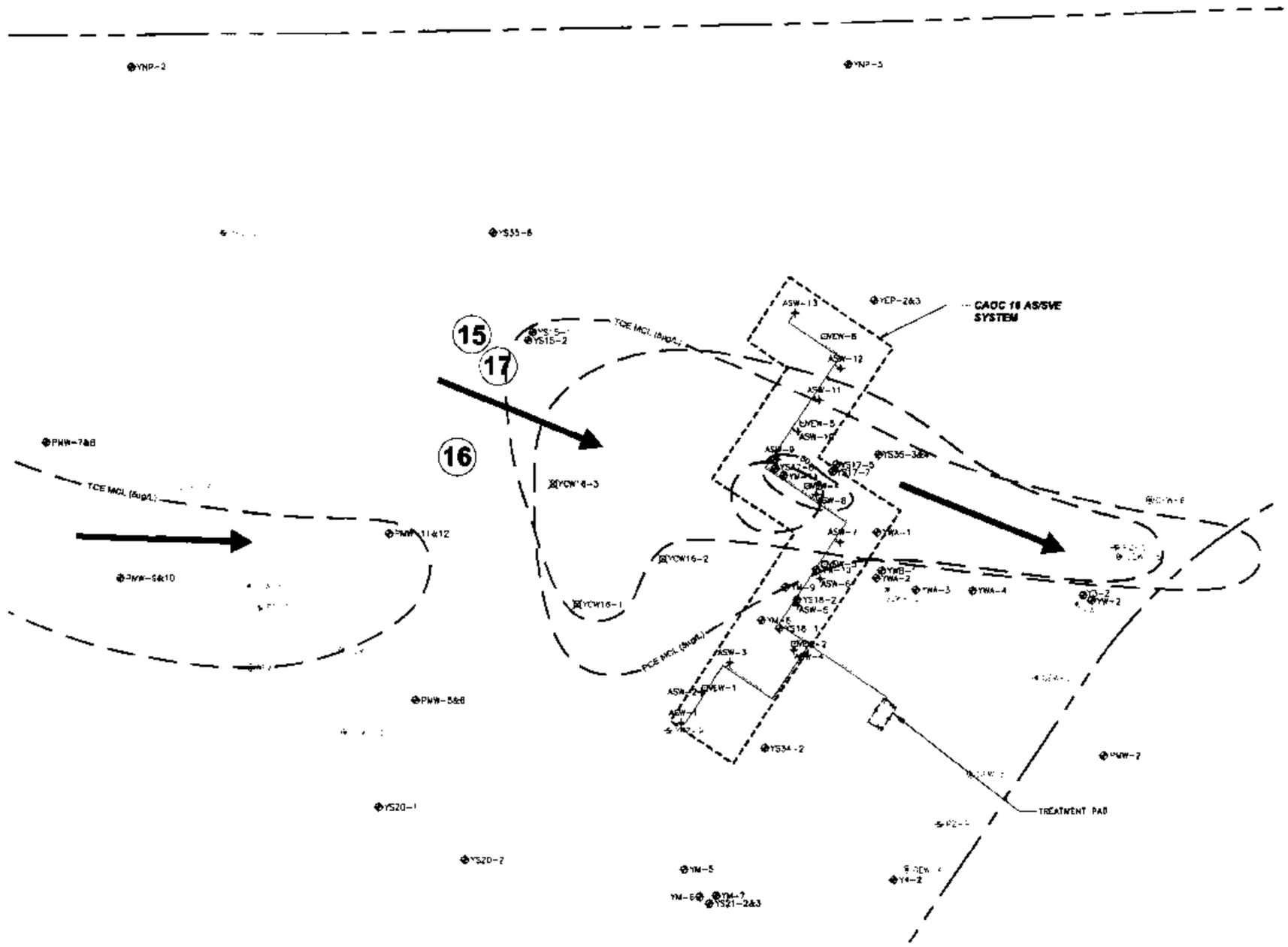
PLOT/UPDATE: DEC 11 2002 15:11:48

NO	DATE	REVISION	BY	CH	APPROVED



LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- COMBINATION WELL
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- VAPOR EXTRACTION PIPING
- AIR SPARGING PIPING
- (16) CAOC 16
- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)
- BASE BOUNDARY
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

AS/SVE	AIR SPARGING/SOIL VAPOR EXTRACTION
CAOC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA GENERAL DEVELOPMENT MAP, OCTOBER 1989; BECHTEL, 1990 (1988 RFA WORKPLAN); CH2M, 1996 (ANNUAL GROUNDWATER MONITORING REPORT, 1995). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRILL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
CAOC 16 AS/SVE SYSTEM

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MI	APPROVED	DCN:	
CHECKED BY: MI	%HOSANCAD, PE	FWSD-RAC-03-0116	
DATE: 12-06-02		CTO: 0049	
SIZE: D	SCALE: AS NOTED	DRAWING NO. FIGURE 4-5	0

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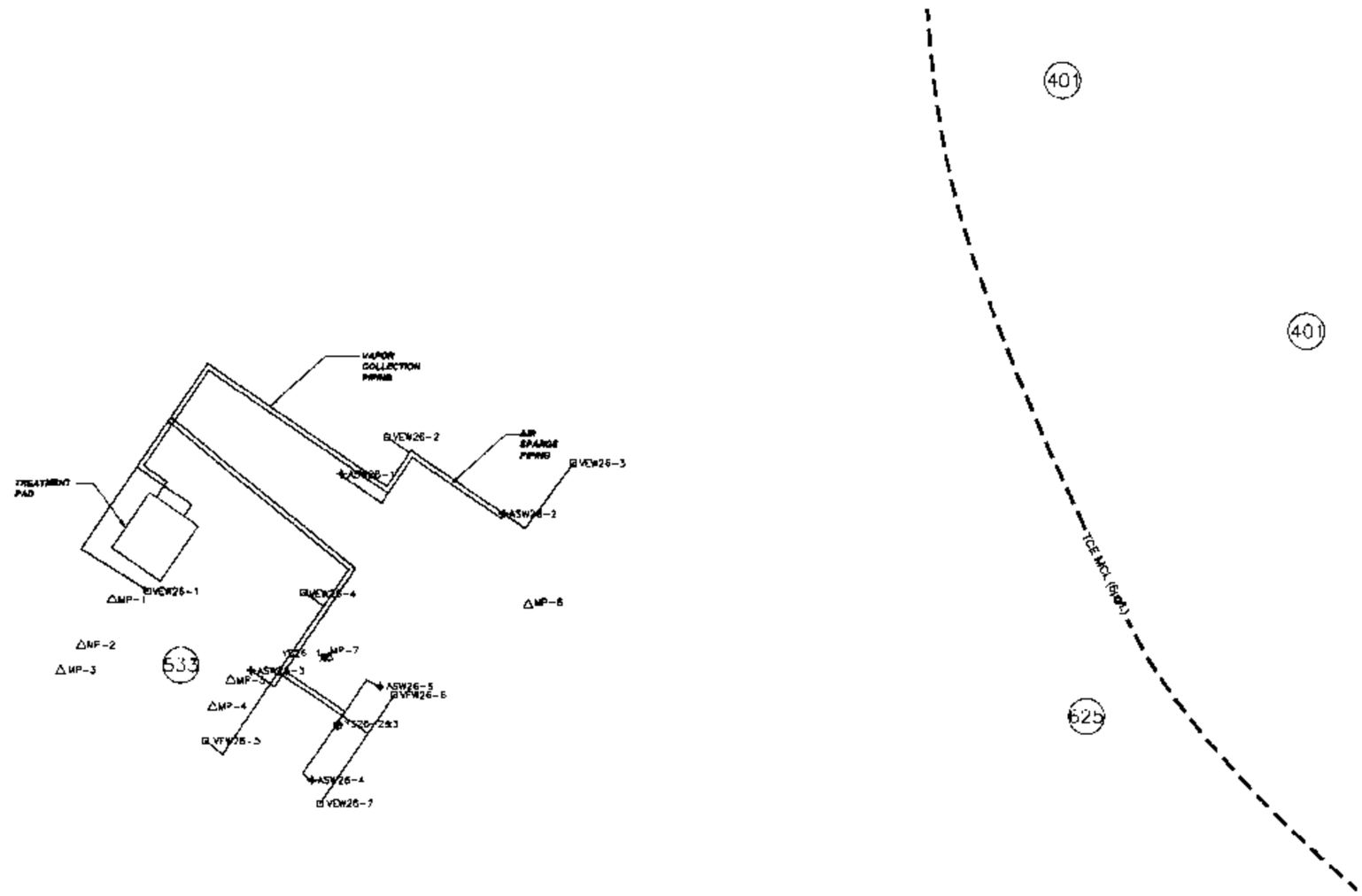
NO	DATE	REVISION	BY	CH	APPROVED



LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- LIST LOCATION
- GROUNDWATER MONITORING WELL
- GROUNDWATER MONITORING WELL OR PIEZOMETER (DECOMMISSIONED)
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- VAPOR MONITORING PROBE
- TCE CONCENTRATION CONTOUR (µg/L)

ABBREVIATIONS:

AS/SVE	AIR SPARGING/SOIL VAPOR EXTRACTION
CAOC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
µg/L	MICROGRAMS PER LITER

N

0 40 80
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1986 (BCHTEL, 1998 (1998 RFA WORKPLAN) CH2M, 1999 (ANNUAL GROUNDWATER MONITORING REPORT 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
CAOC 20 AS/SVE SYSTEM

MARINE CORP'S LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER
ENVIRONMENTAL CORPORATION

DRAWN BY: SO	APPROVED: WH	DCN: FWSD-RAC-03-0116	
CHECKED BY: JB	WH	CTO: 0049	
DATE: 12-06-02			
SIZE: D	SCALE: AS NOTED	DRAWING NO: FIGURE 4-6	0

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PLOT/UPDATE: DEC 09 2002 10:01:25

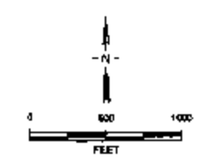
NO	DATE	REVISION	BY : CH	APPROVED

LEGEND:

- (1) LANDFILL NORTH OF THE GOLF COURSE
- (3) GOLF COURSE WASTEWATER DISPOSAL AREA
- (7) DRUM STORAGE AREA AND LANDFILL
- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)
- BASE BOUNDARY
- CAOC BOUNDARY
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

CAOC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER



SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1988 BECHTEL, 1998 (1998 RFA WORKPLAN) CH2M, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998) LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

NEBO MAIN BASE
SOIL CAOCs AND GROUNDWATER PLUMES REQUIRING REMEDIAL ACTION
MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED: VH	DCN: 03-0116	
CHECKED BY: VH	VH	CTO: 0049	
DATE: 12-06-02			
SIZE: D	SCALE: AS NOTED	DRAWING NO: FIGURE 4-7	0

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PLOT/UPDATE: DEC 09 2002 10:09:23

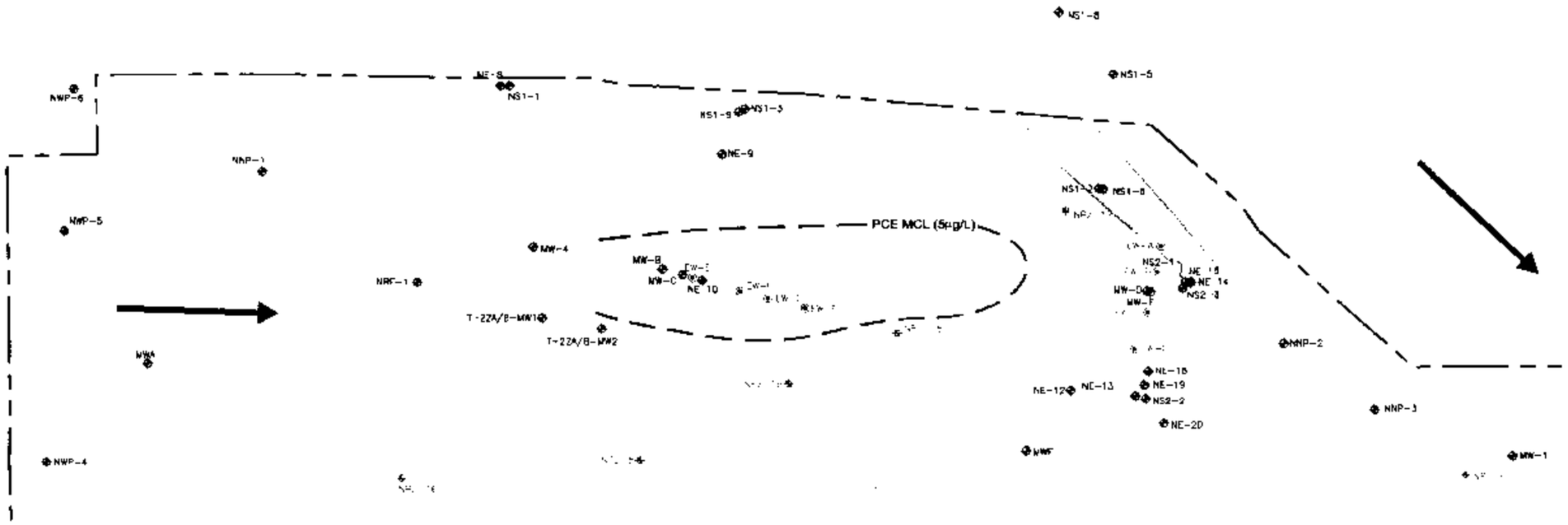
NO	DATE	REVISION	BY	CH	APPROVED

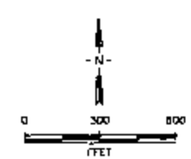
LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE BOUNDARY
- PCE CONCENTRATION CONTOUR (µg/L)
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

CAOC	CERCLA AREA OF CONCERN
GETS	GROUNDWATER EXTRACTION AND TREATMENT SYSTEM
MCL	MAXIMUM CONTAMINANT LEVEL
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER





SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1998 BECHTEL 1998 (1996 IRA WORKPLAN) DWN. 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

NEBO MAIN BASE
NEBO NORTH GETS (CAOC 38)

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED: VH	DCN: FWSC-RAC-02-0116
CHECKED BY: JB	VH	CTO: 0049
DATE: 12-09-02	VH	
SIZE: D	SCALE: AS NOTED	DRAWING NO: FIGURE 4-8

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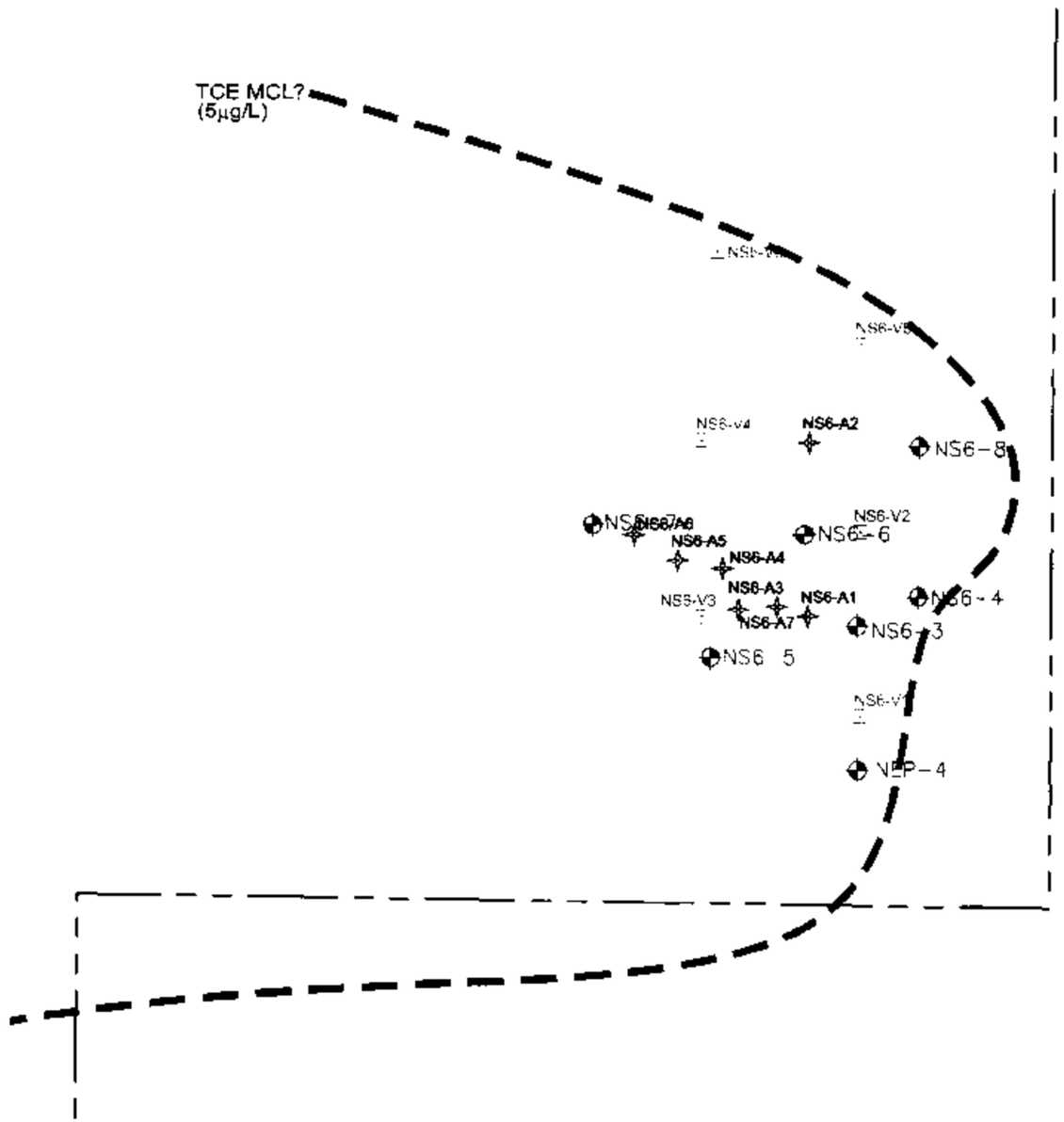
NO	DATE	REVISION	BY	CH	APPROVED



LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- FENCE
- TANKS
- GROUNDWATER MONITORING WELL
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- BASE BOUNDARY
- TCE CONCENTRATION CONTOUR (µg/L)

ABBREVIATIONS:

AS/SVE	AIR SPARGING/SOIL VAPOR EXTRACTION SYSTEM
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
µg/L	MICROGRAMS PER LITER

N

0 50 100
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1988 SECITE, 1996 (1995 RFA WORKPLAN) DMM 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998) LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

NEBO MAIN BASE

NEBO SOUTH AS/SVE SYSTEM (CAOC 36)

MARINE CORPS LOGISTICS BASE

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED	DCN:	
CHECKED BY: JB	VH	F4SO-RAC-03-0116	
DATE: 12-06-02	VH	CTO: 0049	
SIZE: D	SCALE: AS NOTED	DRAWING NO. FIGURE 4-9	0

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PLOT/UPDATE: DEC 09 2002 10:17:47

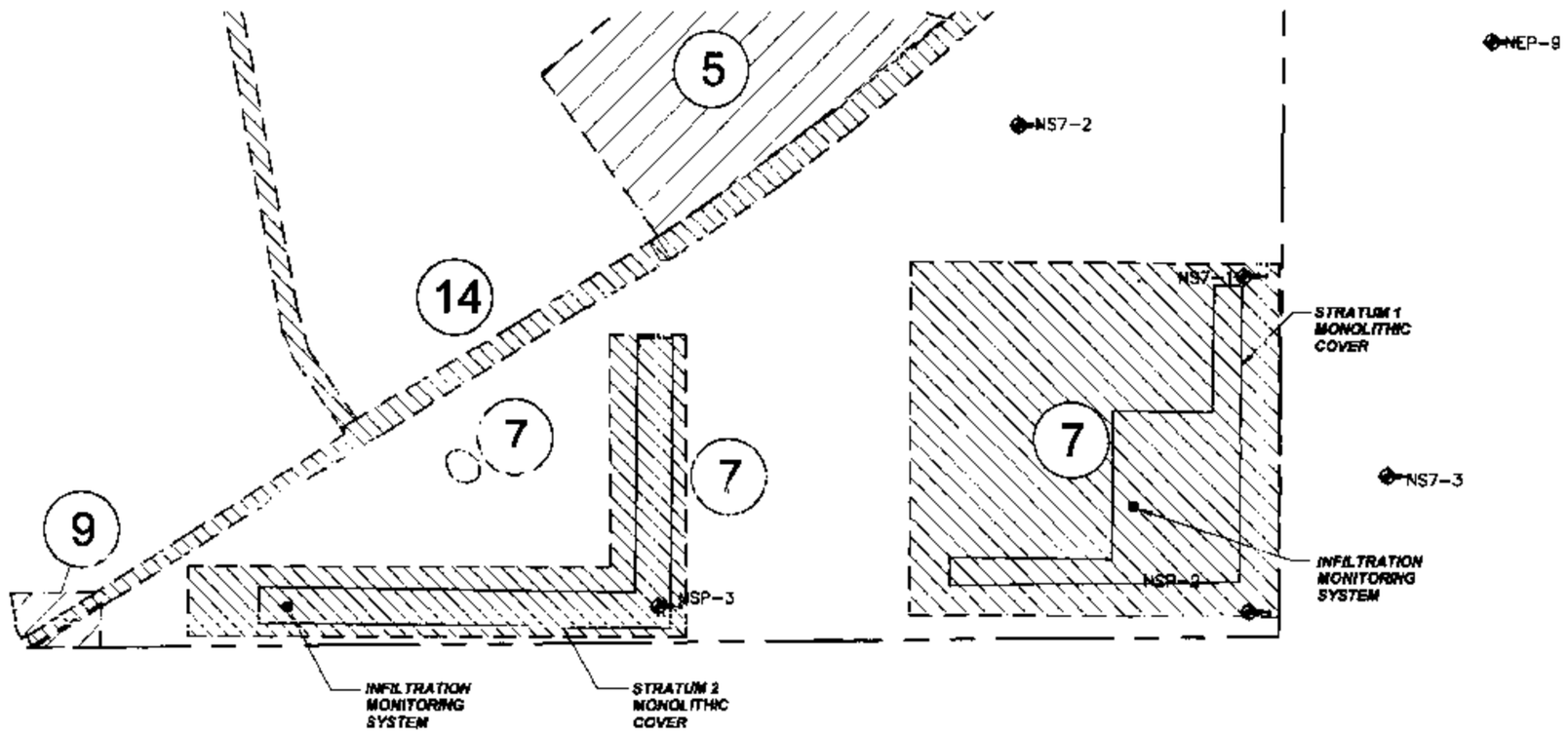
NO	DATE	REVISION	BY	CH	APPROVED

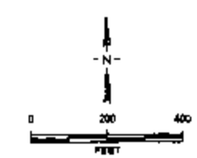
LEGEND:

- (5) CHEMICAL STORAGE AREA
- (7) DRUM STORAGE AREA AND LANDFILL
- (9) FUEL DISPOSAL AREA
- (14) DRAINAGE CHANNEL AND MOJAVE RIVERBED
- BASE BOUNDARY
- ◆ GROUNDWATER MONITORING WELL

ABBREVIATIONS:

CAOC CERCLA AREA OF CONCERN





SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 BECHTEL, 1989 (1988 RFA WORKPLAN) CH2M, 1996 (ANNUAL GROUNDWATER MONITORING REPORT, 1995). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRILL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

NEBO MAIN BASE
CAOC 7 CAPS

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED	DCN# 03-0118	
CHECKED BY: VH	VH		
DATE 12-05-02	VH	C'TD. 0049	
SIZE D	SCALE AS NOTED	DRAWING NO FIGURE 4-10	0

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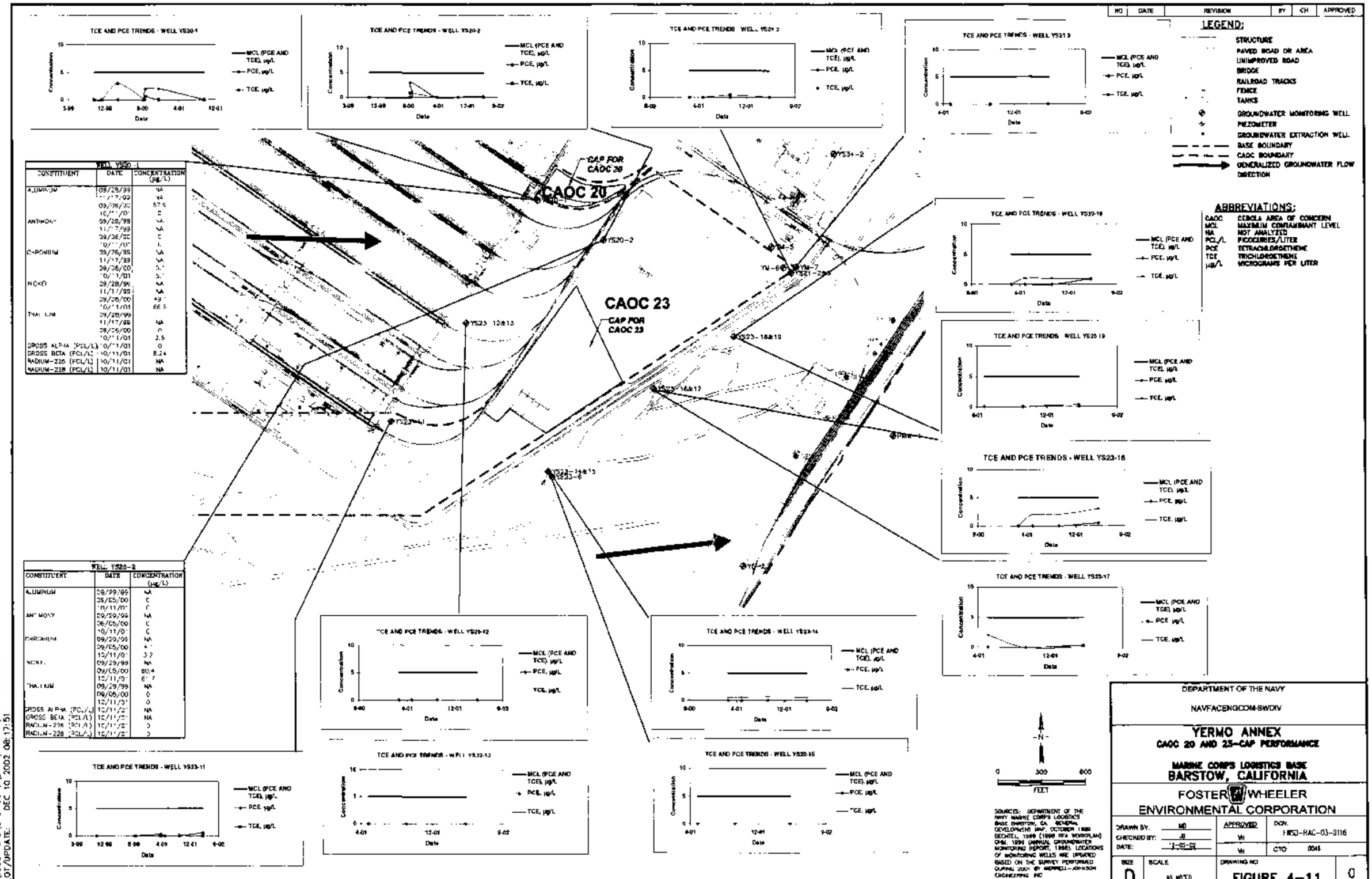
NO	DATE	REVISION	BY	CH	APPROVED



WELL YS20-1

CONSTITUENT	DATE	CONCENTRATION (µg/L)
ALUMINUM	09/28/99	NA
	11/17/99	NA
	09/06/00	57.9
	10/11/01	0
ANTIMONY	09/28/99	NA
	11/17/99	NA
	09/06/00	0
	10/11/01	0
CHROMIUM	09/28/99	NA
	11/17/99	NA
	09/06/00	5.1
	10/11/01	5.1
NICKEL	09/28/99	NA
	11/17/99	NA
	09/06/00	49.1
	10/11/01	66.5
THALLIUM	09/28/99	
	11/17/99	NA
	09/06/00	0
	10/11/01	2.5
GROSS ALPHA (PCI/L)	10/11/01	0
GROSS BETA (PCI/L)	10/11/01	8.24
RADIUM-226 (PCI/L)	10/11/01	NA
RADIUM-228 (PCI/L)	10/11/01	NA

WELL YS20-2

CONSTITUENT	DATE	CONCENTRATION (µg/L)
ALUMINUM	09/29/99	NA
	06/05/00	0
	10/11/01	0
ANTIMONY	09/29/99	NA
	06/05/00	0
	10/11/01	0
CHROMIUM	09/29/99	NA
	06/05/00	4.1
	10/11/01	3.7
NICKEL	09/29/99	NA
	06/05/00	80.4
	10/11/01	67.7
THALLIUM	09/29/99	NA
	06/05/00	0
	10/11/01	0
GROSS ALPHA (PCI/L)	10/11/01	NA
GROSS BETA (PCI/L)	10/11/01	NA
RADIUM-226 (PCI/L)	10/11/01	0
RADIUM-228 (PCI/L)	10/11/01	0

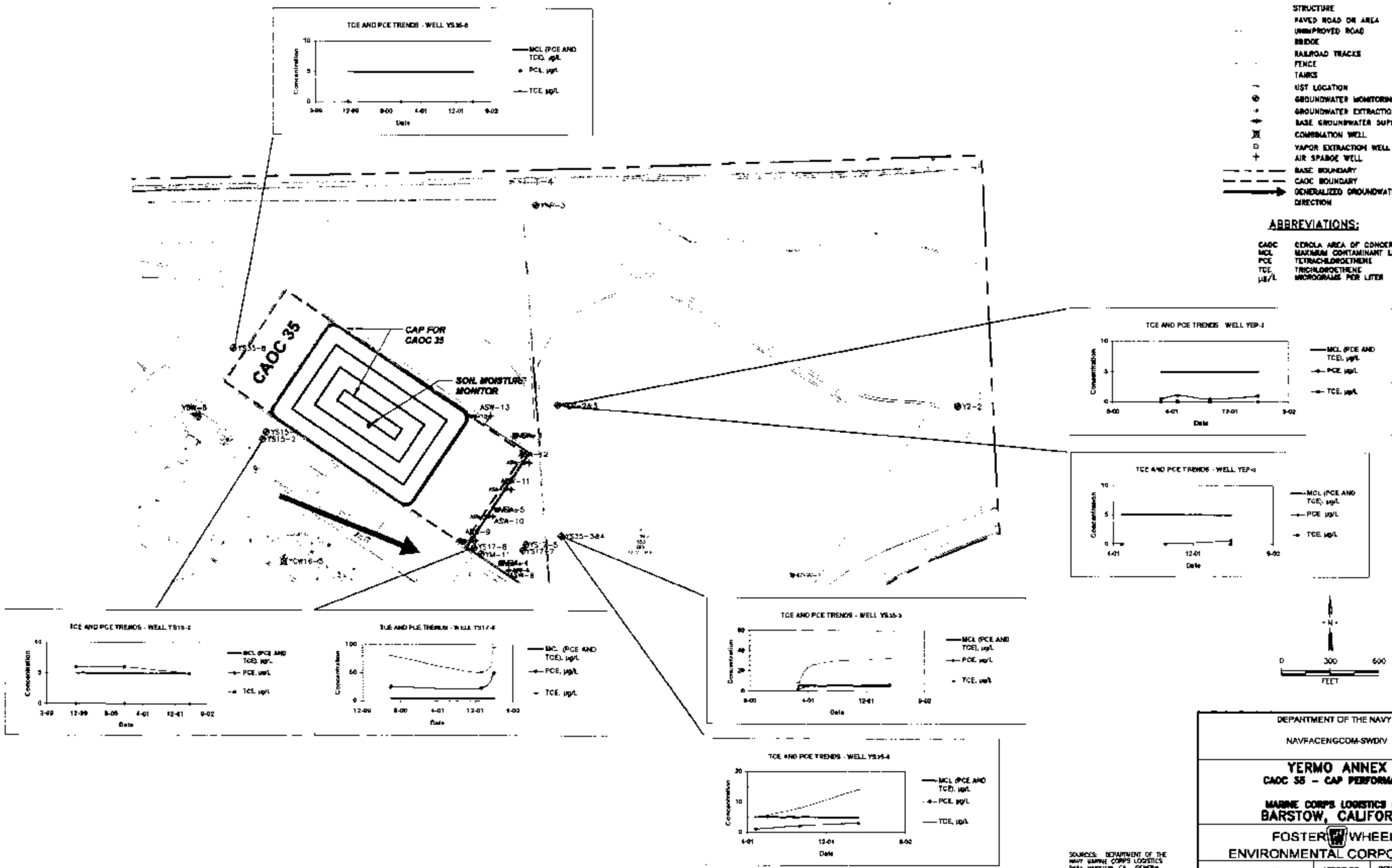
NO	DATE	REVISION	BY	CH	APPROVED

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- COMBINATION WELL
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- BASE BOUNDARY
- CAOC BOUNDARY
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

CAOC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
PCE	TETRACHLOROETHENE
TCE	TRICHLOROETHENE
µg/L	MICROGRAMS PER LITER



SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1998 BECHTEL, 1998 (1998 RFA WORKPLAN) BNM, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MORELLA-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
CAOC 35 – CAP PERFORMANCE

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MC	APPROVED	DCN: FWSD-RAD-03-0116	
CHECKED BY: JB	WH		
DATE: 12-05-02	WH	CTO: 0049	
SIZE: D	SCALE: AS NOTED	DRAWING NO: FIGURE 4-12	0

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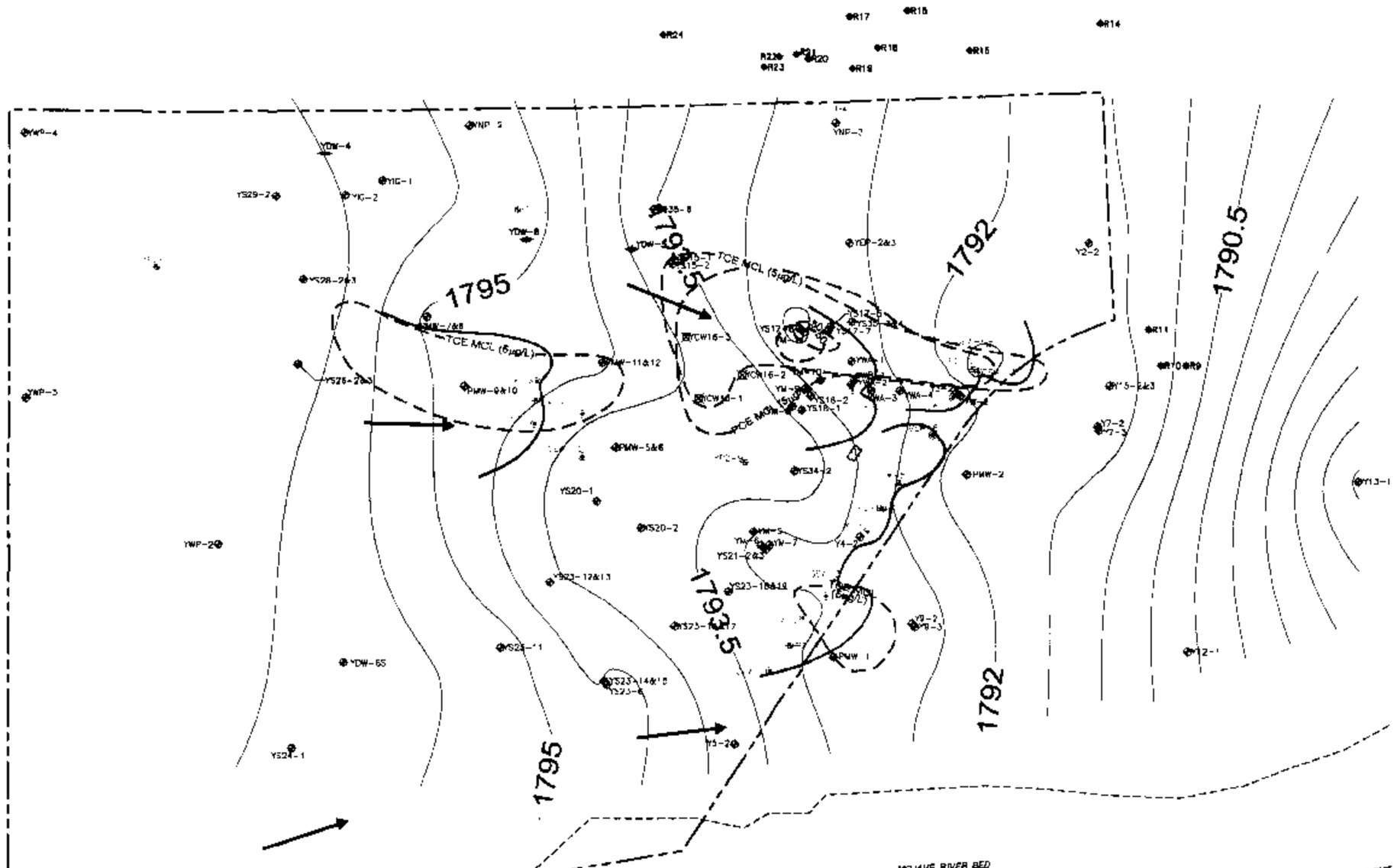
PLOT/UPDATE: DEC 12 2002 08:37:47

NO	DATE	REVISION	BY	CH	APPROVED



LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- RESIDENTIAL WATER SUPPLY WELL
- COMBINATION WELL
- PCE CONCENTRATION CONTOUR (5µg/L)
- TCE CONCENTRATION CONTOUR (5µg/L)
- BASE BOUNDARY
- —1796— GROUNDWATER ELEVATION CONTOUR (ELEVATION IN FEET AMSL)
- GENERALIZED GROUNDWATER FLOW DIRECTION
- PREDICTED HYDRAULIC CAPTURE ZONE

ABBREVIATIONS:

AMSL	ABOVE MEAN SEA LEVEL
CAOC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER

0 600 1200
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 BECHTEL, 1999 (1998 RFI WORKPLAN) DMI, 1998 (ANNUAL GROUNDWATER MONITORING REPORT, 1998) LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRILL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
CAOC 37 - PLUME CONTAINMENT

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER
ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED	DCN: FWSD-RAC-03-01165	
CHECKED BY: JB			
DATE: 12-05-02		CTO: 0049	
SIZE: D	SCALE: AS NOTED	DRAWING NO: FIGURE 4-13	0

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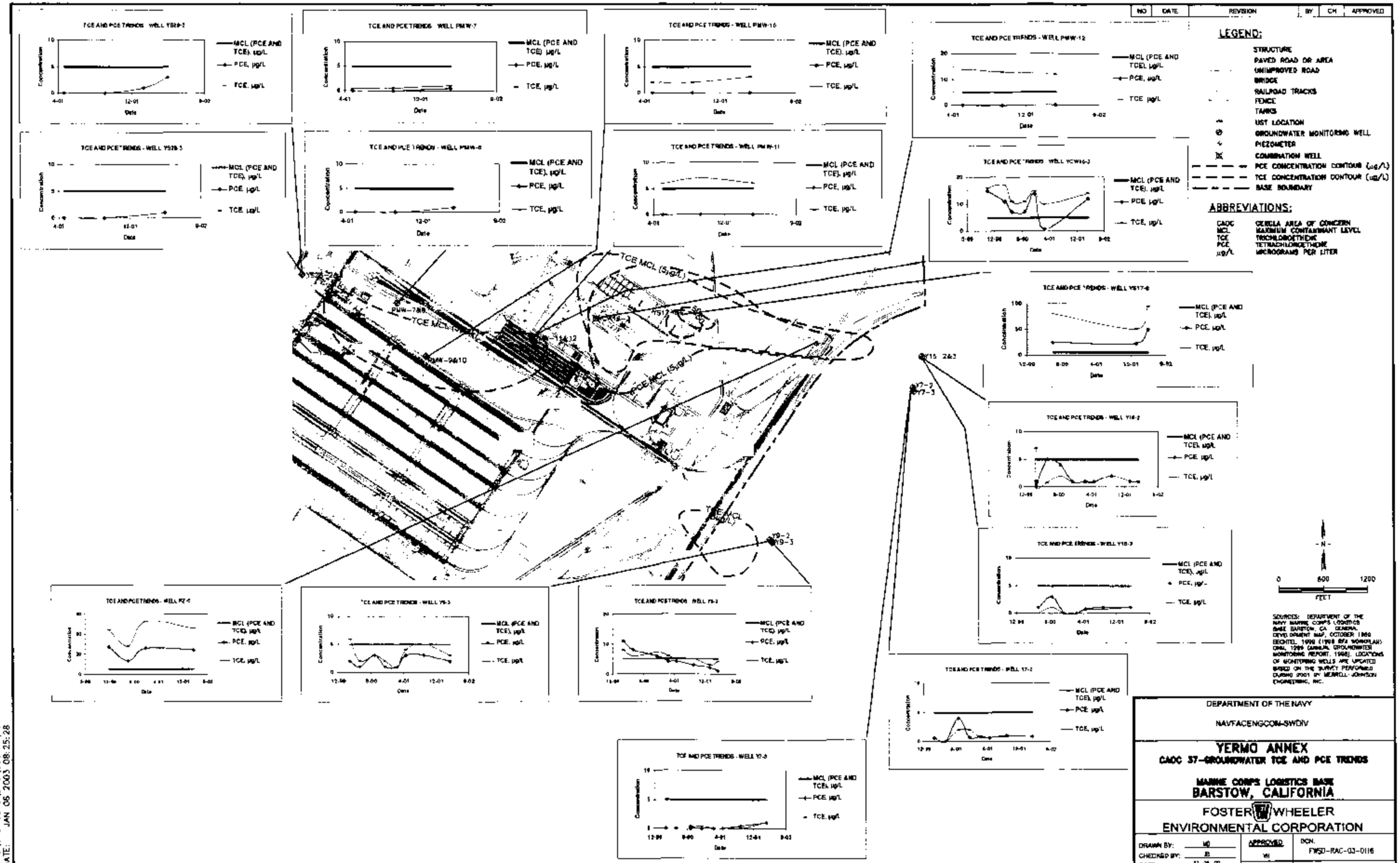
PLOT/UPDATE: DEC 05 2002 16:28:17

NO	DATE	REVISION	BY	CH	APPROVED



DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX

CAOC 37–GROUNDWATER TCE AND PCE TRENDS

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MO		APPROVED	DCN.
CHECKED BY: JB		VH	FWSD–RAC–03–0116
DATE: 12-26-02		VH	CTO: 0049
SIZE D	SCALE AS NOTED	DRAWING NO FIGURE 4–14	0

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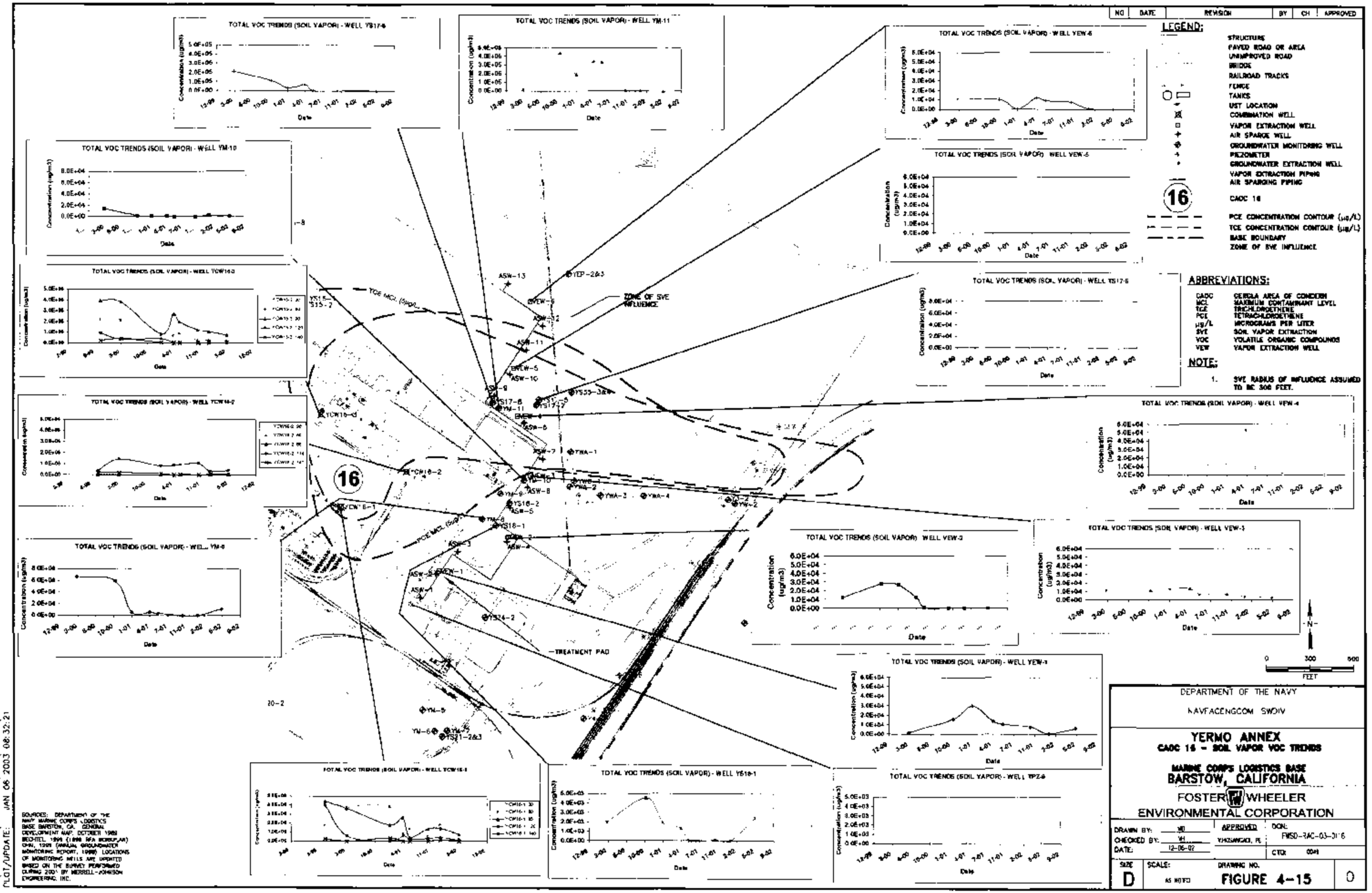
PLOT/UPDATE: JAN 06 2003 08:25:28

NO	DATE	REVISION	BY	CH	APPROVED



LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- COMBINATION WELL
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- VAPOR EXTRACTION PIPING
- AIR SPARGING PIPING
- 16 — CAOC 16
- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)
- BASE BOUNDARY
- ZONE OF SVE INFLUENCE

ABBREVIATIONS:

CAOC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER
SVE	SOIL VAPOR EXTRACTION
VOC	VOLATILE ORGANIC COMPOUNDS
VEW	VAPOR EXTRACTION WELL

NOTE:

1. SVE RADIUS OF INFLUENCE ASSUMED TO BE 300 FEET.

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTON, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 BECHTEL 1994 (1996 RFA WORKPLAN) CH2M, 1997 (ANNUAL GROUNDWATER MONITORING REPORT, 1996) LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM SWDIV

YERMO ANNEX

CAOC 16 - SOIL VAPOR VOC TRENDS

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED:	DCN:	
CHECKED BY: VH	YAKSANGKO, PE	FWSD-RAC-03-0116	
DATE: 12-06-02		CTO: 0049	
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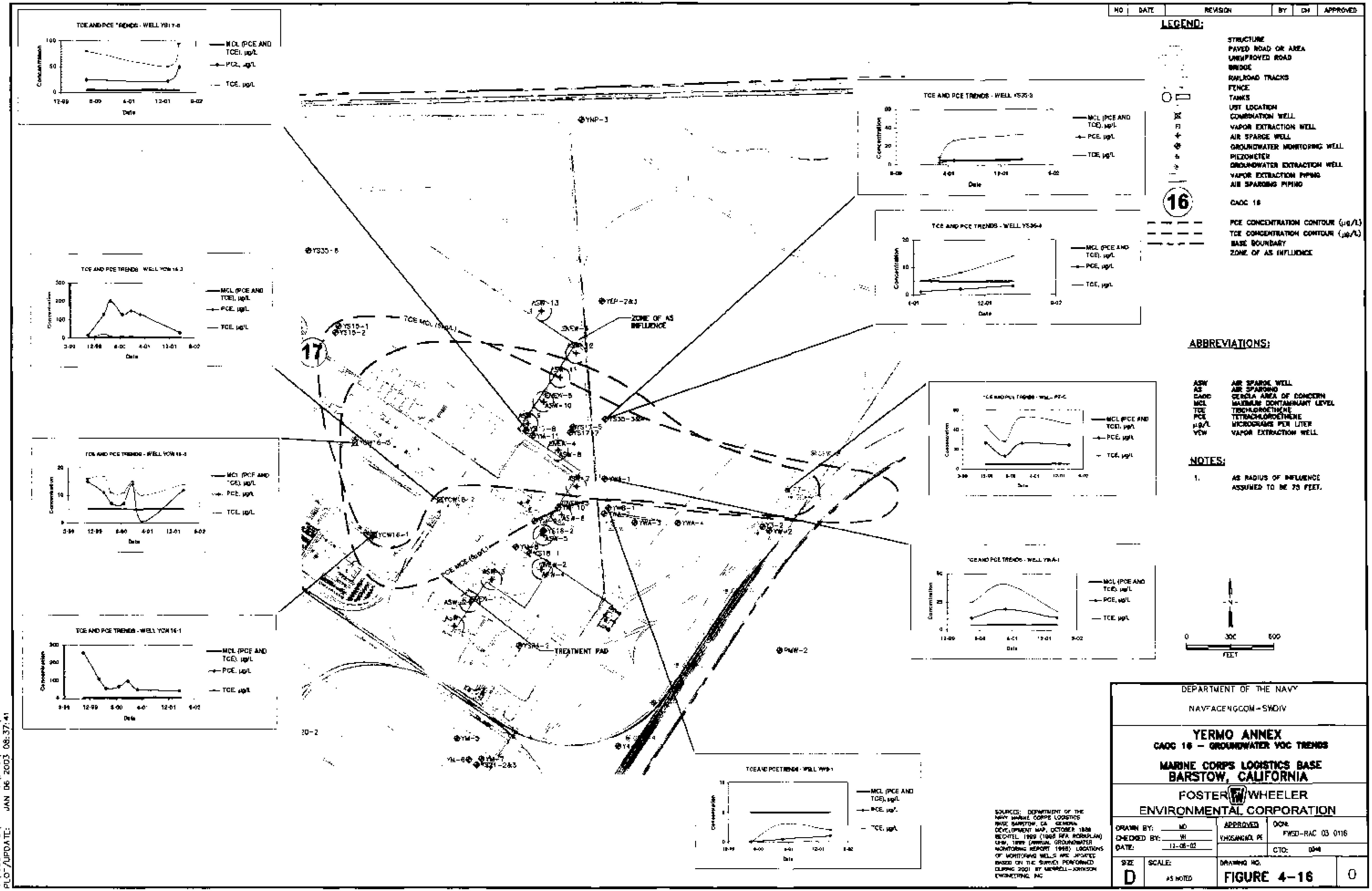

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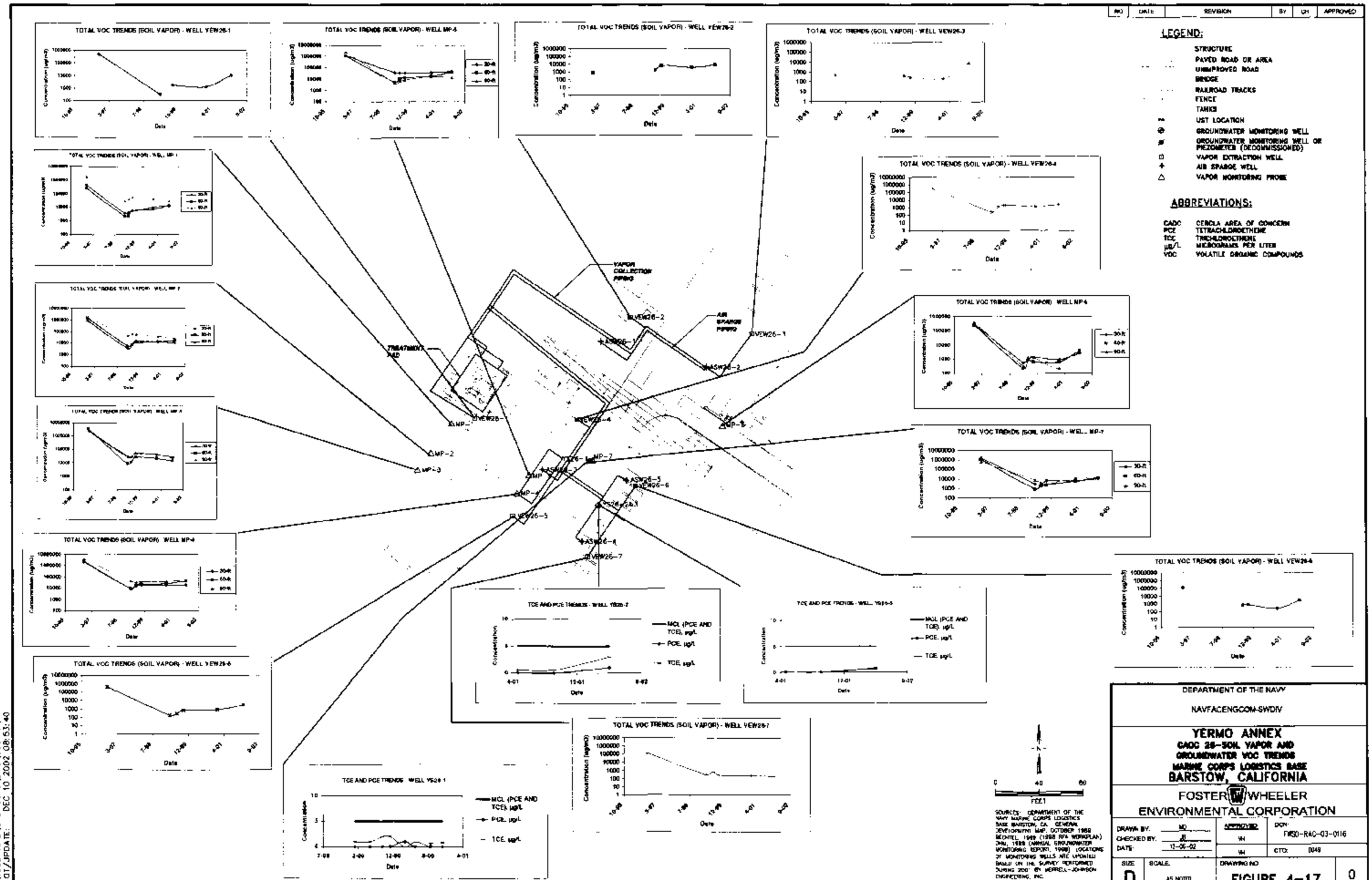

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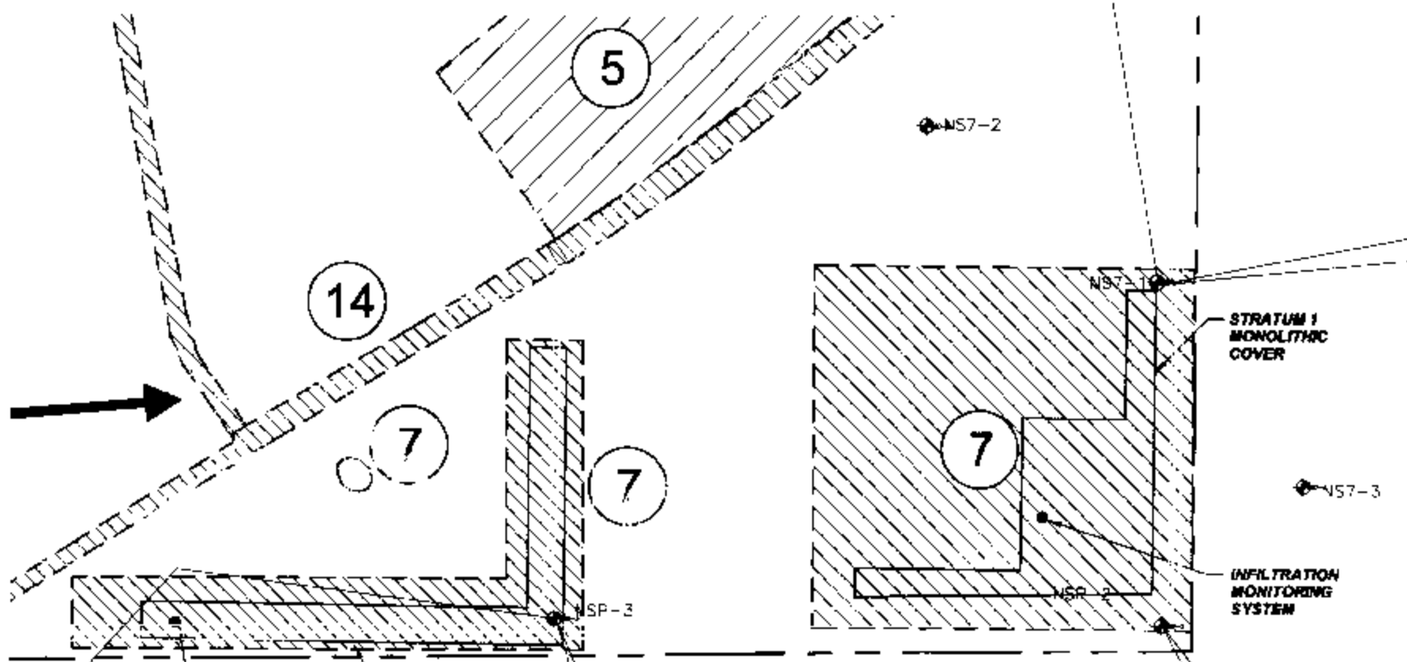

WELL NS7-1		
POLLUTANT	DATE	CONCENTRATION (µg/L)
TETRACHLOROETHENE	11/16/99	0
	05/22/00	0
	12/14/00	0.4
	05/10/01	0
TRICHLOROETHENE	11/16/99	0
	05/22/00	0
	12/14/00	0.5
	05/10/01	0

WELL NS7-1		
POLLUTANT	DATE	CONCENTRATION (µg/L)
ALUMINUM	11/16/99	NA
	05/22/00	46.3
	05/10/01	28.2
ANTIMONY	11/16/99	NA
	05/22/00	0
	05/10/01	0
BARIUM	11/16/99	56.6
	05/22/00	NA
	05/10/01	NA
CALCIUM	11/16/99	33500
	05/22/00	NA
	05/10/01	NA
CHROMIUM	11/16/99	NA
	05/22/00	6
	05/10/01	6.3
MAGNESIUM	11/16/99	4470
	05/22/00	NA
	05/10/01	NA
NICKEL	11/16/99	NA
	05/22/00	0.8
	05/10/01	0
POTASSIUM	11/16/99	4220
	05/22/00	NA
	05/10/01	NA
SODIUM	11/16/99	136000
	05/22/00	NA
	05/10/01	NA
THALLIUM	11/16/99	NA
	05/22/00	0
	05/10/01	0

WELL NS7-1		
POLLUTANT	DATE	CONCENTRATION (µg/L)
ALDRIN	05/10/01	0
ALPHA-BHC	05/10/01	0
ALPHA-CHLORDANE	05/10/01	0
BETA-BHC	05/10/01	0
4,4'-DDD	05/10/01	0
4,4'-DDE	05/10/01	0
4,4'-DDT	05/10/01	0
DELTA-BHC	05/10/01	0
DIELDRIN	05/10/01	0
ENDOSULFAN	05/10/01	0
ENDOSULFAN I	05/10/01	0
ENDOSULFAN SULFATE	05/10/01	0
ENDRIN ALDEHYDE	05/10/01	0
ENDRIN KETONE	05/10/01	0
ENDRIN	05/10/01	0
GAMMA-BHC	05/10/01	0
GAMMA-CHLORDANE	05/10/01	0
HEPTACHLOR EPOXIDE	05/10/01	0
HEPTACHLOR	05/10/01	0
METHOXYCHLOR	05/10/01	0

LEGEND:

- (5) CHEMICAL STORAGE AREA
- (7) DRUM STORAGE AREA AND LANDFILL
- (14) DRAINAGE CHANNEL AND MOJAVE RIVERBED
- ◆ GROUNDWATER MONITORING WELL
- BASE BOUNDARY
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

BHC	BENZENE HEXACHLORIDE
COIC	CERCLA AREA OF CONCERN
DDD	DICHLORO DIPHENYL DICHLOROETHANE
DDE	DICHLORO DIPHENYL DICHLOROETHENE
DDT	DICHLORO DIPHENYL TRICHLOROETHENE
µg/L	MICROGRAMS PER LITER

WELL NSP-3		
POLLUTANT	DATE	CONCENTRATION (µg/L)
ALUMINUM	11/16/99	NA
	05/24/00	59
	05/14/01	0
ANTIMONY	11/16/99	NA
	05/24/00	0
	05/14/01	0
BARIUM	11/16/99	75.5
	05/24/00	NA
	05/14/01	NA
CALCIUM	11/16/99	37500
	05/24/00	NA
	05/14/01	NA
CHROMIUM	11/16/99	NA
	05/24/00	4.5
	05/14/01	14.5
MAGNESIUM	11/16/99	8320
	05/24/00	NA
	05/14/01	NA
NICKEL	11/16/99	NA
	05/24/00	2.78
	05/14/01	3.4
POTASSIUM	11/16/99	5400
	05/24/00	NA
	05/14/01	NA
SODIUM	11/16/99	49500
	05/24/00	NA
	05/14/01	NA
THALLIUM	11/16/99	NA
	05/24/00	0
	05/14/01	0

WELL NSP-3		
POLLUTANT	DATE	CONCENTRATION (µg/L)
ALDRIN	05/14/01	0
ALPHA-BHC	05/14/01	0
ALPHA-CHLORDANE	05/14/01	0
BETA-BHC	05/14/01	0
4,4'-DDD	05/14/01	0
4,4'-DDE	05/14/01	0
4,4'-DDT	05/14/01	0
DELTA-BHC	05/14/01	0
DIELDRIN	05/14/01	0
ENDOSULFAN I	05/14/01	0
ENDOSULFAN	05/14/01	0
ENDOSULFAN SULFATE	05/14/01	0.022
ENDRIN ALDEHYDE	05/14/01	0
ENDRIN KETONE	05/14/01	0
ENDRIN	05/14/01	0
GAMMA-BHC	05/14/01	0
GAMMA-CHLORDANE	05/14/01	0
HEPTACHLOR EPOXIDE	05/14/01	0
HEPTACHLOR	05/14/01	0
METHOXYCHLOR	05/14/01	0

WELL NSP-3		
POLLUTANT	DATE	CONCENTRATION (µg/L)
TETRACHLOROETHENE	11/15/99	0
	05/24/00	0
	12/13/00	0
	05/14/01	0
TRICHLOROETHENE	11/16/99	0
	05/24/00	0
	12/13/00	0
	05/14/01	0

WELL NSP-2		
POLLUTANT	DATE	CONCENTRATION (µg/L)
ALUMINUM	11/15/99	NA
	05/22/00	72.4
ANTIMONY	11/15/99	NA
	05/22/00	0
BARIUM	11/15/99	36.1
	05/22/00	NA
CALCIUM	11/15/99	33800
	05/22/00	NA
CHROMIUM	11/15/99	NA
	05/22/00	4.3
MAGNESIUM	11/15/99	5030
	05/22/00	NA
NICKEL	11/15/99	NA
	05/22/00	0
POTASSIUM	11/15/99	4450
	05/22/00	NA
SODIUM	11/15/99	51800
	05/22/00	NA
THALLIUM	11/15/99	NA
	05/22/00	0

WELL NSP-2		
POLLUTANT	DATE	CONCENTRATION (µg/L)
TETRACHLOROETHENE	11/15/99	0
	05/22/00	0
	12/13/00	0
	05/14/01	0
TRICHLOROETHENE	11/15/99	0.3
	05/22/00	-
	12/13/00	0
	05/14/01	0

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 BECHTEL, 1995 (1995 RFA WORKPLAN) CH2M, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRITT-JOHNSON ENGINEERING, INC.

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FEET

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

NEBO MAIN BASE

CAOC 7 - CAP PERFORMANCE

MARINE CORPS LOGISTICS BASE

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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CHECKED BY: WI	WI	03-0116	
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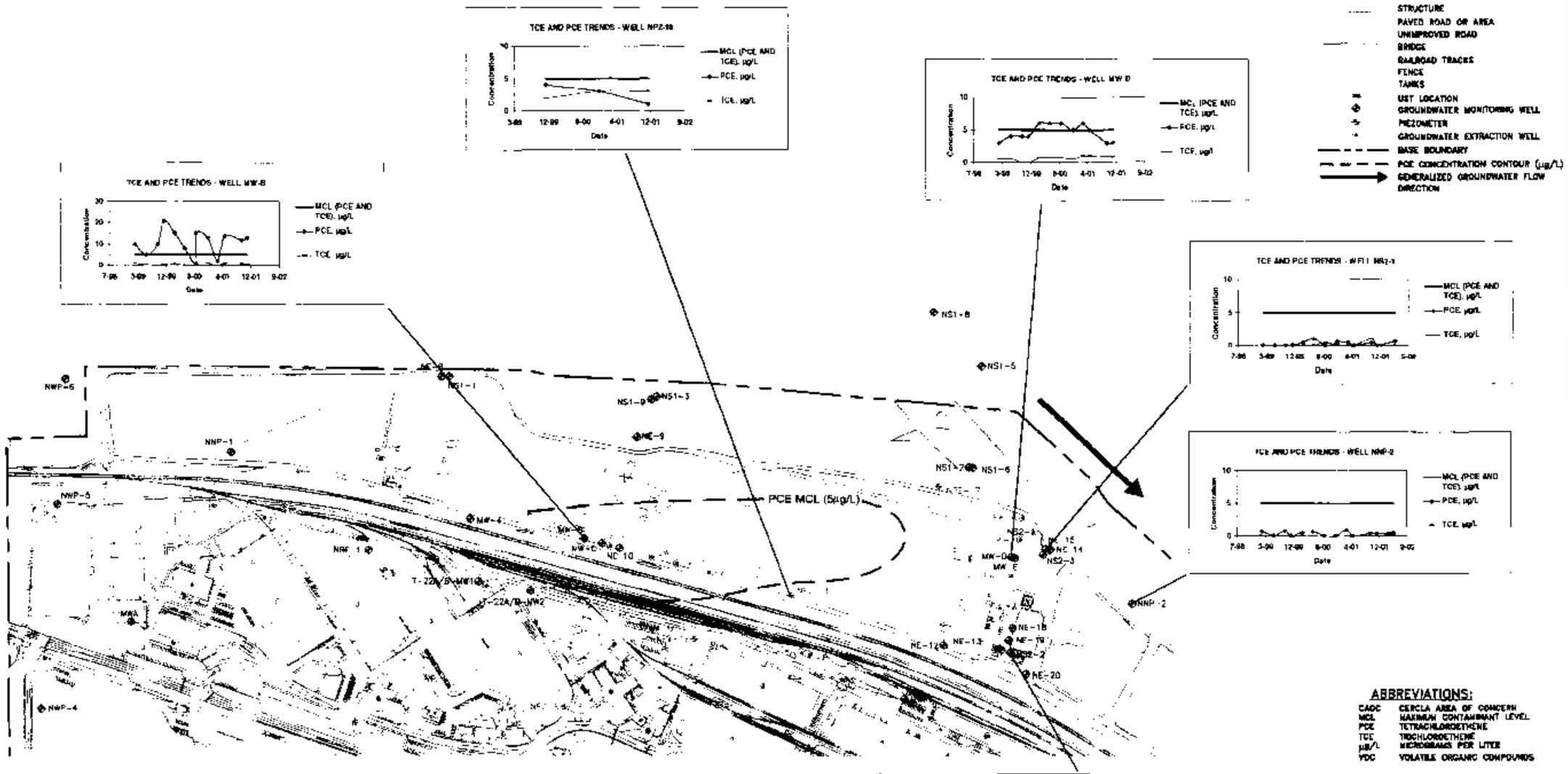
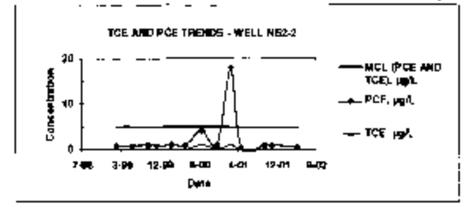


LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE BOUNDARY
- PCE CONCENTRATION CONTOUR (µg/L)
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

CADC	CERCLA AREA OF CONCERN
MCL	MAXIMUM CONTAMINANT LEVEL
PCE	TETRACHLOROETHENE
TCE	TRICHLOROETHENE
µg/L	MICROGRAMS PER LITER
VOC	VOLATILE ORGANIC COMPOUNDS



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SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA GENERAL DEVELOPMENT MAP, OCTOBER 1989 BECHTEL 1990 (1990 RFA WORKPLAN) CH2M 1992 (ANNUAL GROUNDWATER MONITORING REPORT, 1992). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRILL—JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM—SWDIV

NEBO MAIN BASE

CADC 38—NEBO NORTH GROUNDWATER VOC TRENDS

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED: WH	DCN: FWSD-RAC-03-0116	
CHECKED BY: JB	WH	CTO: 0049	
DATE: 12-06-02			
SIZE: D	SCALE: AS NOTED	DRAWING NO. FIGURE 4-19	0

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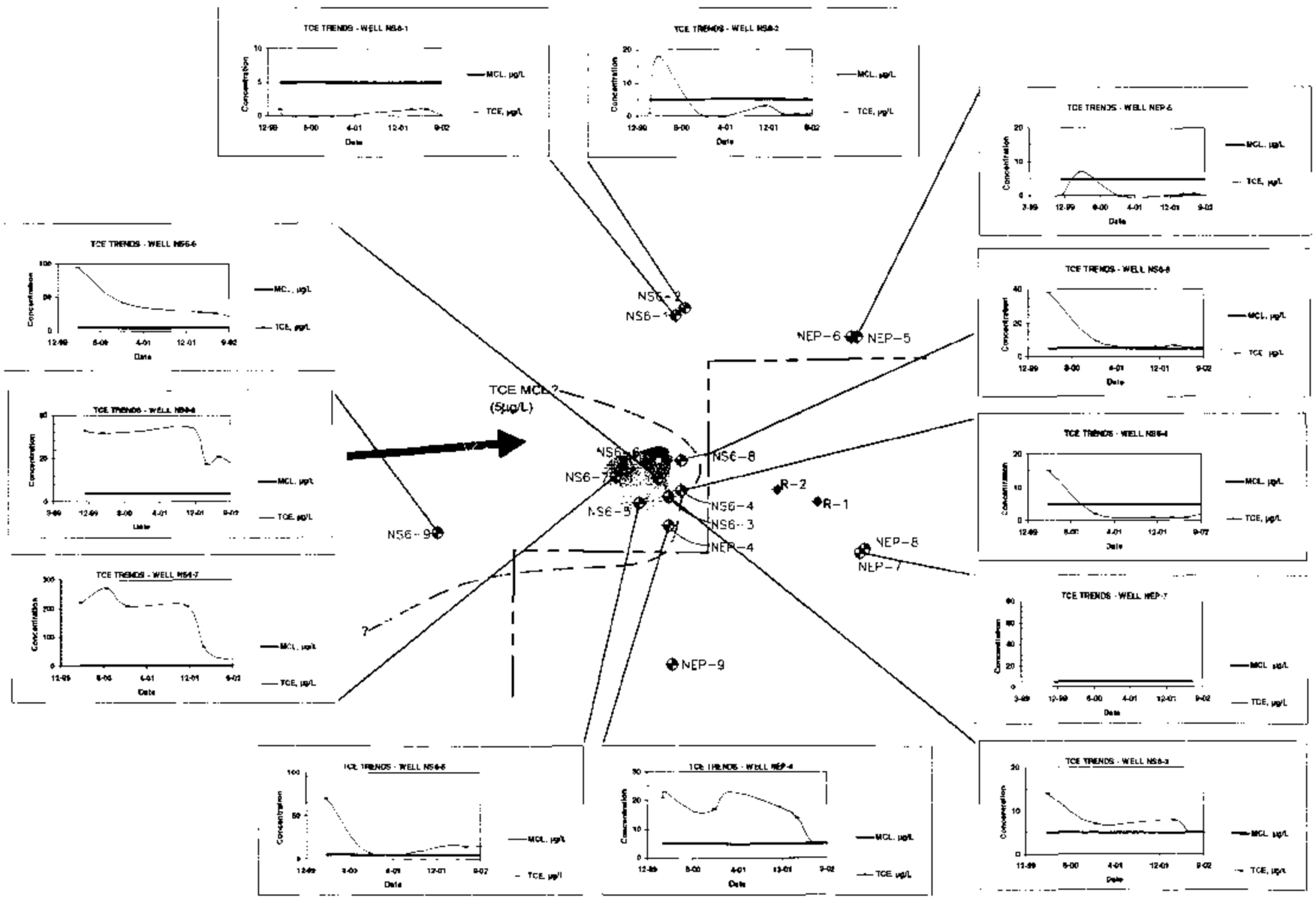

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- LIST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- RESIDENTIAL WATER SUPPLY WELL
- BASE WATER SUPPLY WELL
- USGS WELLS
- BASE BOUNDARY
- PCE CONCENTRATION CONTOUR (µg/L)
- GENERALIZED GROUNDWATER FLOW DIRECTION
- AREA OF SPARGE INFLUENCE

ABBREVIATIONS:

MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER
VOC	VOLATILE ORGANIC COMPOUND

N

0 200 400
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1988 BLUHILL, 1997 (1996 RFI WORKPLAN) CH2M, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRILL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

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NEBO MAIN BASE

CAOC 38 – NEBO SOUTH GROUNDWATER VOC TRENDS

CAOC 6 – NEBO SOUTH

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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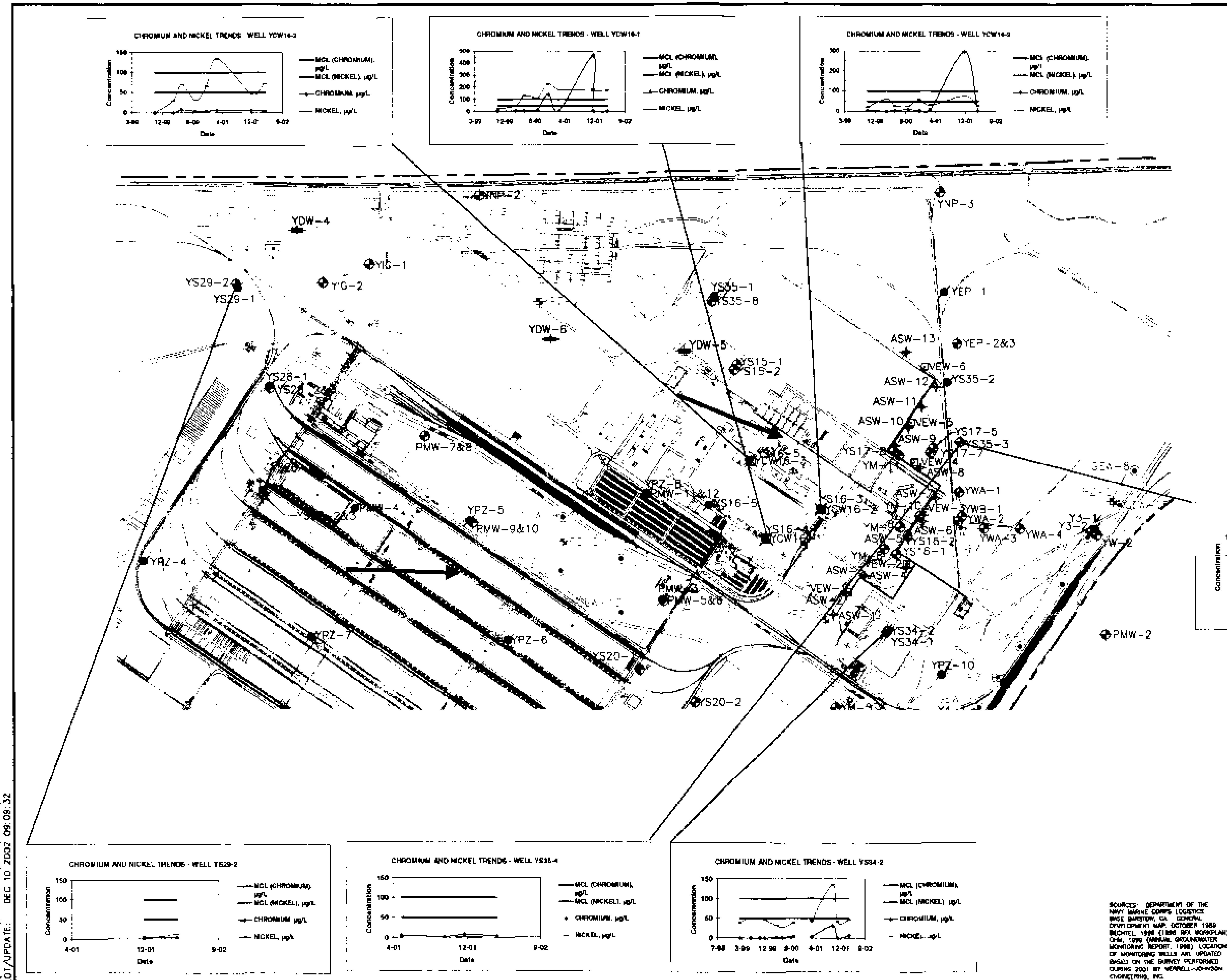

LEGEND:

STRUCTURE
PAVED ROAD OR AREA
UNIMPROVED ROAD
BRIDGE
RAILROAD TRACKS
FENCE
TANKS
UST LOCATION
GROUNDWATER MONITORING WELL
PIEZOMETER
GROUNDWATER EXTRACTION WELL
BASE GROUNDWATER SUPPLY WELL
RESIDENTIAL WATER SUPPLY WELL
GROUNDWATER MONITORING WELL OR PIEZOMETER (DECOMMISSIONED)
COMBINATION WELL
VAPOR EXTRACTION WELL
AIR SPARGE WELL
VAPOR MONITORING PROBE
BASE BOUNDARY
GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

MCL MAXIMUM CONTAMINANT LEVEL
µg/L MICROGRAMS PER LITER

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989. BECHTEL, 1996 (1996 RFI WORKPLAN), CH2M, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998) LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY
NAVFACENGCOM-SWDIV

YERMO ANNEX
METALS IN GROUNDWATER

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY	MD	APPROVED	DCN: FWSD-RAC-03-0116
CHECKED BY	JB	WI	
DATE	12-06-02	WI	CTO- 0049
SIZE D	SCALE: AS NOTED	DRAWING NO. FIGURE 4-21	0

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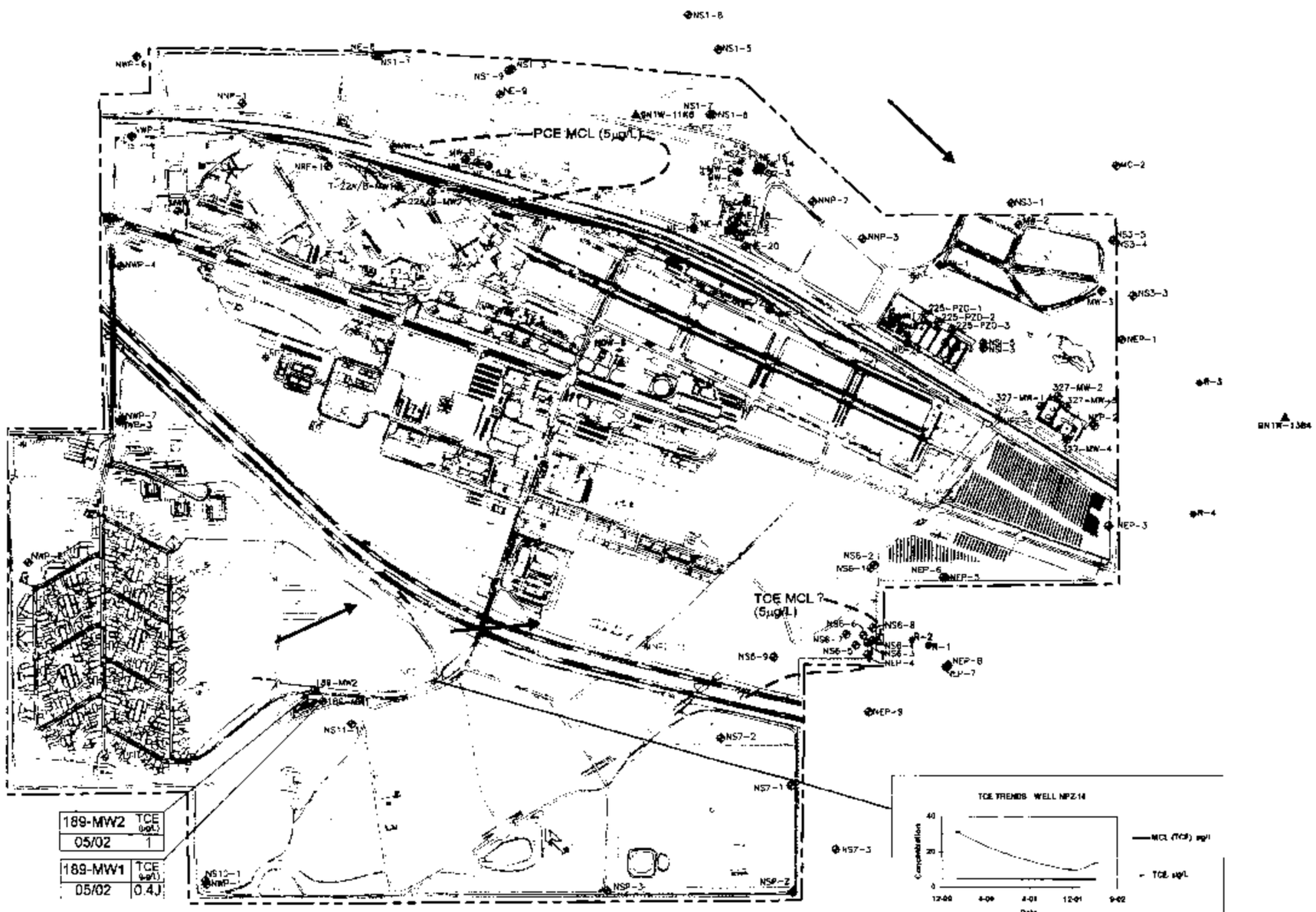

189-MW2	TCE (µg/L)
05/02	1

189-MW1	TCE (µg/L)
05/02	0.4J

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1988 BECHTEL 1999 (1998 RPA WORKPLAN) ORM 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING INC.

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- RESIDENTIAL WATER SUPPLY WELL
- BASE WATER SUPPLY WELL
- USGS WELLS
- BASE BOUNDARY
- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
VOC	VOLATILE ORGANIC COMPOUNDS
µg/L	MICROGRAMS PER LITER

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0 500 1000

FEET

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

NEBO MAIN BASE

VOCs AT NPZ-14

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED	DCN:	
CHECKED BY: JB	VH	FWSD-RAC-03-0116	
DATE: 12-06-02	VH	CTO: 0049	
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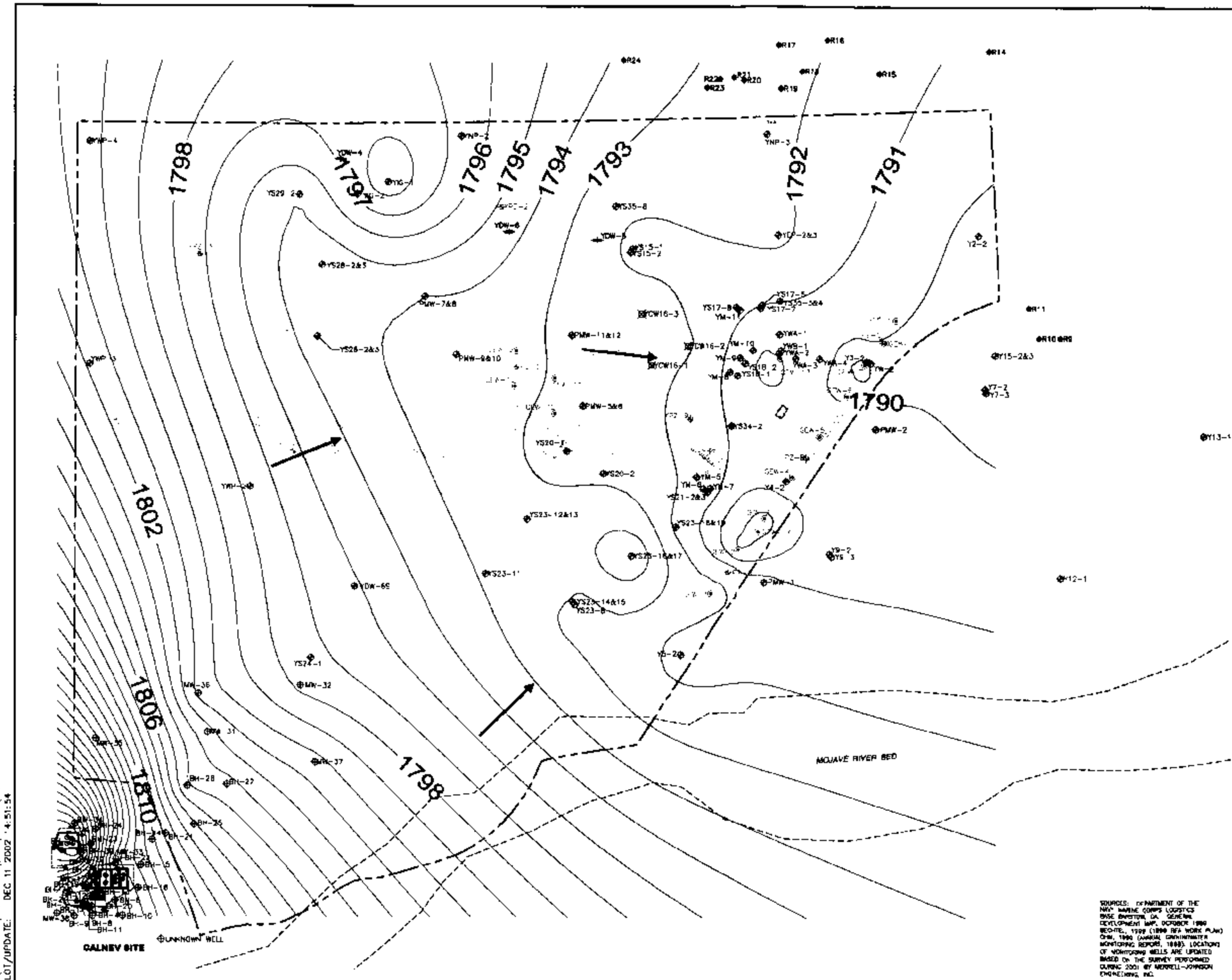

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- BASE BOUNDARY
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- RESIDENTIAL WATER SUPPLY WELL
- COMBINATION WELL
- CALNEY WELL
- —1796— GROUNDWATER ELEVATION CONTOUR (ELEVATION IN FEET AMSL)
- GENERALIZED GROUNDWATER FLOW DIRECTION

ABBREVIATIONS:

AMSL	ABOVE MEAN SEA LEVEL
GW	GROUNDWATER
FT	FEET

YERMO

GROUNDWATER ELEVATION IN SELECTED WELLS OCTOBER 2002

WELL	GW ELEVATION (IN FT. AMSL)
YCW16-2	1792.15
YS20-1	1792.53
YS23-11	1793.88
Y2-2	1795.73
GEW-7	1788.14
PZ-9	1793.43
Y8-3	1790.55
YS28-3	1794.57
*BH-7	1817.86
*BH-15	*811.79
*BH-28	*822.79
*MW-32	1797.75
*MW-34	*824.57

NOTE:

*DATA OBTAINED FROM GROUNDWATER ELEVATION MEASUREMENT AND INTERIM CORRECTIVE ACTION MEASURES REPORT THIRD QUARTER – 2002 FOR CALNEY SITE. (CH2MHILL, 2002)

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0 600 1200
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SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 (EC-ITE, 1989 (1989 RFA WORK PLAN) CH2M, 1990 (ANNUAL GROUNDWATER MONITORING REPORT, 1989). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
GROUNDWATER LEVEL MAP (OCTOBER 2002)
YERMO ANNEX
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MO	APPROVED:	DCN	
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DATE: 12-06-02	VH	CTO: 0049	
SIZE D	SCALE AS NOTED	DRAWING NO FIGURE 6-1	0

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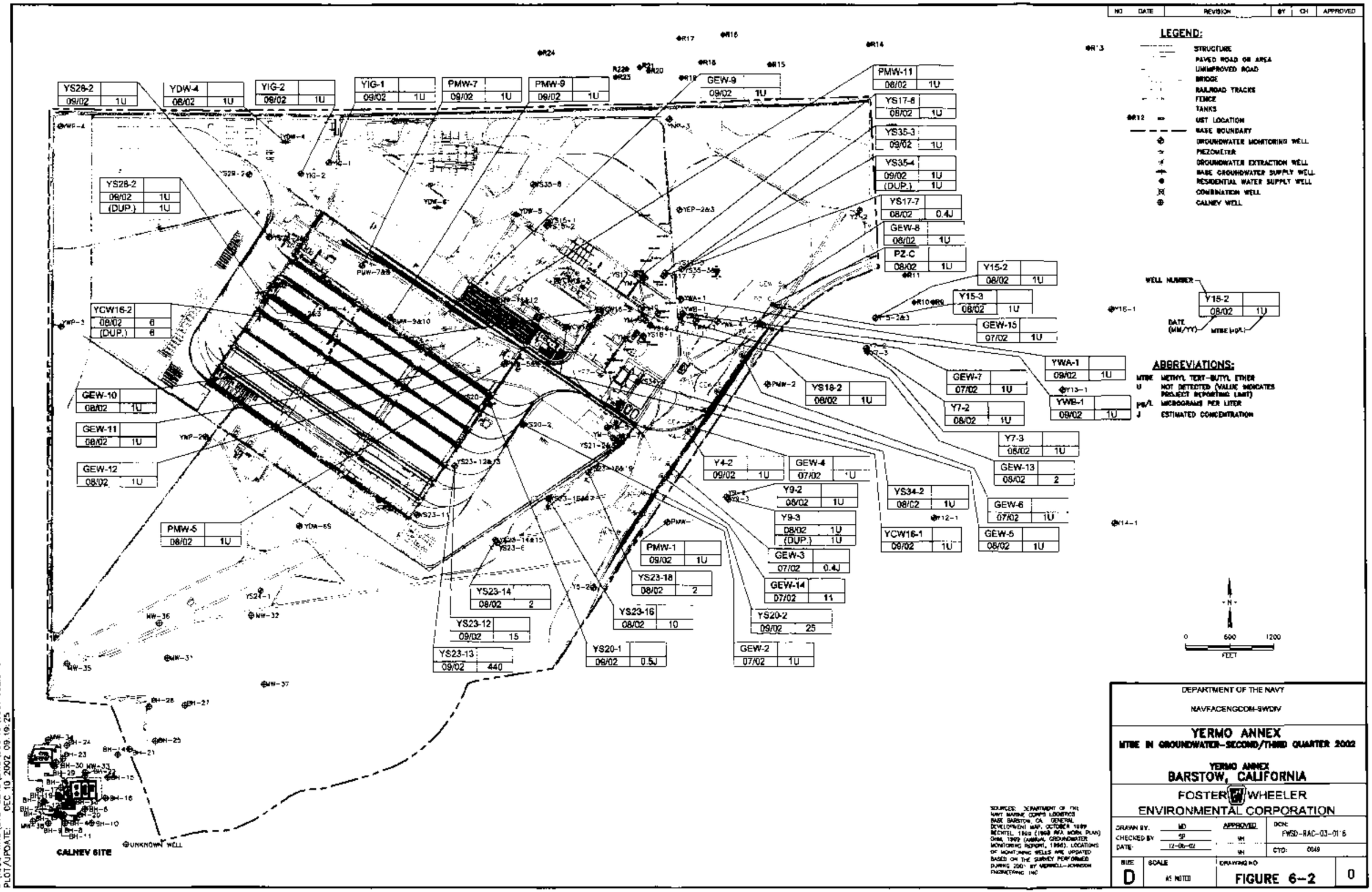

APPENDIX A

SUMMARY OF ANALYTICAL DATA - YERMO ANNEX

(This information is contained on the accompanying compact disk.)

APPENDIX A:
SUMMARY OF ANALYTICAL DATA -YERMO ANNEX

TABLE OF CONTENTS

Table A-l Yermo Annex -Analytical Results Summary for VOCs for Downgradient Plume Wells

Table A-2 Yermo Annex -Analytical Results Summary for General Chemistry Parameters for Downgradient Plume Wells

Table A-3 Yermo Annex -Analytical Results Summary for VOCs for System Performance Wells

Table A-4 Yermo Annex -Analytical Results Summary for General Chemistry Parameters for System Performance Wells

Table A-5 Yermo Annex -Analytical Results Summary for Metals for Metals Monitoring Wells

Table A-6 Yermo Annex -Analytical Results Summary for VOCs for Water Supply/ Recharge Wells

Table A-7 Yermo Annex -Analytical Results Summary for General Chemistry Parameters for Recharge Wells

Table A-8 Yermo Annex -Analytical Results Summary for VOCs for CAOC 20 Wells

Table A-9 Yermo Annex -Analytical Results Summary for Metals, General Chemistry Parameters, and Radiological Parameters for CAOC 20 Wells

Table A-10 Yermo Annex -Analytical Results Summary for VOCs for CAOC 23 Wells

Table A-11 Yermo Annex -Analytical Results Summary for General Chemistry Parameters for CAOC 23 Wells

Table A-12 Yermo Annex -Analytical Results Summary for VOCs for CAOC 35 Wells

Table A-13 Yermo Annex -Analytical Results Summary for General Chemistry Parameters for CAOC 35 Wells

NOTES FOR THE TABLES IN APPENDIX A

B	analyte detected in the associated blank (organic analysis)
B	detected concentration is between the Instrument Detection Limit (DDL) and Method Detection Limit (MDL) (inorganic analysis)
CAOC	CERCLA Area of Concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP VOA	Contract Laboratory Program -Volatile Organic Analysis
EPA	United States Environmental Protection Agency
FD	field duplicate
INF	influent
INT	intermediate
J	estimated value
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
µg/L	micrograms per liter
N	nitrogen
NA	not analyzed
NE	not established
OU	Operable Unit
pCi/L	picocuries per liter
R	rejected
U	not detected (value indicates detection limit)
U J	not detected at an estimated detection limit
VOC	volatile organic compound

APPENDIX B

SYSTEM PERFORMANCE SUMMARIES - CAOC 37 (OU 1) GROUNDWATER REMEDIATION SYSTEMS

(This information is contained on the accompanying compact disk.)

APPENDIX B:
SYSTEM PERFORMANCE SUMMARIES -CAOC 37 (OU 1) GROUNDWATER REMEDIATION SYSTEMS

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CLP VOA	Contract Laboratory Program - Volatile Organic Analysis
Cone.	concentration
Cum.	cumulative
DCE	dichloroethene
EPA	United States Environmental Protection Agency
FD	field duplicate ft feet
GAC	granular activated carbon
GETS	groundwater extraction and treatment system
gal	gallons
gpm	gallons per minute
hr	hour
hrs	hours
J	estimated value
J B	estimated value for the sample. Also detected in the blank
lbs	pounds
lbs/day	pounds per day
mg/L	milligrams per liter
µg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
MM gal	million gallons
MCLB	Marine Corps Logistics Base
MP	Monitoring point
MTBE	methyl tert-butyl ether
N	nitrogen
NA	not analyzed
NE	not established
O&M	operation and maintenance
OU	Operable Unit
PCE	tetrachloroethene (perchloroethene)
SCFM	standard cubic feet per minute
TCE	trichlorothene
TO	toxic organic
U	not detected (value indicates detection limit)
U J	not detected at an estimated detection limit
VEW	vapor extraction well
VOC	volatile organic compound vs. versus

APPENDIX C

SUMMARY OF ANALYTICAL DATA - NEBO MAIN BASE

(This information is contained on the accompanying compact disk.)

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B	analyte detected in the associated blank (organic analysis)
CLP VOA	Contract Laboratory Program - Volatile Organic Analysis
EPA	United States Environmental Protection Agency
FD	field duplicate
J	estimated value
J B	estimated value for the sample, also detected in the blank
MCL	maximum contaminant level
mg/L	milligrams per liter
µG/L	micrograms per liter
N	nitrogen
NA	not analyzed
NE	not established
OU	Operable Unit
R	rejected
U	not detected (value indicates detection limit)
U J	not detected at an estimated detection limit

APPENDIX D

ASSESSMENT OF EXPOSURE ASSUMPTIONS, TOXICITY DATA, CLEANUP LEVELS, AND RAOS FOR OU 1 THROUGH OU 6

Southwest Division
Naval Facilities Engineering Command
Contracts Department
1220 Pacific Highway, Building 127, Room 112
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CONTRACT NO. N68711-98-D-5713
CTO NO. 0049

APPENDIX D

ASSESSMENT OF EXPOSURE ASSUMPTIONS, TOXICITY DATA, CLEANUP LEVELS, AND RAOs FOR OU 1 THROUGH OU 6

Revision 0
December 2002

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

DCN: FWSD-RAC-03-0116

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ABBREVIATIONS AND ACRONYMS

ARAR	applicable or relevant and appropriate requirement
BMP	Base Master Plan
CAOC	CERCLA Area of Concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
4,4,4-DDD	l, l-dichloro-2-2-bis(4-chlorophenyl) ethane
DoN	Department of the Navy
DTSC	Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
FWENC	Foster Wheeler Environmental Corporation
GETS	Groundwater Extraction and Treatment System
IRIS	Integrated Risk Information System
JEG	Jacobs Engineering Group
MCL	maximum contaminant level
MCLB	Marine Corps Logistics Base
mg/kg	milligram per kilogram
MTBE	methyl-tert-butyl-ether
µg/L	micrograms per liter
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
OU	Operable Unit
PRG	preliminary remediation goal
RAO	Remedial Action Objective
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
TBC	to be considered
TPH	total petroleum hydrocarbons

1.0 INTRODUCTION

The work described in this Appendix was performed by Foster Wheeler Environmental Corporation (FWENC) to support the technical assessment of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Areas of Concern (CAOCs) under Operable Units (OUs) 1 through 6 at the Marine Corps Logistics Base (MCLB) Barstow.

As part of the technical assessment, Question B asks whether the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of the remedy are still valid. When evaluating this question, it is important to consider changes in standards, newly promulgated standards or "to be considered" (TBC) standards, changes in exposure pathways, changes in land use, or if any new contaminants and/or contaminant sources and/or remedy by-products have been identified. Question B will be answered by addressing the OUs as grouped within the Records of Decision (RODs).

Three RODs have been signed for OUs 1 through 6, as follows:

1. Requiring no further action

2. Requiring institutional controls to protect health and environment

3. Requiring cleanup, or remedial action

2.0 OPERABLE UNITS 1 AND 2

2.1 CHANGES IN ARARS AND TO-BE-CONSIDERED STANDARDS

Applicable or relevant and appropriate requirements (ARARs) provided in OU 1 and 2 were reviewed and evaluated to determine if any modifications of these ARARs had occurred that might affect the RAOs in the ROD or operation of the various groundwater treatment systems had occurred since the ROD was finalized.

Based on the evaluation, several of the chemical-specific ARARs (for example, federal or state drinking water maximum contaminant levels (MCLs), Lahontan Regional Water Quality Control Board (RWQCB) Basin Plan, or other RWQCB resolutions) originally cited in the ROD have been revised. These changes have the potential to affect the operation of the Groundwater Extraction and Treatment System (GETS) of OUs 1 and 2 and their associated discharges.

2.1.1 Changes in Maximum Contaminant Level Standards

Changes to the State of California primary drinking water standards have occurred since the publication of the *OUs 1 and 2 ROD* (JEG, 1998a). Neither methyl-tert-butyl ether (MTBE) nor ethylbenzene were originally presented in the *OUs 1 and 2 ROD* (JEG, 1998a) as having listed drinking water standards. MTBE is a chemical for which a new standard has been promulgated, while the standard for ethylbenzene was revised. In addition, secondary drinking water standards for these chemicals have also changed. In the ROD, non-zero secondary drinking water standards were determined to be an ARAR. Table D.2-1 lists constituents for which standards have changed. These revised standards have a limited effect on the protectiveness of the selected remedies within OUs 1 and 2. While MTBE has been detected in monitoring wells in the southwest portion of OU 1, the GETS has been upgraded to treat MTBE. The other constituents noted in Table D.2-1 are not typically present in the GETS influent.

2.1.2 Revisions to Waste Discharge Requirements for Land Disposal of Treated Groundwater

The California Regional Water Quality Control Board - Lahontan Region governs the discharge of treated groundwater through Board Order No. 6-93-106. This order was not considered to be a chemical-specific ARAR, but rather a "to-be-considered" (TBC) standard. TBCs are used to provide guidance in the protectivity of a remedy when an ARAR does not exist. The National Contingency Plan (NCP) Preamble states that TBCs, "should not be required as cleanup standards because they are, by definition, generally neither promulgated nor enforceable, so they do not have the same status under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as do ARARs."

Order No. 6-93-106 contains discharge specifications that include 30-day median and daily maximum values for chemical discharge and specifies a monitoring program. This order was amended by Order No. 6-93-106A1 in September 1999 and contains changes to detection limits of organic constituents, primary drinking water standards (MCLs), secondary drinking water standards, as well as changes to the 30-day Daily Median and Maximum discharge limits. Table D.2-2 details the changes in the amended order. Changes listed in Table D.2-1 that are repeated in the amended order have not been repeated in Table D.2-2. The changes in Table D.2-2 have no impact on the OU 1 and OU 2 GETS.

2.2 CHANGES IN EXPOSURE PATHWAYS

Land use throughout the areas impacted by the contaminants addressed by the OU 1 and 2 ROD has remained the same. No land use changes are expected in the future. If a land use change were to be proposed, sufficient information has been included in the Base Master Plan (BMP) to ensure that potential activities would not interfere with the remedies nor would they have the potential to cause risk to human health or the environment. In conjunction with this, no new human health or ecological routes of exposure or receptors have been identified.

Physical site conditions have been altered as a result of the operation of the various groundwater treatment systems. Groundwater flow velocities have slowed and have changed directionally. These changes were identified and actions were taken to install additional wells to monitor the plume migrations and size. Because these actions have been conducted and the plume characteristics are continually monitored, the remedies remain protective, and no additional measures are expected.

2.3 CHANGES IN TOXICITY AND OTHER CONTAMINANT CHARACTERISTICS

Three groundwater contaminants have undergone revisions for toxicity according to the Environmental Protection Agency's (EPA) Integrated Risk Information System (IRIS). These contaminants include carbon disulfide, chloroform, 1,1-dichloroethene. Reference doses and carcinogenicities were revised. These changes; however, are not expected to affect the protectiveness of the selected remedies within OU 1 and 2 due to the fact that MCLs are used as treatment standards.

3.0 OPERABLE UNITS 3 AND 4

The CERCLA Areas of Concern (CAOCs) in OUs 3 and 4 requiring review under the 5-Year Review process include two CAOCs where site actions were conducted (CAOCs 20 and 23) and five CAOCs where only BMP modifications were required (CAOCs 2, 5, 11, 18, and 34).

3.1 CHANGES IN ARARS AND TO-BE-CONSIDERED STANDARDS

ARARs and TBC standards for OUs 3 and 4 were reviewed and evaluated to determine if any modifications had occurred that might affect the remedial action objectives as stated in the ROD or the protectiveness of the remedy.

Based on the evaluation, several of the chemical-specific ARARs (for example, federal or state drinking water MCLs, RWQCB Lahontan Region Basin Plan, or other RWQCB resolutions) originally cited in the ROD have changed. However, these changes do not affect the protectiveness of the remedy under OUs 3 and 4 because groundwater is being addressed separately under OUs 1 and 2. None of the location-specific ARARs including the Endangered Species and Migratory Bird Acts, and the Archaeological and Historical Preservation Act provisions of the ROD have changed since the ROD was finalized. In addition, the action-specific ARARs cited in the ROD, which relate to landfill closure and discharges from waste to land, have not changed in a manner that affects the protectiveness of the remedy.

3.2 CHANGES IN EXPOSURE PATHWAYS

Land use throughout the areas impacted by the contaminants addressed by the *OUs 3 and 4 ROD* (JEG, 1997) has remained the same since the ROD was finalized. No land use changes are expected in the future. If a land use change or on-site construction were to be proposed, sufficient information has been included in the BMP to ensure that potential activities would not interfere with the remedies nor would they have the potential to cause risk to human health or the environment.

3.3 CHANGES IN TOXICITY AND OTHER CONTAMINANT CHARACTERISTICS

All of the contaminants with OU 3 and 4 were reviewed against IRIS to determine if any revisions in toxicity or carcinogenicity had occurred that could potentially affect the protectiveness of the remedy. Nineteen (19) chemical constituents indicated revisions. The concentrations of these chemical constituents remaining in the soil were compared to the Preliminary Remediation Goals (PRGs) developed by EPA Region 9. The PRGs were used as a tool to judge whether there was the potential that a remedy was no longer protective. The results are detailed below.

3.3.1 CAOC 2

Arsenic exceeds both the residential and industrial PRGs for soil as shown in Table D.3-1. l, l-dichloro-2-2-bis(4-chlorophenyl) ethane (4,4,4-DDD) and manganese both exceed the residential PRGs for soil. A removal action was conducted to excavate the most contaminated soils from the CAOC. Both arsenic and manganese are believed to be naturally occurring metals and the pesticide concentration is consistent with that found basewide. Groundwater is being addressed under OUs 1 and 2. Construction activities require notification of the MCLB Barstow Environmental Department. For these reasons, the remedy remains protective of human health and the environment.

3.3.2 CAOC 5

Arsenic was the only constituent which exceeded its PRG as shown in Table D.3-2. Because metals at this site are believed to be naturally occurring, and construction activities require notification of the MCLB Barstow Environmental Department, the remedy remains protective of human health and the environment.

3.3.3 CAOC 11

Arsenic exceeded both its residential and industrial PRGs. Benzo(a) pyrene and 4,4,4-DDE both exceeded their respective residential PRGs as shown in Table D.3-3. Only one detection of Benzo(a) pyrene was present at the site and arsenic was not considered site related by the ROD. In addition, pesticide levels were consistent with that which is found throughout the base. Construction activities require notification of the MCLB Barstow Environmental Department. Because of these reasons, as well as the fact that the site is currently unoccupied, with no future plans to occupy, the remedy remains protective of human health and the environment.

3.3.4 CAOC 18

Arsenic exceeded both its residential and industrial soil PRGs as shown in Table D.3-4. Aroclor 1260 exceeded the residential soil PRG. According to the ROD arsenic was not considered site-related and detections of PCBs were below the EPA guidance level of 1 milligram per kilogram (mg/kg) for a residential land-use scenario. In addition, Site 18 is currently unoccupied property with no plans for future usage. Construction activities require notification of the MCLB Barstow Environmental Department. Because of these reasons, the remedy remains protective of human health and the environment.

3.3.5 CAOC 20

Arsenic was the only contaminant which exceeded the residential and industrial soil PRGs as shown in Table D.3-5. Because the concrete cap and existing final cover, which is equivalent to an engineered cap, are considered the presumptive remedy, changes in toxicity are not applicable. The remedy remains protective of human health and the environment.

3.3.6 CAOC 23

Arsenic and Aroclor 1254 both exceeded their respective PRGs as shown in Table D.3-6. Because a concrete cap was placed over the CAOC, the remedy remains protective of human health and the environment.

3.3.7 CAOC 34

Aroclor 1260, arsenic, and benzo[a] pyrene exceeded residential and industrial PRGs as shown in Table D.3-7. A removal action was conducted to remove the most contaminated soils and the foundation of the new waste water treatment plant covers CAOC 34 soils. Therefore potential future exposures have been eliminated. Additionally, the BMP has been amended to indicate that low levels of benzo[a] pyrene remain in soils beneath the treatment plant. Construction activities require notification of the MCLB Barstow Environmental Department. Because these measures have been taken, the remedy remains protective of human health and the environment.

4.0 OPERABLE UNITS 5 AND 6

The CAOCs in OUs 5 and 6 requiring review under the 5-Year Review process include two CAOCs where site actions were conducted (CAOCs 7 and 35) and seven CAOCs where only BMP modifications were required (CAOCs 1, 3, 7, 14, 15/17, 16, 21, 26, and 35).

4.1 CHANGES IN ARARS AND TO-BE-CONSIDERED STANDARDS

ARARs and TBC standards for OUs 5 and 6 were reviewed and evaluated to determine if any modifications had occurred that might affect the remedial action objectives as stated in the ROD or the protectiveness of the remedy.

Based on the evaluation, several of the chemical-specific ARARs (for example, federal or state drinking water MCLs, RWQCB Lahontan Region Basin Plan, or other RWQCB resolutions originally cited in the ROD have changed. However, these changes do not affect the protectiveness of the remedy under OUs 5 and 6 because groundwater is being addressed separately under OUs 1 and 2. None of the location-specific ARARs including the Endangered Species and Migratory Bird Acts, and the Archaeological and Historical Preservation Act provisions of the ROD have changed since the ROD was finalized. In addition, the action-specific ARARs cited in the ROD, which relate to landfill closure and discharges from waste to land, have not changed in a manner that affects the protectiveness of the remedy.

4.2 CHANGES IN EXPOSURE PATHWAYS

Land use throughout the areas impacted by the contaminants addressed by the *OUs 5 and 6 ROD* (JEG, 1998b) has remained the same since the ROD was finalized. No land use changes are expected in the future. If a land use change were to be proposed, sufficient information has been included in the BMP to ensure that potential activities would not interfere with the remedies nor would they have the potential to cause risk to human health or the environment.

In the ROD, CAOC 7 was considered to have the potential to have significant impacts to burrowing animals, including the desert tortoise, a federally threatened species. Because of this, a tortoise-proof fence was installed surrounding the base of the existing Nebo Main Base perimeter fence as well as the fence surrounding the landfill. During a site visit, it was noted that the tortoise fence is no longer secure in many areas and could allow tortoises to pass through and have access to the landfill. It is recommended that the tortoise-proof fence be repaired to prevent this exposure pathway.

4.3 CHANGES IN TOXICITY AND OTHER CONTAMINANT CHARACTERISTICS

All of the contaminants with OU 3 and 4 were reviewed against IRIS to determine if any revisions in toxicity or carcinogenicity had occurred that could potentially affect the protectiveness of the remedy. Nineteen (19) chemical constituents indicated revisions. The concentrations of these chemical constituents remaining in the soil were compared to the PRGs developed by EPA Region 9. The PRGs were used as a tool to judge whether there was the potential that a remedy was no longer protective. The results are detailed below.

4.3.1 CAOC 1 - Landfill North of the Golf Course

Arsenic and benzo[a] pyrene both exceed their respective residential and industrial PRGs as shown in Table D.4-1. The arsenic was not considered to be site-related and the benzo[a] pyrene was thought to be related to the disposal of asphalt at the CAOC. The BMP was amended to include a description of the benzo[a] pyrene and indicates that any future actions must be coordinated through the MCLB Barstow Environmental Department. For these reasons, the remedy remains protective of human health and the environment.

4.3.2 CAOC 3 - Wastewater Disposal Area

Arsenic is the only constituent which exceeds its residential or industrial PRG as shown in Table D.4-2. The ROD states that all metals were believed to be naturally occurring, therefore, the remedy remains protective of human health and the environment.

4.3.3 CAOC 7 - Drum Storage and Landfill Areas

Aroclor 1254 and Arsenic both exceed their respective residential and industrial soil PRGs as shown in Table D.4-3. Because the remedy includes a cap, which is considered a presumptive remedy, the changes in toxicity are not applicable. The remedy remains protective of human health and the environment.

4.3.4 CAOC 14 - Drainage Channels and Mojave Riverbed Outfalls

Aroclor 1260, arsenic, and benzo[a] pyrene all exceeded their respective residential and industrial soil PRGs as shown in Table D.4-4. Arsenic was considered to be naturally occurring. PCB detections were all below the EPA guidance level of 1 mg/kg for residential soils. The benzo[a] pyrene was considered low-level and therefore was noted in the BMP. Construction activities require notification of the MCLB Barstow Environmental Department. For these reasons, the remedy remains protective of human health and the environment.

4.3.5 CAOC 15/17 - Oil Storage/Spillage and Industrial Wastewater Treatment Plant Areas

Both arsenic and hexavalent chromium exceed their respective residential and industrial soil PRGs as shown in Table D.4-5. In addition, benzo[a] pyrene exceeds its residential soil PRO. The arsenic was considered to be naturally occurring. This site is currently unoccupied and there are no plans for future usage. Because of these factors, the low levels of contaminants remaining on site and the depths at which they are present reduces the potential for on-site exposure. Construction activities require notification of the MCLB Barstow Environmental Department. For these reasons, the remedy remains protective of human health and the environment.

4.3.6 CAOC 16 - Building 573 and Perimeter Area

Analytical data were not available for CAOC 16 due to the nature of the site. Maintenance operations are ongoing and a building was placed over the contaminated area. Construction activities require notification of the MCLB Barstow Environmental Department. The maintenance of a stable surface environment over the suspected contamination allows the remedy to maintain protectiveness towards human health and the environment.

4.3.7 CAOC 21 - Industrial Waste Disposal Area

Arsenic and Aroclor 1260 were both present at levels greater than their respective residential and industrial PRGs as shown in Table D.4-6. 4,4,4-DDD was present at levels exceeding its residential soil RBC. A removal action was completed to address residual PCB contamination. All soils at concentrations greater than 1 mg/kg (EPA's guidance level) were excavated and disposed of. The Arsenic was believed to be naturally occurring. Pesticide detections were consistent with those found throughout the base. In addition, CAOC 21 is currently unoccupied property with no existing structures or facilities which greatly reduces any potential for on-site human exposure. Construction activities require notification of the MCLB Barstow Environmental Department. For these reasons, the remedy remains protective of human health and the environment.

4.3.8 CAOC 26 - Building 533 Waste Disposal Area

Only arsenic exceeded its residential and industrial soil PRGs as shown in Table D.4-7; however, it was believed that it was naturally occurring. Construction activities require notification of the MCLB Barstow Environmental Department. Concerns regarding the potential for vapor-phase contaminants to escape from the subsurface and impact future on-site receptors led to an amendment of the BMP. System performance monitoring and ambient air sampling show the potential hazards do not exist thus far. Because of this, the remedy remains protective of human health and the environment. Appendix E includes modeling of impacts (both to aboveground receptors and groundwater) of vapor-phase contamination.

4.3.9 CAOC 35 - Class III Landfill

Both arsenic and Aroclor 1242 exceed their respective residential and industrial soil PRGs as shown in Table D.4-8. Benzo[a] pyrene exceeds its residential soil PRO. Because the cap is considered the presumptive remedy, changes in toxicity are not applicable and the remedy remains protective of human health and the environment. The cap is inspected on a regular basis and maintained.

5.0 REFERENCES

Jacobs Engineering Group (JEG). 1997. *Operable Units 3 and 4, Final Record of Decision Report.* June.

JEG. 1998a. *Operable Units 1 and 2, Final Record of Decision Report*. April.

JEG. 1998b. *Operable Units 5 and 6, Record of Decision Report*. January.

TABLES

TABLE D.2-1

CHANGES TO MCLs APPLICABLE TO GROUNDWATER AT OU 1 AND 2

Chemical Constituent	Standard Type	Previous Standard (μg/L)	Current Standard (μg/L)
MTBE	Primary	None	13
Ethylbenzene	Primary	1760 (not included in the ROD)	700
MTBE	Secondary	None	5[1]
TPH (C2-C15)	Secondary	Not included in ROD	50[1]
TPH (C16-46)	Secondary	Not included in ROD	100[1]
Ethylbenzene	Secondary	Not included in ROD	29[1]

Notes:

MTBE – methyl tert-butyl ether

μg/L – micrograms per liter

MCL – maximum contaminant level

OU – Operable Unit

ROD – Record of Decision

TPH – total petroleum hydrocarbons

1 – taste and odor threshold

TABLE D.2-2

CHANGES TO ORDER NO. 6-93-106 BY AMENDED ORDER 6-93-106A1

Standard	Chemical Constituent	Previous Standard (mg/L)	Current Standard (μg/L)
Detection limits for constituents in treated water	Benzene	0.5 mg/L	0.1
Detection limits for constituents in treated water	MTBE	40 mg/L	0.5
Detection limits for constituents in treated water	TBA	None	5.0
Discharge limitations	TPH (C2-C15)	<50 for TPH (C2-46) 30-day median 100 for TPH (C2-C46) daily maximum	<50 30-day median 50 – daily maximum
Discharge limitations	TPH (C16-C46)	<50 for TPH (C2-46) 30 day median 100 for TPH (C2-C46) daily maximum	< 50 30-day median 100 daily maximum
Discharge limitations	MTBE	<40 30-day median 40 daily maximum	<0.5 30-day median 5 –daily maximum
Discharge limitations	TBA	None	<5 30-day median 50 daily maximum

Notes:

MTBE – *methyl tert-butyl ether*

μg/L – micrograms per liter

mg/L – milligrams per liter

TBA – Tertiary butyl alcohol

TPH – Total Petroleum Hydrocarbons

TABLE D.3-1

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 2

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs (mg/kg)	Concentration at 3-13 feet bgs (mg/kg)	Concentration at below 13 feet bgs(mg/kg)
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**17.6**	**12.1**	**2.1**
Barium	5,400 non-cancer	100,000 non-cancer	207	192	68.3
Beryllium	150 non-cancer	2,200 non-cancer	1.2	0.91	0.61
Boron	5,500 non-cancer	79,000 non-cancer	88.2	75.3	24.8
Carbon disulfide	360 non-cancer	720 non-cancer	0.0011	NA	0.0011
Chromium	210 cancer	450 cancer	22	20.6	8.4
4,4,4-DDD	2.4 cancer	17 cancer	**4.490**	0.00072	NA
Manganese	1,800 non-cancer	32,000 non-cancer	**11,000**	**3,440**	1,520
Mercury	23 non-cancer	610 non-cancer	0.05	NA	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.3-2

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 5

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Aroclor 1260	0.22 cancer	1.0 cancer	NA	0.180	NA
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**5.06**	**7.3**	**5.0**
Barium	5,400 non-cancer	100,000 non-cancer	100	369	71.2
Beryllium	150 non-cancer	2,200 non-cancer	0.45	0.67	0.28
Boron	5,500 non-cancer	79,000 non-cancer	57.4	46.9	41.7
Chloroform	0.24 cancer	0.52 cancer	NA	0.003	NA
Chromium	210 cancer	450 cancer	14.1	25.1	52.5
4,4,4-DDD	2.4 cancer	17 cancer	NA	**23**	NA
Manganese	1,800 non-cancer	32,000 non-cancer	243	354	189
Mercury	23 non-cancer	610 non-cancer	0.334	0.229	0.104

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.3-3

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 11

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**4.2**	**2.61**	**2.91**
Barium	5,400 non-cancer	100,000 non-cancer	616	105	132
Benzo[a]pyrene	0.062 cancer	0.29 cancer	**0.062**	NA	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.53	0.73	0.50
Boron	5,500 non-cancer	79,000 non-cancer	15.3	25.7	4
Chromium	210 cancer	450 cancer	14.6	14.5	30.4
4,4,4-DDD	2.4 cancer	17 cancer	**2.9**	NA	NA
Manganese	1,800 non-cancer	32,000 non-cancer	303	238	296
Mercury	23 non-cancer	610 non-cancer	1.4	NA	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.3-4

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 18

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Aroclor 1254	0.22 cancer	1.0 cancer	NA	NA	0.0056
Aroclor 1260	0.22 cancer	1.0 cancer	**0.0468**	NA	NA
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**10.2**	**4.5**	**2.1**
Barium	5,400 non-cancer	100,000 non-cancer	169	114	86.5
Benzo[a]pyrene	0.062 cancer	0.29 cancer	0.0338	NA	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.97	0.87	0.95
Boron	5,500 non-cancer	79,000 non-cancer	48.9	30.8	45.3
Carbon disulfide	360 non-cancer	720 non-cancer	0.001	NA	NA
Chromium	210 cancer	450 cancer	16.4	15.9	11.1
4,4,4-DDD	2.4 cancer	17 cancer	0.00026	NA	0.00012
Manganese	1,800 non-cancer	32,000 non-cancer	224	303	472
Mercury	23 non-cancer	610 non-cancer	0.01	NA	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.3-5

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 20

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**2.6**	**3.5**	**9.17**
Barium	5,400 non-cancer	100,000 non-cancer	235	39.8	114
Beryllium	150 non-cancer	2,200 non-cancer	0.743	NA	0.849
Boron	5,500 non-cancer	79,000 non-cancer	16.3	NA	4.3
Chromium	210 cancer	450 cancer	12.9	4.44	16.2
Manganese	1,800 non-cancer	32,000 non-cancer	286	99.8	617
Mercury	23 non-cancer	610 non-cancer	ND	ND	0.0573

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

ND – non detectable

PRG – Preliminary Remediation Goal

TABLE D.3-6

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 23

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Aroclor 1254	0.22 cancer	1.0 cancer	**0.251**	**0.776**	ND
Aroclor 1260	0.22 cancer	1.0 cancer	0.100	ND	ND
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**5**	**17.3**	**5.7**
Barium	5,400 non-cancer	100,000 non-cancer	471	428	153
Beryllium	150 non-cancer	2,200 non-cancer	0.70	0.50	1.4
Boron	5,500 non-cancer	79,000 non-cancer	40.2	27.4	120
Carbon disulfide	360 non-cancer	720 non-cancer	ND	0.001	ND
Chromium	210 cancer	450 cancer	20	11	29.1
4,4,4-DDD	2.4 cancer	17 cancer	0.059	0.074	ND
Manganese	1,800 non-cancer	32,000 non-cancer	753	216	686
Mercury	23 non-cancer	610 non-cancer	0.09	0.22	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

ND – non detectable

PRG – Preliminary Remediation Goal

TABLE D.3-7

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 34

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Aroclor 1260	0.22 cancer	1.0 cancer	**2.5**	**0.310**	NA
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**3.5**	**3.5**	**37**
Barium	5,400 non-cancer	100,000 non-cancer	120	110	118
Benzo[a]pyrene	0.062 cancer	0.29 cancer	**1.600**	NA	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.36	0.65	0.86
Boron	5,500 non-cancer	79,000 non-cancer	10.4	8.6	11.9
Carbon disulfide	360 non-cancer	720 non-cancer	NA	2	NA
Chromium	210 cancer	450 cancer	44.4	45.6	22.7
4,4,4-DDD	2.4 cancer	17 cancer	0.084	0.0063	NA
Manganese	1,800 non-cancer	32,000 non-cancer	174	598	430
Mercury	23 non-cancer	610 non-cancer	0.49	NA	0.11

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.4-1

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 1

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Aroclor 1254	0.22 cancer	1.0 cancer	0.100	NA	NA
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**7.6**	**6.2**	NA
Barium	5,400 non-cancer	100,000 non-cancer	197	133	NA
Benzo[a]pyrene	0.062 cancer	0.29 cancer	**0.580**	NA	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.65	0.41	NA
Boron	5,500 non-cancer	79,000 non-cancer	65.6	31.2	NA
Chromium	210 cancer	450 cancer	19.1	17.2	NA
4,4,4-DDD	2.4 cancer	17 cancer	0.011	NA	NA
Manganese	1,800 non-cancer	32,000 non-cancer	615	501	NA
Mercury	23 non-cancer	610 non-cancer	0.13	NA	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.4-2

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 3

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**7.7**	**5.6**	NA
Barium	5,400 non-cancer	100,000 non-cancer	234	162	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.91	0.85	NA
Boron	5,500 non-cancer	79,000 non-cancer	57	43.5	NA
Chromium	210 cancer	450 cancer	17.6	24.3	NA
4,4,4-DDD	2.4 cancer	17 cancer	0.0041	NA	NA
Manganese	1,800 non-cancer	32,000 non-cancer	556	569	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.4-3

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 7

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Aroclor 1254	0.22 cancer	1.0 cancer	**2.700**	NA	NA
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**7.4**	NA	**5.1**
Barium	5,400 non-cancer	100,000 non-cancer	358	NA	1560
Benzene	0.65 cancer	1.5 cancer	0.001	NA	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.55	NA	0.67
Boron	5,500 non-cancer	79,000 non-cancer	88.3	NA	NA
Chromium	210 cancer	450 cancer	84.5	NA	32.6
4,4,4-DDD	2.4 cancer	17 cancer	0.390	NA	NA
Manganese	1,800 non-cancer	32,000 non-cancer	570	NA	309
Mercury	23 non-cancer	610 non-cancer	0.34	NA	0.19

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.4-4

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 14

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet (bgs)	Concentration at 3-13 feet (bgs)	Concentration at below 13 feet (bgs)
Aroclor 1254	0.22 cancer	1.0 cancer	0.043	NA	NA
Aroclor 1260	0.22 cancer	1.0 cancer	**0.330**	NA	NA
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**6**	NA	NA
Barium	5,400 non-cancer	100,000 non-cancer	144	NA	NA
Benzo[a]pyrene	0.062 cancer	0.29 cancer	**0.380**	NA	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.59	NA	NA
Boron	5,500 non-cancer	79,000 non-cancer	34.9	NA	NA
Chromium	210 cancer	450 cancer	37.3	NA	NA
4,4,4-DDD	2.4 cancer	17 cancer	0.160	NA	NA
Manganese	1,800 non-cancer	32,000 non-cancer	532	NA	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.4-5

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 15/17

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Aroclor 1260	0.22 cancer	1.0 cancer	0.052	NA	NA
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**3.6**	**5.4**	NA
Barium	5,400 non-cancer	100,000 non-cancer	100	131	NA
Benzo[a]pyrene	0.062 cancer	0.29 cancer	NA	**0.078**	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.67	NA	NA
Boron	5,500 non-cancer	79,000 non-cancer	7.4	25.3	NA
Chromium	210 cancer	450 cancer	79.5	14.9	NA
Chromium VI	0.2 cancer (CAL-Modified PRG)	64 cancer	**0.96**	**12.3**	NA
Manganese	1,800 non-cancer	32,000 non-cancer	336	350	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.4-6

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 21

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Aroclor 1260	0.22 cancer	1.0 cancer	0.120	**5.712**	NA
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**10**	**2.7**	**11.5**
Barium	5,400 non-cancer	100,000 non-cancer	359	184	116
Benzo[a]pyrene	0.062 cancer	0.29 cancer	NA	NA	0.052
Beryllium	150 non-cancer	2,200 non-cancer	1.1	0.48	0.95
Boron	5,500 non-cancer	79,000 non-cancer	81.1	47.1	113
Chloroform	0.24 cancer	0.52 cancer	NA	NA	0.002
Chromium	210 cancer	450 cancer	23.1	12.10	24
4,4,4-DDD	2.4 cancer	17 cancer	**6.8**	**3.5**	NA
Manganese	1,800 non-cancer	32,000 non-cancer	684	332	653
Mercury	23 non-cancer	610 non-cancer	0.64	NA	NA
Phosphoric Acid, Dioctadecyl	None	None	NA	NA	1.3468

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.4-7

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 26

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**5.5**	**1.4**	NA
Barium	5,400 non-cancer	100,000 non-cancer	114	66.8	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.53	0.24	NA
Boron	5,500 non-cancer	79,000 non-cancer	26.7	12.8	NA
Chromium	210 cancer	450 cancer	18.1	5.1	NA
Manganese	1,800 non-cancer	32,000 non-cancer	253	69.4	NA
Mercury	23 non-cancer	610 non-cancer	0.1	NA	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

TABLE D.4-8

COMPARISON OF PRGs VERSUS REMAINING CONSTITUENT CONCENTRATIONS AT CAOC 35

Constituent	Residential Soil PRG (mg/kg)	Industrial Soil PRG (mg/kg)	Concentration at 0-3 feet bgs	Concentration at 3-13 feet bgs	Concentration at below 13 feet bgs
Aroclor 1242	0.22 cancer	1.0 cancer	NA	NA	**4.0**
Arsenic	22 non-cancer 0.39 cancer	440 non-cancer 2.7 cancer	**3**	**2.1**	**3.2**
Barium	5,400 non-cancer	100,000 non-cancer	95.9	69.2	125
Benzo[a]pyrene	0.062 cancer	0.29 cancer	NA	**0.082**	NA
Beryllium	150 non-cancer	2,200 non-cancer	0.40	NA	0.40
Boron	5,500 non-cancer	79,000 non-cancer	12.4	NA	14.3
Chromium	210 cancer	450 cancer	9	19.2	12.7
Manganese	1,800 non-cancer	32,000 non-cancer	411	181	286
Mercury	23 non-cancer	610 non-cancer	0.74	NA	NA
Naphthalene	56 non-cancer	190 non-cancer	NA	0.360	NA

Notes:

bgs – below ground surface

CAOC – Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern

4,4,4-DDD – 1,1-dichloro-2-2-bis(4-chlorophenyl)ethane

mg/kg – milligrams per kilogram

NA – not applicable

PRG – Preliminary Remediation Goal

APPENDIX E

CAOC 26 ASSESSMENT

Southwest Division
Naval Facilities Engineering Command
Contracts Department
1220 Pacific Highway, Building 127, Room 112
San Diego, California 92132-5190

CONTRACT NO. N68711-98-D-5713
CTO NO. 0049

APPENDIX E

CAOC 26 ASSESSMENT

Revision 0
December 2002

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

DCN: FWSD-RAC-03-0116

FOSTER WHEELER ENVIRONMENTAL CORPORATION
1230 Columbia Street, Suite 500
San Diego, CA 92101

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ABBREVIATIONS AND ACRONYMS

˚C	degrees Celsius
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter
AS	air sparging
bgs	below ground surface
CAOC	CERCLA Area of Concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cis-l, 2-DCE	cis-l,2-dichloroethylene
cm	centimeters
cm^3/cm^3	cubic centimeter per cubic centimeter
days/yr	days per year
DCBM	dibromochloromethane
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
ft^3	cubic feet
ft^3/min	cubic feet per minute
FWENC	Foster Wheeler Environmental Corporation
g/cm^3	grams per cubic centimeter
g/yr	grams per year
gm/cm-s^2	grams per centimeter per square second
GSC	General Sciences Corporation
HI	hazard index
HQ	hazard quotient
JEG	Jacobs Engineering Group
JVIM	Johnson and Ettinger Vapor Intrusion Model
kg/hr	kilograms per hour
kg/m^3	kilograms per cubic meters
lbs	pounds
m	meters
m/s	meters per second
m^2	square meters
m^3/kg	cubic meters per kilogram
mg/kg	milligrams per kilogram
mg/m^3	milligrams per cubic meter
N/A	not applicable
NA	not available
NC	non-carcinogen
NRCS	Natural Resources Conservation Service
OU	Operable Unit
PCE	tetrachloroethene

ABBREVIATIONS AND ACRONYMS
(Continued)

ppb	parts per billion
RfC	reference concentration
ROD	Record of Decision
S	sand
scfm	standard cubic feet minute
SVE	soil vapor extraction
SVMP	soil vapor monitoring probe
TCE	trichloroethene
TEF	Technical and Economic Feasibility
URi	inhalation unit risk
URF	unit risk factor
VOC	volatile organic compound

1.0 INTRODUCTION

This appendix has been prepared in support of the technical assessment of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Area of Concern (CAOC) 26 air sparging/soil vapor extraction (AS/SVE) system.

1.1 BACKGROUND

CAOC 26 encompasses a packaging and maintenance shop (Building 533) and the area around it (see Figure E.1-1). Both vadose zone and groundwater at CAOC 26 were contaminated with volatile organic compounds (VOCs). The soil portion of CAOC 26 is covered under Operable Unit (OU) 5 and OU 6. The *OUs 5 and 6, Final Record of Decision (ROD) Report* [Jacobs Engineering Group (JEG), 1998a] states that the "No Action" alternative was selected for the soils at CAOC 26. The groundwater portion of CAOC is covered under OU 1. As noted in the *OUs 1 and 2 ROD* (JEG, 1998b) the remedy for the groundwater at OU 1 consists of groundwater extraction at the Base boundary and downgradient of CAOC 26. The CAOC 26 AS/SVE system was installed to reduce contaminant mass in the vadose and saturated zones near and downgradient of CAOC 26.

1.1.1 CAOC 26 AS/SVE System Description

AS/SVE consists of injecting air into the saturated zone to treat the contaminated groundwater. The air injected into the saturated zone by means of AS wells "strips" the VOCs from the groundwater and transfers the VOC vapors to the unsaturated zone (vadose zone). The VOC-laden vapors are extracted from the vadose zone by the SVE wells and processed through a VOC treatment system prior to discharge to the atmosphere. The SVE wells also extract existing VOCs from the vadose zone, if any.

The CAOC 26 AS/SVE system consists of the following:

- Five dual-depth clustered AS wells, screened from approximately 180 to 185 feet below ground surface (bgs), and from approximately 205 to 210 feet bgs
- Seven SVE wells screened from 135 to 155 feet bgs
- Seven triple-completion soil vapor monitoring probes (SVMPs) with vapor sampling screens at 30, 60, and 90 feet bgs
- An air compressor (to inject air) rated for 250 standard cubic feet minute (scfm)
- An extraction blower (to extract soil vapor) rated for 1,400 scfm
- Vapor-phase treatment system consisting of two vapor phase granular activated carbon vessels [1,800 pounds (lbs) each] in series to treat VOCs in the extracted soil vapor, prior to discharge to the atmosphere

Figure E.l-2 shows a schematic of the AS/SVE process and the CAOC 26 AS/SVE system.

1.1.2 Operation

Operation of the CAOC 26 AS/SVE system first started in December 1996 and continued through December 1998. The CAOC 26 AS/SVE system was shut down on various occasions throughout its 2 years of operation, and was operated for a total of 18 months during the 2-year operational period. As of December 1998, approximately 1,140 lbs of VOCs were removed from the subsurface. These consisted of approximately 265.5 lbs of trichloroethene (TCE), 858.5 lbs of tetrachloroethene (PCE), and 16.0 lbs of cis-l,2-dichloroethylene (cis-l,2-DCE).

The CAOC 26 AS/SVE system has not been in operation since 1998. Approval for ceasing operation was obtained via the *Draft Final CAOC 26 Technical and Economic Feasibility (TEF) Report* (CAOC 26 TEF Report) [Foster Wheeler Environmental Corporation (FWENC), 2000].

1.1.3 Soil Vapor Sampling

As noted in the *CAOC 26 TEF Report* (FWENC, 2000), soil vapor samples from the soil vapor probes are collected annually (see Appendix B for results). An increase in VOCs was noted in 2001, but was of a low magnitude relative to VOC levels prior to system startup.

1.2 ASSESSMENT APPROACH

The assessment approach for CAOC 26 consists of the following three elements:

1. Evaluation of the impact of increase in VOCs in the shallow probes to potential aboveground receptors - the Johnson and Ettinger Vapor Intrusion Model (JVIM) [U.S. Environmental Protection Agency (EPA), 2001] was used to quantify this impact.

2. Ability of existing SVE wells to extract vapor from shallow soils - flow channel modeling was used to evaluate this.

3. Evaluation of impact of increase in VOCs in deep probes to groundwater - the SESOIL model was used to quantify the impact.

The evaluations are discussed in Sections 2.0, 3.0, and 4.0, respectively.

2.0 JOHNSON AND ETTINGER VAPOR INTRUSION MODEL

2.1 INTRODUCTION

The JVIM was used to calculate potential risk for a worker at the site exposed to chemical vapors migrating into an on-site building from surface and subsurface soil below the building. These risk calculations indicate that there is no potential adverse risk to workers from chemical vapors migrating into the on-site building for levels at least ten times the current chemical concentrations. The model and guidance used for the calculations were obtained from the EPA (2001). The model obtained from the EPA is a template, which provides the equations, chemical properties, and default values for the model parameters. Site-specific parameters can be entered into the template to develop site-specific risks. For CAOC 26, soil gas concentrations from on-site monitoring points were readily available; therefore, the Johnson and Ettinger soil gas model[1] was used for the site-specific computations.

The JVIM is a one-dimensional model that estimates the vapor concentration in an indoor space from the vapor concentration at the source of the contamination. The model assumes that at the top of contamination, molecular diffusion moves the chemical toward the soil surface and reaches the building's zone of influence. At the building's zone of influence, convective air movement transports the chemical vapors through cracks between the basement or slab floor and foundation. Risks are calculated using the chemical vapor concentrations in the building. The chemical-specific building vapor concentration calculations utilize parameters related to soil type, chemical concentration, distance from ground surface to the contaminant source, the area of the building below grade, the exposure interval, and the building ventilation rate. The building ventilation rate incorporates the volume of the building, the building air exchange rate, and the size of the cracks at the building foundation. The model estimates the chemical vapor concentrations as a steady-state solution (infinite source) as the extent of the vapor source is not defined.

The EPA guidance (EPA, 2001) provides the assumptions and limitations of the model; some of the key assumptions and limitations are listed below:

- Contaminant vapors enter the building primarily through cracks and other openings in the walls and foundation.

- All vapors originating from below the building will enter the building unless the floor and walls are perfect vapor barriers.

[1] EPA provides several models with solutions to the Johnson and Ettinger equations, of which, the new soil gas model is most appropriate since it can calculate indoor air concentrations and health risks based on empirical soil gas concentrations and sampling depth information.

- All soil properties in any horizontal plane are homogenous.
- The areal extent of contamination is greater than that of the building floor that is in contact with the soil.
- The model does not account for biodegredation, hydrolysis, or other transformation processes.

2.2 VAPOR INTRUSION CALCULATIONS

The Johnson and Ettinger soil gas model template provided by the EPA has two tiers: the first for screening and the second which allows more site-specific data to be used. Properties of the chemicals, site-specific soil properties, and site-specific structural properties of the building are utilized in both tiers of the model. Both models assume an infinite contaminant source. In the screening model, site-specific data can be used for the most-sensitive parameters (soil gas sampling depth, porosity, and exposure factors) while the other parameters are set equal to their central tendency or upper bound values (EPA, 2001). Site-specific parameters used in the screening model are shown in Tables E.2-la to E.2-ld. The second-tier or "advanced" model allows site-specific values to be used for most of the model parameters (including dimensions of building and soil properties for up to three distinct strata). Site-specific parameters used in the advanced model are shown in Tables E.2-2a to E.2-d.

Tier 1 and Tier 2 vapor intrusion calculations for CAOC 26 were completed for three soil gas sampling depths on site: 30 feet bgs, 60 feet bgs, and 90 feet bgs. Vapor intrusion calculations were not performed using soil gas sampling data from 130 to 140 feet bgs because, based on previous experience with the model, it is unlikely that vapor concentrations present at these depths (depths greater than 30 feet bgs) would reach the surface and migrate into the on-site building.

The vapor intrusion modeling was completed for five VOCs detected in highest concentrations on site: PCE, m/p-xylene, o-xylene, ethylbenzene, dibromochloromethane (DCBM), as well as for TCE. Concentrations of these contaminants used in the vapor intrusion model, except TCE, were based on the highest levels detected in the first quarter 2002 sampling event. TCE was not detected in any of the monitoring points in this sampling; therefore, the current TCE concentration was assumed equal to the detection limit of 130 micrograms per liter (µg/L). Vapor intrusion risks were calculated for exposure to both the current and two. five, and ten times the current VOC concentrations beneath the site. The concentrations utilized in the current, two, five, and ten times screening and advanced model calculations are provided in Tables E.2-1a through E.2-ld and E.2-2a through E.2-2d, respectively.

Modeling outputs are included for PCE, m/p-xylene, o-xylene, ethylbenzene, DCBM, and TCE in Attachments 1 through 6 (provided in electronic format only), respectively.

Potential risks from exposure to the above-listed VOC vapors migrating into the CAOC 26 building were calculated for an industrial worker based on EPA exposure factors for the scenario (EPA, 1991) [2]. The EPA exposure factors conservatively assume that the worker would spend 8 hours per day, 5 days per week, 50 weeks per year, for 25 years, working inside the building. Realistically, a worker would likely spend less time working in the building; therefore, the use of the conservative assumptions made for work duration overestimates risk. The exposure parameters used in the screening and advanced model calculations are provided in Tables E.2-la through E.2-ld and E.2-2a through E.2-2d, respectively.

To characterize the risk each chemical poses to an on-site worker, the estimated vapor concentration for each chemical in the building is used to quantify the dose of the chemical. The doses are combined with toxicity parameters to estimate whether the calculated intake levels pose a threat to human health. Potential non-cancer health effects are assessed by comparing the estimated average exposure rate with an exposure level at which no adverse health effects are expected to occur from a long period of exposure; this comparison gives a ratio known as the hazard quotient (HQ). HQ values are computed for each non-carcinogenic chemical. The sum of HQs is known as a hazard index (HI). Carcinogenic risk is estimated as the incremental probability of an individual developing cancer over a lifetime as a result of a chemical exposure. Carcinogenic risks are evaluated by multiplying the estimated average exposure rate by the chemical's cancer toxicity value, resulting in an estimate of the excess lifetime cancer risk (ELCR).

Toxicity values for all six VOCs were included in the EPA model template. Inhalation unit risk factor (URF) is the cancer toxicity parameter for inhalation. In the model template, PCE, TCE, and DCBM are considered carcinogenic chemicals. The EPA model considers o-xylene, m/p-xylene, and ethylbenzene to be non-carcinogenic chemicals and calculates the risk using a reference concentration (RfC), the non-carcinogenic inhalation toxicity value. PCE, TCE, and DCBM do not have RfCs; therefore, only ELCRs were calculated for these chemicals. Because o-xylene, m/p-xylene, and ethylbenzene are considered to be non-carcinogens, only non-cancer risk values (HQs) were calculated for this chemical.

2.3 RESULTS AND CONCLUSIONS

The potential risks from inhalation of VOC vapors migrating into a building at CAOC 26 at the Yermo Annex were calculated for workers in the building using conservative assumptions. Vapor intrusion risks were calculated using the JVEM. The vapor intrusion modeling was completed for five VOCs detected in the highest concentrations on site: PCE, m/p-xylene, o-xylene, ethylbenzene, DCBM, as well as for TCE (which was not detected in the recent sampling activities, but is a contaminant of interest at the site). Vapor intrusion risks were

[2] Actually, the default value of 30 years of exposure was used, along with the EPA-based 250 weeks/year.

calculated for exposure to current and two, five, and ten times the current VOC concentrations for three depth-based scenarios based on soil gas sampling locations on site: 30 feet, 60 feet, and 90 feet bgs.

For the worker, the ELCR value for each carcinogenic chemical was summed to produce total cancer risk. Likewise, the HQ value for each non-carcinogenic chemical was summed to produce the HI, or total non-cancer risk for vapor inhalation in the on-site building. Tables E.2-3a through E.2-3d list the ELCR and HI values for each of the depth-based scenarios for the screening model and Tables E.2-4a through E.2-4d for the advanced model.

ELCR and HI for each of the depth-based scenarios are plotted against the VOC concentration level for the screening model in Figures E.2-1 and for the advanced model in Figure E.2-2. As shown in Figures E.2-1 and E.2-2, for both models, vapor intrusion risks for current and two, five, and ten times the current concentrations are below the target HI of 1.0 and within or below the EPA ELCR target range of 1×10^{-6} to 1×10^{-6} (EPA, 1989). If the estimated risk is at or below the EPA target HI or within or below the EPA target ELCR, the chemical is considered unlikely to pose an unacceptable carcinogenic health risk.

It should be noted that the JVIM calculations were based on soil gas data from 30 feet bgs. Impact to aboveground receptors would more likely result from shallower contamination. If soil gas levels at the 30-foot depth show an increase in the future, shallow soil gas surveys should be considered to allow re-evaluation of potential impacts using the JVIM.

In conclusion, based on the results of the risk calculations (using conservative assumptions), there is no potential adverse risk to workers from VOC vapors present beneath the site migrating into the on-site building for levels at least 10 times the current concentrations.

3.0 SVE FLOW CHANNEL MAPPING

3.1 TECHNIQUE

The vacuum response data obtained during system operation were used to map channels as follows:

1. Draw equipotential lines based on observed vacuum data

2. Draw flow channels to approximate equivalent flow through each of the channels by applying the following rules of flow-net construction:

   - Equipotential lines intersect the flow lines at right angles

   - Ground surface is an equipotential line

   - Flow elements formed by the flow net have the same pressure drop and flow rate as adjacent flow elements from adjacent flow channels

3.2 MAPPING RESULTS

SVE flow channel mapping was done for three well-screen configurations: 1) existing screening from 150 to 160 feet, 2) hypothetical screening from 40 to 50 feet, and 3) hypothetical screening from 90 to 100 feet.

Flow channels were generated for the existing configuration using SVE field vacuum data from probe locations. Flow channels were generated for the hypothetical configurations by best-guess estimation using general flow-path construction rules described above; the flow nets are shown as Figures E.3-1 through E.3-3. Flow channels to a radial distance of approximately 40 to 45 feet for each configuration were compared.

Well Screen Configuration	Channel Volume (ft^3) (porosity = 0.3)	Channel Flow (ft^3/min)	Air Changes per Year	Air Change Ratio with Existing Configuration	Hypothetical Cleanup Time
40 to 50 feet	45,200	81	942	6	3 to 6 months (assumed)
90 to 100 feet	114,400	54	248	1.9	5 to 10 months
150 to 160 feet	150,700	45	157	1	18 months to 3 years

Notes:
ft^3 - cubic feet
ft^3/min - cubic feet per minute

Flow channel characteristics and air-change rates were calculated. The analysis indicates that the 40 to 50 feet configuration produces an air change rate that is six times higher than the rate achieved with the 150 to 160 feet configuration. In other words, the shallow zone at approximately 30 feet will clean up 6 times faster with wells screened at 40 to 50 feet than with wells screened at the current configuration of about 150 to 160 feet. Thus, estimating a cleanup time of approximately 3 to 6 months with the 40 to 50 feet configuration, it would take about 18 months to 3 years to achieve comparable remediation with the 150 to 160 feet configuration.

Modeling indicates that cleanup in the shallow zone can be achieved with the current configuration, but at a slower rate by approximately six times than that achieved by an optimal well-screen configuration. This modeling is validated by Round 5 soil-gas probe data which show comparable VOC percent reductions among the different probe depths at 30 feet, 60 feet, and 90 feet; that is to say, significant reduction is being observed at all depths using the 150- to 160-foot well-screen configuration.

4.0 SESOIL

4.1 SESOIL MODEL DESCRIPTION

SESOIL is a one-dimensional vertical transport model for the unsaturated zone. The model is based on mass balance and equilibrium partitioning of the chemical among all its phases (dissolved, sorbed, vapor, and pure). SESOIL is designed to perform long-term solutions of chemical transport and transformations in the soil. The model uses theoretically derived equations to represent water transport, sediment transport on the land surface, chemical transformation, and migration of the chemical to the atmosphere and groundwater. The objective of the modeling effort was to predict PCE mass flux from the unsaturated zone to the saturated zone at CAOC 26.

SESOIL employs a statistical routine to model the hydrologic cycle. The hydrologic cycle modeled in SESOIL is an adaptation of the water balance dynamics theory of Eagleson (Eagleson, 1970), which can be described as a dimensionless analytical representation of an annual water balance. The hydrologic cycle is applied on a monthly basis and considers rainfall, surface runoff, capillary rise, soil moisture, evapotranspiration, soil properties, and climatic properties to determine the infiltration of water into the soil. In addition, SESOIL accounts for the varying permeabilities of the unsaturated zone (to a maximum of four layers) when modeling chemical transport through the unsaturated zone to groundwater. The advective velocity of the water is a season-dependent distribution of modeled values through a multilayered soil system.

4.2 SESOIL INPUT PARAMETERS AND ASSUMPTIONS

The processes simulated in SESOIL include three cycles: hydrologic, sediment, and pollutant. SESOIL requires site-specific data for the following categories:

- Soil Properties and Compartments
- Climate
- Chemistry
- Pollutant Load

The hydrologic cycle includes rainfall, surface runoff, infiltration, soil water content, evapotranspiration, and groundwater runoff. The sediment cycle includes sediment washload as a result of storms that produce sufficient precipitation to induce erosion from surface runoff. The pollutant cycle includes advection, volatilization, adsorption/desorption, and degradation. Output from the model provides information on water and sediment transport, contaminant fate, and migration through the vadose zone to groundwater.

The sediment washload cycle was turned off in the model simulations because pollutant surface runoff was assumed to be negligible.

4.2.1 Soil Compartments

SESOIL allows the user to compartmentalize the unsaturated zone into discreet intervals based on intrinsic soil characteristics. The contaminated area was represented as seven polygons with each polygon extending from ground surface to groundwater (hence, seven soil columns). Each polygonal column was correlated to the lithologic profile of a soil boring advanced within the boundaries of the polygon. SESOIL allows for a lithologic profile of up to four layers and each layer can be divided into 10 sub-layers for varying chemical input. Other soil parameters required are: bulk density, disconnectedness index, effective porosity, organic carbon content, cation exchange capacity, and Freundlich equation exponent. Soil characteristics and lithologic and chemical profiles of the soil represented by each column, soil column dimensions, and associated number of model cells are shown in Table E.4-1.

Cation exchange capacity was assumed to be negligible in the model simulation due to insufficient data.

4.2.2 Climate

Climatological data are required for the hydrologic cycle of the model. These data were obtained from the climatological database compiled by General Sciences Corporation (GSC) in its Riskpro version of SESOIL. Data collected from the weather station at the Daggett Edison Plant, located about 37 kilometers from Barstow, were used in the model simulations. Table E.4-2 shows the climatological data used for the models.

4.2.3 Chemistry

Soil concentration profiles for PCE were derived from soil gas data obtained from seven vapor probes and the seven SVE wells at CAOC 26. Each vapor probe or well was correlated with the polygon in which the probe or well was located for the PCE profiling. Soil concentrations at 30, 60, 90, and 120 feet bgs were estimated by assuming equilibrium between the vapor and dissolved phases of PCE in the soil pore fluid using the following equations:

$$Cw = C_{sg} / H$$
$$C_s = C_w \times K_{oc} \times f_{oc} + C_w \times w/r_w$$

Where:

C_w = concentration in the soil pore fluid
C_{sg} = concentration in soil gas
C_s = concentration in soil
H = Henry's Law constant
K_{oc} = partitioning coefficient
f_{oc} = fraction of organic carbon
w = moisture content
r_w = density of water

PCE profiles for each polygon were generated by assuming constant-concentration soil intervals. These intervals were as follows: 1) 0 to 59 feet bgs, 2) 60 to 89 feet bgs, 3) 90 to 129 feet bgs, 4) 130 to 150 feet bgs. The concentration of each soil interval was correlated with the soil concentrations calculated at the probe locations. Table E.4-1 shows the chemical concentration profiles of the polygons for PCE at Round 5 (data collected on January 16, 2002).

Chemical parameters include solubility, diffusivity, Henry's constant, KOC, molecular weight, hydrolysis, biodegradation, and complexation. The latter three processes were assumed to be negligible during the model simulations for conservativeness.

4.2.4 Pollutant Loading

SESOIL can load the chemical either continuously or instantaneously. PCE was loaded instantaneously according to the PCE profiles generated as described in the Chemistry section. No horizontal variability in concentration was assumed within each soil column.

4.2.5 Results

Modeling simulation time was 100 years with a 1-month time step. Three model simulations were performed: one using Round 5 soil vapor data, one using Round 5 soil vapor data multiplied by 2 (2x), and one using Round 5 soil vapor data multiplied by 10 (10x).

4.3 GROUNDWATER MIXING BENEATH SOIL COLUMNS USING AT123D

The fate of chemicals upon exit from the unsaturated zone into the groundwater can be tracked using a complementary analytical groundwater transport model, AT123D. AT123D computes the spatial-temporal concentration distribution (*xyz*-coordinate system as a function of time) of chemicals in an aquifer system (Yeh, 1981). The fate-and-transport processes incorporated into the model are:

- Advection transport
- Hydrodynamic dispersion and molecular diffusion
- Adsorption
- Biological/chemical decay

The model assumes a homogeneous, isotropic aquifer with horizontal flow lines (implying an allowable gradient of no more than a few percent) and a uniform flow field.

4.3.1 Input Parameters

In OSC's Riskpro, SESOIL and AT123D are linked so that the mass loading to the groundwater predicted by SESOIL can be automatically transferred to AT123D. For each simulation, SESOIL outputs a SESOIL-AT123D data-link file that contains input data for AT123D. Input values from the SESOIL-AT 123D data-link file are as follows:

- Mass to groundwater [kilograms per hour (kg/hr)]
- Application area [square meters (m^2)]
- Total simulation length (hours)
- Soil bulk density [kilograms per cubic meters (kg/m^3)]
- Chemical decay rate (l/hour)
- Time step (hours)
- Hydraulic conductivity [meters per second (m/s)]
- Effective porosity
- Distribution coefficient (for adsorption) [cubic meters per kilogram (m^3/kg)]

Other parameters input to the model:

- Longitudinal dispersivity (m)
- Transverse dispersivity (m)
- Vertical dispersivity (m)

Table E.4-3 shows the annual mass-to-groundwater input values that were produced by SESOIL, and Table E.4-4 shows the values used for the remaining input parameters.

4.3.2 Results

Modeling simulation time was 100 years with a 1-month time step. The modeled *xy*-distributions of PCE concentrations in groundwater at z= 0 at 100 years based on the three sets of soil vapor data are shown on Figures E.4-1 through E.4-3. The simulation performed using the Round 5 data produced a maximum concentration of 0.22 parts per billion (ppb) (100 years at the source); the simulation performed using the 2x Round 5 data produced a maximum concentration of 0.44 ppb (100 years at the source); and the simulation performed using the 10x Round 5 data produced a maximum concentration of 2.2 ppb (100 years at the source). Overall, modeled concentrations were below maximum contaminant levels for PCE.

The following additional data processing was performed:

- extrapolations to estimate the soil-gas concentrations (expressed as a multiplier of Round 5 soil gas concentrations) that will lead to a 5 ppb PCE concentration in groundwater at times t = 5, 10, 30, 50, 75, and 100 years (see Figure E.4-4)

- plot of soil-gas concentrations (expressed as a multiplier of Round 5 soil gas concentrations) as a function of the time to reach 5 ppb PCE in groundwater (see Figure E.4-5)

These additional plots indicate that significantly higher soil gas concentrations would be required to produce a 5 ppb PCE concentration in groundwater during the next 100 years.

It should be noted that the 100-year duration is a program limitation. Discussions with the model author at GSC indicate that this duration was given to GSC by the EPA when the program was written and will not be changed (GSC, 2000).

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the assessment of CAOC 26, the following conclusions can be made.

1. Based on the results of the JVIM risk calculations (using conservative assumptions), there is no potential adverse risk to workers from VOC vapors present beneath the site migrating into a theoretical on-site building for levels at least 10 times the current concentrations.

2. Flow channel mapping indicates that cleanup in the shallow zone (if required as a result of increases in soil gas VOC levels) can be achieved with the current SVE well configuration, but at a slower rate by approximately six times than that achieved by an optimal well-screen configuration.

3. SESOIL and AT123D modeling indicate PCE concentrations in groundwater below MCLs under conservative conditions.

The following are recommendations for CAOC 26:

1. Soil vapor probes should be sampled on an annual basis.

2. The JVIM calculations were based on soil gas data from 30 feet bgs. Impact to aboveground receptors would more likely result from shallower contamination. If soil gas levels at the 30-foot depth show an increase in the future by a factor of five, shallow soil gas surveys should be considered to allow re-evaluation of potential impacts using the JVIM calculations.

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TABLES

TABLE E.2-1a

VAPOR INTRUSION CALCULATION PARAMETERS (SCREENING MODEL)
CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
PCE Max Detect[a] ($\mu g/m^3$)	26500	26500[c]	30500[d]
M/P Xylenes Max Detect[a] ($\mu g/m^3$)	4600	5300[c]	5300[d]
O-Xylenes Max Detect[a] ($\mu g/m^3$)	1200	1500[c]	1500[d]
Ethylbenzene[a] ($\mu g/m^3$)	2900	2900[c]	2900[d]
Dibromochloromethane[a] ($\mu g/m^3$)	19800	19800	22700
TCE[a][e] ($\mu g/m^3$)	130	130	130
Depth Below Grade To Bottom Of Enclosed Floor[a] (cm)	15	15	15
Soil Gas Sampling Depth Below Grade[a] (cm)	915	1830	2745
Soil Temp[a] (°C)	23	23	23
Vadose Zone NRCS Soil Type[a]	S	S	S
Vadose Zone Dry Bulk Density[b] (g/cm^3)	1.5	1.5	1.5
Soil Total Porosity[b] (unitless)	0.43	0.43	0.43
Soil Water-Filled Porosity[a] (cm^3/cm^3)	0.375	0.375	0.375
Avg Time for Carcinogens[b] (years)	70	70	70
Avg Time for Non-Carcinogen[b] (years)	30	30	30
Exposure Duration [b] (years)	30	30	30
Exposure Frequency[a] (days/yr)	250	250	250

TABLE E.2-1a

VAPOR INTRUSION CALCULATION PARAMETERS (SCREENING MODEL)
CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
URi (PCE) $(\mu g/m^3)^{-1}$	5.80E-07	5.80E-07	5.80E-07
URi (m/p-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (o-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Ethylbenzene) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Dibromochloromethane) $(\mu g/m^3)^{-1}$	2.40E-05	2.40E-05	2.40E-05
RfC (PCE) (mg/m^3)	NA	NA	NA
RfC (m/p-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (o-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (Ethylbenzene) (mg/m^3)	1.00E+00	1.00E+00	1.00E+00
RfC (Dibromochloromethane) (mg/m^3)	NA	NA	NA

Notes:

(a) - site-specific value

(b) - default value

(c) - highest concentration detected 0-60 feet

(d) - highest concentration detected 0-90 feet

(e) - TCE concentration is assumed equivalent to reporting limit since TCE was not detected in samples

°C - degrees Celsius

$\mu g/m^3$ - micrograms per cubic meter

cm - centimeters

cm^3/cm^3 - cubic centimeter per cubic centimeter

days/yr - days per year

g/cm^3 - grams per cubic centimeter

mg/m^3 - millgrams per cubic meter

NA - not available

NC - non-carcinogen

NRCS - Natural Resources Conservation Service

PCE - tetrachloroethene

RfC - reference concentration

S - sand

TCE - trichloroethene

temp - temperature

URi - inhalation unit risk

TABLE E.2-1b

VAPOR INTRUSION CALCULATION PARAMETERS (SCREENING MODEL)
2x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
PCE Max Detect[a] ($\mu g/m^3$)	53000	53000[c]	61000[d]
M/P Xylenes Max Detect[a] ($\mu g/m^3$)	9200	10600[c]	10600[d]
O-Xylenes Max Detect[a] ($\mu g/m^3$)	2400	3000[c]	3000[d]
Ethylbenzene[a] ($\mu g/m^3$)	5800	5800[c]	5800[d]
Dibromochloromethane[a] ($\mu g/m^3$)	39600	39600[c]	45400[d]
TCE[a][e] ($\mu g/m^3$)	260	260	260
Depth Below Grade To Bottom Of Enclosed Floor[a] (cm)	15	15	15
Soil Gas Sampling Depth Below Grade[a] (cm)	915	1830	2745
Soil Temp[a] (°C)	23	23	23
Vadose Zone NRCS Soil Type[a]	S	S	S
Vadose Zone Dry Bulk Density[b] (g/cm^3)	1.5	1.5	1.5
Soil Total Porosity[b] (unitless)	0.43	0.43	0.43
Soil Water-Filled Porosity[a] (cm^3/cm^3)	0.375	0.375	0.375
Avg Time for Carcinogens[b] (years)	70	70	70
Avg Time for Non-Carcinogen[b] (years)	30	30	30
Exposure Duration [b] (years)	30	30	30
Exposure Frequency[a] (days/yr)	250	250	250
URi (PCE) $(\mu g/m^3)^{-1}$	5.80E-07	5.80E-07	5.80E-07
URi (m/p-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (o-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Ethylbenzene) $(\mu g/m^3)^{-1}$	NC	NC	NC

TABLE E.2-1b

VAPOR INTRUSION CALCULATION PARAMETERS (SCREENING MODEL)
2x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
URi (Dibromochloromethane) $(\mu g/m^3)^{-1}$	2.40E-05	2.40E-05	2.40E-05
URi (TCE) $(\mu g/m^3)^{-1}$	1.70E-06	1.70E-06	1.70E-06
RfC (PCE) (mg/m^3)	NA	NA	NA
RfC (m/p-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (o-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (Ethylbenzene) (mg/m^3)	1.00E+00	1.00E+00	1.00E+00
RfC (Dibromochloromethane) (mg/m^3)	NA	NA	NA
RfC (TCE) (mg/m^3)	NA	NA	NA

Notes:
(a) - site-specific value
(b) - default value
(c) - 2 times highest concentration detected 0-60 feet
(d) - 2 times highest concentration detected 0-90 feet
(e) - based on 2 times the reporting limit for TCE

°C - degrees Celsius
$\mu g/m^3$ - micrograms per cubic meter
cm - centimeters
cm^3/cm^3 - cubic centimeter per cubic centimeter
days/yr - days per year
g/cm^3 - grams per cubic centimeter
mg/m^3 - millgrams per cubic meter
NA - not available
NC - non-carcinogen
NRCS - Natural Resources Conservation Service
PCE - tetrachloroethene
RfC - reference concentration
S - sand
TCE - trichloroethene
temp - temperature
URi - inhalation unit risk

TABLE E.2-1c

VAPOR INTRUSION CALCULATION PARAMETERS (SCREENING MODEL)
5x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
PCE Max Detect[a] ($\mu g/m^3$)	132500	132500[c]	152500[d]
M/P Xylenes Max Detect[a] ($\mu g/m^3$)	23000	26500[c]	26500[d]
O-Xylenes Max Detect[a] ($\mu g/m^3$)	6000	7500[c]	7500[d]
Ethylbenzene[a] ($\mu g/m^3$)	14500	14500[c]	14500[d]
Dibromochloromethane[a] ($\mu g/m^3$)	99000	99000[c]	113500[d]
TCE[a][e] ($\mu g/m^3$)	650	650	650
Depth Below Grade To Bottom Of Enclosed Floor[a] (cm)	15	15	15
Soil Gas Sampling Depth Below Grade[a] (cm)	915	1830	2745
Soil Temp[a] (°C)	23	23	23
Vadose Zone NRCS Soil Type[a]	S	S	S
Vadose Zone Dry Bulk Density[b] (g/cm^3)	1.5	1.5	1.5
Soil Total Porosity[b] (unitless)	0.43	0.43	0.43
Soil Water-Filled Porosity[a] (cm^3/cm^3)	0.375	0.375	0.375
Avg Time for Carcinogens[b] (years)	70	70	70
Avg Time for Non-Carcinogen[b] (years)	30	30	30
Exposure Duration [b] (years)	30	30	30
Exposure Frequency[a] (days/yr)	250	250	250
URi (PCE) $(\mu g/m^3)^{-1}$	5.80E-07	5.80E-07	5.80E-07
URi (m/p-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC

TABLE E.2-1c

VAPOR INTRUSION CALCULATION PARAMETERS (SCREENING MODEL)
5x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
URi (o-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Ethylbenzene) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Dibromochloromethane) $(\mu g/m^3)^{-1}$	2.40E-05	2.40E-05	2.40E-05
RfC (PCE) (mg/m^3)	NA	NA	NA
RfC (m/p-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (o-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (Ethylbenzene) (mg/m^3)	1.00E+00	1.00E+00	1.00E+00
RfC (Dibromochloromethane) (mg/m^3)	NA	NA	NA

Notes:
(a) - site-specific value
(b) - default value
(c) - highest concentration detected 0-60 feet
(d) - highest concentration detected 0-90 feet
(e) - based on 5 times the reporting limit for TCE

°C - degrees Celsius
$\mu g/m^3$ - micrograms per cubic meter
cm - centimeters
cm^3/cm^3 - cubic centimeter per cubic centimeter
days/yr - days per year
g/cm^3 - grams per cubic centimeter
mg/m^3 - millgrams per cubic meter
NA - not available
NC - non-carcinogen
NRCS - Natural Resources Conservation Service
PCE - tetrachloroethene
RfC - reference concentration
S - sand
TCE - trichloroethene
temp - temperature
URi - inhalation unit risk

TABLE E.2-1d

VAPOR INTRUSION CALCULATION PARAMETERS (SCREENING MODEL)
10x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
PCE Max Detect[a] ($\mu g/m^3$)	265000	265000[c]	305000[d]
M/P Xylenes Max Detect[a] ($\mu g/m^3$)	46000	53000[c]	53000[d]
O-Xylenes Max Detect[a] ($\mu g/m^3$)	12000	15000[c]	15000[d]
Ethylbenzene[a] ($\mu g/m^3$)	29000	29000[c]	29000[d]
Dibromochloromethane[a] ($\mu g/m^3$)	198000	198000[c]	227000[d]
TCE[a][e] ($\mu g/m^3$)	1300	1300	1300
Depth Below Grade To Bottom Of Enclosed Floor[a] (cm)	15	15	15
Soil Gas Sampling Depth Below Grade[a] (cm)	915	1830	2745
Soil Temp[a] (°C)	23	23	23
Vadose Zone NRCS Soil Type[a]	S	S	S
Vadose Zone Dry Bulk Density[b] (g/cm^3)	1.5	1.5	1.5
Soil Total Porosity[b] (unitless)	0.43	0.43	0.43
Soil Water-Filled Porosity[a] (cm^3/cm^3)	0.375	0.375	0.375
Avg Time for Carcinogens[b] (years)	70	70	70
Avg Time for Non-Carcinogen[b] (years)	30	30	30
Exposure Duration [b] (years)	30	30	30
Exposure Frequency[a] (days/yr)	250	250	250
URi (PCE) $(\mu g/m^3)^{-1}$	5.80E-07	5.80E-07	5.80E-07
URi (m/p-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (o-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC

TABLE E.2-1d

VAPOR INTRUSION CALCULATION PARAMETERS (SCREENING MODEL)
10x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
URi (Ethylbenzene) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Dibromochloromethane) $(\mu g/m^3)^{-1}$	2.40E-05	2.40E-05	2.40E-05
RfC (PCE) (mg/m^3)	NA	NA	NA
RfC (m/p-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (o-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (Ethylbenzene) (mg/m^3)	1.00E+00	1.00E+00	1.00E+00
RfC (Dibromochloromethane) (mg/m^3)	NA	NA	NA

Notes:

(a) - site-specific value
(b) - default value
(c) - highest concentration detected 0-60 feet
(d) - highest concentration detected 0-90 feet
(e) - Based on 10 times the reporting limit for TCE

°C - degrees Celsius
$\mu g/m^3$ - micrograms per cubic meter
cm - centimeters
cm^3/cm^3 - cubic centimeter per cubic centimeter
days/yr - days per year
g/cm^3 - grams per cubic centimeter
mg/m^3 - millgrams per cubic meter
NA - not available
NC - non-carcinogen
NRCS - Natural Resources Conservation Service
PCE - tetrachloroethene
RfC - reference concentration
S - sand
TCE - trichloroethene
temp - temperature
URi - inhalation unit risk

TABLE E.2-2a

VAPOR INTRUSION CALCULATION PARAMETERS (ADVANCED MODEL)
CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
PCE Max Detect[a] ($\mu g/m^3$)	26500	26500[c]	30500[d]
M/P Xylenes Max Detect[a] ($\mu g/m^3$)	4600	5300[c]	5300[d]
O-Xylenes Max Detect[a] ($\mu g/m^3$)	1200	1500[c]	1500[d]
Ethylbenzene[a] ($\mu g/m^3$)	2900	2900[c]	2900[d]
Dibromochloromethane[a] ($\mu g/m^3$)	19800	19800	22700
TCE[a][e] ($\mu g/m^3$)	130	130	130
Depth Below Grade To Bottom Of Enclosed Floor[a] (cm)	15	15	15
Soil Gas Sampling Depth Below Grade[a] (cm)	915	1830	2745
Average Soil Temp[a] (°C)	23	23	23
Thickness of Soil Stratum[a] (cm)	915	1830	2745
Soil Stratum NRCS Soil Type[a]	S	S	S
Soil Stratum Soil Dry Bulk Density[b] (g/cm^3)	1.5	1.5	1.5
Soil Stratum Soil Total Porosity[b] (unitless)	0.43	0.43	0.43
Stratum A Soil-Water Filled Porosity[a] (cm^3/cm^3)	0.375	0.375	0.375
Enclosed Space Floor Thickness[b] (cm)	15	15	15
Soil-bldg Pressure Differential[b] ($g/cm\text{-}s^2$)	40	40	40
Enclosed Space Floor Length[a] (cm)	30145	30145	30145
Enclosed Space Floor Width[a] (cm)	5547	5547	5547
Enclosed Space Height[b] (cm)	488	488	488
Floor-Wall Seam Crack Width[b] (cm)	0.1	0.1	0.1
Indoor Air Exchange Rate[b] (1/h)	0.45	0.45	0.45
Avg Time for Carcinogens[b] (years)	70	70	70
Avg Time for Non-Carcinogens[b] (years)	30	30	30
Exposure Duration[b] (years)	30	30	30
Exposure Frequency[a] (days)	250	250	250
URi (PCE) $(\mu g/m^3)^{-1}$	5.80E-07	5.80E-07	5.80E-07

TABLE E.2-2a

VAPOR INTRUSION CALCULATION PARAMETERS (ADVANCED MODEL)
CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
URi (m/p-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (o-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Ethylbenzene) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Dibromochloromethane) $(\mu g/m^3)^{-1}$	2.40E-05	2.40E-05	2.40E-05
RfC (PCE) (mg/m^3)	NA	NA	NA
RfC (m/p-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (o-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (Ethylbenzene) (mg/m^3)	1.00E+00	1.00E+00	1.00E+00
RfC (Dibromochloromethane) (mg/m^3)	NA	NA	NA

Notes:
(a) - site-specific value
(b) - default value
(c) - highest concentration detected 0-60 feet
(d) - highest concentration detected 0-90 feet
(e) - TCE concentration is assumed equivalent to RL since TCE was not detected in samples

°C - degrees Celsius
$\mu g/m^3$ - micrograms per cubic meter
cm - centimeters
cm^3/cm^3 - cubic centimeter per cubic centimeter
g/cm^3 - grams per cubic centimeter
$g/cm\text{-}s^2$ - grams per centimeter per square second
h - hour
mg/m^3 - millgrams per cubic meter
NA - not available
NC - non-carcinogen
NRCS - Natural Resources Conservation Service
PCE - tetrachloroethene
RfC - reference concentration
S - sand
TCE - trichloroethene
temp - temperature
URi - inhalation unit risk

TABLE E.2-2b

VAPOR INTRUSION CALCULATION PARAMETERS (ADVANCED MODEL)
2x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
PCE Max Detect[a] ($\mu g/m^3$)	53000	53000[c]	61000[d]
M/P Xylenes Max Detect[a] ($\mu g/m^3$)	9200	10600[c]	10600[d]
O-Xylenes Max Detect[a] ($\mu g/m^3$)	2400	3000[c]	3000[d]
Ethylbenzene[a] ($\mu g/m^3$)	5800	5800[c]	5800[d]
Dibromochloromethane[a] ($\mu g/m^3$)	39600	39600[c]	45400[d]
TCE[a][e] ($\mu g/m^3$)	260	260	260
Depth Below Grade To Bottom Of Enclosed Floor[a] (cm)	15	15	15
Soil Gas Sampling Depth Below Grade[a] (cm)	915	1830	2745
Average Soil Temp[a] (°C)	23	23	23
Thickness of Soil Stratum[a] (cm)	915	1830	2745
Soil Stratum NRCS Soil Type[a]	S	S	S
Soil Stratum Soil Dry Bulk Density[b] (g/cm^3)	1.5	1.5	1.5
Soil Stratum Soil Total Porosity[b] (unitless)	0.43	0.43	0.43
Stratum A Soil-Water Filled Porosity[a] (cm^3/cm^3)	0.375	0.375	0.375
Enclosed Space Floor Thickness[b] (cm)	15	15	15
Soil-bldg Pressure Differential[b] ($g/cm\text{-}s^2$)	40	40	40
Enclosed Space Floor Length[a] (cm)	30145	30145	30145
Enclosed Space Floor Width[a] (cm)	5547	5547	5547
Enclosed Space Height[b] (cm)	488	488	488
Floor-Wall Seam Crack Width[b] (cm)	0.1	0.1	0.1
Indoor Air Exchange Rate[b] (1/h)	0.45	0.45	0.45
Avg Time for Carcinogens[b] (years)	70	70	70
Avg Time for Non-Carcinogens[b] (years)	30	30	30
Exposure Duration[b] (years)	30	30	30

TABLE E.2-2b

VAPOR INTRUSION CALCULATION PARAMETERS (ADVANCED MODEL)
2x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
Exposure Frequency[(a)] (days)	250	250	250
URi (PCE) $(\mu g/m^3)^{-1}$	5.80E-07	5.80E-07	5.80E-07
URi (m/p-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (o-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Ethylbenzene) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Dibromochloromethane) $(\mu g/m^3)^{-1}$	2.40E-05	2.40E-05	2.40E-05
URi (TCE) $(\mu g/m^3)^{-1}$	1.70E-06	1.70E-06	1.70E-06
RfC (PCE) (mg/m^3)	NA	NA	NA
RfC (m/p-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (o-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (Ethylbenzene) (mg/m^3)	1.00E+00	1.00E+00	1.00E+00
RfC (Dibromochloromethane) (mg/m^3)	NA	NA	NA
RfC (TCE) (mg/m^3)	NA	NA	NA

Notes:

(a) - site-specific value
(b) - default value
(c) - highest concentration detected 0-60 feet
(d) - highest concentration detected 0-90 feet
(e) - based on 2 times the reporting limit for TCE

°C - degrees Celsius
$\mu g/m^3$ - micrograms per cubic meter
cm - centimeters
cm^3/cm^3 - cubic centimeter per cubic centimeter
g/cm^3 - grams per cubic centimeter
$g/cm\text{-}s^2$ - grams per centimeter per square second
h - hour
mg/m^3 - millgrams per cubic meter
NA - not available
NC - non-carcinogen
NRCS - Natural Resources Conservation Service
PCE - tetrachloroethene
RfC - reference concentration
S - sand
TCE - trichloroethene
temp- temperature
URi - inhalation unit risk

TABLE E.2-2c

VAPOR INTRUSION CALCULATION PARAMETERS (ADVANCED MODEL)
5x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
PCE Max Detect[a] ($\mu g/m^3$)	132500	132500[c]	152500[d]
M/P Xylenes Max Detect[a] ($\mu g/m^3$)	23000	26500[c]	26500[d]
O-Xylenes Max Detect[a] ($\mu g/m^3$)	6000	7500[c]	7500[d]
Ethylbenzene[a] ($\mu g/m^3$)	14500	14500[c]	14500[d]
Dibromochloromethane[a] ($\mu g/m^3$)	99000	99000[c]	113500[d]
TCE[a][e] ($\mu g/m^3$)	650	650	650
Depth Below Grade To Bottom Of Enclosed Floor[a] (cm)	15	15	15
Soil Gas Sampling Depth Below Grade[a] (cm)	915	1830	2745
Average Soil Temp[a] (°C)	23	23	23
Thickness of Soil Stratum[a] (cm)	915	1830	2745
Soil Stratum NRCS Soil Type[a]	S	S	S
Soil Stratum Soil Dry Bulk Density[b] (g/cm^3)	1.5	1.5	1.5
Soil Stratum Soil Total Porosity[b] (unitless)	0.43	0.43	0.43
Stratum A Soil-Water Filled Porosity[a] (cm^3/cm^3)	0.375	0.375	0.375
Enclosed Space Floor Thickness[b] (cm)	15	15	15
Soil-bldg Pressure Differential[b] ($g/cm\text{-}s^2$)	40	40	40
Enclosed Space Floor Length[a] (cm)	30145	30145	30145
Enclosed Space Floor Width[a] (cm)	5547	5547	5547
Enclosed Space Height[b] (cm)	488	488	488
Floor-Wall Seam Crack Width[b] (cm)	0.1	0.1	0.1
Indoor Air Exchange Rate[b] (1/h)	0.45	0.45	0.45
Avg Time for Carcinogens[b] (years)	70	70	70
Avg Time for Non-Carcinogens[b] (years)	30	30	30

TABLE E.2-2c

VAPOR INTRUSION CALCULATION PARAMETERS (ADVANCED MODEL)
5x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
Exposure Duration[(b)] (years)	30	30	30
Exposure Frequency[(a)] (days)	250	250	250
URi (PCE) $(\mu g/m^3)^{-1}$	5.80E-07	5.80E-07	5.80E-07
URi (m/p-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (o-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Ethylbenzene) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Dibromochloromethane) $(\mu g/m^3)^{-1}$	2.40E-05	2.40E-05	2.40E-05
URi (TCE) $(\mu g/m^3)^{-1}$	1.70E-06	1.70E-06	1.70E-06
RfC (PCE) (mg/m^3)	NA	NA	NA
RfC (m/p-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (o-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (Ethylbenzene) (mg/m^3)	1.00E+00	1.00E+00	1.00E+00
RfC (Dibromochloromethane) (mg/m^3)	NA	NA	NA
RfC (TCE) (mg/m^3)	NA	NA	NA

Notes:

(a) - site-specific value
(b) - default value
(c) - highest concentration detected 0-60 feet
(d) - highest concentration detected 0-90 feet
(e) - based on 5 times the reporting limit for TCE

°C - degrees Celsius
$\mu g/m^3$ - micrograms per cubic meter
cm - centimeters
cm^3/cm^3 - cubic centimeter per cubic centimeter
g/cm^3 - grams per cubic centimeter
$g/cm\text{-}s^2$ - grams per centimeter per square second
h - hour
mg/m^3 - millgrams per cubic meter
NA - not available
NC - non-carcinogen
NRCS - Natural Resources Conservation Service
PCE - tetrachloroethene
RfC - reference concentration
S - sand
TCE - trichloroethene
temp- temperature
URi - inhalation unit risk

TABLE E.2-2d
VAPOR INTRUSION CALCULATION PARAMETERS (ADVANCED MODEL)
10x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
PCE Max Detect[a] ($\mu g/m^3$)	265000	265000[c]	305000[d]
M/P Xylenes Max Detect[a] ($\mu g/m^3$)	46000	53000[c]	53000[d]
O-Xylenes Max Detect[a] ($\mu g/m^3$)	12000	15000[c]	15000[d]
Ethylbenzene[a] ($\mu g/m^3$)	29000	29000[c]	29000[d]
Dibromochloromethane[a] ($\mu g/m^3$)	198000	198000[c]	227000[d]
TCE[a][e] ($\mu g/m^3$)	1300	1300	1300
Depth Below Grade To Bottom Of Enclosed Floor[a] (cm)	15	15	15
Soil Gas Sampling Depth Below Grade[a] (cm)	915	1830	2745
Average Soil Temp[a] (°C)	23	23	23
Thickness of Soil Stratum[a] (cm)	915	1830	2745
Soil Stratum NRCS Soil Type[a]	S	S	S
Soil Stratum Soil Dry Bulk Density[b] (g/cm^3)	1.5	1.5	1.5
Soil Stratum Soil Total Porosity[b] (unitless)	0.43	0.43	0.43
Stratum A Soil-Water Filled Porosity[a] (cm^3/cm^3)	0.375	0.375	0.375
Enclosed Space Floor Thickness[b] (cm)	15	15	15
Soil-bldg Pressure Differential[b] ($g/cm\text{-}s^2$)	40	40	40
Enclosed Space Floor Length[a] (cm)	30145	30145	30145
Enclosed Space Floor Width[a] (cm)	5547	5547	5547
Enclosed Space Height[b] (cm)	488	488	488
Floor-Wall Seam Crack Width[b] (cm)	0.1	0.1	0.1
Indoor Air Exchange Rate[b] (1/h)	0.45	0.45	0.45
Avg Time for Carcinogens[b] (years)	70	70	70

TABLE E.2-2d
VAPOR INTRUSION CALCULATION PARAMETERS (ADVANCED MODEL)
10x CURRENT CONTAMINANT LEVELS

Parameters	0-30 feet	0-60 feet	0-90 feet
Avg Time for Non-Carcinogens[(b)] (years)	30	30	30
Exposure Duration[(b)] (years)	30	30	30
Exposure Frequency[(a)] (days)	250	250	250
URi (PCE) $(\mu g/m^3)^{-1}$	5.80E-07	5.80E-07	5.80E-07
URi (m/p-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (o-Xylenes) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Ethylbenzene) $(\mu g/m^3)^{-1}$	NC	NC	NC
URi (Dibromochloromethane) $(\mu g/m^3)^{-1}$	2.40E-05	2.40E-05	2.40E-05
RfC (PCE) (mg/m^3)	NA	NA	NA
RfC (m/p-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (o-Xylenes) (mg/m^3)	7.00E+00	7.00E+00	7.00E+00
RfC (Ethylbenzene) (mg/m^3)	1.00E+00	1.00E+00	1.00E+00
RfC (Dibromochloromethane) (mg/m^3)	NA	NA	NA

Notes:

(a) - site-specific value
(b) - default value
(c) - highest concentration detected 0-60 feet
(d) - highest concentration detected 0-90 feet
(e) - Based on 10 times the reporting limit for TCE

°C - degrees Celsius
$\mu g/m^3$ - micrograms per cubic meter
cm - centimeters
cm^3/cm^3 - cubic centimeter per cubic centimeter
g/cm^3 - grams per cubic centimeter
$g/cm\text{-}s^2$ - grams per centimeter per square second
h - hour
mg/m^3 - millgrams per cubic meter
NA - not available
NC - non-carcinogen
NRCS - Natural Resources Conservation Service
PCE - tetrachloroethene
RfC - reference concentration
S - sand
TCE - trichloroethene
temp - temperature
URi - inhalation unit risk

TABLE E.2-3a

VAPOR INTRUSION SUMMARY, SCREENING MODEL CALCULATIONS
CURRENT CONTAMINANT LEVELS

	0-30 feet bgs		0-60 feet bgs		0-90 feet bgs	
	ELCR	HQ	ELCR	HQ	ELCR	HQ
PCE	2.2E-09	NA	1.1E-09	NA	8.5E-10	NA
o-xylenes	NC	8.70E-08	NC	5.40E-08	NC	3.60E-08
m/p-xylenes(1)	NC	2.70E-07	NC	1.50E-07	NC	1.00E-07
ethylbenzene	NC	1.10E-06	NC	5.60E-07	NC	3.70E-07
dibromochloromethane	2.00E-07	NA	9.90E-08	NA	7.60E-08	NA
TCE	3.80E-11	NA	1.90E-11	NA	1.20E-11	NA
TOTAL RISK	2.0E-07	1.46E-06	1.0E-07	7.64E-07	7.7E-08	5.06E-07

Notes:

(1) Model allows computation of HI for m- and p-xylene separately; result is more conservative of two values

ELCR - excess lifetime cancer risk
bgs - below ground surface
HI - hazard index (summation of HQs)
HQ - hazard quotient
NA - not available
NC - non-carcinogenic
PCE - tetrachloroethene
TCE - trichloroethene

TABLE E.2-3b

VAPOR INTRUSION SUMMARY, SCREENING MODEL CALCULATIONS
2x CURRENT CONTAMINANT LEVELS

	0-30 feet bgs		0-60 feet bgs		0-90 feet bgs	
	ELCR	HQ	ELCR	HQ	ELCR	HQ
PCE	4.5E-09	NA	2.2E-09	NA	1.7E-09	NA
o-xylenes	NC	1.70E-07	NC	1.10E-07	NC	7.20E-08
m/p-xylenes(1)	NC	5.40E-07	NC	3.10E-07	NC	2.10E-07
ethylbenzene	NC	2.30E-06	NC	1.10E-06	NC	7.50E-07
dibromochloromethane	4.00E-07	NA	2.00E-07	NA	1.50E-07	NA
TCE	7.50E-11	NA	3.80E-11	NA	2.50E-11	NA
TOTAL RISK	4.0E-07	3.01E-06	2.0E-07	1.52E-06	1.5E-07	1.03E-06

Notes:

(1) Model allows computation of HI for m- and p-xylene separately; result is more conservative of two values

ELCR - excess lifetime cancer risk
bgs - below ground surface
HI - hazard index (summation of HQs)
HQ - hazard quotient
NA - not available
NC - non-carcinogenic
PCE - tetrachloroethene
TCE - trichloroethene

TABLE E.2-3c

VAPOR INTRUSION SUMMARY, SCREENING MODEL CALCULATIONS
5x CURRENT CONTAMINANT LEVELS

	0-30 feet bgs		0-60 feet bgs		0-90 feet bgs	
	ELCR	HQ	ELCR	HQ	ELCR	HQ
PCE	1.1E-08	NA	5.4E-09	NA	4.3E-09	NA
o-xylenes	NC	4.30E-07	NC	2.70E-07	NC	1.80E-07
m/p-xylenes(1)	NC	1.30E-06	NC	7.70E-07	NC	5.10E-07
ethylbenzene	NC	5.70E-06	NC	2.80E-06	NC	1.90E-06
dibromochloromethane	9.90E-07	NA	5.00E-07	NA	3.80E-07	NA
TCE	1.90E-11	NA	9.40E-11	NA	6.20E-11	NA
TOTAL RISK	1.0E-06	7.43E-06	5.1E-07	3.84E-06	3.8E-07	2.59E-06

Notes:

(1) Model allows computation of HI for m- and p-xylene separately; result is more conservative of two values

ELCR - excess lifetime cancer risk
bgs - below ground surface
HI - hazard index (summation of HQs)
HQ - hazard quotient
NA - not available
NC - non-carcinogenic
PCE - tetrachloroethene
TCE - trichloroethene

TABLE E.2-3d

VAPOR INTRUSION SUMMARY, SCREENING MODEL CALCULATIONS
10x CURRENT CONTAMINANT LEVELS

	0-30 feet bgs		0-60 feet bgs		0-90 feet bgs	
	ELCR	HQ	ELCR	HQ	ELCR	HQ
PCE	2.2E-08	NA	1.1E-08	NA	8.5E-09	NA
o-xylenes	NC	8.70E-07	NC	5.40E-07	NC	3.60E-07
m/p-xylenes(1)	NC	2.70E-06	NC	1.50E-06	NC	1.00E-06
ethylbenzene	NC	1.10E-05	NC	5.60E-06	NC	3.70E-06
dibromochloromethane	2.00E-06	NA	9.90E-07	NA	7.60E-07	NA
TCE	3.80E-10	NA	1.90E-10	NA	1.20E-10	NA
TOTAL RISK	2.0E-06	1.46E-05	1.0E-06	7.64E-06	7.7E-07	5.06E-06

Notes:

(1) Model allows computation of HI for m- and p-xylene separately; result is more conservative of two values

ELCR - excess lifetime cancer risk
bgs - below ground surface
HI - hazard index (summation of HQs)
HQ - hazard quotient
NA - not available
NC - non-carcinogenic
PCE - tetrachloroethene
TCE - trichloroethene

TABLE E.2-4a

VAPOR INTRUSION SUMMARY, ADVANCED MODEL CALCULATIONS
CURRENT CONTAMINANT LEVELS

	0-30 feet bgs		0-60 feet bgs		0-90 feet bgs	
	ELCR	HQ	ELCR	HQ	ELCR	HQ
PCE	2.1E-09	NA	1.1E-09	NA	8.4E-10	NA
o-xylenes	NC	8.00E-08	NC	5.20E-08	NC	3.50E-08
m/p-xylenes(1)	NC	2.50E-07	NC	1.50E-07	NC	1.00E-07
ethylbenzene	NC	1.10E-06	NC	5.40E-07	NC	3.70E-07
dibromochloromethane	1.70E-07	NA	9.10E-08	NA	7.20E-08	NA
TCE	3.50E-11	NA	1.80E-11	NA	1.20E-11	NA
TOTAL RISK	1.72E-07	1.43E-06	9.21E-08	7.42E-07	7.29E-08	5.05E-07

Notes:

(1) Model allows computation of HI for m- and p-xylene separately; result is more conservative of two values

ELCR - excess lifetime cancer risk
bgs - below ground surface
HI - hazard index (summation of HQs)
HQ - hazard quotient
NA - not available
NC - non-carcinogenic
PCE - tetrachloroethene
TCE - trichloroethene

TABLE E.2-4b

VAPOR INTRUSION SUMMARY, ADVANCED MODEL CALCULATIONS
2x CURRENT CONTAMINANT LEVELS

	0-30 feet bgs		0-60 feet bgs		0-90 feet bgs	
	ELCR	HQ	ELCR	HQ	ELCR	HQ
PCE	4.2E-09	NA	2.2E-09	NA	1.7E-09	NA
o-xylenes	NC	1.60E-07	NC	1.00E-07	NC	7.00E-08
m/p-xylenes(1)	NC	5.00E-07	NC	3.00E-07	NC	2.00E-07
ethylbenzene	NC	2.10E-06	NC	1.10E-06	NC	7.30E-07
dibromochloromethane	3.40E-07	NA	1.80E-07	NA	1.40E-07	NA
TCE	7.10E-11	NA	3.60E-11	NA	2.40E-11	NA
TOTAL RISK	3.44E-07	2.76E-06	1.82E-07	1.50E-06	1.42E-07	1.00E-06

Notes:

(1) Model allows computation of HI for m- and p-xylene separately; result is more conservative of two values

ELCR - excess lifetime cancer risk
bgs - below ground surface
HI - hazard index (summation of HQs)
HQ - hazard quotient
NA - not available
NC - non-carcinogenic
PCE - tetrachloroethene
TCE - trichloroethene

TABLE E.2-4c

VAPOR INTRUSION SUMMARY, ADVANCED MODEL CALCULATIONS
5x CURRENT CONTAMINANT LEVELS

	0-30 feet bgs		0-60 feet bgs		0-90 feet bgs	
	ELCR	HQ	ELCR	HQ	ELCR	HQ
PCE	1.1E-08	NA	5.4E-09	NA	4.2E-09	NA
o-xylenes	NC	4.00E-07	NC	2.60E-07	NC	1.70E-07
m/p-xylenes(1)	NC	1.30E-06	NC	7.50E-07	NC	5.00E-07
ethylbenzene	NC	5.30E-06	NC	2.70E-06	NC	1.80E-06
dibromochloromethane	8.50E-07	NA	4.60E-07	NA	3.60E-07	NA
TCE	1.80E-10	NA	9.10E-11	NA	6.10E-11	NA
TOTAL RISK	8.61E-07	7.00E-06	4.65E-07	3.71E-06	3.64E-07	2.47E-06

Notes:

(1) Model allows computation of HI for m- and p-xylene separately; result is more conservative of two values

ELCR - excess lifetime cancer risk
bgs - below ground surface
HI - hazard index (summation of HQs)
HQ - hazard quotient
NA - not available
NC - non-carcinogenic
PCE - tetrachloroethene
TCE - trichloroethene

TABLE E.2-4d

VAPOR INTRUSION SUMMARY, ADVANCED MODEL CALCULATIONS
10x CURRENT CONTAMINANT LEVELS

	0-30 feet bgs		0-60 feet bgs		0-90 feet bgs	
	ELCR	HQ	ELCR	HQ	ELCR	HQ
PCE	2.1E-08	NA	1.1E-08	NA	8.4E-09	NA
o-xylenes	NC	8.00E-07	NC	5.20E-07	NC	3.50E-07
m/p-xylenes(1)	NC	2.50E-06	NC	1.50E-06	NC	1.00E-06
ethylbenzene	NC	1.10E-05	NC	5.40E-06	NC	3.70E-06
dibromochloromethane	1.70E-06	NA	9.10E-07	NA	7.20E-07	NA
TCE	3.50E-10	NA	1.80E-10	NA	1.20E-10	NA
TOTAL RISK	1.72E-06	1.43E-05	9.21E-07	7.42E-06	7.29E-07	5.05E-06

Notes:

(1) Model allows computation of HI for m- and p-xylene separately; result is more conservative of two values

ELCR - excess lifetime cancer risk
bgs - below ground surface
HI - hazard index (summation of HQs)
HQ - hazard quotient
NA - not available
NC - non-carcinogenic
PCE - tetrachloroethene
TCE - trichloroethene

TABLE E.4-1

SOIL COLUMN PROFILES/CHARACTERISTICS

Polygon #	Area	Lithologic Profile				Chemical Profile			
		interval	soil type(s)	log k	number of sublayers	interval	Round 5 1/02 data	2x Round 5 data	10x Round 5 data
	(feet^2)	(feet bgs, feet bgs)		(m/s)		(feet bgs, feet bgs)	(mg/kg)	(mg/kg)	(mg/kg)
1	17,300	(0,40)	SM,SP	-5	8	(0,59)	5.86	11.72	58.61
		(40,60)	SM, ML, SC	-6	4	(60,89)	4.28	8.55	42.77
		(130,60)	SP,SM,ML	-5	10	(90,129)	19.40	38.81	194.04
		(150,130)	SC/CL, SP	-7	4	(130,150)	2.69	5.39	26.93
2	2,400	(0,15)	SP,SM	-5	3	(0,59)	6.89	13.78	68.90
		(15,55)	SM,ML,CL	-6	8	(60,89)	9.50	19.01	95.04
		(55,105)	SP,SW,SM	-5	10	(90,129)	16.39	32.79	163.94
		(105,150)	SC,ML,SP	-7	9	(130,150)	2.69	5.39	26.93
3	7,100	(0,15)	SP,SM	-5	3	(0,59)	16.55	33.10	165.52
		(15,55)	SM,ML,CL	-6	8	(60,89)	8.79	17.58	87.91
		(55,105)	SP,SW,SM	-5	10	(90,129)	14.18	28.35	141.76
		(105,150)	SC,ML,SP	-7	9	(130,150)	2.69	5.39	26.93
4	19,900	(0,15)	SW	-4	3	(0,59)	10.53	21.07	105.33
		(15,50)	SM,SC	-6	7	(60,89)	17.82	35.64	178.20
		(50,150)	SW,SM	-4	20	(90,129)	24.16	48.31	241.55
						(130,150)	1.27	2.53	12.67
5	5,300	(0,20)	SC,SM,ML	-7	4	(0,59)	20.99	41.98	209.88
		(20,106)	SP,SM,CL	-6	10	(60,89)	15.13	30.25	151.27
		(106,137)	CL,SC,ML	-8	6	(90,129)	8.79	17.58	87.91
		(137,150)	SP,SM	-5	3	(130,150)	1.58	3.17	15.84
6	27,000	(0,60)	SM,SW,SP	-5	10	(0,59)	0.13	0.27	1.35
		(60,70)	SC	-7	2	(60,89)	0.13	0.27	1.35
		(70,150)	SW,SP,SM	-5	16	(90,129)	1.03	2.06	10.30
						(130,150)	0.13	0.27	1.35
7	19,000	(0,7)	SC	-7	1	(0,59)	5.07	10.14	50.69
		(7,21)	SW	-4	3	(60,89)	3.64	7.29	36.43
		(21,32)	SM,MH/ML	-6	2	(90,129)	7.92	15.84	79.20
		(32,150)	SM,SW,SP	-5	10	(130,150)	1.58	3.17	15.84

Notes:

Soil Parameter	Value	Basis of value
bulk density	1.7 g/cm3	site-specific data
disconnectedness index	3.9	data from nearby site
effective porosity	0.3	site-specific data
organic carbon content	0.001	site-specific data
cation exchange capacity	0	process neglected
Freundlich eq. exponent	1	linear adsorption assumed

bgs - below ground surface
g/cm^3 - grams per cubic centimeter
m/s - meters per second
mg/kg - milligrams per kilogram

TABLE E.4-2

CLIMATOLOGICAL DATA
DAGGETT EDISON PLANT, APPROXIMATELY 37 KILOMETERS FROM BARSTOW

Month	Length (days)	Air Temperature (°C)	Cloud Cover Fraction	Humidity	Albedo	Evapotran-spiration (cm/day)	Precipitation (cm)	Duration (days)	# of Storms
October	30.4	19.11	0.2	0.4	0.19	calculated	0.43	0.07	0.43
November	30.4	12.44	0.35	0.3	0.19	calculated	0.58	0.15	0.68
December	30.4	8.44	0.45	0.45	0.19	calculated	0.63	0.13	0.57
January	30.4	7.83	0.55	0.45	0.19	calculated	1.35	0.20	1.42
February	30.4	9.94	0.4	0.35	0.19	calculated	0.93	0.13	1.15
March	30.4	12.28	0.45	0.35	0.19	calculated	0.98	0.15	1.64
April	30.4	16.33	0.4	0.4	0.19	calculated	0.44	0.09	0.6
May	30.4	20.56	0.3	0.25	0.19	calculated	0.15	0.04	0.21
June	30.4	24.94	0.2	0.3	0.19	calculated	0.09	0.01	0.13
July	30.4	29.17	0.3	0.3	0.19	calculated	0.34	0.07	0.28
August	30.4	28.33	0.2	0.35	0.19	calculated	0.92	0.12	0.89
September	30.4	25.11	0.2	0.3	0.19	calculated	0.84	0.08	0.61

Notes:

°C - degrees Celsius
cm - centimeter
cm/day - centimeters per day

TABLE E.4-3

ANNUAL PCE MASS FLUX TO GROUNDWATER

Year	PCE Mass Flux (g/yr)			Year	PCE Mass Flux (g/yr)		
	Round 5	2x	10x		Round 5	2x	10x
1	0.00	0.00	0.00	51	0.77	1.55	7.75
2	0.00	0.00	0.00	52	0.79	1.58	7.90
3	0.00	0.00	0.00	53	0.81	1.61	8.07
4	0.00	0.00	0.00	54	0.82	1.65	8.24
5	0.06	0.12	0.59	55	0.84	1.68	8.41
6	0.12	0.24	1.18	56	0.86	1.72	8.59
7	0.26	0.51	2.57	57	0.88	1.76	8.78
8	0.26	0.52	2.58	58	1.33	2.67	13.29
9	0.26	0.52	2.59	59	1.37	2.75	13.68
10	0.26	0.52	2.59	60	1.39	2.79	13.91
11	0.26	0.52	2.60	61	1.41	2.84	14.13
12	0.26	0.52	2.61	62	1.44	2.88	14.36
13	0.26	0.52	2.62	63	1.46	2.93	14.60
14	0.26	0.52	2.63	64	1.48	2.98	14.85
15	0.26	0.53	2.64	65	1.51	3.03	15.09
16	0.37	0.74	3.71	66	1.53	3.08	15.35
17	0.50	1.01	5.05	67	1.56	3.13	15.60
18	0.51	1.01	5.06	68	1.59	3.19	15.87
19	0.51	1.02	5.08	69	1.61	3.24	16.14
20	0.51	1.02	5.11	70	1.64	3.30	16.41
21	0.53	1.06	5.29	71	1.67	3.35	16.69
22	0.53	1.06	5.32	72	1.70	3.41	16.97
23	0.54	1.07	5.35	73	1.73	3.47	17.25
24	0.54	1.08	5.38	74	1.75	3.53	17.54
25	0.54	1.08	5.42	75	1.78	3.59	17.84
26	0.55	1.09	5.45	76	1.81	3.65	18.14
27	0.55	1.10	5.49	77	1.84	3.71	18.44
28	0.55	1.11	5.54	78	1.87	3.77	18.75
29	0.56	1.12	5.58	79	1.91	3.83	19.06
30	0.56	1.13	5.63	80	1.94	3.89	19.37
31	0.57	1.14	5.69	81	1.97	3.96	19.69
32	0.57	1.15	5.74	82	2.00	4.02	20.01
33	0.58	1.16	5.81	83	2.03	4.09	20.33
34	0.59	1.17	5.87	84	2.07	4.15	20.66
35	0.59	1.19	5.94	85	2.10	4.22	20.98
36	0.60	1.20	6.02	86	2.13	4.29	21.32
37	0.61	1.22	6.10	87	2.17	4.35	21.65
38	0.62	1.23	6.18	88	2.20	4.42	21.98
39	0.63	1.25	6.27	89	2.23	4.49	22.32
40	0.64	1.27	6.36	90	2.27	4.56	22.66
41	0.65	1.29	6.46	91	2.30	4.62	23.00
42	0.66	1.31	6.57	92	2.33	4.69	23.34
43	0.67	1.33	6.68	93	2.37	4.76	23.68
44	0.68	1.36	6.79	94	2.40	4.83	24.03
45	0.69	1.38	6.91	95	2.44	4.90	24.37
46	0.70	1.41	7.04	96	2.47	4.97	24.72
47	0.72	1.43	7.17	97	2.51	5.04	25.06
48	0.73	1.46	7.30	98	2.54	5.11	25.41
49	0.74	1.49	7.45	99	2.58	5.18	25.75
50	0.76	1.52	7.59	100	2.61	5.25	26.10

Notes:

g/yr - grams per year

PCE - tetrachloroethene

TABLE E.4-4

AT 123D SIMULATION PARAMETERS

Parameter	Value	Unit(s) of Measure	Basis of Value
Mass to groundwater	SESOIL out file	kg/hr	data import from SESOIL simulation
Application area	2,508	m^2	(46m x 55m) assumed area in MIXCELL simulation
Total simulation length	876,000	hours	(100 years)
Soil bulk density	1.7	kg/m^3	assumed value in VLEACH simulation
Chemical decay rate	N/A	1/hr	degradation processes assumed to be negligible
Time step	730	hours	(1 month)
Hydraulic conductivity	2.00E-04	m/s	assumed value in MIXCELL simulation
Effective porosity	0.31	unitless	assumed value in MIXCELL simulation
Distribution coefficient (for adsorption)	2.38E-04	m^3/kg	assumed value in SESOIL simulation
Longitudinal dispersivity	50	m	literature value (Yeh, 1981)
Transverse dispersivity	10	m	literature value (Yeh, 1981)
Vertical dispersivity	1	m	literature value (Yeh, 1981)
Hydraulic gradient	0.003	unitless	assumed value in MIXCELL simulation

Notes:

kg/hr - kilogram per hour
kg/hr - kilograms per hour
kg/m^3 - kilogram per cubic meter
m - meters
m/s - meters per second
m^2 - square meters
m^3/kg - cubic meters per kilogram
N/A - not applicable

FIGURES

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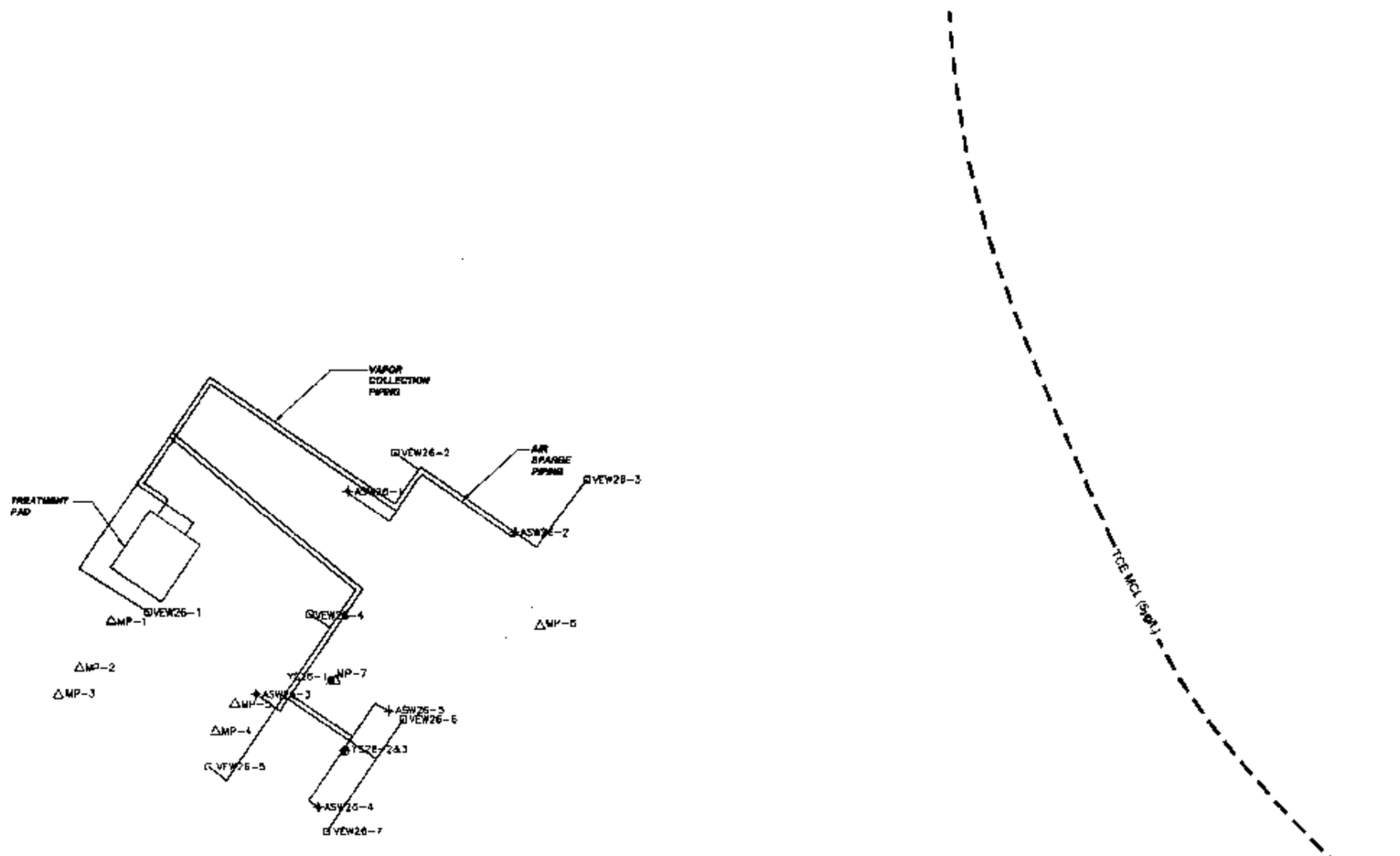
LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- GROUNDWATER MONITORING WELL OR PIEZOMETER (DECOMMISSIONED)
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- VAPOR MONITORING PROBE
- TCE CONCENTRATION CONTOUR (µg/L)



ABBREVIATIONS:

µg/L	MICROGRAMS PER LITER
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE

N

0 40 80

FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP OCTOBER 1988 BECHTEL 1998 (1998 RPA WORKPLAN) ORM, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY WERRELL JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
CAOC 28 SITE MAP

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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CHECKED BY: JB	YH	CTO: 0049	
DATE: 12-06-02			
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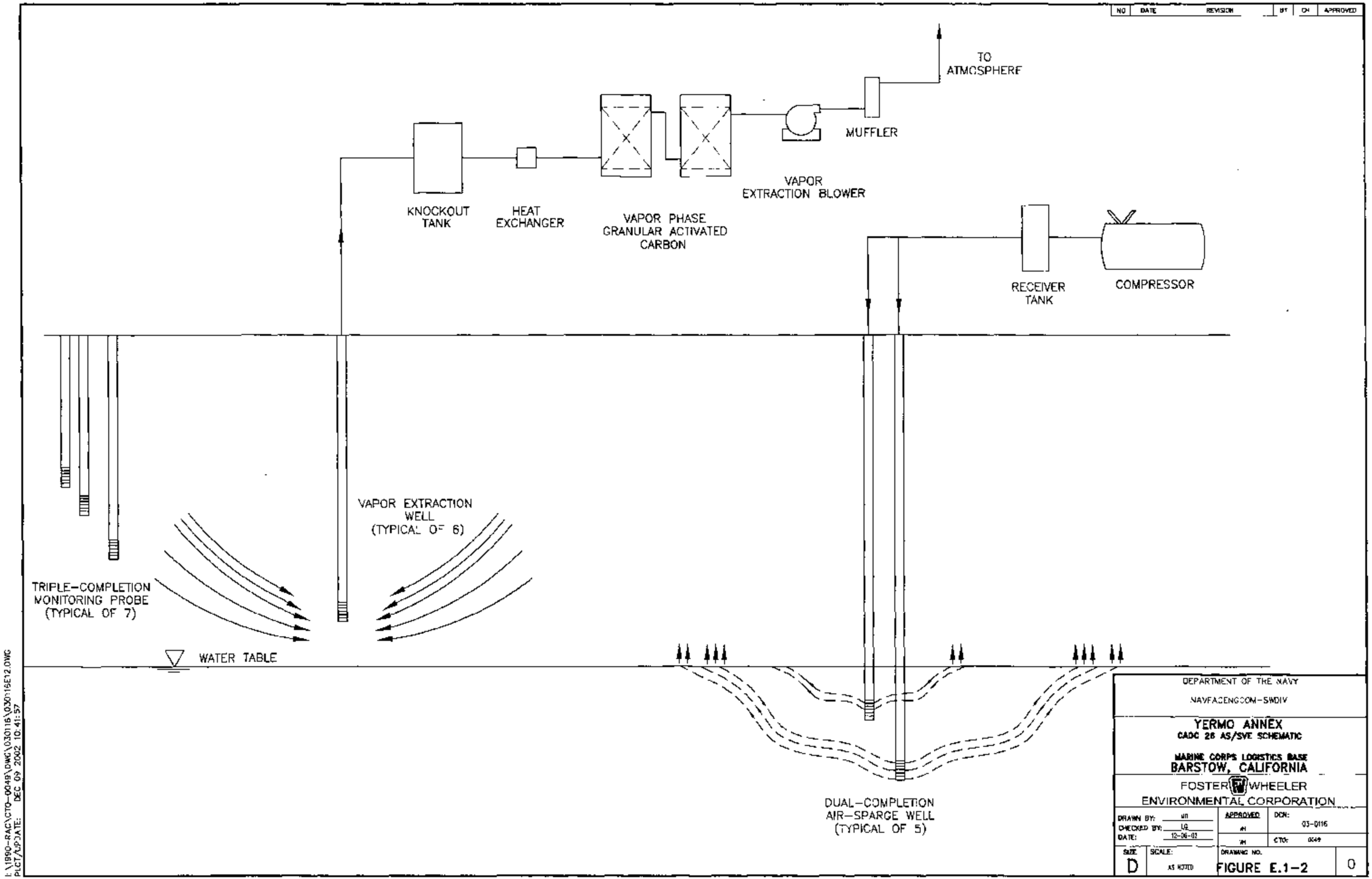
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CK
APPROVED
TO ATMOSPHERE
MUFFLER
VAPOR EXTRACTION BLOWER
KNOCKOUT TANK
HEAT EXCHANGER
VAPOR PHASE GRANULAR ACTIVATED CARBON
RECEIVER TANK
COMPRESSOR
VAPOR EXTRACTION WELL (TYPICAL OF 6)
TRIPLE-COMPLETION MONITORING PROBE (TYPICAL OF 7)
WATER TABLE
DUAL-COMPLETION AIR-SPARGE WELL (TYPICAL OF 5)
DEPARTMENT OF THE NAVY
NAVFACENGCOM-SWDIV
YERMO ANNEX
CADC 26 AS/SVE SCHEMATIC
MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA
FOSTER WHEELER
ENVIRONMENTAL CORPORATION
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CHECKED BY: LG
DATE: 12-06-02
APPROVED
AH
AH
DCN: 03-0116
CTO: 0049
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FIGURE E.1-2
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FIGURE E.2-1
SCREENING MODEL: SOIL GAS CONCENTRATIONS vs. ELCR and HI

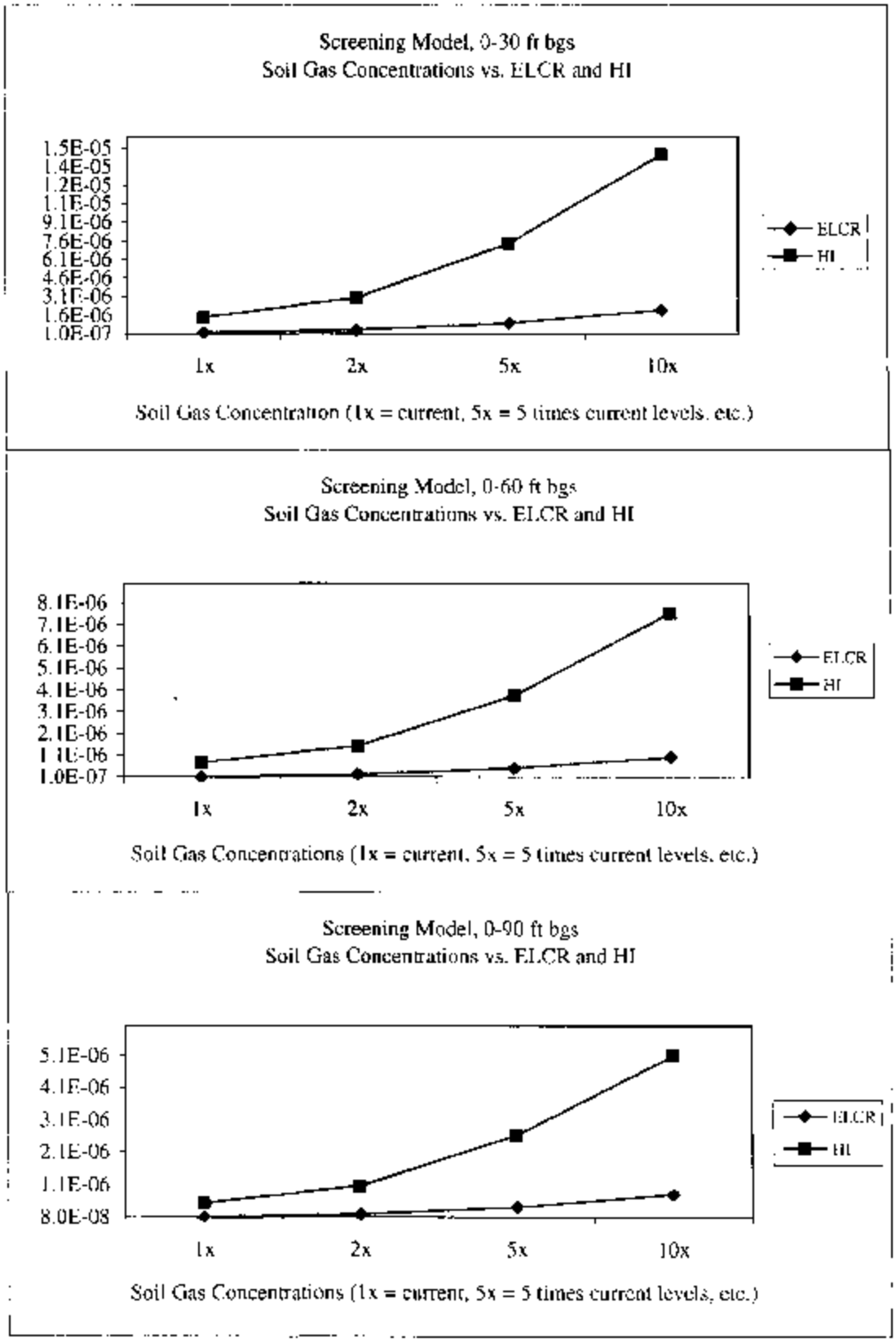
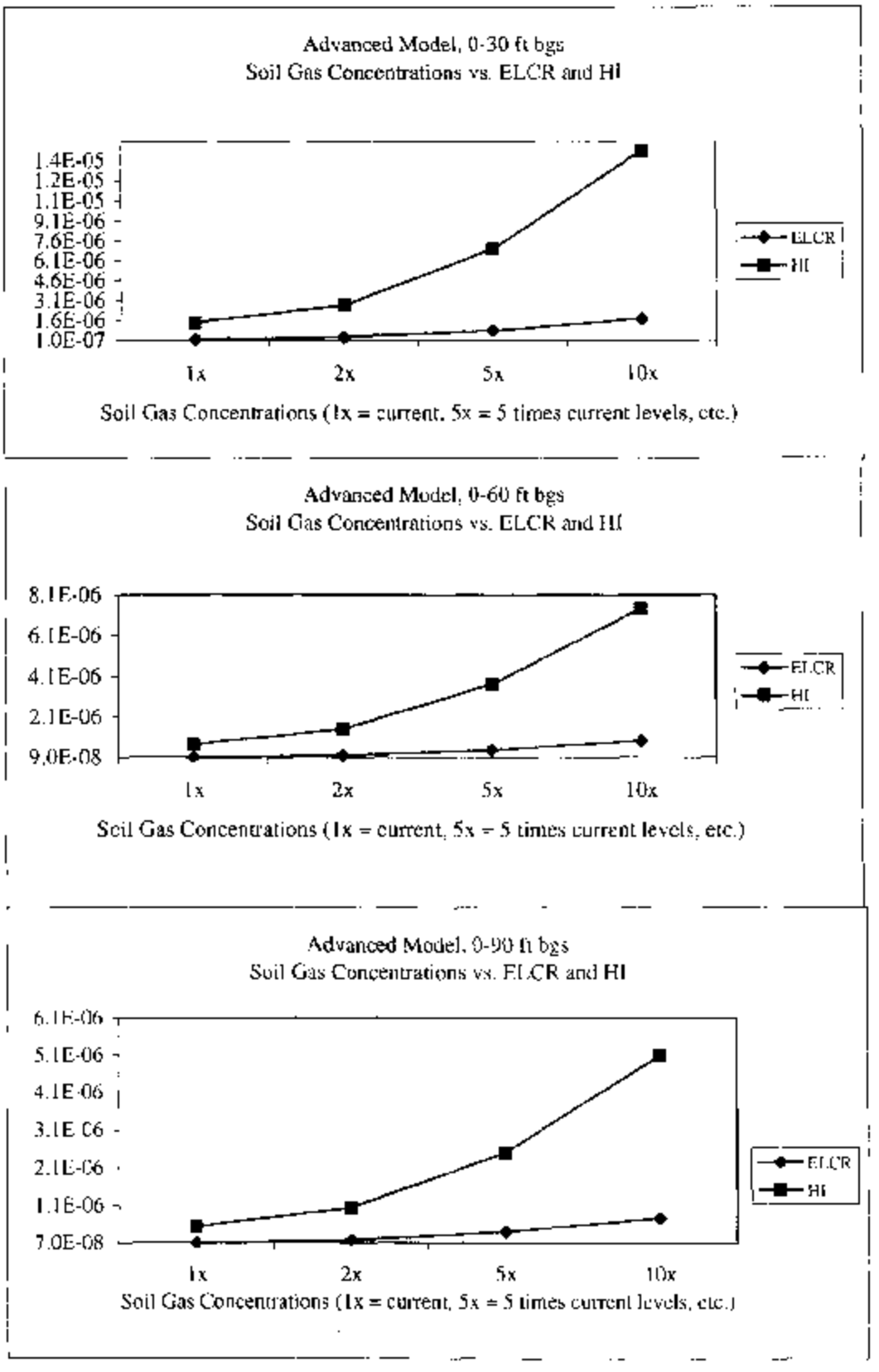


FIGURE E.2-2
ADVANCED MODEL: SOIL GAS CONCENTRATIONS vs. ELCR and HI



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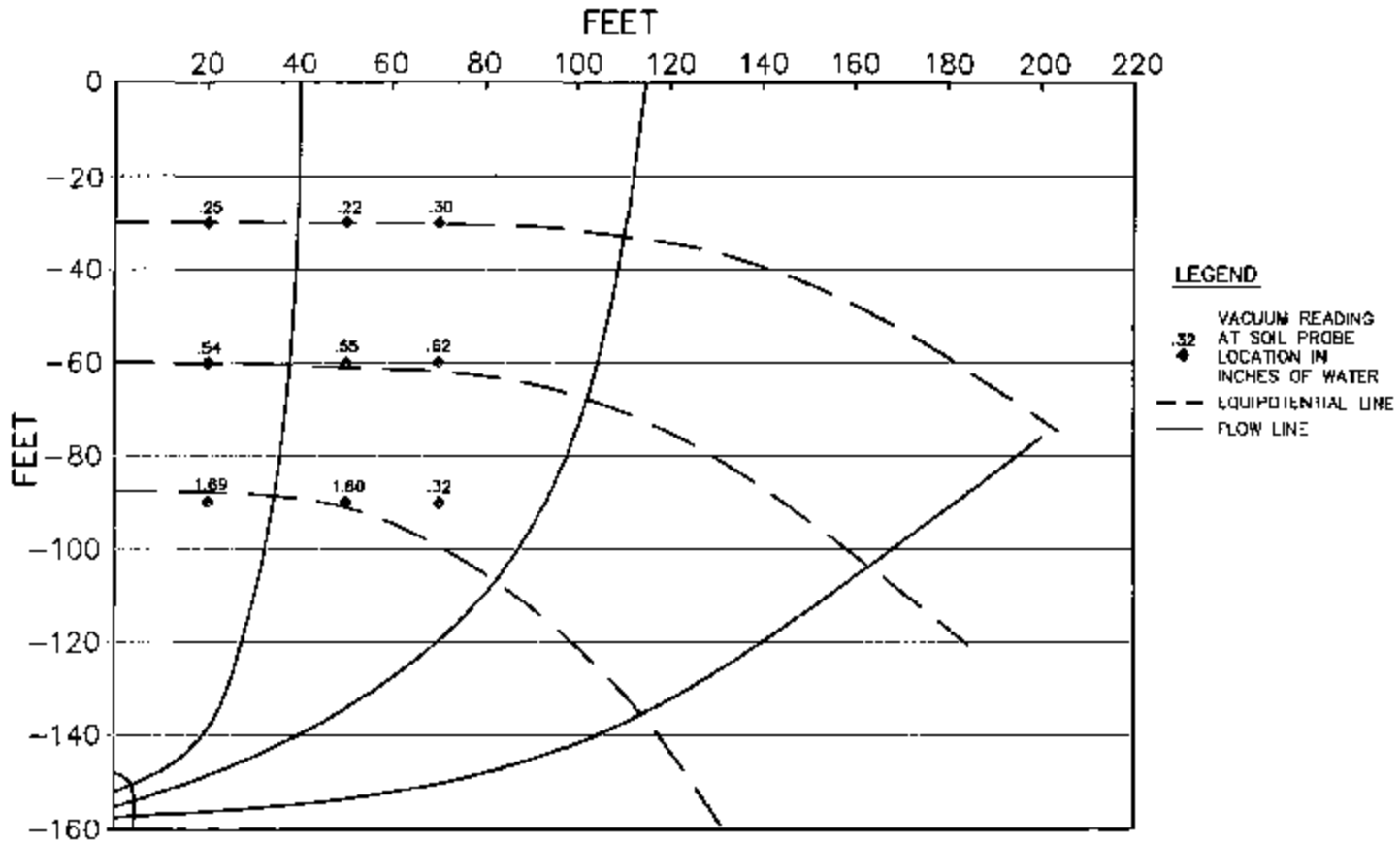

Figure E.3-1
COAC 26 – FLOW CHANNELS
SCREEN: 150 TO 160 FEET BGS

YERMO ANNEX – BARSTOW, CALIFORNIA

FOSTER WHEELER
ENVIRONMENTAL CORPORATION

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DATE: 12/06/02	REV: REVISION 0		CTO: #0049	030116E3.DWG

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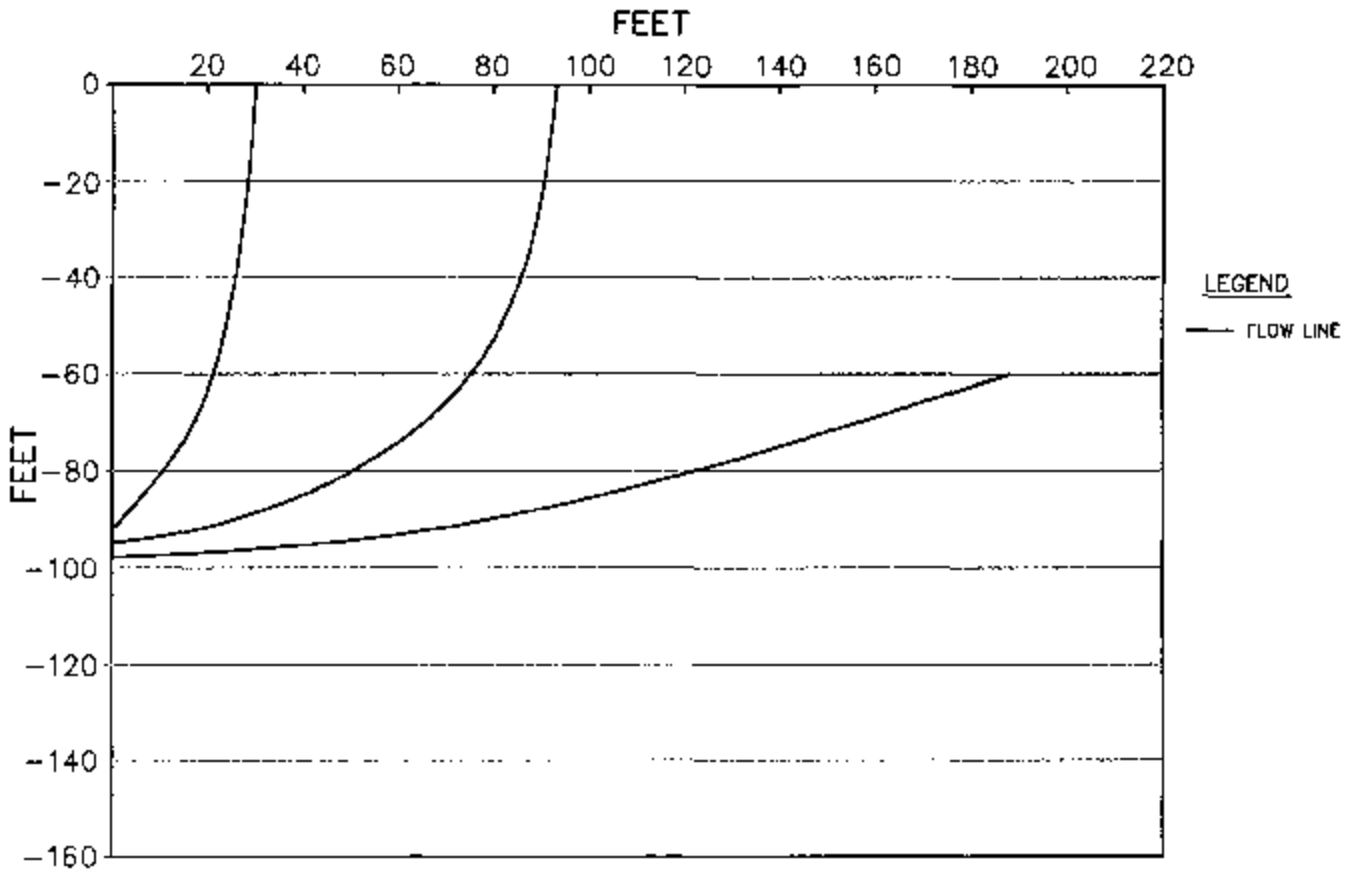

Figure E.3-2
CAOC 26 - FLOW CHANNELS
SCREEN: 90 TO 100 FEET BGS

YERMO ANNEX - BARSTOW, CALIFORNIA

FOSTER WHEELER
ENVIRONMENTAL CORPORATION

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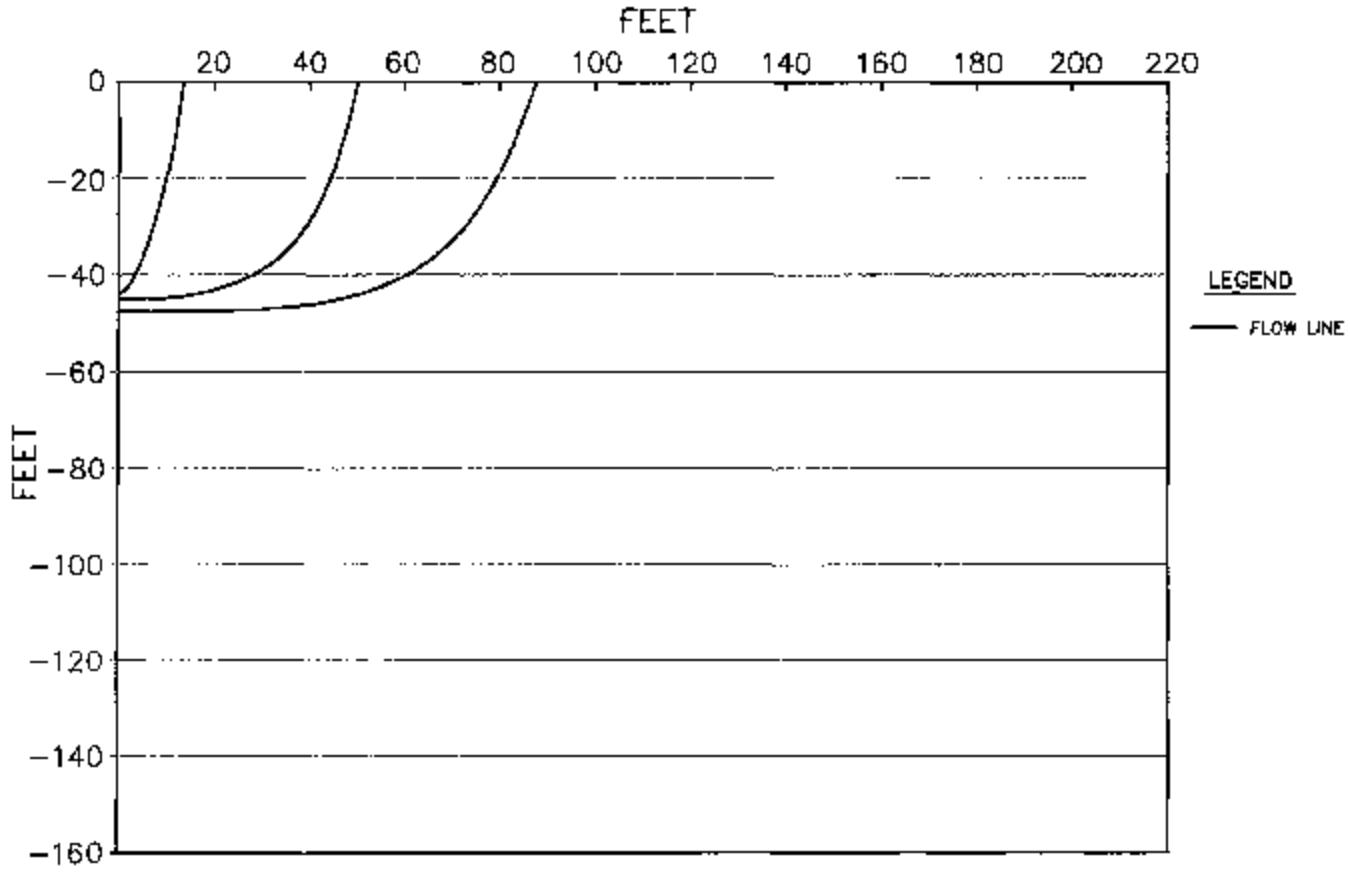


Figure E.3-3
CAOC 26 - FLOW CHANNELS
SCREEN: 40 TO 50 FEET BGS

YERMO ANNEX - BARSTOW, CALIFORNIA

FOSTER WHEELER
ENVIRONMENTAL CORPORATION

FIGURE 5.4-1
P(*) DISTRIBUTION AT z = 0 m, t = 100 years
(ROUNDS DATA)

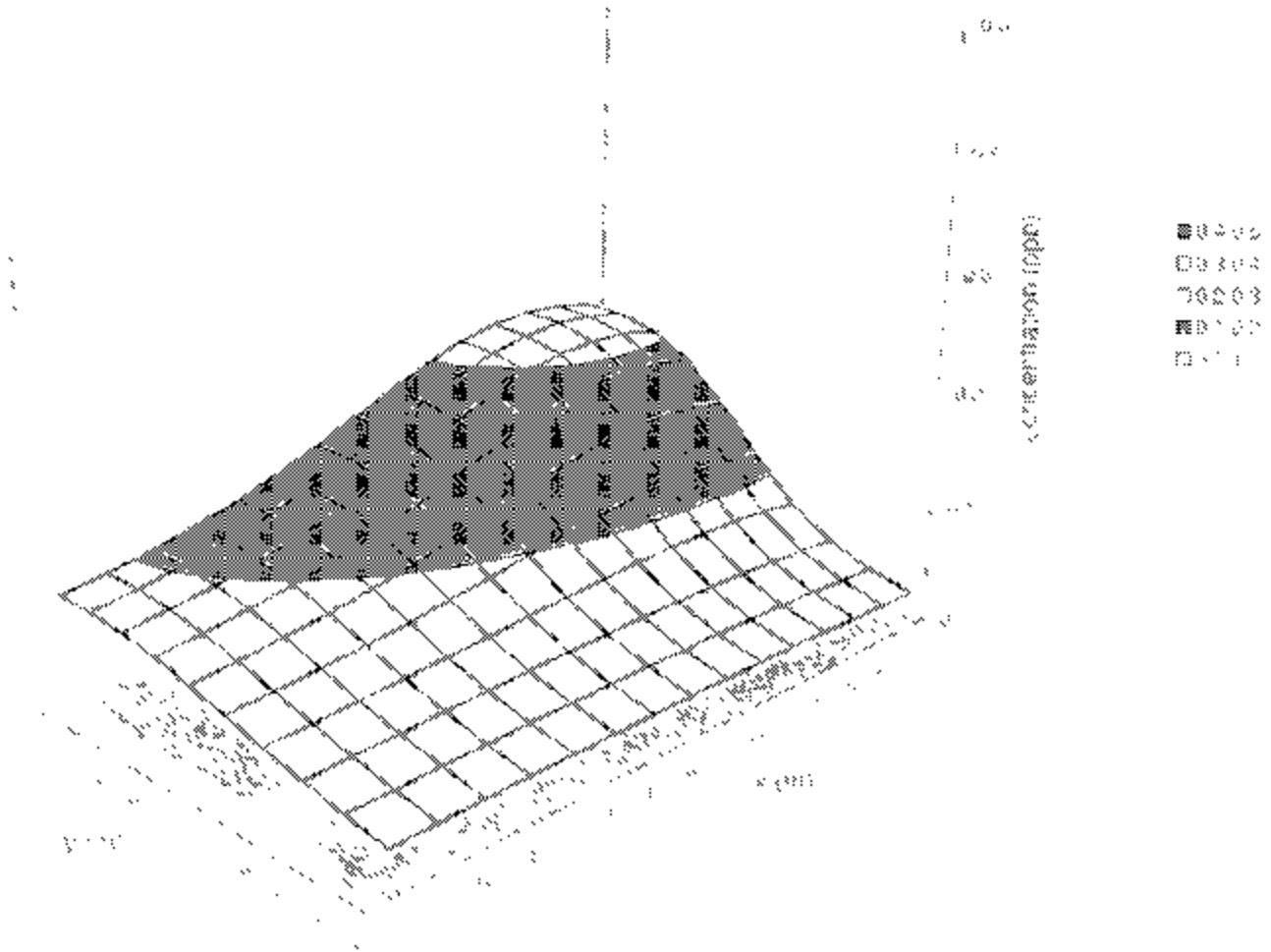


FIGURE 1.4.2
PDF DISTRIBUTION AT $t = 0$ and $t = 100$ years
(2X BOR MD5 DATA)

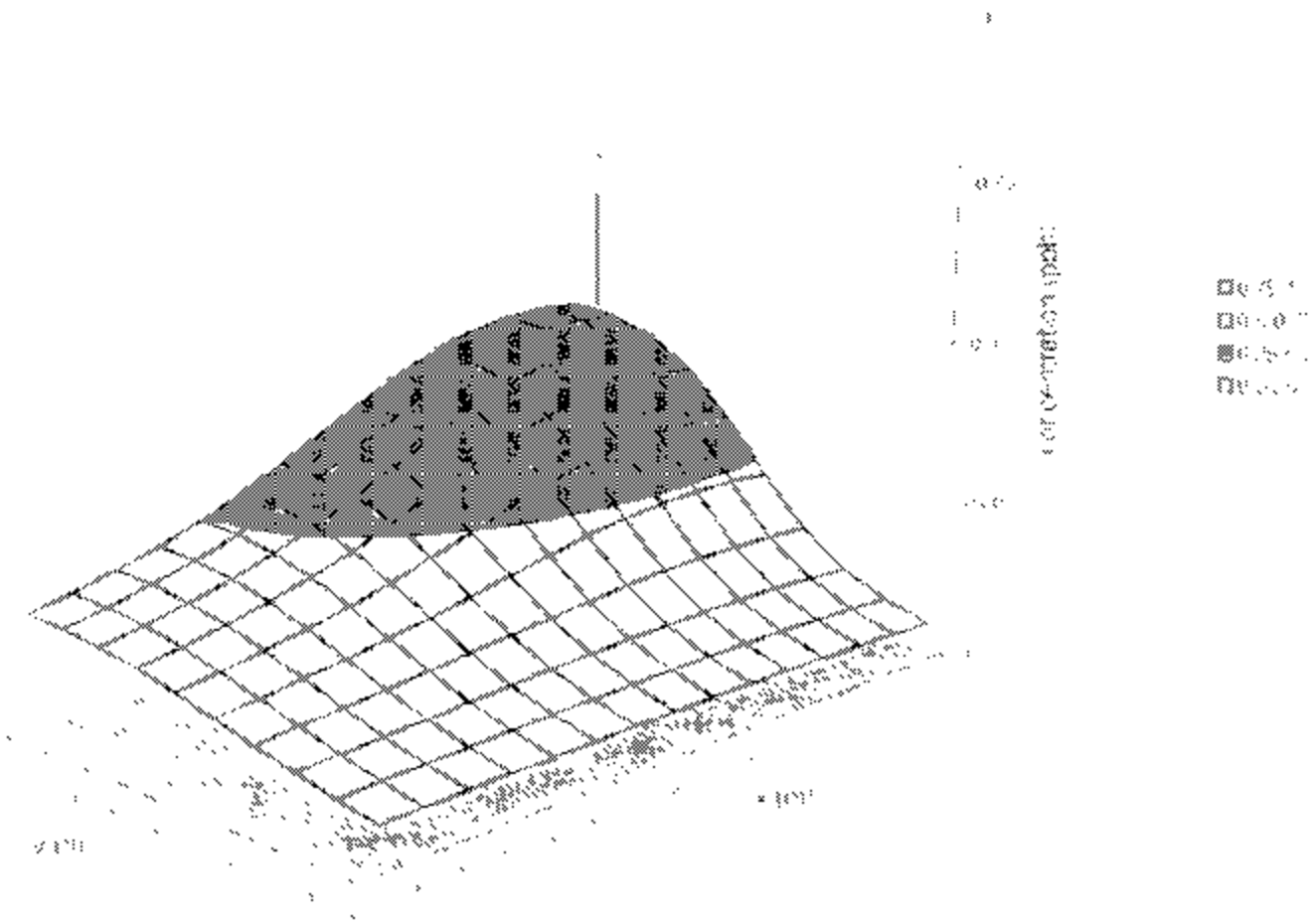


FIGURE F4.3
PCE DISTRIBUTION AT z = 0 m, t = 100 years
(BACKGROUND DATA)

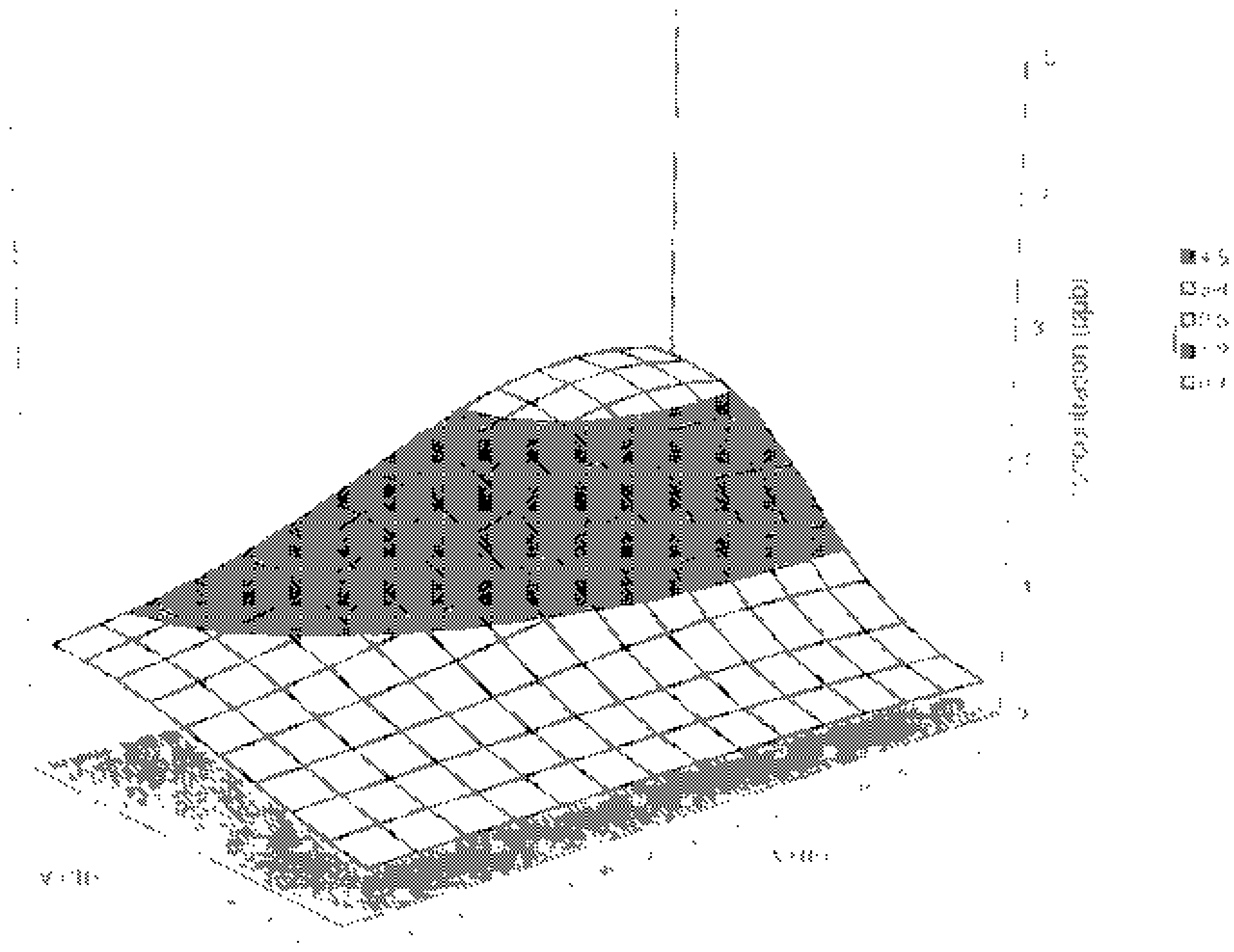
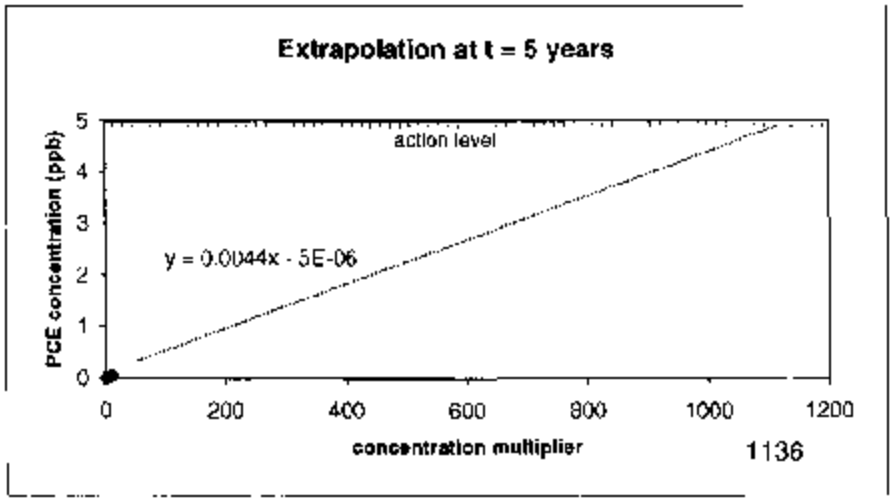
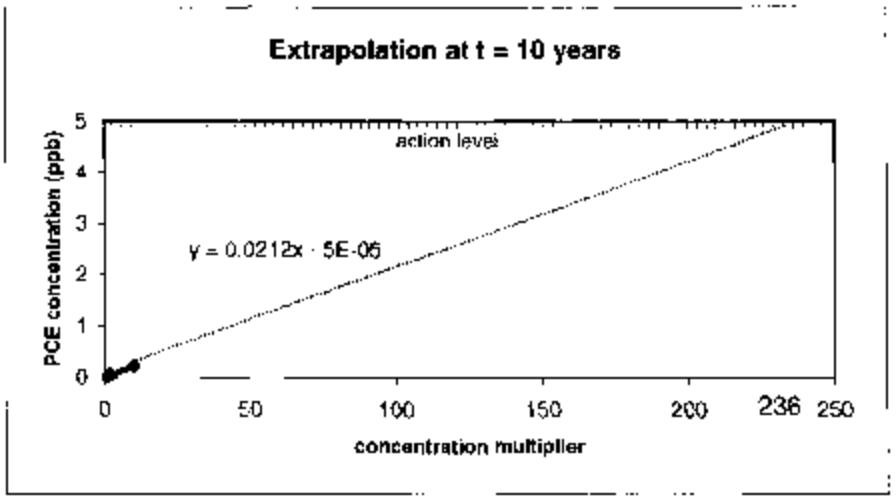


FIGURE E.4-4
CONCENTRATION MULTIPLIER EXTRAPOLATIONS





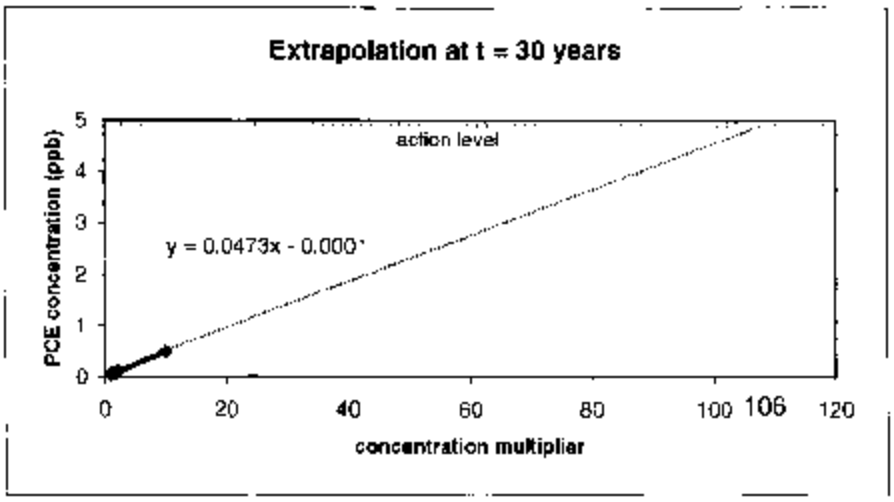
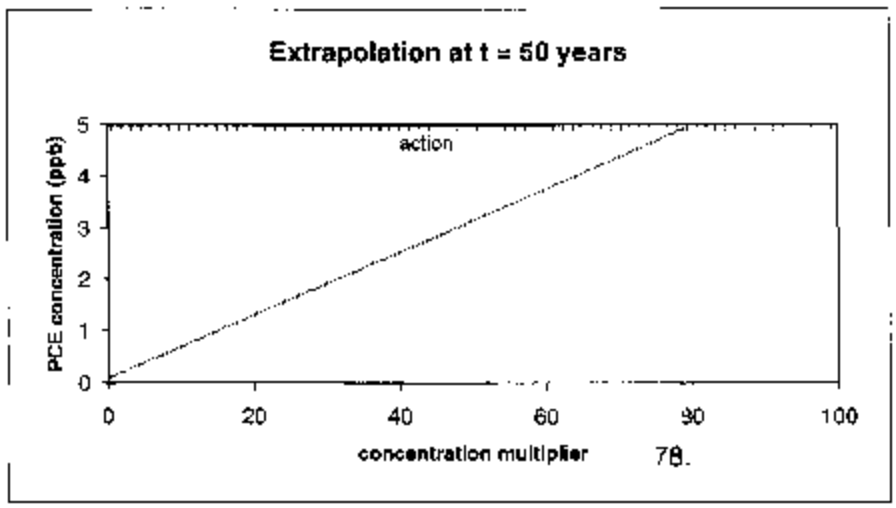
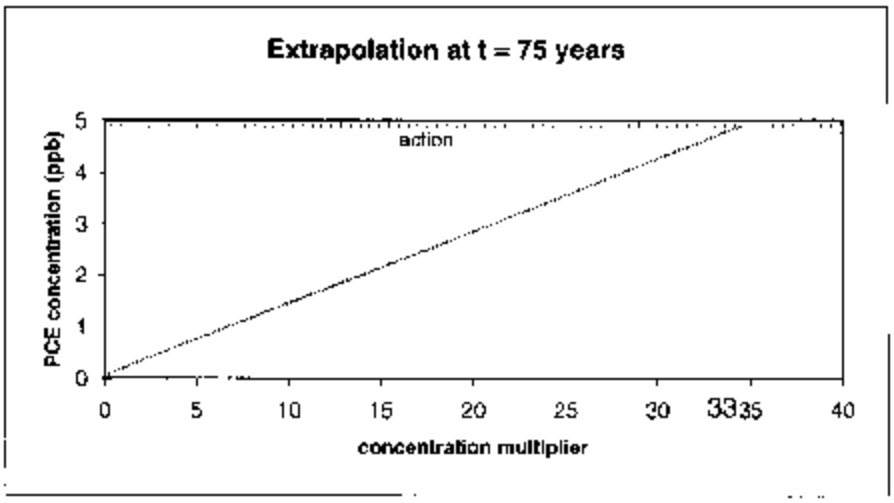


FIGURE E.4-4
CONCENTRATION MULTIPLIER EXTRAPOLATIONS





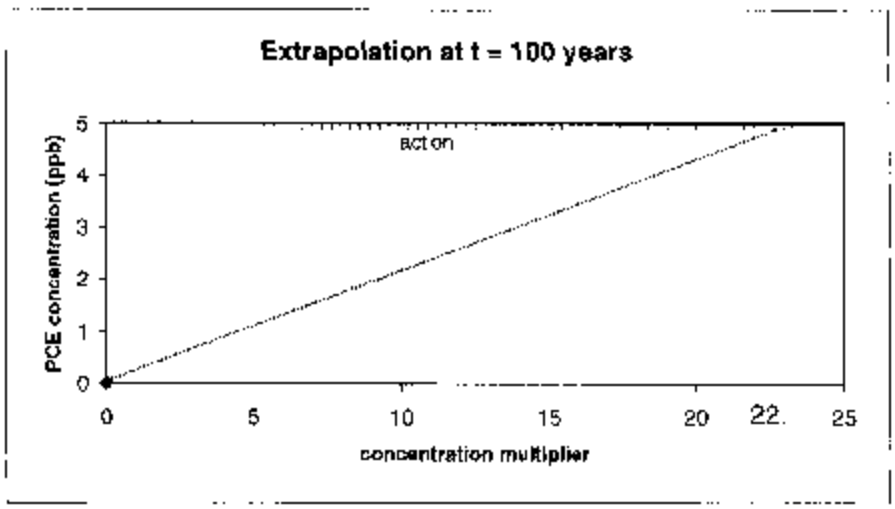
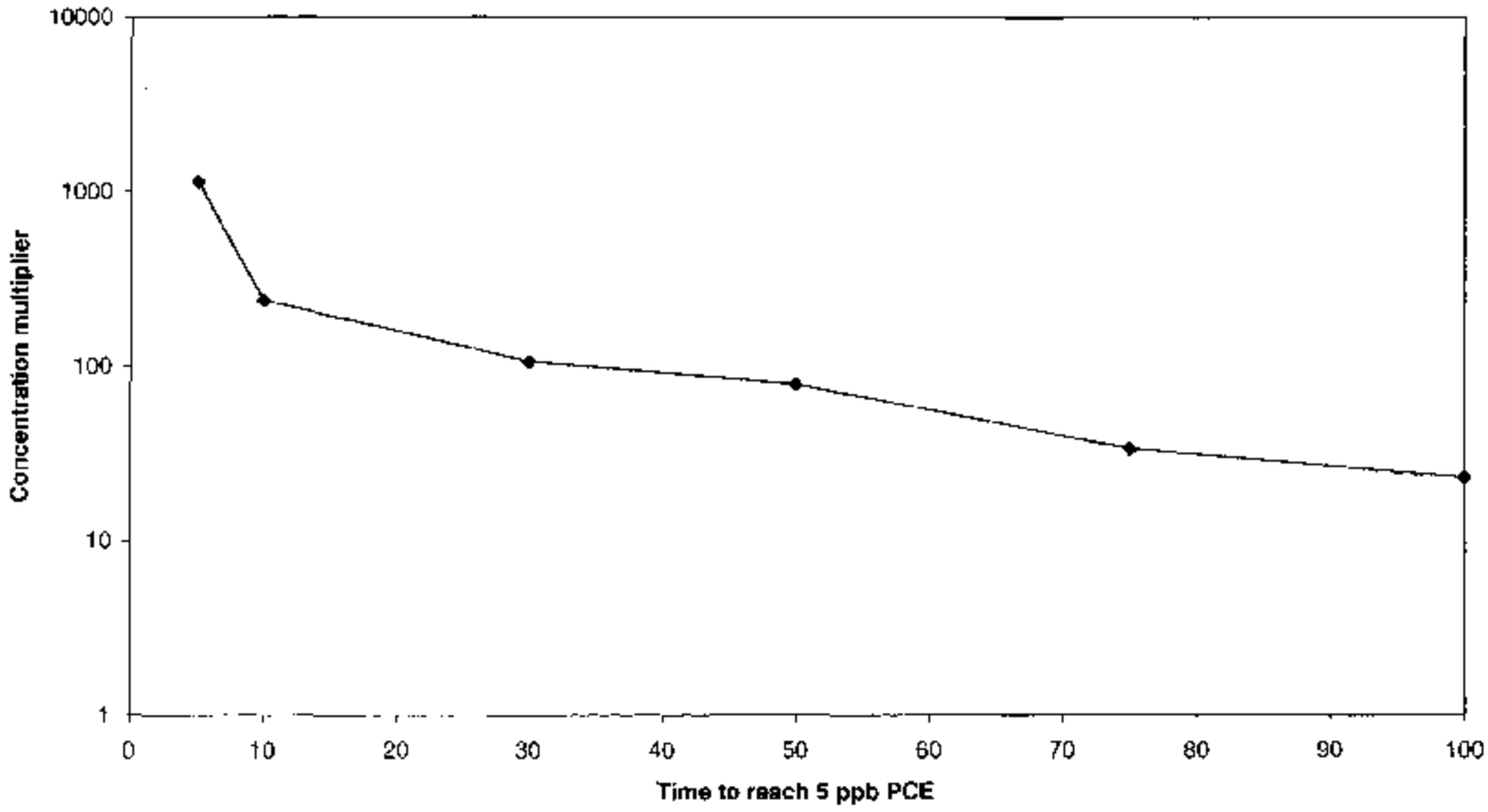


FIGURE E.4-5
MULTIPLIER-TIME CURVE FOR 5 ppb PCE



Notes:

ppb - parts per billion in water

ATTACHMENT 1

JVIM OUTPUTS - PCE

(This information is contained on the accompanying compact disk.)

ATTACHMENT 2

JVIM OUTPUTS - m/p-xylene

(This information is contained on the accompanying compact disk.)

ATTACHMENT 3

JVIM OUTPUTS - o-xylene

(This information is contained on the accompanying compact disk.)

ATTACHMENT 4

JVIM OUTPUTS - ethylbenzene

(This information is contained on the accompanying compact disk.)

ATTACHMENT 5

JVIM OUTPUTS - DCBM

(This information is contained on the accompanying compact disk.)

ATTACHMENT 6

JVIM OUTPUTS - TCE

(This information is contained on the accompanying compact disk.)

APPENDIX F

CAOC 37 GETS ASSESSMENT

Southwest Division
Naval Facilities Engineering Command
Contracts Department
1220 Pacific Highway, Building 127, Room 112
San Diego, California 92132-5190

CONTRACT NO. N68711-98-D-5713
CTO NO. 0049

APPENDIX F

CAOC 37 GETS ASSESSMENT

Revision 0
December 2002

MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

DCN: FWSD-RAC-03-0116

FOSTER WHEELER ENVIRONMENTAL CORPORATION
1230 Columbia Street, Suite 500
San Diego, CA 92101

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Figure F.4-4 Yermo Annex - Model-Simulated Groundwater Flow and Particle Pathways - Scenario 3 (Wells GEW-4, 6, 7, 9, 13, 14, and 15 Pumping at Reduced Capacity)

ABBREVIATIONS AND ACRONYMS

bgs	below ground surface
CAOC	CERCLA Area of Concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm/sec	centimeters per second
ft/day	feet per day
ft^3/day	Cubic feet per day
FS	Feasibility Study
FWENC	Foster Wheeler Environmental Corporation
GETS	groundwater extraction and treatment system
gpm	gallons per minute
gpm/ft	gallons per minute per foot
JEG	Jacobs Engineering Group, Inc.
Kh	horizontal hydraulic conductivity
Kv	vertical hydraulic conductivity
MCL	maximum contaminant level
MCLB	Marine Corps Logistics Base
ME	mean error
MTBE	methyl tert-butyl ether
msl	mean sea level
na	not available
OHM	OHM Remediation Services Corp.
OU	Operable Unit
PCE	tetrachloroethene
Q_{ave}	average flow rate
RI	Remedial Investigation
RMSE	root mean square error
ROI	radius of influence
TCE	trichloroethene
VOC	volatile organic compound

1.0 INTRODUCTION

The work described in this appendix was performed by Foster Wheeler Environmental Corporation (FWENC) to support the technical assessment of the groundwater extraction and treatment system (GETS) at the Yermo Annex [Operable Unit (OU) 1] of the Marine Corps Logistics Base (MCLB), Barstow, California, under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) area of Concern (CAOC) 37. This evaluation was performed as part of the five-year review process.

1.1 BACKGROUND

The following sections provide a general background associated with the GETS at the Yermo Annex, including a brief description of the hydrogeologic conditions at the site and a short summary of the operational history of the system.

1.1.1 General Site Information

MCLB Barstow is located in the central Mojave Desert region of San Bernardino County, California, and consists of the Nebo Main Base and the Yermo Annex (Figure F.1-1). The Yermo Annex, is located approximately 7 miles east of the city of Barstow and covers an area of approximately 1,680 acres. It is bounded by Interstate 15 to the north and the Mojave River to the south.

At the Yermo Annex, the presence of trichloroethene (TCE) and tetrachloroethene (PCE) was identified in the groundwater at the Yermo Annex during the Remedial Investigation (RI) for the MCLB [Jacobs Engineering Group, Inc. (JEG), 1995]. A GETS was built and started in 1996 to provide hydraulic containment and mass reduction of the dissolved volatile organic compound (VOC) plumes at the Yermo Annex.

Since that time, the groundwater at Yermo has been monitored on a quarterly basis via a network of wells to evaluate the performance of the GETS. A map containing all of the locations of all the groundwater monitoring and extraction wells is provided in Figure F.1-2, which also includes an interpretation of the TCE and PCE plume boundaries based on the first quarter 2002 sampling results.

1.1.2 Hydrogeologic Setting

The Yermo Annex of MCLB Barstow lies within the west/northwest-trending Barstow Basin, which is approximately bounded by the Blackwater/Calico Faults to the northeast and by the Lenwood Fault to the southwest. The Barstow Basin dips sharply to the southeast and is filled with a sequence of late Tertiary to early Quaternary alluvial deposits. Surface sediments

throughout the basin typically consist of windblown sand and recent alluvial deposits derived from the Mojave River or shed from adjacent highlands.

The sediments underlying the Yermo Annex are essentially composed of a thick sequence (up to 600 feet) of alluvial fan deposits of gravel, sand, silt, and clay. Beneath these deposits lies a sequence of low permeability Tertiary volcanic and sedimentary rocks (Densmore, Cox, and Crawford, 1997). These rocks likely constitute bedrock in this area. Geophysical survey data and lithologic logging of deep exploratory boreholes performed during the RI identified the top of bedrock at approximately 600 feet below ground surface (bgs) (JEG, 1995).

Two separate aquifers have been identified in the area surrounding the Yermo Annex, the regional aquifer, and the more localized Mojave River aquifer (Densmore, Cox, and Crawford, 1997). Beneath Yermo, the Mojave River aquifer is generally composed of the saturated sediments that extend from the surface to a depth of approximately 200 feet bgs. This aquifer is underlain by a regional aquifer which consists of the saturated sediments between approximately 200 feet bgs and bedrock at about 600 feet bgs beneath the eastern boundary of the Yermo Annex.

Groundwater typically occurs at approximately 165 to 170 feet bgs and flows to the east/ southeast. A map including a representative example of static groundwater elevation and flow patterns (based on data from December 2001) is provided in Figure F.1-3. Preliminary testing conducted after the installation of the GETS indicates that the aquifer is unconfined and possesses an average hydraulic conductivity of 4×10^{-2} centimeters per second (cm/sec) with an overall specific yield of 0.3 [OHM Remediation Services Corp. (OHM), 1997].

1.1.3 Operational History

The GETS at OU 1 was designed to provide hydraulic containment of the dissolved VOC plumes beneath the Yermo Annex and to minimize additional off-site migration of groundwater contaminants. It was installed in 1996 and originally consisted of 13 extraction wells that conveyed the extracted groundwater to a central facility for treatment with granular activated carbon. The treatment facility was designed to handle a maximum capacity of 1,600 gallons per minute (gpm).

Of the original 13 extraction wells, eight were installed along the eastern boundary of the Yermo Annex (GEW-1 through GEW-8), four were installed near the central portion of the Base in Lot 487 (GEW-9 through GEW-12), and one was placed near the northeast corner of Building 573 (GEW-13). The locations of the wells are indicated in Figure F.1-2, which also includes interpretations of the dissolved VOC plumes based on the first quarter 2002 sampling results.

When the GETS first began operation in 1996, the total flow rate extracted from all 13 wells ranged from approximately 800 to 1,200 gpm, with the average rate typically observed around

l, 000gpm. However, due to a steady decline in regional aquifer levels across the greater Barstow area, groundwater levels in the Yermo Annex have consistently dropped by approximately 2 to 4 feet per year since the GETS was installed. As a result of this decline, the average total flow rate produced by all 13 wells had dropped to approximately 500 gpm by January 2001.

In January 2001, the system was placed on standby due to the detection of methyl tert-butyl ether (MTBE) (from a potential off-base source) in groundwater wells located in the southern and southeastern portions of the base. The extraction wells were temporarily shut down to minimize the potential for drawing the MTBE further downgradient and to allow time to upgrade the treatment facility to accommodate the additional loading created by the MTBE.

While the system was on standby, other upgrades, unrelated to the MTBE issue, were made to the system. Between December 2001 and February 2002, two new extraction wells, GEW-14 and GEW-15, were installed on the northern and southern ends of the line of barrier wells along the eastern boundary of the Annex. These wells were installed to replace the existing wells, GEW-1 and GEW-8, that were pumping at a relatively low capacity and have had a history of operating at low efficiencies. The GETS infiltration galleries were also rehabilitated in February and March 2002 to improve the recharge of the system effluent back into the aquifer.

The GETS was restarted on May 31, 2002 and has been in operation since that time. However, upon restarting the system, the regional, decline in groundwater levels had reached a point to where they have had significant effect on the operating capacities of a majority of the extraction wells in the GETS. Flow rates had to be significantly reduced in order to maintain enough water to sustain pumping in most of the wells. Details regarding the most current status (as of September 2002) of each of the groundwater extraction wells are provided in Section 2.1.

1.2 ASSESSMENT APPROACH

The performance of the GETS was assessed as follows:

1. Extraction Well Performance - Trends in flow rate and specific capacity over the duration of GETS operation were evaluated, the radius of influence (ROI) for the extraction wells was compared to the values used for the design of well spacing.

2. Computer model simulations were performed to provide a comprehensive evaluation of groundwater flow patterns.

Extraction well performance is discussed in Section 2.0, and modeling is discussed in Sections 3.0 through 6.0.

2.0 EXTRACTION WELL PERFORMANCE

The following sections provide a brief evaluation of the overall performance of the individual groundwater extraction wells at OU 1. The evaluations are based on comparison of current operating parameters to historical values. Replacement extraction wells, GEW-14 and GEW-15, are discussed only briefly in the following sections as they have only been in operation since May 31,2002.

2.1 FLOW RATES

When the GETS was installed at OU 1, the original groundwater extraction wells (GEW-1 through GEW-13) were completed with submersible pump systems capable of producing approximately 100 gpm from each well (with an operating range of 40 to 110 gpm) for total flow capacity from all 13 wells of about 1,300 gpm.

Shortly after the system was started in 1996, the 13 original extraction wells were producing an average total flow rate of approximately 800 to 1,000 gpm. However, the steady decline in regional water levels has resulted in reduced pumping capacities for most of the wells in the system. A brief assessment of the changing flow rates is provided in this section.

Flow rates for each of the original 13 wells, averaged for each month from the time the system was started, are provided in Table F.2-1. The table also includes monthly values for the overall total flow rate produced by all 13 wells in combination. Graphical presentations of the flow rates versus time for each well, including trendlines, are provided in Figure F.2-1 (GEW-1 through GEW-4), Figure F.2-2 (GEW-5 through GEW-8), and Figure F.2-3 (GEW-9 through GEW-13).

Based on the results provided in Table F.2-1, the average flow rates in individual wells have decreased from 1 to 93 percent between December 1996 and June 2002. In fact, flow rates have decreased by more than 50 percent in 10 of the 13 wells (GEW-1 through 6, GEW-8, and GEW-10 through 12) over that time period. These decreases are illustrated by the steeply sloping trendlines observed in Figures F.2-1 through F.2-3.

Several modifications have been made to the GETS recently in response to the declining flow rates observed in the extraction wells. Wells GEW-1 and GEW-8 were replaced with two new, slightly deeper extraction wells in the spring of 2002. Wells GEW-1 and GEW-8, located along the southern and northern ends of the eastern barrier line, respectively (see Figure F.1-2), have each well have been producing water at a rate of less than 20 gpm since May 2000 (see Table F.2-1), well below the designed operating capacity of the pump systems. In fact, GEW-8 had been producing less than 10 gpm since August 2000.

Therefore, between January and May 2002, GEW-1 and GEW-8 were taken offline and replaced with deeper wells, GEW-14 and GEW-15 (Figure F.1-2). The screen intervals for both GEW-14 and GEW-15 were installed approximately 50 to 75 feet below the current water table to extend the useful lifetime of these wells. GEW-14 was positioned between GEW-2 and GEW-3 to optimize hydraulic capture of the southernmost dissolved TCE plume at OU I, and GEW-15 was placed approximately between GEW-7 and GEW-8 to optimize the capture of the northernmost dissolved TCE/PCE plumes at the Yermo Annex.

In addition, extraction wells, GEW-5, GEW-10, GEW-11, and GEW-12, were taken out of service in September 2002 due to poor production capacities observed after the GETS was restarted in May 2002. All four of these wells were producing water at flow rates of 16 gpm or less in June 2002, values well under the operating specifications for the pump systems installed in those wells. It is expected that the removal of these four wells from service will not likely reduce the hydraulic containment of the dissolved contaminants at the Yermo Annex as they are located too far away from the current plume boundaries to exert a significant influence.

2.2 SPECIFIC CAPACITY

One common method of evaluating the performance of a production or extraction well is to calculate the specific capacity of that well. The specific capacity of a given well is defined as the ratio of the pumping or discharge rate to the corresponding drawdown within that well. It is calculated by dividing the flow rate by the measured drawdown in the well and Is typically expressed in gallons per minute per foot of drawdown.

Specific capacity values for GEW-1 through GEW-13 have been monitored on a quarterly basis (for the most part) since the startup of the system in 1996. The quarterly specific capacity results are provided in Table F.2-2 and plotted graphically against time in Figures F.2-4 through F.2-6.

Based on the trends observed in Table F.2-2 and Figures F.2-4 through F.2-6, specific capacity values in all of the extraction wells, except GEW-1 and GEW-5, have generally decreased between the startup of the GETS in December 1996 and December 2000. However, for many of the wells, the individual specific capacity values vary considerably from one quarter to the next. This variation is likely due to the way in which the drawdown values are calculated, as many factors apart from pumping itself can affect the water level within a given well at any given time.

For example, if the cones of depression for two adjacent pumping wells should overlap, the drawdown measured in either of the wells will be increased by some amount if both wells are actively pumping. All of the extraction wells at the Yermo Annex lie adjacent to one or more extraction wells and are designed to have overlapping influences. Therefore, the drawdown in a given extraction well should be measured with only that well pumping and all other wells being off.

In addition, the static water level within a given well must be measured accurately to calculate a reliable value for drawdown. Measurement of this value could be masked by pumping in nearby or adjacent wells or variations in groundwater levels within the aquifer itself. In light of the declining regional water levels at the Yermo Annex, direct comparison of the specific capacity values between each quarter may not accurately reflect the actual changes in well performance.

The overall trend of declining specific capacities observed in the majority of the extraction wells at the Yermo Annex is likely due to the regional drop in groundwater levels, which has resulted in reduced flow rates and lower water levels in all of the wells.

2.3 RADIUS OF INFLUENCE

Although flow rates and specific capacity values provide useful information regarding the performance of individual extraction wells, estimates of the pumping ROI for each well can likely provide a better indication of the overall effectiveness of the system to provide hydraulic containment of the dissolved contaminants. An assessment of the ROI for the groundwater extraction wells at OU 1 is provided in the following paragraphs.

At the time of installation, all of the original groundwater extraction wells, except GEW-13, were placed approximately 600 feet apart from one another. For barrier wells, GEW-1 through GEW-8, the wells were placed 600 feet apart from one another to form a northeast to southwest trending line along the eastern margin of the site. Wells GEW-9 through GEW-12 were placed in a quadrangular configuration in the central portion of the facility with the same spacing of 600 feet between wells. Based on this spacing, each well would require an ROI of 300 feet in order for the hydraulic influence of each well to overlap with that of adjacent wells.

Shortly after the original 13 extraction wells were completed in 1996, an extensive aquifer/pump test program was conducted to estimate the initial flow rates for each well and to provide information with respect to the hydrologic properties of the aquifer (OHM, 1997). From these tests, the ROI values for 8 of the 13 wells were determined by extrapolation of distance-drawdown data collected from nearby observation wells and piezometers. Estimated values of the ROI or extent of the cone of depression for each of the Yermo Annex extraction wells ranged from 600 to over 1000 feet at the time of the tests (OHM, 1997). Based on these results, a well spacing of 600 feet was more than adequate to create overlapping influence of adjacent wells and provide hydraulic control of the dissolved contaminants.

However, the reduction in flow rates and specific capacities resulting from the regional decline in groundwater levels have also resulted in a steady decrease in the ROI for each well. For the purposes of this assessment, an estimate of current ROI values can be obtained using the Thiem equation for steady radial flow in an unconfined aquifer under the following assumptions (Fetter, 1994).

1. The aquifer is unconfined and is underlain by a horizontal aquiclude.

2. The well is pumped at a constant rate.

3. Equilibrium has been reached and there is no further change in drawdown over time.

Assuming that these conditions hold true for the Yermo Annex, estimates of the ROI at various pumping rates can be estimated using empirically derived aquifer parameters for the site with the Thiem equation as outlined below.

Steady Radial Flow in an Unconfined Aquifer (Thiem equation):

$$Q = (2\pi rh)K(dh/dr)$$

Where:

Q = flow or pumping rate
h = saturated thickness of the aquifer
K = hydraulic conductivity of aquifer materials
dh/dr = hydraulic gradient

Rearrange equation, solve for r:

$$r = \frac{Q}{(2\pi h)K(dh/dr)}$$

Based on pump test data from OHM (1997):

K = 0.04 cm/sec
= 113.4 ft/day
dh/dr = 0.001 (based on Figure F.l-3)

Inserting values into the rearranged Thiem equation and reducing:

$$r = \frac{Q(ft^3 / day)}{(6.28)(113.4\ ft/day)(0.00l)\ h\ (ft)}$$

$$r = (1.42)\ Q/h$$

where Q is expressed in cubic feet per day (ft^3/day) and h in ft.

From the reduced form of the equation above, the ROI (expressed as r above) is dependent on two variables: the pumping rate (Q) and the saturated thickness of the aquifer (h). A list of ROI values based on a range of anticipated pumping rates is provided in Table F.2-3.

Table F.2-3 also includes several different values for the saturated thickness of the aquifer (h). Because the groundwater extraction wells at the Yermo Annex do not penetrate the full extent of the aquifer, the approximate lengths of saturated screen interval for the wells were used for (h) values as an estimate for this evaluation. The values of 40 and 25 feet were selected to represent the range of saturated screen that would be expected in light of the declining water levels.

The results of the initial aquifer/pump tests performed prior to the system startup provide a useful check of the applicability of this method of evaluation and the assumptions inherent to it. For example, the test data indicated that the ROI values for most wells pumping at approximately 100 gpm ranged from roughly 600 to 1,000 feet or more. The calculated ROI values using the Thiem equation for the wells pumping at 100 gpm range from 683 .4 to 1,093.5 feet for saturated thickness (h) values of 40 and 25 feet, respectively (Table F.2-3). This indicates that the general assumptions and use of the Thiem equation provide a good approximation of ROI values for this assessment.

The majority of the original 13 groundwater extraction wells at the Yermo Annex currently have screened intervals that are submerged approximately 20 to 30 feet into the aquifer. Based on the calculated values provided in Table F.2-3, these wells would need to pump at a rate of slightly over 25 gpm to maintain a ROI of 300 feet. As of June 2002, five wells are currently pumping at flow rates above 75 gpm (GEW-7, GEW-9, GEW-13, GEW-14, and GEW-15) and the remaining four wells currently in operation are pumping above 25 gpm (GEW-2, GEW-3, GEW-4, and GEW-6) (see Table F.2-1).

With respect to the ROI values alone, four of the remaining nine wells in operation are approaching the point where their range of influence will fall short of 300 feet. However, it is difficult to predict how this will affect the hydraulic capture of the dissolved plumes based on these values alone. Therefore, a more complete assessment of the potential effects of changes in the ROI, including predictions of the resulting hydraulic capture, was performed using computer-aided groundwater model simulations of current and potential future conditions. A detailed description of the modeling effort is provided in Section 3.0.

3.0 GROUNDWATER FLOW MODEL DEVELOPMENT

The previous section (Section 2.0) provides an indication of the performance of individual groundwater extraction wells during the period covered by the five-year review process. In addition to the assessment of individual extraction well performances provided in Section 2.0, computer-aided model simulations were also performed to provide a more comprehensive evaluation of groundwater flow patterns beneath OU 1. Details regarding the development of the conceptual model used for the groundwater beneath the Yermo Annex are provided in the following sections.

The Yermo Annex groundwater model was developed using the MODFLOW software program, a three-dimensional finite-difference groundwater flow model (McDonald and Harbaugh, 1988). Groundwater flow pathways, based on the resulting simulated flow field, were computed and displayed using MODPATH (Pollock, 1989), a separate software program. Another software program, Groundwater VISTAS (Rumbaugh, 1998), was used as a pre-processor and post-processor for both MODFLOW and MODPATH.

3.1 MODEL OBJECTIVES

Groundwater modeling for the MCLB Barstow was originally conducted by JEG as part of the RI/Feasibility Study (FS) (JEG, 1996). The results of the original modeling were used to support the design specifications for the GETS at OU 1. Several years later, an updated conceptual hydrogeologic model was developed by FWENC to simulate the effects of replacing and relocating two groundwater extraction wells on the hydraulic containment of the dissolved contaminant plumes (FWENC, 2001). The current modeling effort was performed in conjunction with the five-year review process in order to meet the following objectives.

- To establish a current baseline model for the hydraulic containment of the contaminant plumes to account for recent changes in the operating conditions of the system. These changes are outlined below.

- To simulate the effects of removing selected wells from the system would have on the hydraulic containment of the dissolved contaminant plumes. In particular, the model was used to evaluate operating efficiencies in light of the regional decline in groundwater levels within the Yermo Annex groundwater basin.

Some of the changes that were incorporated into the updated conceptual model include:

- Incorporating the observed/measured flow rates of GEW-14 and GEW-15 to reflect actual operating conditions

- Expanding the model grid to include areas upgradient to the base that may have a future impact on the operation of the GETS.

- Recalibrating the baseline model to include the reduced flow rates currently observed in the majority of the extraction wells (due to declining regional water levels) and to reflect the most recent interpretations of the dissolved contaminant plumes.

3.2 MODEL SETUP

The conceptual hydrogeologic model for the Yermo Annex was developed based on site-specific geologic and hydrogeologic information provided in the *Draft Final RI Report for OUs 1 and 2, MCLB Barstow, California* (JEG, 1995), and the groundwater modeling section of the *Draft Final FS Report for OUs 1 and 2, MCLB Barstow, California* (JEG, 1996). A description of the hydrogeologic parameters used in the model is provided in Section 2.2 of the latter, and a brief list of assumptions is provided below.

The primary assumptions used in the OU 1 groundwater flow model include:

- The average hydraulic conductivity for the aquifer is 0.04 cm/sec.
- The overall specific yield for the aquifer is 0.3.
- The northern, eastern, southern, and western grid boundaries were defined as constant head cells. Constant head, by definition, is a boundary where the head (groundwater elevation) does not change during the course of a simulation.
- All flow simulations represent steady state conditions.
- The total flux into the model domain from the infiltration galleries is equal to the total flux extracted by the GEWs.

3.2.1 Numerical Model Domain

The numerical domain of the model covers an area of 219,000,000-square feet, encompassing all of the main areas of interest at Yermo Annex, including several important off-base elements. For the model, a three-dimensional finite-difference grid was constructed using three layers, with 231 rows and 261 columns (for a total of 180,873 cells) to represent the area. A graphical illustration of the numerical model domain is provided in Figure F.3-1.

In order to accurately evaluate the effects of the GEWs on groundwater, the model area near the wells was defined using a relatively fine finite-difference grid. The grid spacing in the area near the extraction wells was 25 feet, and was increased to 100 feet towards the model boundaries. Grid spacing increases or decreases were set at increments no greater than 1.5 times the spacing of the adjacent cell (or block) to prevent numerical model instabilities. Because the grid system is very fine near the extraction wells, the wells were located near the center of the smaller cells with greater accuracy.

3.2.2 Aquifer Thickness

To simulate the effects of extracting groundwater from deeper intervals, the aquifer beneath the Yermo Annex was subdivided into three layers for the simulations. A variable aquifer thickness, ranging from 17 feet to 30 feet, was used for Layer 1. All 13 original extraction wells (GEW-1 through GEW-13) and the two newly installed wells (GEW-14 and GEW-15) were located in Layer 1.

A second layer, Layer 2, was added assuming a constant thickness of 70 feet to simulate the deep drinking water pumping wells, and to account for any possible vertical flux to the extraction wells. This is a conservative approach, as it prevents overestimation of capture zones and underestimation of necessary extraction rates.

To evaluate the vertical flow movement for potential future study related to deeper portions of the aquifer, a third layer, Layer 3, was added underneath Layer 2. The bottom of Layer 3 approximately follows the elevation of bedrock illustrated in the cross section map of page 6-17 of the *Draft Final RI Report for OUs 1 and 2, MCLB Barstow, California* (JEG, 1995). The thickness of this layer varies from 110 feet in the western portion of the site to 270 feet at the eastern end.

3.2.3 Boundary Conditions

Model boundaries should be selected at appropriate regional locations far enough away from the site to minimize influences of the boundaries to the groundwater flow in the area of interest. For this model, the boundaries were specified as constant head boundaries with a sufficient distance from the Yermo Annex GETS to minimize their influence. A section of the Mojave River is located within the model area, but it was not directly set as a boundary condition as it remains dry for most of the year.

Regional groundwater flow beneath the Yermo Annex is typically observed from west to the east. However, groundwater measurements obtained from the Calnev site (located southwest of the Yermo Annex; see Figure F.l-2) indicate a significant amount of groundwater mounding in the southwest corner that has resulted in an observed local groundwater flow direction from southwest to the northeast in that area.

Because the regional groundwater levels are steadily declining, the constant head boundary condition must also vary with time. For this reason, the model has been calibrated twice using groundwater elevation measurements for two different time periods. The initial hydraulic gradient for the first model calibration was set using groundwater elevation measurements from December 2000. Constant heads in Layer 1 were assigned based on the hydraulic gradients developed from the measured water levels and ranged from 1,800 feet above mean sea level at the northwestern boundary of the model grid to 1,790 feet above msl at the southeastern

boundary. The boundary conditions for Layer 2 and Layer 3 were set to the same as those in Layer 1.

The constant head boundary condition was adjusted for the second calibration and future simulation based on the groundwater elevation measurements obtained during June 2002. In general, the groundwater elevations for the constant head boundary of June 2002 are about three feet lower than those for December 2000. The Calnev survey data, which show a significant groundwater mounding, were used to calculate the constant head boundary condition in the southwest comer of the modeling area for both calibrations.

3.2.4 Extraction Wells

A total of 13 groundwater extraction wells were included in the first model calibration. These wells represent the original wells in operation at the Yermo Annex. Groundwater extraction rates for each individual well were based on the actual rates observed in 2000. Table F.3-1 includes the flow rates used for the first model calibration.

Two existing drinking water wells, YDW-4 and YDW-5, were also used for the model calibration and simulations. Pumping rates for the two drinking water wells were assigned based on actual average values for the year, for a total of approximately 160 gpm. Because these two wells are deep screened, their pumping rates were equally divided between the two layers. The drinking water well, YDW-3, was not simulated in the model because it has been decommissioned.

3.2.5 Infiltration Galleries

The treated groundwater effluent from the OU 1 GETS is returned to the subsurface through infiltration galleries that serve to recharge the local aquifer. For the model simulations, the infiltration galleries were treated as groundwater injection wells. Total flux into the model domain from the infiltration galleries was set equal to the total flux extracted through the groundwater extraction wells. This mass balance was maintained for all of the model simulations.

3.2.6 Hydraulic Conductivity

Aquifer tests conducted at the Yermo Annex indicated an average horizontal hydraulic conductivity value of approximately 115 feet per day (ft/day) (JEG, 1995). The value used in a previous flow modeling effort for the Yermo Annex was 142 ft/day (JEG, 1995). These two values were used as initial estimates for model calibration. However, the final estimate of horizontal hydraulic conductivity after model calibration was 130 ft/day for model Layer 1, 100 ft/day for model Layer 2, and 50 ft/day for model Layer 3. Model Layer 3 represents the deeper portions of the aquifer, which are below the vertical influence zone of the extraction wells. The model calibration results indicated that the model simulations were not sensitive to the horizontal

hydraulic conductivity of Layer 3. It should be noted that previous modeling efforts were conducted with an assumed thickness of 50 to 70 feet for Layer 3, considerably thinner than the 100 to 270 feet used for the model simulations presented in this report.

Vertical hydraulic conductivity (K_V) values of model layers representing aquifer zones were assigned initial values that are ratios of the equivalent horizontal hydraulic conductivity. In practice, the K_V is often unknown, as is the case for Yermo Annex site. The calibrated ratios of K_H to K_V for this effort were selected as 10 to l (K_H: K_V = 10:1).

3.2.7 Recharge

The regional recharge from the ground surface was set at 10 percent of the regional precipitation for the area. Regional precipitation at the Yermo Annex is approximately 5 inches per year. It was assumed that 90 percent of precipitation is lost to evaporation and evapotranspiration. The average recharge for the paved areas was reduced by another 50 percent due to water entering storm drains and leaving the site.

3.3 MODEL CALIBRATION

The steady-state groundwater flow model was calibrated by two phases: calibration under conditions of heavy pumping and verification based on the most current static groundwater levels. The hydraulic parameters were first calibrated to the hydraulic conditions at the Yermo Annex site observed during December 2000. December 2000 represents the latest heavy pumping season from which site-wide water-level data are available.

The existing groundwater extraction wells and drinking water wells typically exert a heavy influence on the aquifer. In addition, the infiltration galleries also have a strong hydraulic influence on groundwater beneath the Yermo Annex site. The hydraulic response to these influences provides valuable information with respect to the aquifer characteristics and allows for a more defensible calibration. The calibration processes and future simulations will be based on similar influences and aquifer responses. Therefore, the uncertainty of the future aquifer responses to new stresses during model simulations is reduced.

For the first model calibration, all 13 of the original extraction wells were assumed to be pumping at the average flow rates observed in December 2000 (Table F.3-1). The results of the model calibration are provided in Table F.3-2 as a comparison of the measured water levels to those predicted by the model.

The first model calibration results listed in Table F.3-2 indicate that the simulated heads correspond closely to the observed heads. The observed head in wells YWA-3 and YW-2 (measured on December 27, 2000) were considered outliers as the measured water levels appear unusually high compared to those observed in nearby wells and to previous measurements for the same wells. Therefore, the observed water levels at these two wells were not included as

calibration targets.

Among the groundwater elevation measurements obtained from 15 wells at the Calnev facilities, seven measurements near the model boundary were used to calculate the boundary value. The remaining eight observations, from the wells located relatively far away from the boundary, were used in conjunction with measurement data from the Yermo Annex for the model calibration.

The residual standard deviation, a statistical measure of the calibration error, was 0.50 feet between the simulated and measured heads, which constitutes only 2.2 percent of the maximum head difference amongst the measured heads. Values less than approximately 10 to 15 percent are generally considered an indication of a good calibration (Groundwater VISTAS; Rumbaugh, 1998).

The model was also recalibrated to match the hydraulic conditions at the Yermo Annex site observed on June 5, 2001. Groundwater measurements from June 5, 2001, represent static conditions when all of the existing groundwater extraction wells were shut off, except for the drinking water wells. These groundwater observations provide current information with respect to the most recent constant head boundary conditions. This information is crucial to estimate the effects of the steady decline in regional water levels.

All hydraulic parameters of the flow model remain the same except the boundary condition during the second phase of the model calibration. Essentially, this phase of model calibration is also a verification process. The second model calibration results listed in Table F.3-3 indicate a good match between the simulated heads and the observed heads. The residual standard deviation was 0.52 feet between the simulated and measured heads, which constitutes only 2.0 percent of the maximum head difference between the observed and simulated head results.

It is important to note that the first calibration data set and the second calibration or verification data are independent of one another. The statistical summary of residuals for both sets of calibration results have been shown to fall within acceptable limits of error, therefore the model is considered "verified" based on accepted practices (Anderson and Woessner, 1992).

4.0 MODEL SIMULATIONS

Once calibrated, the resulting computer model was used to simulate a baseline groundwater flow pattern and predict future flow patterns under a range of hydrologic conditions. Future flow simulations included various scenarios to evaluate the effects of the steady decline in regional water levels and reduced production in the groundwater extraction wells. Descriptions of each of the model simulations are provided below.

4.1 BASELINE SIMULATION

Recently, two replacement extraction wells, GEW-14 and GEW-15, were installed to increase the containment of the downgradient portion of the dissolved plumes by replacing two existing wells (GEW-1 and GEW-8, respectively) that had been operating at reduced efficiencies for some time. The two new wells are included in the baseline simulation with all other existing wells except GEW-1 and GEW-8. For the baseline conditions, it was assumed that the GETS would operate at an average rate of 520 gpm, similar to the current average pumping rate for June 2002 (Table F.4-1). Extraction rates for each individual well are provided in Table F.4-1.

An additional drinking water well, YDW-6, was recently installed at the site, but is not currently in operation as of June 2002. This well was therefore not included in the baseline simulation. For the baseline simulation, the total pumping rate for YDW-4 and YDW-5 (from the model calibration) was equally divided between the two wells, resulting in a rate of 80 gpm for each well.

Figure F.4-1 illustrates the model-predicted groundwater particle flow pathways under the baseline conditions, including the contaminant plume boundaries interpreted from the first quarter 2002 sampling results. For the particle tracking analysis, some particles were released near the current plume boundaries to simulate potential downgradient contaminant migration pathways.

With the exception of a small number of particles released along the easternmost extent of the northern and southern maximum contaminant level (MCL) plume boundaries (as interpreted), all of the simulated particle paths illustrated in Figure F.4-1 indicate capture of the on-Base portions of the plumes by the currently operating extraction wells. The baseline results indicate that the current operating parameters of the existing extraction wells are providing sufficient containment of the on-Base portions of the dissolved contaminant plumes at OU 1.

4.2 SIMULATION SCENARIOS

In addition to the baseline simulation, the groundwater model constructed for the Yermo Annex was also used to predict the effects of the declining regional water levels by simulating reduced pumping rates in some wells. Three separate scenarios were selected to represent the most

plausible set of predicted operating conditions for the GETS for the near future. A description of each scenario, including a brief discussion of the simulation results, is provided below.

4.2.1 Scenario 1

Scenario 1 involves nine wells (GEW-2, GEW-3, GEW-4, GEW-6, GEW-7, GEW-9, GEW-13, GEW-14, and GEW-15) pumping at the same rates used for the baseline simulation (Table F.4-1), but Wells GEW-5, GEW-10, GEW-11, and GEW-12 were shut off. Each of these four wells have been consistently operating at a relatively low capacity for the past several quarters due to the declining water levels. Two of these four wells (GEW-5 and GEW-12) are also located at a considerable distance cross-gradient to the current plume boundaries and have had minimal effect on the plumes for some time.

This scenario is intended to simulate the most current set of operating conditions as these same four wells have been shut down as of September 2002. The model simulated flow patterns for Scenario 1 are illustrated graphically in Figure F. 4-2.

Based on the simulation results for Scenario 1 (Figure F.4-2), shutting down GEW-5, GEW-10, GEW-11, and GEW-12 will not significantly reduce hydraulic capture of the on-Base dissolved contaminants. In fact, the model predicted simulation for Scenario 1 indicates a pattern of hydraulic containment similar to that predicted for baseline conditions (Figure F.4-1), with only few differences.

Under Scenario 1, the water particles originally captured by GEW-5 in the baseline simulation are drawn into GEW-6 and do not reach off Base. In addition, particles released near Wells GEW-10 and GEW-11 are captured by Wells GEW-9 and GEW-13, respectively. Because of its location with respect to the plume, the turning off of GEW-12 appears to have no effect on the capture of the CAOC 26 plume.

4.2.2 Scenario 2

Scenario 2 involves seven wells (GEW-2, GEW-3, GEW-7, GEW-9, GEW-13, GEW-14, and GEW-15) pumping at the baseline rates (Table F.4-1) with Wells GEW-4, GEW-5, GEW-6, GEW-10, GEW-11, and GEW-12 shut off. It extends the logic of Scenario 1 by shutting off two more wells along the eastern barrier that are located some distance cross-gradient to the contaminant plumes and likely have little effect on their capture. The model simulated flow patterns for Scenario 2 are illustrated graphically in Figure F.4-3.

Based on the computer predicted results, almost all of the on-Base portions of the contaminant plumes would be captured under the conditions simulated for Scenario 2. The simulated particle flow paths for Scenario 2 do show some groundwater flowing off Base in the central portion of the barrier, approximately between Y4-2 and GEW-5. However, the flow lines in that area represent clean water that has not been affected by VOCs.

4.2.3 Scenario 3

Under the previous two scenarios, five of the extraction wells (GEW-7, GEW-9, GEW-13, GEW-14, and GEW-15) were assumed to be pumping at their current rates (approximately 75 gpm or more). Scenario 3 represents a prediction of future conditions under which the pumping rates at four of these wells are reduced to 50 gpm (GEW-7, GEW-13, GEW-14, and GEW-15), and Wells GEW-9, GEW-4, and GEW-6 were set to 25 gpm each. This scenario represents future effects of declining water levels across the region and beneath OU 1. The model simulated results for Scenario 3 are illustrated in Figure F.4-4.

The model results for Scenario 3 indicate that even under the influence of reduced pumping rates, the on-Base portions of the dissolved contaminant plumes at the Yermo Annex will be contained on site and kept from migrating off-Base (Figure F.4-4). It is observed that the flow lines associated with Scenario 3 are almost similar to those resulting from the previous two scenarios, with one notable exception described below.

In Figure F.4-4, the flow lines emanating from or passing through the northwest portion of the TCE plume at CAOC 26 are not pulled into GEW-9 at 25 gpm, but are drawn toward the Base supply/drinking water well, YDW-5, which pumps at a much higher rate (80 gpm for the model). This could result in the pulling of dissolved contaminants into influent at YDW-5 and spreading of the overall extent of the CAOC 26 plume.

4.3 SUMMARY AND CONCLUSIONS OF MODELING

The results of the groundwater model simulations indicate that the groundwater extraction and treatment system at OU 1 is currently providing adequate capture and hydraulic containment of the on-Base portions of the dissolved contaminant plumes beneath the Yermo Annex. It was noted that the model results for Scenarios 1 and 2 indicate that taking Wells GEW-4, GEW-5, GEW-6, GEW-10, GEW-11, and GEW-12 offline would not reduce the capture of the on-Base plumes.

In addition, the model simulation for the anticipated conditions of reduced pumping in most of the pumping wells (Scenario 3) indicates that the CAOC 37 GETS is capable of providing containment and capture of the on-Base portions of the VOC plumes, even as the regional water levels decline. However, the model predictions for these conditions do indicate that a portion of the CAOC 26 TCE plume would be drawn toward the Base supply/drinking water well, YDW-5, due to reduced pumping rates in GEW-9.

5.0 SENSITIVITY ANALYSIS IN THE MODEL CALIBRATION PROCESS

Model calibration is a process used to identify the parameters, boundary conditions, and stresses that enable the numerical model to produce simulated hydraulic heads and fluxes that match values observed in the field measurements, within a pre-established range of errors (Anderson and Woessner, 1992).

The steady-state groundwater flow model was calibrated using an iterative process to match the observed hydraulic head values measured on December 27, 2000. This process consisted of four phases:

1. Calibration of horizontal hydraulic conductivity
2. Adjustment of constant head elevations at the boundary
3. Adjustment of groundwater recharge distribution
4. Calibration of vertical leakance

Feedback from review of particle-tracking simulation results was also used to further calibrate the groundwater flow model.

Error in the calibration was measured by two major statistical methods: the mean error (ME) and the root mean square error (RMSE). The ME is the mean difference between measured heads and simulated heads; the RMSE or residual standard deviation is the average of the squared differences. Calibration of the Yermo Annex numerical groundwater model resulted in a relatively close match between simulated and observed hydraulic heads.

The model calibration process also serves as a continuous sensitivity analysis that helps identify input parameters that are sensitive to reductions of the model calibration residual. Based on the calibration process, the sensitivity of the input parameters for the Yermo Annex model was assessed and is listed below in order of decreasing sensitivity:

1. Hydraulic conductivity
2. Boundary conditions
3. Recharge
4. Leakance between model layers (see Section 3.2.2 for description of layers)

The following sections summarize the sensitivity analysis process and results. As Layer 1 and Layer 2 represent the same hydrogeologic formation, Layer 1 sensitivity analysis results are presented in the form of tables in this report. Observations from the sensitivity analysis results for Layer 2 and Layer 3 are described in the following sections.

5.1 HYDRAULIC CONDUCTIVITY

Calibration results provided in Table F.5-1 indicate that both the RMSE and the ME are sensitive to the horizontal hydraulic conductivity in the first model layer. The final calibrated hydraulic conductivity value, 130 ft/day, was selected based on the lowest RMSE, a relatively small ME value, and consistency with the results obtained from the field pump test (OHM, 1997) and previous modeling work (JEG, 1996).

Similar sensitivity analyses were also performed for the horizontal hydraulic conductivity in the second and third model layers. The results indicted that these parameter are also sensitive to the RMSE and the ME, but the sensitivity is reduced as the thickness of the aquifer increases.

5.2 BOUNDARY CONDITIONS

Adjustment of constant head elevations at the boundary also significantly affected the results of the model calibration. Uniform increases or decreases in elevation of the constant head boundary resulted in equivalent changes to the ME, with no changes to the RMSE (Table F.5-2). Non-uniform changes in constant head elevations, such as change in the gradient along the boundary or change in head at certain locations, may alter the regional hydraulic gradient and affect both the RMSE and ME. A number of combinations of constant head change at different locations were tested (and eliminated) during the calibration process.

5.3 RECHARGE

Results from calibration process and sensitivity analysis indicate that of the two aquifer stresses, groundwater recharge and boundary conditions, groundwater recharge has a much lesser effect on the regional flow pattern than do the boundary conditions. This may be due to the fact that the majority of water recharged to the aquifer is derived from regional groundwater flow and not from precipitation. In the sensitivity analysis, recharge rates were varied from 50 percent below to 50 percent above the calibrated recharge rates. The results (Table F.5-3) indicate that the recharge rate has a minor impact on the ME and no impact on the RMSE.

5.4 LEAKANCE BETWEEN MODEL LAYERS

Among the input parameters, vertical leakance between model layers was the least sensitive parameter affecting the model calibration result. The leakance term is used by MODFLOW to compute the vertical flow between two cells upper and below. The value of the leakance term is a function of vertical hydraulic conductivity and cell thickness. Because the vertical hydraulic conductivity is defined by using the ratios of K_H to K_V as discussed in Section 3.2.6, the sensitivity analysis for the leakance term was performed by varying the ratios of K_H to K_V The results reported here are only for the ratios assigned for model Layer 1 and Layer 2. Results in Table F.5-4 indicate that it may have significant impact on the results only when the ratio is greater than 20. The insensitivity of the model to vertical leakance is likely due to the fact that

the first two model layers actually represent one hydrogeologic formation. The shallow aquifer was artificially separated into two model layers to account for well screens installed at upper or lower depths. The summary statistics of the case with the ratio of 2 shows the lowest RMSE. The final value selected for model calibration was 10, as this value is commonly used for modeling exercises.

6.0 MODEL LIMITATIONS

The conclusions presented herein regarding the optimal modification scenarios for the existing GETS are based on available data and the conceptual and numerical models developed for the site. Model development involved conceptualization and simplification of the actual site conditions to a numerical model that is only detailed to the level necessary for meeting the modeling objectives.

Specifically, the current three-dimensional model was intended to evaluate large-scale, long-term average effects of the extraction system, assuming only three layers and a minimum cell size of 25 feet. Therefore, the model cannot be used to evaluate the three-dimensional local effects of extraction in the vicinity of the wells. Discrepancies between simulated and actual conditions due to variation of hydrogeologic conditions on a scale smaller than that of the model should be expected.

To the extent that actual site conditions may differ from those interpreted, or future operations may differ from those assumed, the model results may not be representative of actual future groundwater conditions. However, for the objectives of modeling to aid in evaluating the current and predicted effectiveness of the GETS, the modeling results provide a reasonable basis for the interpretations and conclusions provided herein.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the assessment of the performance of individual groundwater extraction wells and the overall effectiveness of the GETS, the following conclusions can be made:

1. Since the startup of the GETS in December 1996, declining regional groundwater levels in the Yermo Annex area have resulted in reduced flow rates and diminished hydraulic influence for many of the groundwater extraction wells at OU 1.

2. The wells that have maintained the highest flow rates and greatest influence (GEW-7, GEW-9, GEW-13, GEW-14, and GEW-15) are located in the areas of highest VOC concentrations and are likely to be the most effective.

3. Taking Wells GEW-4, GEW-5, GEW-6, GEW-10, GEW-11, and GEW-12 offline is not expected to reduce the hydraulic capture of the on-Base portions of the VOC plumes at OU 1.

4. Predicted model scenarios involving future reduced pumping at the wells, GEW-7, GEW-9, GEW-13, GEW-14, and GEW-15, indicates that GETS is expected to continue to provide adequate capture of the on-Base contaminant plumes.

5. Reduced pumping at GEW-9 may result in portions of the CAOC 26 plume being drawn toward or into the Base supply/drinking water well, YDW-5.

The following are recommendations for future operation of the GETS:

1. Capture should be evaluated on an annual basis, and installation of additional wells should be considered if loss of capture jeopardizes containment at the MCL boundaries.

2. Wells that have minimal or insignificant effect on capture should be taken offline.

8.0 REFERENCES

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TABLES

TABLE F.2-1

HISTORICAL AVERAGE FLOW RATES FOR GROUNDWATER EXTRACTION WELLS

Date	Flow Rate[1] in gpm[3]															
	GEW-1	GEW-2	GEW-3	GEW-4	GEW-5	GEW-6	GEW-7	GEW-8	GEW-9	GEW-10	GEW-11	GEW-12	GEW-13	GEW-14[5]	GEW-15[5]	Total Flow
Dec-96	49.1	61.6	100.1	100.0	66.9	70.1	101.0	60.1	99.7	97.1	63.5	61.3	101.0	N/A[4]	N/A	**1031.5**
Jan-97	47.9	54.1	100.3	100.7	56.4	68.6	99.5	68.3	94.7	98.3	73.7	33.8	100.5	N/A	N/A	**996.8**
Feb-97	54.2	80.6	100.7	79.6	41.1	62.1	84.7	79.6	88.6	73.4	57.1	77.7	100.8	N/A	N/A	**980.1**
Mar-97	47.4	61.6	100.1	100.9	57.6	71.8	99.9	68.8	101.0	98.1	67.6	60.5	100.3	N/A	N/A	**1035.7**
Apr-97	47.5	62.4	99.9	100.3	57.8	71.5	99.7	69.0	101.0	98.3	67.1	62.0	100.6	N/A	N/A	**1037.1**
May-97	47.8	63.1	90.0	100.4	59.9	72.3	79.3	68.5	100.4	98.1	66.7	62.0	100.2	N/A	N/A	**1008.6**
Jun-97	39.6	53.9	87.1	87.9	51.9	63.0	87.5	60.0	75.3	73.6	49.9	46.1	87.9	N/A	N/A	**863.6**
Jul-97	31.3	64.5	99.8	100.5	58.8	72.3	99.8	70.8	75.5	74.3	50.8	47.0	100.0	N/A	N/A	**945.0**
Aug-97	29.5	63.2	99.1	99.9	59.8	71.9	99.0	70.2	100.1	97.2	67.0	63.1	100.0	N/A	N/A	**1019.9**
Sep-97	32.0	59.8	99.2	99.6	59.8	72.4	99.2	71.6	100.4	97.6	68.2	65.0	100.4	N/A	N/A	**1025.2**
Oct-97	34.8	57.0	99.0	100.0	60.0	70.2	99.0	68.4	100.0	97.6	68.4	65.4	100.8	N/A	N/A	**1020.6**
Nov-97	39.6	52.4	98.6	99.7	59.6	66.2	99.0	65.7	100.3	97.2	68.4	64.6	100.2	N/A	N/A	**1011.5**
Dec-97	35.3	52.4	99.0	100.2	66.8	68.0	100.0	68.0	97.0	98.0	70.2	66.6	100.4	N/A	N/A	**1021.9**
Jan-98	36.0	52.0	98.0	100.0	70.7	66.0	100.0	67.0	97.3	97.3	69.3	66.7	100.3	N/A	N/A	**1020.7**
Feb-98	32.6	51.8	97.8	99.2	71.6	67.8	98.8	66.8	99.2	96.8	71.0	67.2	100.2	N/A	N/A	**1020.8**
Mar-98	0.0	46.0	79.6	79.4	56.4	54.6	79.8	52.8	0.0	80.6	0.0	52.4	80.4	N/A	N/A	**662.0**
Apr-98	40.3	64.2	101.0	97.0	70.7	75.0	98.7	66.2	71.9	97.8	49.4	77.0	99.7	N/A	N/A	**1008.8**
May-98	42.8	66.8	105.0	97.0	70.0	76.4	98.8	68.0	100.8	96.6	66.8	90.0	99.8	N/A	N/A	**1078.8**
Jun-98	45.0	45.5	0.0	98.0	35.5	77.5	99.5	68.0	102.0	97.0	68.5	89.5	100.0	N/A	N/A	**926.0**
Jul-98	42.2	44.2	74.0	90.3	69.7	75.8	98.8	64.8	101.2	96.7	55.7	88.1	99.7	N/A	N/A	**1001.1**
Aug-98	40.0	46.5	98.0	66.0	71.3	73.3	99.0	61.3	101.3	96.5	47.0	88.8	99.5	N/A	N/A	**988.3**
Sep-98	37.2	41.4	98.0	68.0	68.6	60.8	99.6	62.2	100.6	96.6	51.6	89.4	99.6	N/A	N/A	**973.6**
Oct-98	37.0	39.3	97.8	65.0	52.3	59.8	99.8	57.0	101.0	96.8	49.3	89.5	99.0	N/A	N/A	**943.3**
Nov-98	36.4	37.8	96.2	52.2	50.4	59.5	99.6	58.9	100.2	96.6	44.4	89.7	99.7	N/A	N/A	**921.6**
Dec-98	38.3	38.7	95.7	50.3	48.7	59.3	100.7	61.3	99.3	96.7	42.7	90.0	99.7	N/A	N/A	**921.3**
Jan-99	24.4	28.0	58.8	31.0	28.0	35.6	64.4	37.8	60.6	40.0	27.2	54.2	59.6	N/A	N/A	**549.6**
Feb-99	38.3	60.0	101.5	62.3	51.0	61.0	103.5	62.8	99.8	99.8	48.8	89.3	98.3	N/A	N/A	**976.0**
Mar-99	0.0	61.0	101.0	65.0	34.0	59.0	97.0	63.0	99.0	99.0	40.0	89.0	97.0	N/A	N/A	**904.0**
May-99	36.3	64.3	91.3	67.0	42.7	47.3	102.0	53.3	99.7	97.3	46.0	88.3	65.3	N/A	N/A	**901.0**
Jun-99	37.7	63.3	70.3	66.0	41.3	46.3	103.0	54.0	99.7	95.7	50.0	87.3	0.0	N/A	N/A	**814.7**
Jul-99	25.4	51.0	53.4	50.6	33.6	36.6	85.4	43.0	80.0	77.6	14.4	69.4	0.0	N/A	N/A	**620.4**
Aug-99	17.0	33.0	52.8	43.0	31.3	34.5	74.5	41.0	75.0	74.3	17.8	65.3	0.0	N/A	N/A	**559.3**

TABLE F.2-1

HISTORICAL AVERAGE FLOW RATES FOR GROUNDWATER EXTRACTION WELLS

Date	Flow Rate[1] in gpm[3]															
	GEW-1	GEW-2	GEW-3	GEW-4	GEW-5	GEW-6	GEW-7	GEW-8	GEW-9	GEW-10	GEW-11	GEW-12	GEW-13	GEW-14[5]	GEW-15[5]	Total Flow
Sep-99	22.3	66.0	67.0	13.8	36.0	34.0	72.5	26.3	98.3	99.0	24.5	44.3	16.8	N/A	N/A	**620.5**
Oct-99	28.8	66.0	54.8	11.0	32.2	20.2	63.0	22.2	98.8	53.8	25.0	38.2	0.0	N/A	N/A	**514.0**
Nov-99	19.8	51.0	43.5	52.5	34.0	21.3	88.5	28.0	95.0	85.0	23.5	25.8	60.8	N/A	N/A	**628.5**
Dec-99	21.2	40.0	59.4	45.0	33.8	22.8	114.6	28.8	104.4	51.0	26.6	36.4	80.0	N/A	N/A	**664.0**
Jan-00	28.3	40.0	43.0	42.7	27.0	22.0	108.7	35.3	92.3	75.0	27.3	29.3	0.0	N/A	N/A	**571.0**
Feb-00	22.5	40.0	41.3	37.5	46.3	21.8	93.8	13.5	91.5	70.0	30.8	24.0	60.0	N/A	N/A	**592.8**
Mar-00	13.4	40.0	42.2	14.2	22.8	22.4	97.4	30.2	116.6	64.0	17.6	30.8	48.0	N/A	N/A	**559.6**
Apr-00	34.5	39.5	39.5	24.0	13.0	24.0	99.5	27.0	117.5	25.0	25.0	30.5	90.5	N/A	N/A	**589.5**
May-00	13.0.	37.0	39.5	28.0	56.0	22.5	108.0	15.0	108.0	47.0	30.5	17.0	100.5	N/A	N/A	**622.0**
Jun-00	34.0	38.0	40.0	30.0	74.0	26.0	107.0	11.0	103.0	45.0	33.0	12.0	0.0	N/A	N/A	**553.0**
Jul-00	26.8	38.0	38.3	36.0	48.8	25.5	96.5	9.3	86.0	40.5	31.5	17.8	74.3	N/A	N/A	**569.0**
Aug-00	29.0	38.0	41.0	41.0	9.0	26.0	80.0	10.0	80.0	37.0	24.0	52.0	89.0	N/A	N/A	**556.0**
Sep-00	24.6	36.4	39.8	39.6	39.8	27.6	92.2	6.2	61.0	29.4	24.2	54.8	91.6	N/A	N/A	**567.2**
Oct-00	24.0	33.3	40.3	37.8	27.8	30.0	90.8	8.0	78.3	19.3	16.5	44.3	90.0	N/A	N/A	**540.0**
Nov-00	0.0	34.0	40.0	37.0	27.0	34.0	90.0	7.5	76.0	18.0	5.5	33.0	90.0	N/A	N/A	**492.0**
Dec-00	0.0	34.0	40.0	37.0	27.0	30.3	90.0	7.0	58.5	18.0	13.5	33.0	90.0	N/A	N/A	**478.3**
Jan-01	0.0	37.5	46.0	34.0	19.0	25.0	104.5	7.0	86.5	39.5	10.0	33.0	101.5	N/A	N/A	**543.5**
Jun-02	0.0	30.0	35.0	35.0	5.0	25.0	50.0	0.0	75.0	15.0	15.0	5.0	100.0	65.0	65.0	**520.0**
% Change[2]	**51%**	**51%**	**65%**	**65%**	**93%**	**64%**	**50%**	**88%**	**25%**	**85%**	**76%**	**92%**	**1%**	**N/A**	**N/A**	**50%**

Notes:

(1) - Flow rates represent values averaged over a given month

(2) - % change represents the change in flow rate between December 1996 flow rate and the most currently available flow rate

(3) - gpm - gallons per minute

(4) - N/A - not applicable

(5) - The recently installed extraction wells (GEW-14 and GEW-15) became operational during June 2002

TABLE F.2-2

HISTORICAL AVERAGE SPECIFIC CAPACITIES FOR GROUNDWATER EXTRACTION WELLS

Date	Specific Capacity in gpm/ft												
	GEW-1	GEW-2	GEW-3	GEW-4	GEW-5	GEW-6	GEW-7	GEW-8	GEW-9	GEW-10	GEW-11	GEW-12	GEW-13
Dec-96	4.3	6.8	32.3	20.3	10.1	11.8	8	24.9	20.5	9.1	11.9	30.5	23.7
Jan-97	4.4	13.6	26.1	19.4	10.6	11.7	23	10.4	21.1	19.3	9.6	16.7	26.2
Feb-98	4.6	6.8	22.4	11.9	10	8.5	20.6	8.5	21.7	19.9	18.9	16.1	29.7
Jun-98	5.3	7.8	20.1	9.9	9.8	8	20.1	8.4	22.3	18.9	6.2	15.5	30.7
Aug-98	4.6	4.9	17.05	6.9	8.4	6.3	22.6	8.4	20.1	20.1	4.4	15.4	38.3
Jul-99	3.5	8.6	6.8	6.8	6	na	17.9	5.9	15.5	15.4	5.5	9.6	na
Oct-99	4.4	6.8	2.9	7.9	6.3	na	20.6	7.3	9.6	11.8	4.1	11.1	na
Dec-99	5.9	5.8	6.8	4.5	6	5.6	11.5	8.9	12.3	10.4	5.2	14	27.6
Apr-00	9.8	4.5	5.2	4.3	4.7	4.7	9	7.1	10.6	8.3	4.3	8.5	16.7
Jun-00	9.7	9.5	7.1	6.1	16.1	4.7	13.9	2.8	10.7	7.1	4.3	2.6	19.2
Sep-00	11.4	6	4.3	5.4	20.8	3.7	9.6	3	11.7	4.2	3.3	6.9	16.3
Dec-00	na	5.9	4.5	4.7	20.8	2.8	10.3	2.8	11.9	3.3	5.8	7.3	15

Notes:
na - not available
gpm/ft - gallons per minute per foot

TABLE F.2-3

CALCULATED VALUES FOR RADIUS OF INFLUENCE OF GROUNDWATER EXTRACTION WELLS

Pumping Rate (Q) (gpm)	Pumping Rate (Q) (ft^3/day)	Drawdown (h) (feet)	Radius of Influence (r) (feet)
100	19252	600	45.6
	19252	400	68.3
	19252	200	136.7
	19252	100	273.4
	19252	50	546.8
	19252	40	683.4
	19252	25	1093.5
75	14438	50	410.0
	14438	40	512.5
	14438	25	820.1
50	9626	50	273.4
	9626	40	341.7
	9626	25	546.8
25	4813	50	136.7
	4813	40	170.9
	4813	25	273.4
10	1925	50	54.7
	1925	40	68.3
	1925	25	109.3

Notes:

Values presented in this table are based on the assumptions and equations presented in Section 2.3 of this report.
gpm - gallons per minute
ft3/day - cubic feet per day

TABLE F.3-1

EXTRACTION WELL FLOW RATES USED FOR MODEL CALIBRATION (DECEMBER 2000)

Extraction Well	Average for December 2000 [Q_{ave} (gpm)]
GEW-1	na[1]
GEW-2	34
GEW-3	40
GEW-4	37
GEW-5	27
GEW-6	25
GEW-7	90
GEW-8	7
GEW-9	75
GEW-10	18
GEW-11	15
GEW-12	33
GEW-13	90
System Total (in gpm)	491

Notes:

[1] – GEW-1 was not in operation in December 2000. For calibration purposes, an arbitrary negligible flow rate was used. However, for the baseline and predictive simulations, the annual average flow rate was used.

gpm – gallons per minute

na – not available

Q_{ave} – December 2000 average flow rate

TABLE F.3-2

RESULTS OF FIRST MODEL CALIBRATION (BASED ON DECEMBER 2000 DATA)

Well	Observed Elevation (feet above msl)	Computed Elevation (feet above msl)	Residual[1] (feet)
PMW-1	1794.20	1794.52	-0.32
PMW-2	1793.17	1793.71	-0.54
PZ-A	1794.76	1794.82	-0.06
PZ-B	1793.94	1793.99	-0.05
PZ-C	1793.63	1793.70	-0.07
PZ-D	1796.62	1796.90	-0.28
Y7-2	1793.52	1793.48	0.04
Y7-3	1793.59	1793.48	0.11
Y9-2	1794.33	1794.07	0.26
Y9-3	1794.39	1794.06	0.33
Y15-2	1793.63	1793.51	0.12
Y15-3	1793.71	1793.51	0.20
Y2-2	1793.75	1793.88	-0.13
Y3-2	1793.24	1792.68	0.56
Y4-2	1794.11	1793.94	0.17
Y5-2	1795.57	1795.37	0.20
YCW16-1	1795.66	1795.78	-0.12
YCW16-2	1795.60	1795.42	0.18
YCW16-3	1795.94	1795.90	0.04
YIG-01	1804.41	1804.35	0.06
YIG-02	1806.75	1806.72	0.03
YNP-3	1796.02	1795.40	0.62
YPZ-2	1798.78	1797.89	0.89
YPZ-3	1800.82	1800.47	0.35
YS15-2	1795.37	1795.92	-0.55
YS17-7	1794.70	1794.78	-0.08
YS20-1	1795.22	1796.72	-1.50
YS20-2	1796.06	1796.35	-0.29
YS22-2	1794.63	1794.26	0.37
YS23-6	1796.44	1796.81	-0.37
YS23-11	1797.17	1798.16	-0.99
YS29-2	1800.33	1800.36	-0.03
YS34-2	1794.90	1794.85	0.05

TABLE F.3-2

RESULTS OF FIRST MODEL CALIBRATION (BASED ON DECEMBER 2000 DATA)

Well	Observed Elevation (feet above msl)	Computed Elevation (feet above msl)	Residual[1] (feet)
YS35-8	1795.62	1796.20	-0.58
YWA-1	1793.92	1794.32	-0.40
YWA-2	1793.55	1793.51	0.04
YWA-4	1793.92	1793.95	-0.03
YWB-1	1794.32	1793.50	0.82
YWB-2	1794.11	1793.14	0.97
BH-14	1813.93	1814.01	-0.08
BH-15	1815.43	1816.09	-0.66
BH-16	1816.16	1816.67	-0.51
BH-25	1810.64	1810.14	0.50
BH-26	1808.89	1809.19	-0.30
BH-27	1808.10	1807.11	0.99
MW-31	1806.92	1806.30	0.62
MW-32	1801.63	1802.55	-0.92

Notes:

[1] – Observed elevation minus computed elevation

msl – mean sea level

YW-2 and YWA-3 were not included as calibration targets, as the measured groundwater levels in these wells are considered outliers.

Statistical Parameters:

Residual Mean	-0.01
Residual Standard Deviation	0.50
Sum of Squares	11.75
Absolute Residual Mean	0.37
Minimum Residual	-1.50
Maximum Residual	0.99
Head Range	22.99
Standard/Head Range	0.02

TABLE F.3-3

RESULTS OF SECOND MODEL CALIBRATION (BASED ON JUNE 2002 DATA)

Well	Observed Elevation (feet above msl)	Computed Elevation (feet above msl)	Residual[1] (feet)
PMW-1	1792.750	1792.403	0.347
PMW-2	1791.980	1791.686	0.294
PMW-5	1793.910	1794.022	-0.112
PMW-6	1793.770	1794.022	-0.252
PMW-7	1795.160	1794.954	0.206
PMW-8	1794.600	1794.954	-0.354
PMW-9	1794.660	1794.984	-0.324
PMW-10	1794.490	1794.984	-0.494
PMW-11	1793.530	1793.826	-0.296
PMW-12	1792.870	1793.826	-0.956
PZ-D	1793.920	1794.488	-0.568
Y4-2	1792.180	1792.318	-0.138
Y5-2	1793.260	1793.114	0.146
Y7-2	1791.830	1791.018	0.812
Y7-3	1791.160	1791.016	0.144
Y9-2	1792.490	1791.880	0.610
Y9-3	1792.200	1791.872	0.328
Y13-1	1789.840	1789.724	0.116
Y15-2	1791.190	1790.995	0.195
Y15-3	1791.080	1790.995	0.085
YCW16-1	1793.790	1793.293	0.497
YCW16-2	1793.320	1792.979	0.341
YCW16-3	1793.490	1793.192	0.298
YDW-6_OLD	1796.670	1798.197	-1.527
YEP-2	1792.660	1792.324	0.336
YEP-3	1792.700	1792.324	0.376
YPZ-2	1793.210	1794.013	-0.803
YS15-2	1793.260	1792.901	0.359
YS20-1	1793.940	1794.342	-0.402
YS21-2	1792.790	1792.994	-0.204
YS21-3	1792.780	1792.994	-0.214

TABLE F.3-3

RESULTS OF SECOND MODEL CALIBRATION (BASED ON JUNE 2002 DATA)

Well	Observed Elevation (feet above msl)	Computed Elevation (feet above msl)	Residual[1] (feet)
YS22-2	1792.420	1792.652	-0.232
YS23-6	1794.230	1794.605	-0.375
YS23-11	1795.300	1795.902	-0.602
YS23-12	1794.680	1795.060	-0.380
YS23-13	1794.770	1795.060	-0.290
YS23-18	1793.370	1793.323	0.047
YS26-2	1796.110	1795.949	0.161
YS26-3	1795.590	1795.949	-0.359
YS28-2	1796.430	1795.508	0.922
YS28-3	1795.840	1795.508	0.332
YS29-2	1796.140	1795.320	0.820
YS34-2	1792.510	1792.758	-0.248
YS35-3	1792.480	1792.336	0.144
YS35-4	1792.260	1792.336	-0.076
YS35-8	1793.560	1792.958	0.602
YWA-1	1791.590	1792.355	-0.765
YWA-2	1792.060	1792.368	-0.308
YWA-3	1792.360	1792.255	0.105
YWA-4	1792.170	1792.094	0.076
YWB-1	1792.350	1792.355	-0.005
YWB-2	1792.180	1792.336	-0.156
BH-14	1813.930	1814.212	-0.282
BH-15	1815.430	1816.250	-0.820
BH-16	1816.160	1816.754	-0.594
BH-25	1810.640	1810.170	0.470
BH-26	1808.890	1809.094	-0.204
BH-27	1808.100	1806.786	1.314
MW-31	1806.920	1805.684	1.236
MW-32	1801.630	1801.136	0.494

TABLE F.3-3

RESULTS OF SECOND MODEL CALIBRATION (BASED ON JUNE 2002 DATA)

Notes:

[1] – Observed elevation minus computed elevation

msl – mean sea level

Statistical Parameters:

Residual Mean	-0.00
Residual Standard Deviation	0.52
Sum of Squares	16.05
Absolute Residual Mean	0.41
Minimum Residual	-1.53
Maximum Residual	1.31
Head Range	26.32
Standard/Head Range	0.02

TABLE F.4-1

FLOW RATES FOR GROUNDWATER EXTRACTION WELLS (JUNE 2002)

Extraction Well	June 2002 Q_{ave} (gpm)
GEW-02	30
GEW-03	35
GEW-04	35
GEW-05	5
GEW-06	25
GEW-07	50
GEW-09	75
GEW-10	15
GEW-11	15
GEW-12	5
GEW-13	100
GEW-14	65
GEW-15	65
System Total (in gpm)	520

Notes:
gpm – gallons per minute
Q_{ave} – flow rate

TABLE F.5-1

SENSITIVITY ANALYSIS OF HORIZONTAL HYDRAULIC CONDUCTIVITY

K (ft/day)	ME (feet)	RMSE (feet)
100	0.04	0.53
110	0.02	0.52
120	0.01	0.51
125	0.00	0.50
130	-0.01	0.50
135	-0.02	0.50
140	-0.02	0.50
150	-0.04	0.50
160	-0.05	0.50
170	-0.06	0.50
180	-0.08	0.50
190	-0.09	0.51
250	-0.16	0.54
300	-0.21	0.58

Notes:

ft/day – feet per day
K – hydraulic conductivity
ME – mean error
RMSE – root mean square error

TABLE F.5-2

SENSITIVITY ANALYSIS OF BOUNDARY HEAD ELEVATION

Change of Boundary Head (feet)	ME (feet)	RMSE (feet)
-0.8	0.80	0.50
-0.6	0.59	0.50
-0.4	0.39	0.50
-0.2	0.19	0.50
0	-0.01	0.50
0.2	-0.21	0.50
0.4	-0.41	0.50
0.6	-0.61	0.50
0.8	-0.81	0.50

Notes:

ME – mean error
RMSE – root mean square error

TABLE F.5-3

SENSITIVITY ANALYSIS OF RECHARGE RATE

Percentage Change of Calibrated Recharge (%)	ME (feet)	RMSE (feet)
-50	0.03	0.50
-40	0.02	0.50
-30	0.01	0.50
-20	0.01	0.50
-10	0.00	0.50
0	-0.01	0.50
10	-0.02	0.50
20	-0.02	0.50
30	-0.03	0.50
40	-0.04	0.50
50	-0.04	0.50

Notes:

ME – mean error
RMSE – root mean square error

TABLE F.5-4

SENSITIVITY ANALYSIS OF LEAKANCE

Ratio of K_h to K_V	ME (feet)	RMSE (feet)
1	-0.03	0.49
2	-0.02	048
3	-0.02	0.49
5	-0.02	0.49
8	-0.02	0.49
9	-0.01	0.50
10	-0.01	0.50
12	-0.01	0.50
15	0.00	0.51
18	0.00	0.52
20	0.00	0.53
50	0.02	0.60

Notes:

K_h – horizontal hydraulic conductivity
K_v – vertical hydraulic conductivity
ME – mean error
RMSE – root mean square error

FIGURES

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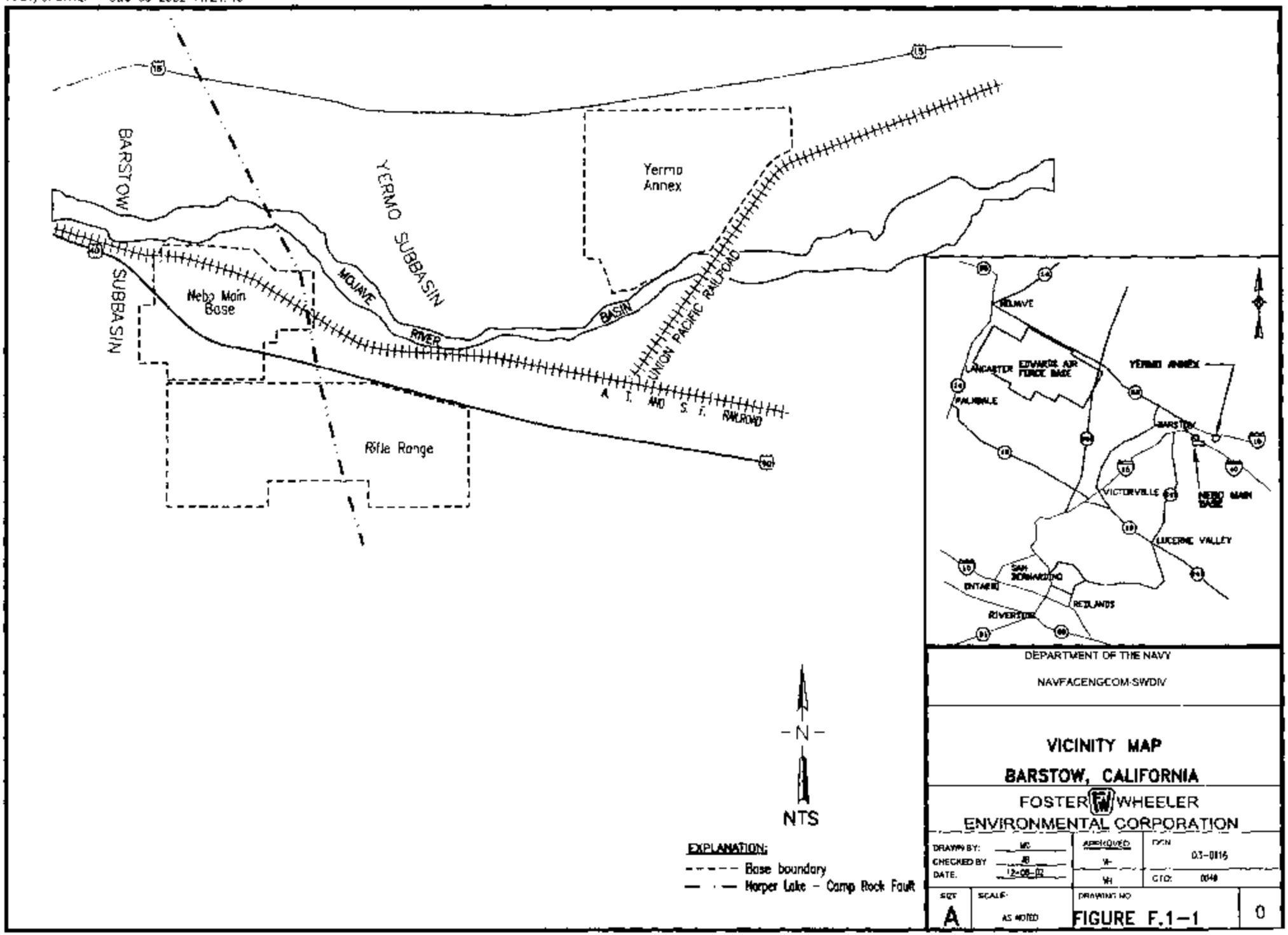

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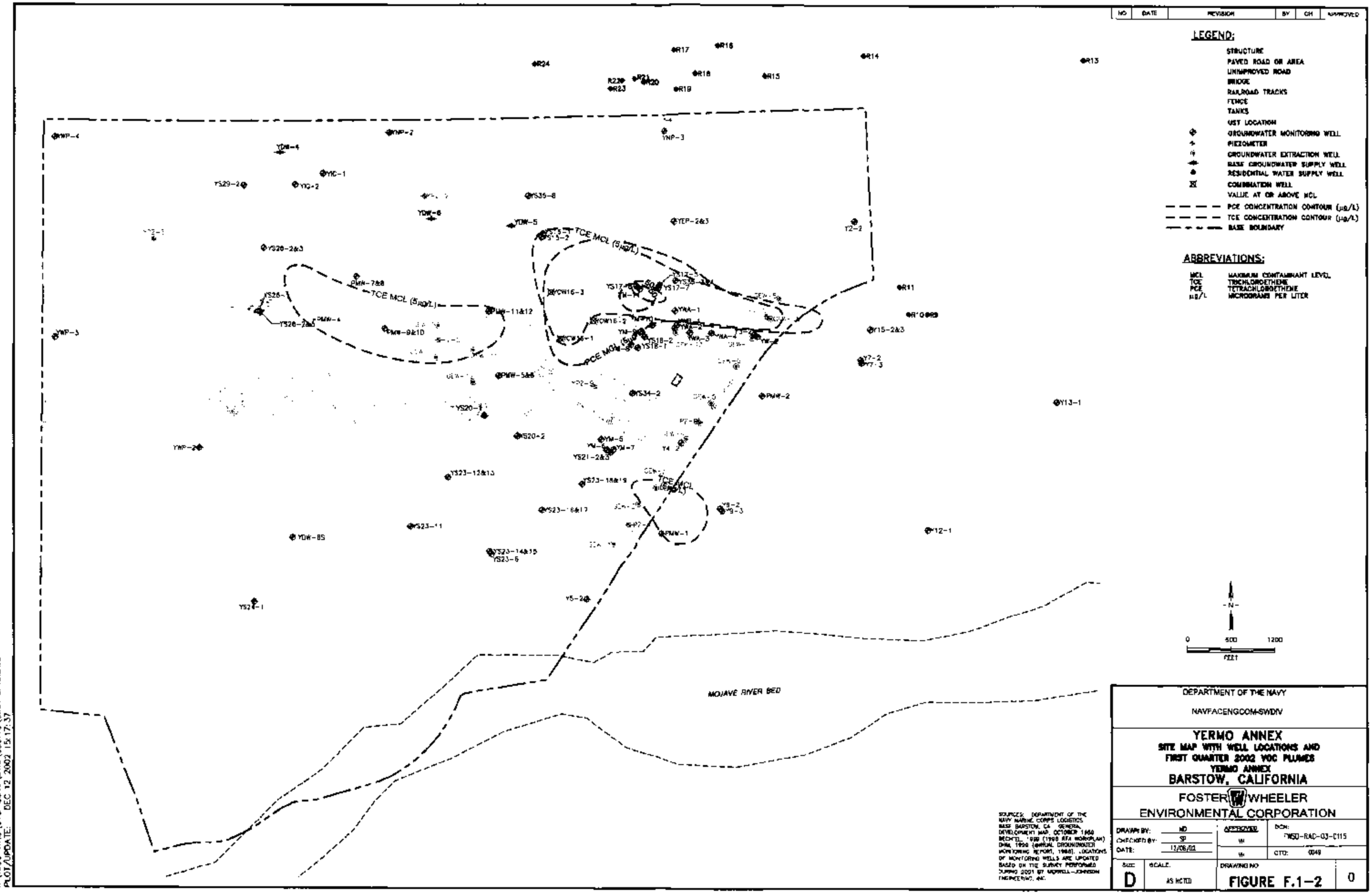

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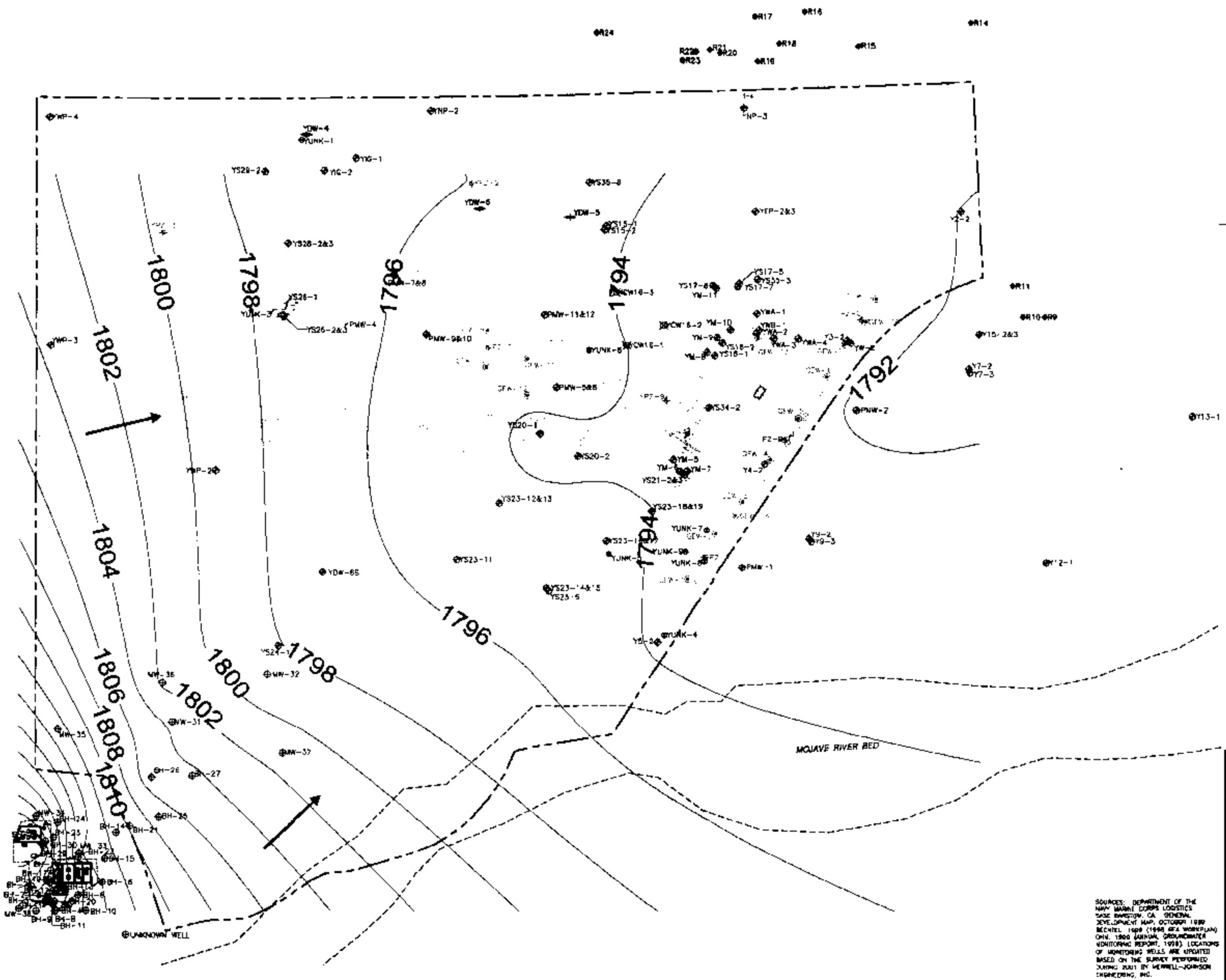

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- RESIDENTIAL WATER SUPPLY WELL
- COMBINATION WELL
- UNKNOWN WELL
- CALNEV WELL
- —1796— GROUNDWATER ELEVATION CONTOUR (ELEVATION IN FEET AMSL)
- GENERALIZED GROUNDWATER FLOW DIRECTION
- BASE BOUNDARY

ABBREVIATIONS:

AMSL	ABOVE MEAN SEA LEVEL
GW	GROUNDWATER
FT.	FEET

YERMO

GROUNDWATER ELEVATION IN SELECTED WELLS, DECEMBER 2001

WELL	GW ELEVATION (IN FT. AMSL)
YCW16-2	1793.43
YS20-2	1793.85
YS23-11	1795.27
YZ-2	1791.98
PZ-C	1792.26
PZ-D	1794.53*
YG-3	1792.80
YS28-2	1797.36
MW-31*	1803.78
MW-32*	1795.49
BH-25*	1807.06
BH-26*	1827.7

* DATA PROVIDED BY CALNEV

-N-

0 600 1200
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 BECHTEL 1992 (1992 RFA WORKPLAN) CH2M 1996 (ANNUAL GROUNDWATER MONITORING REPORT, 1996). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX

MAP OF REPRESENTATIVE STATIC GROUNDWATER FLOW CONDITIONS (BASED ON DECEMBER 2001 DATA)

YERMO ANNEX

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED	DCN	
CHECKED BY: SP	VH	FWSD-RAC-03-0116	
DATE: 12-06-02	VH	CTO: 0049	
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FIGURE F.2-1

GEW FLOW RATES VS. TIME (GEW-1 THROUGH GEW-4)

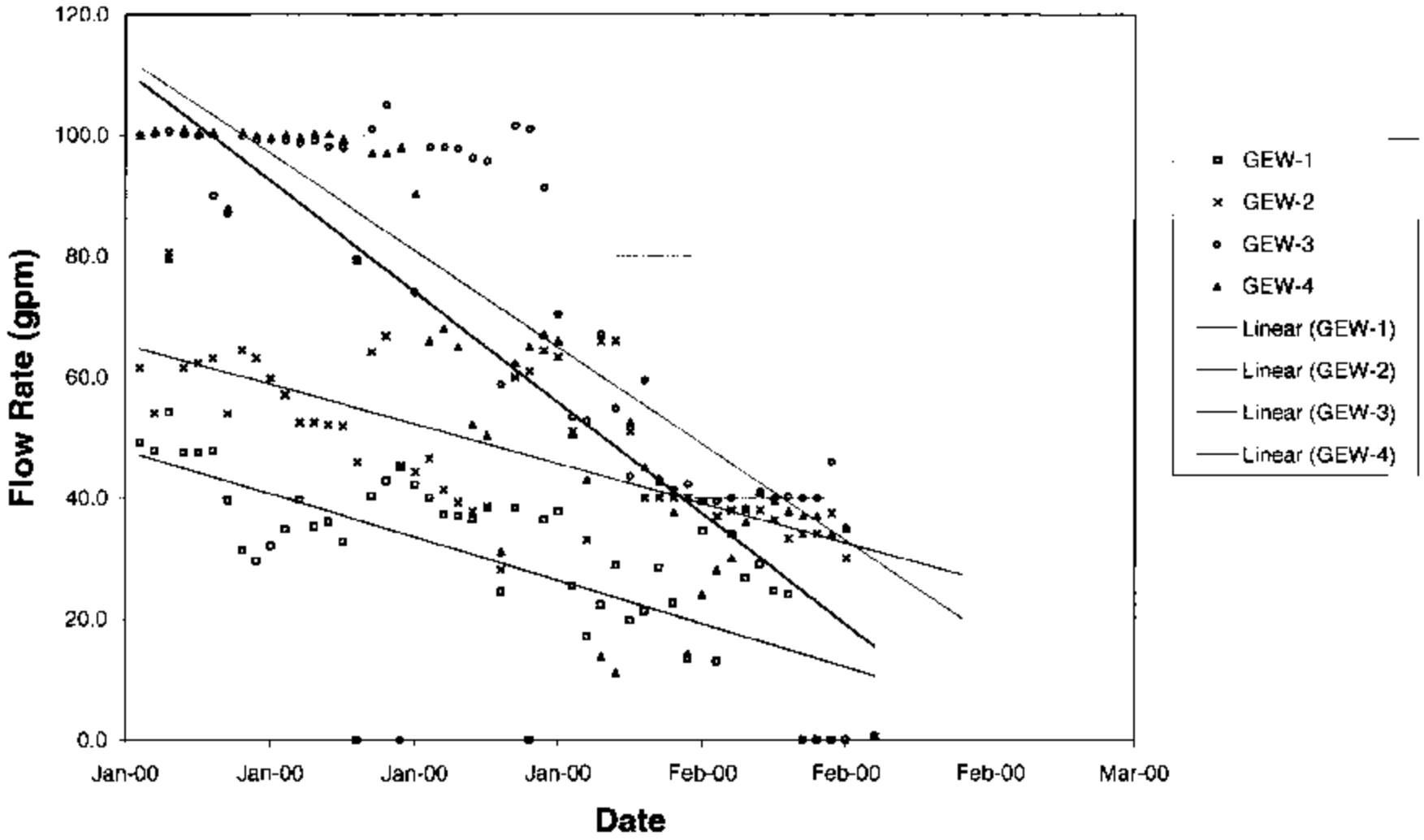


FIGURE F.2-2

GEW FLOW RATES VS. TIME (GEW-5 THROUGH GEW-8)

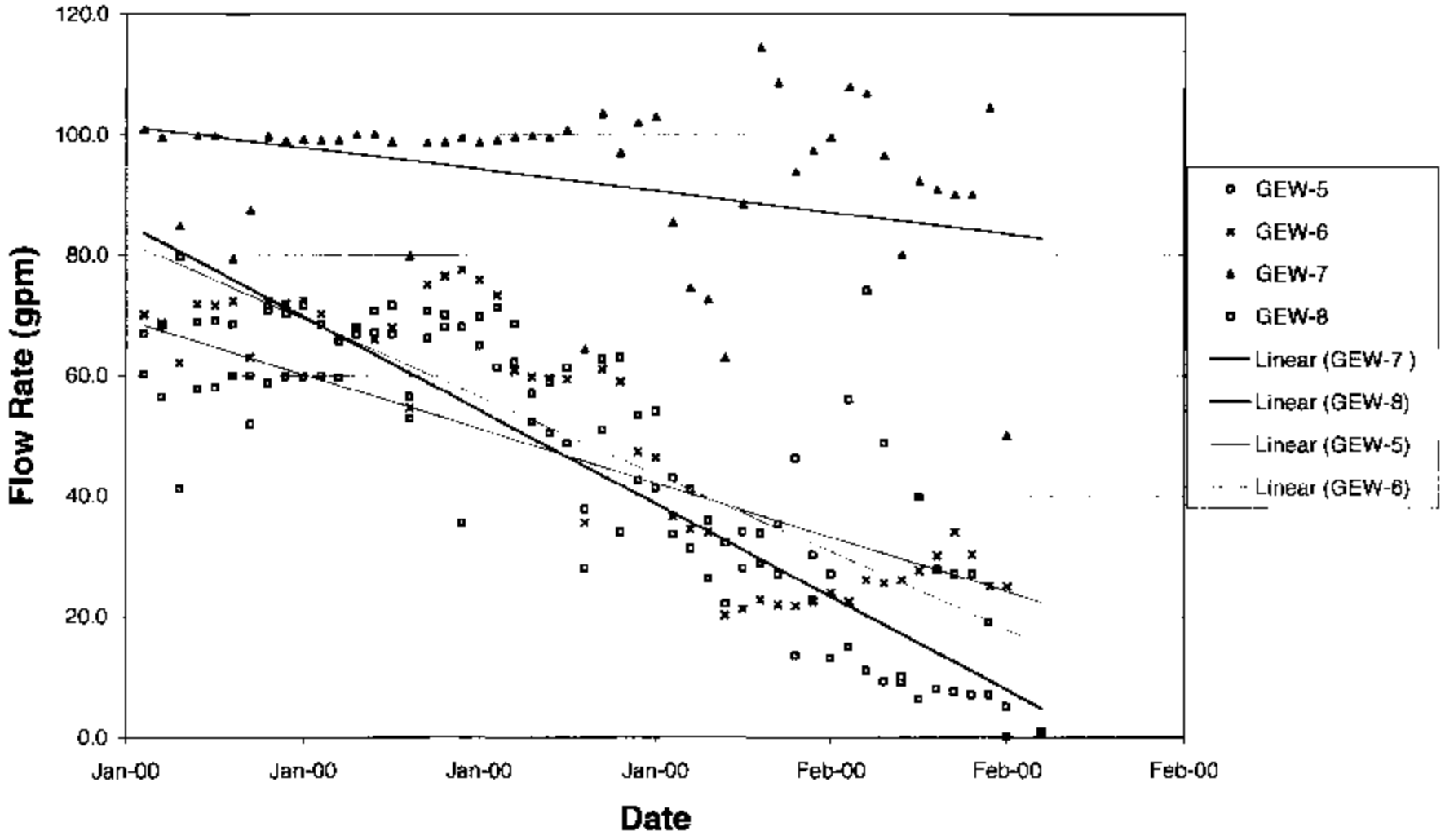


FIGURE F.2-3

GEW FLOW RATES VS. TIME (GEW-9 THROUGH GEW-13)

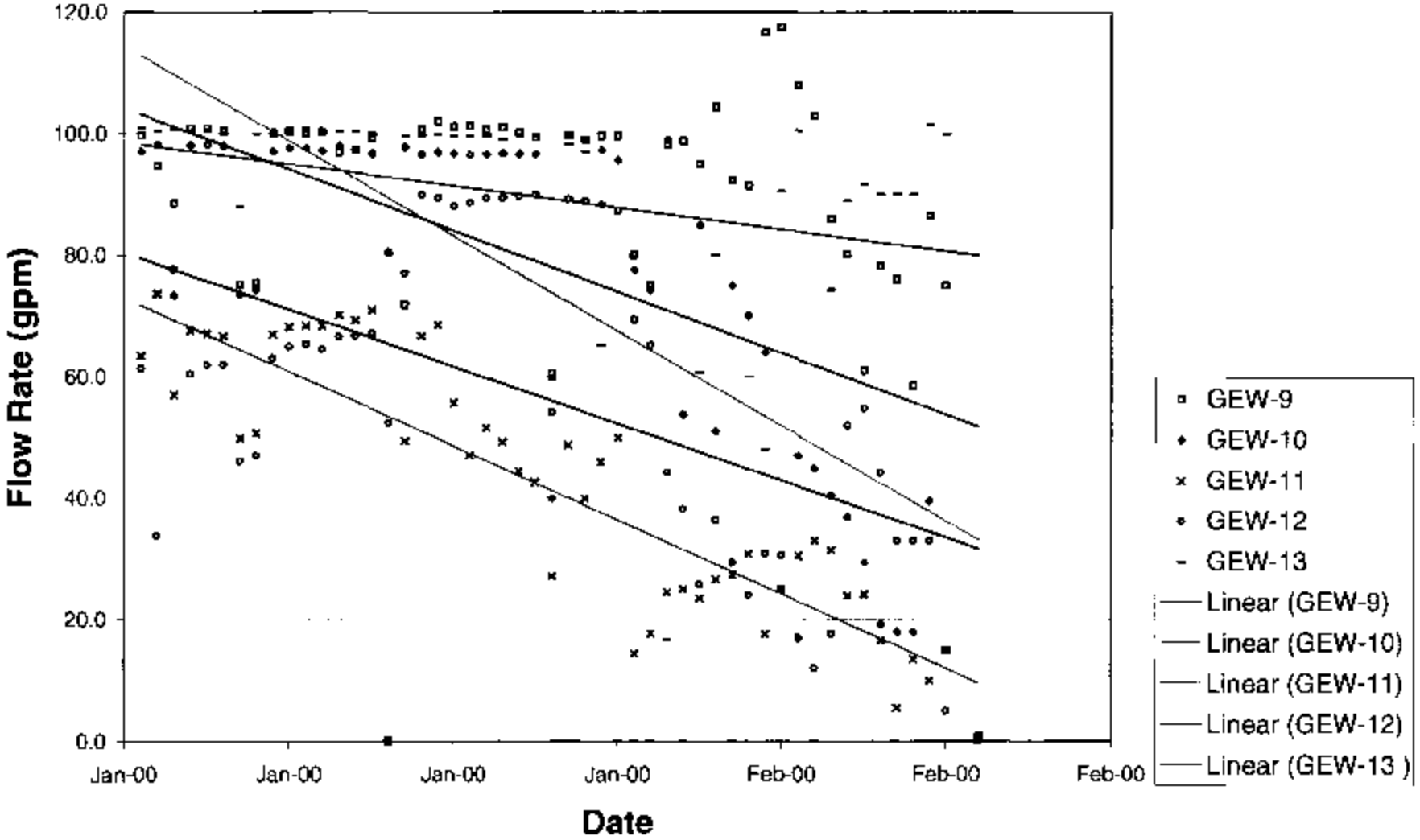


FIGURE F.2-4

SPECIFIC CAPACITIES VS. TIME (GEW-1 THROUGH GEW-4)

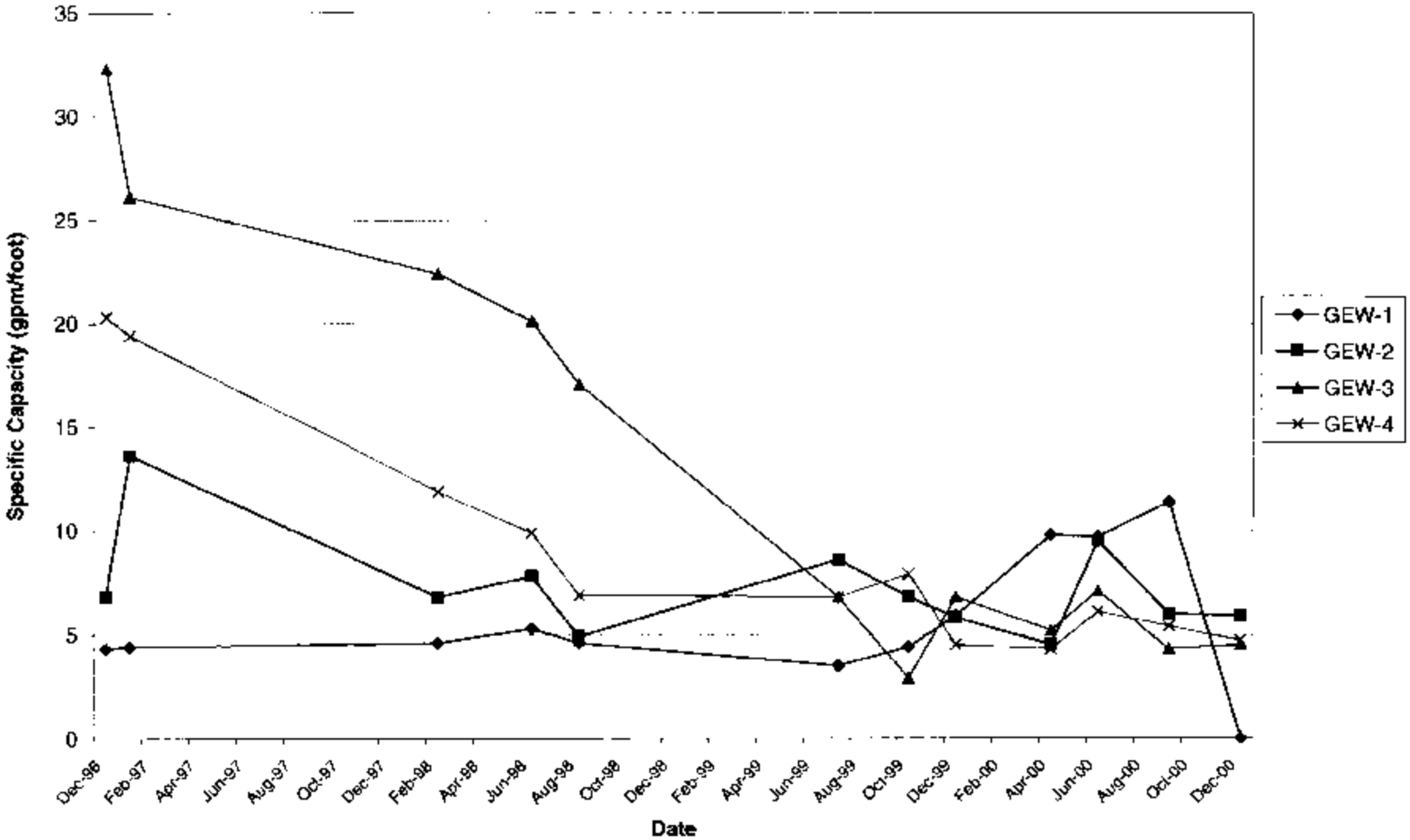


FIGURE F.2-5

SPECIFIC CAPACITIES VS. TIME (GEW-5 THROUGH GEW-8)

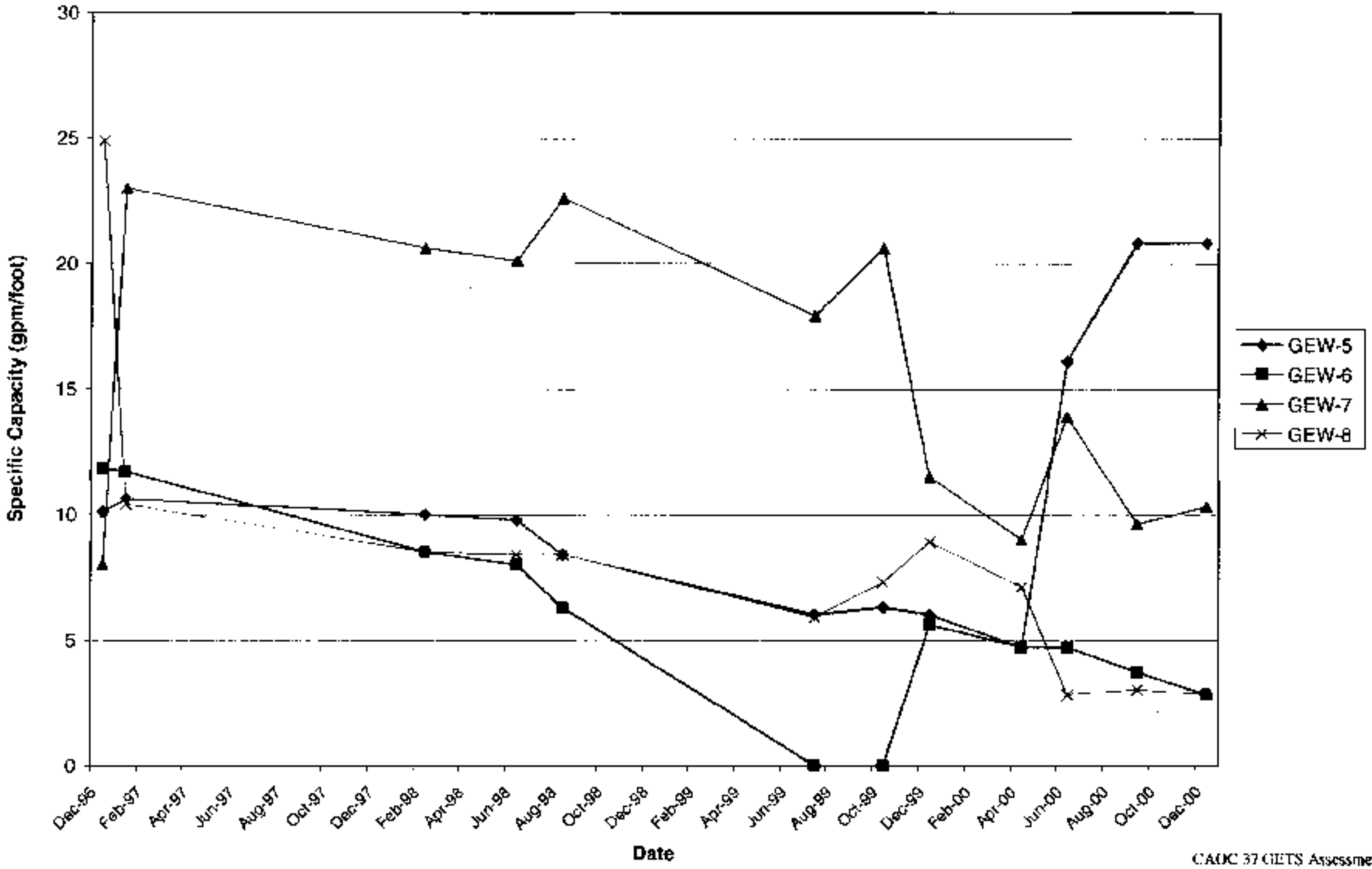
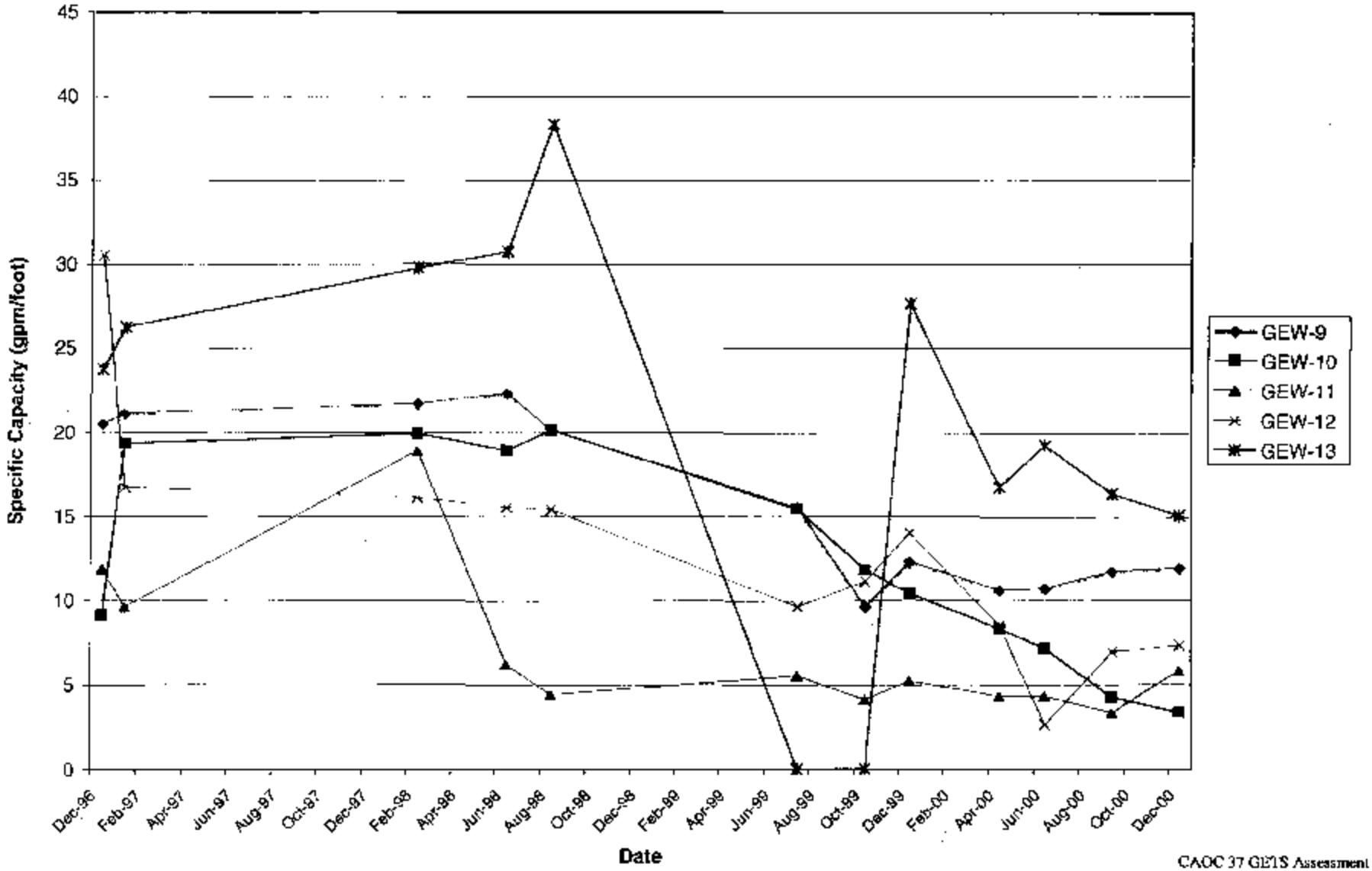


FIGURE F.2-6

SPECIFIC CAPACITIES VS. TIME (GEW-9 THROUGH GEW-13)



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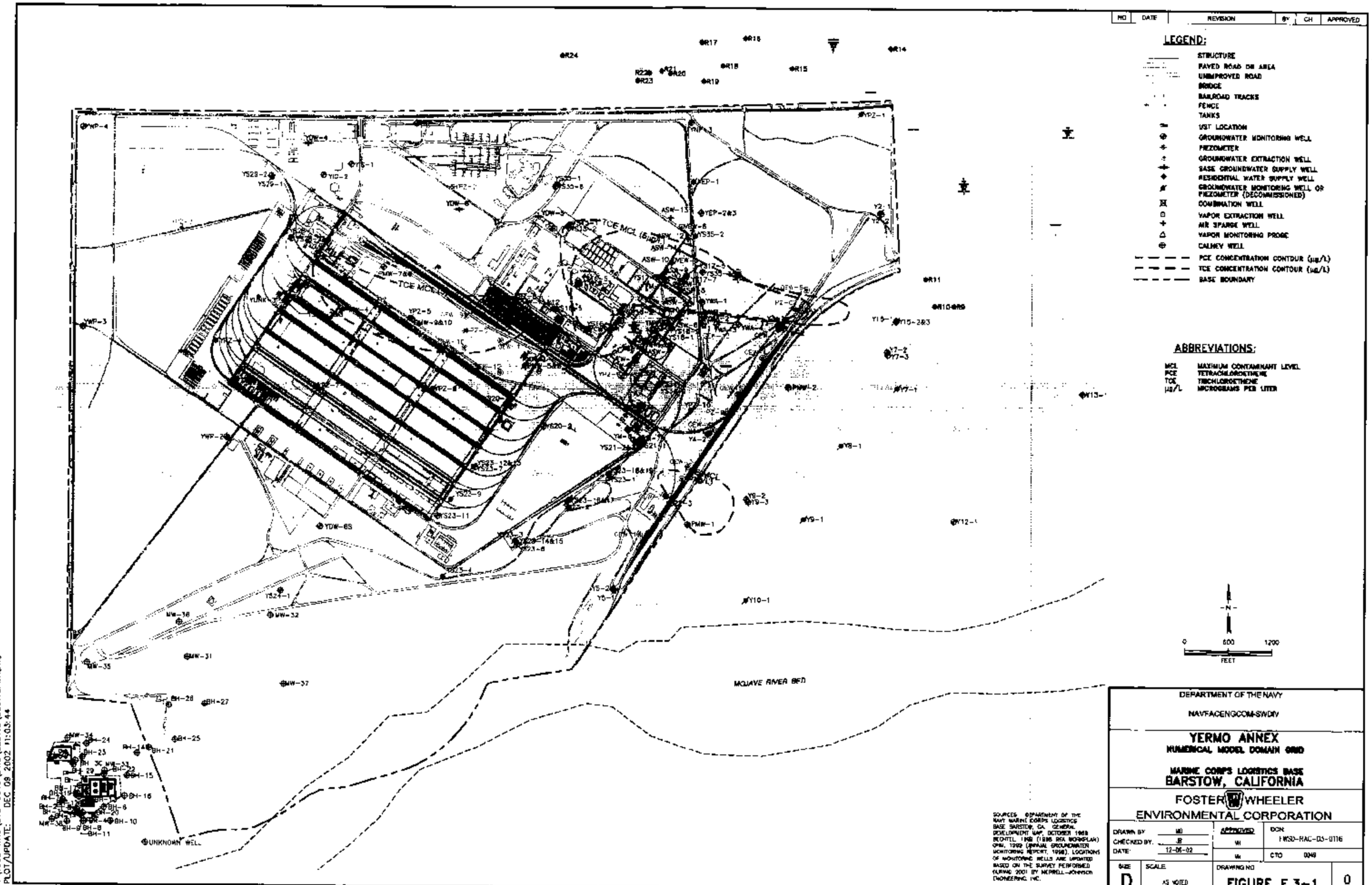

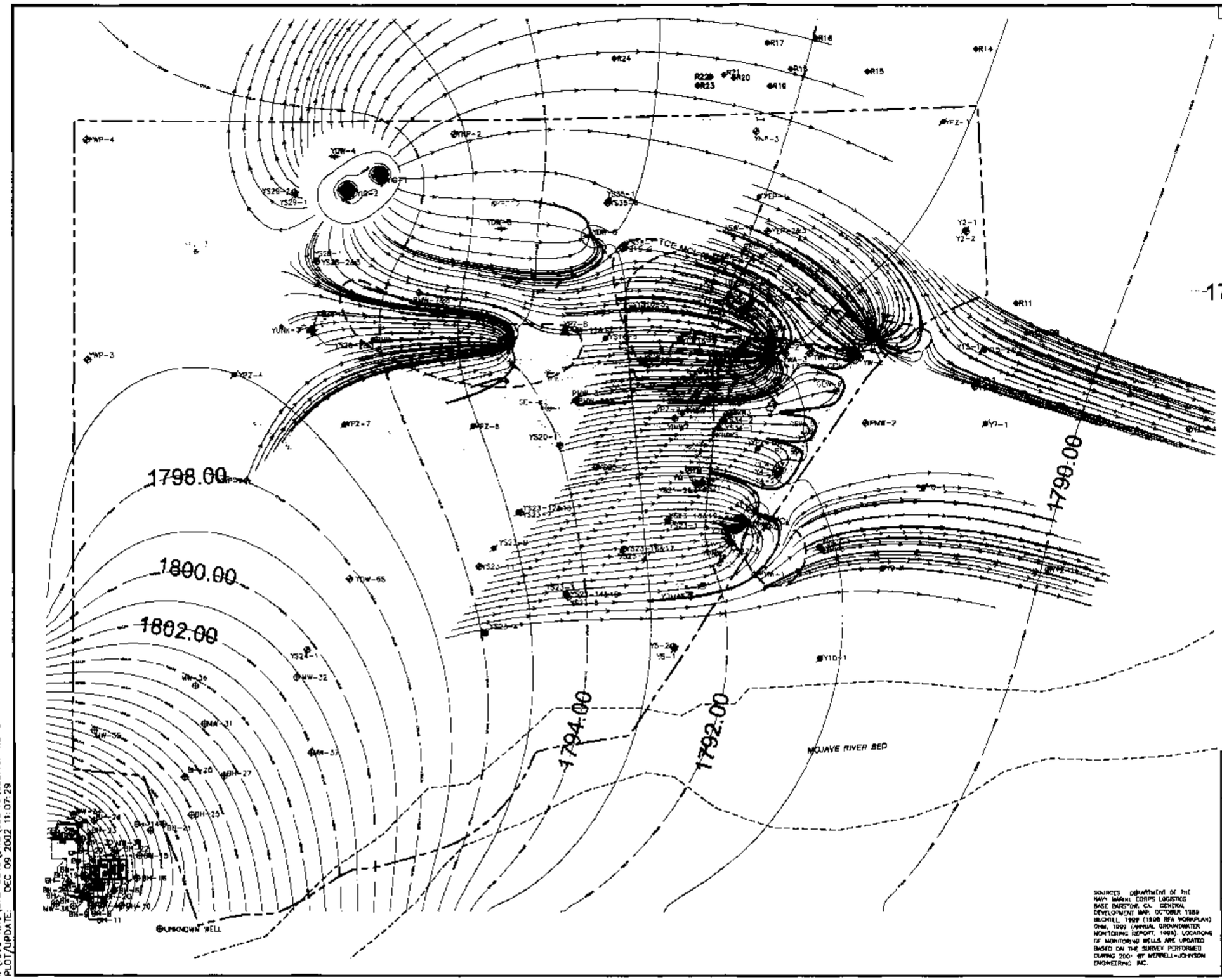

NO	DATE	REVISION	BY	CH	APPROVED

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- RESIDENTIAL WATER SUPPLY WELL
- COMBINATION WELL
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- VAPOR MONITORING PROBE
- CALNEV WELL
- BASE BOUNDARY
- PREDICTED HYDRAULIC CAPTURE ZONE
- 1790.00 — MODEL SIMULATED GROUNDWATER ELEVATION CONTOUR (ELEVATION FEET AMSL)
- MODEL SIMULATED PARTICLE PATHWAY
- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)

ABBREVIATIONS:

AMSL	ABOVE MEAN SEA LEVEL
MCL	MAXIMUM CONTAMINANT LEVEL
PCE	TETRACHLOROETHENE
TCE	TRICHLOROETHENE
µg/L	MICROGRAMS PER LITER

N

0 600 1200
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA. GENERAL DEVELOPMENT MAP, OCTOBER 1989 (BCHTELL, 1989 (1996 RFA WORKPLAN) OHM, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY WERNELL-JOHNSON ENGINEERING INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX

MODEL-SIMULATED GROUNDWATER FLOW AND PARTICLE PATHWAYS-BASELINE CONDITIONS (JUNE 2002)

MARINE CORPS LOGISTICS BASE

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: NO	APPROVED:	DCN: FWSO-RAC-03-0116	
CHECKED BY: JB			
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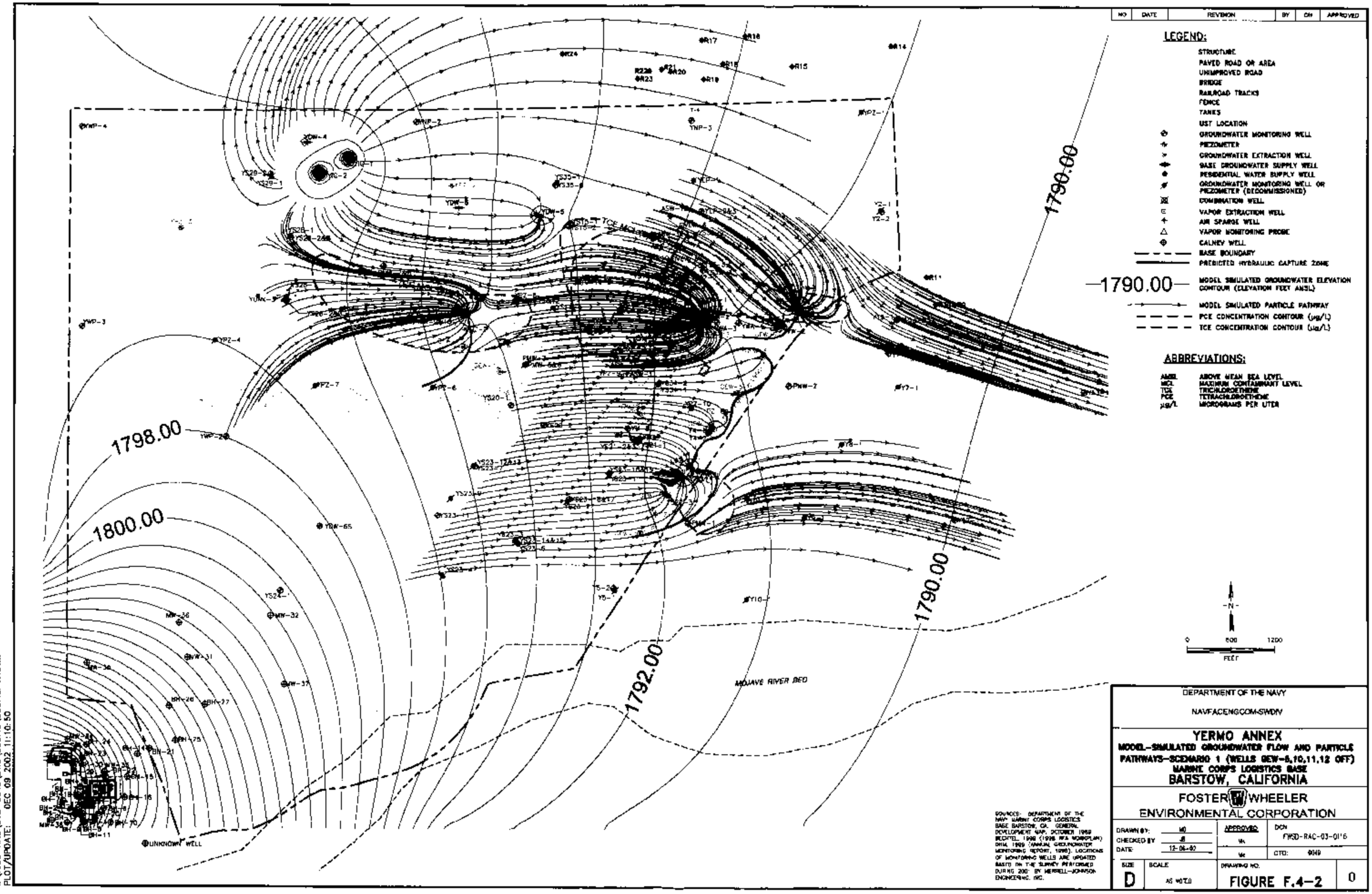

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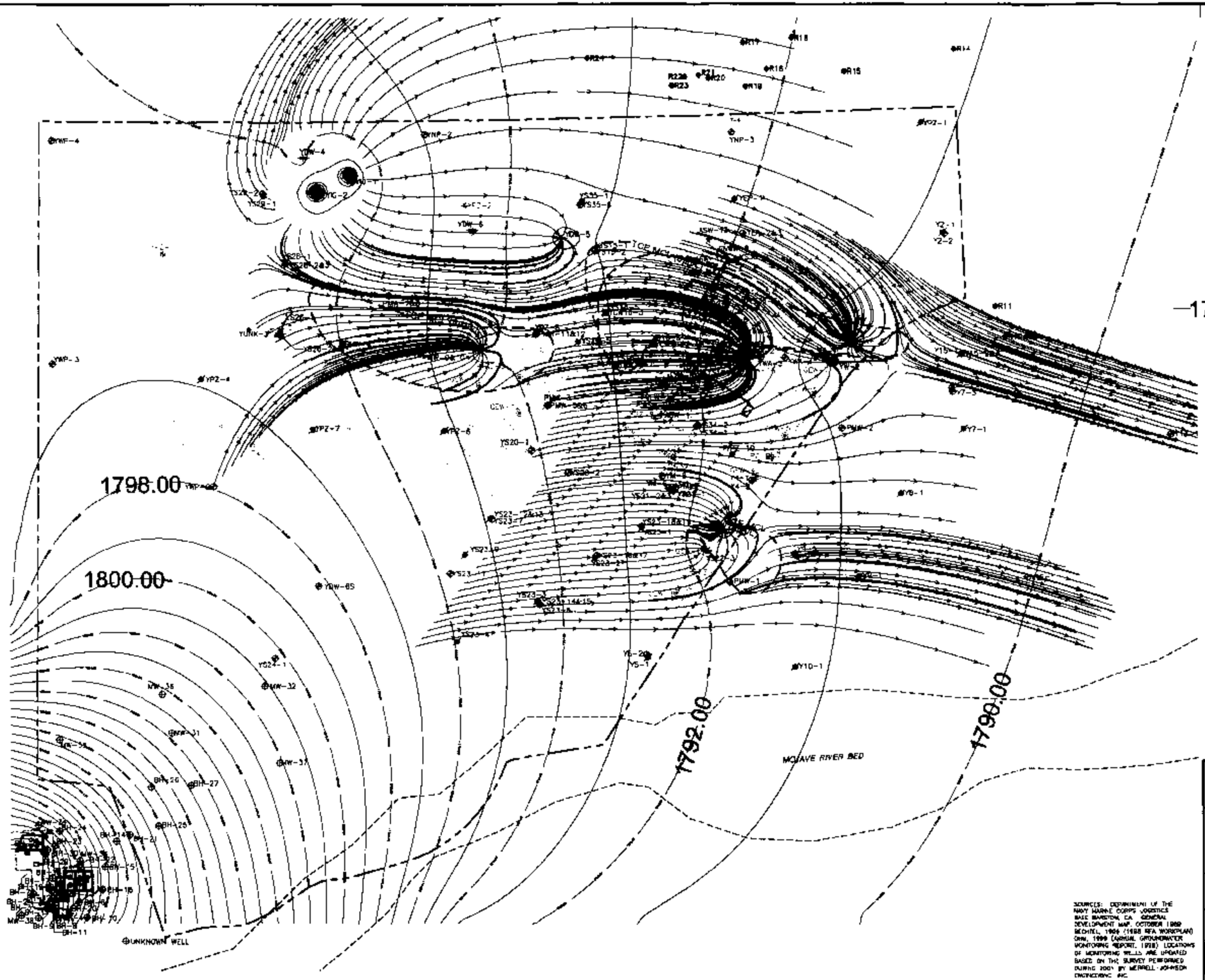

NO	DATE	REVISION	BY	CH	APPROVED

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- RESIDENTIAL WATER SUPPLY WELL
- GROUNDWATER MONITORING WELL OR PIEZOMETER (DECOMMISSIONED)
- COMBINATION WELL
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- VAPOR MONITORING PROBE
- CALMEV WELL
- BASE BOUNDARY
- PREDICTED HYDRAULIC CAPTURE ZONE
- —1790.00— MODEL SIMULATED GROUNDWATER ELEVATION CONTOUR (ELEVATION FEET AMSL)
- MODEL SIMULATED PARTICLE PATHWAY
- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)

ABBREVIATIONS:

AMSL	ABOVE MEAN SEA LEVEL
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER

N

0 600 1200
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW, CA GENERAL DEVELOPMENT MAP, OCTOBER 1988 SEDITEL, 1996 (1988 RFA WORKPLAN) ORN, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998) LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRELL-JOHNSON ENGINEERING INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX

MODEL-SIMULATED GROUNDWATER FLOW AND PARTICLE PATHWAYS—SCENARIO 2 (WELLS GEW-4,5,6,10,11,12 OFF)

MARINE CORPS LOGISTICS BASE

BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

DRAWN BY: MD	APPROVED: VH	DCN: FWSD-RAC-03-0116	
CHECKED BY: JB	VH	CTO: 0049	
DATE: 12-06-02			
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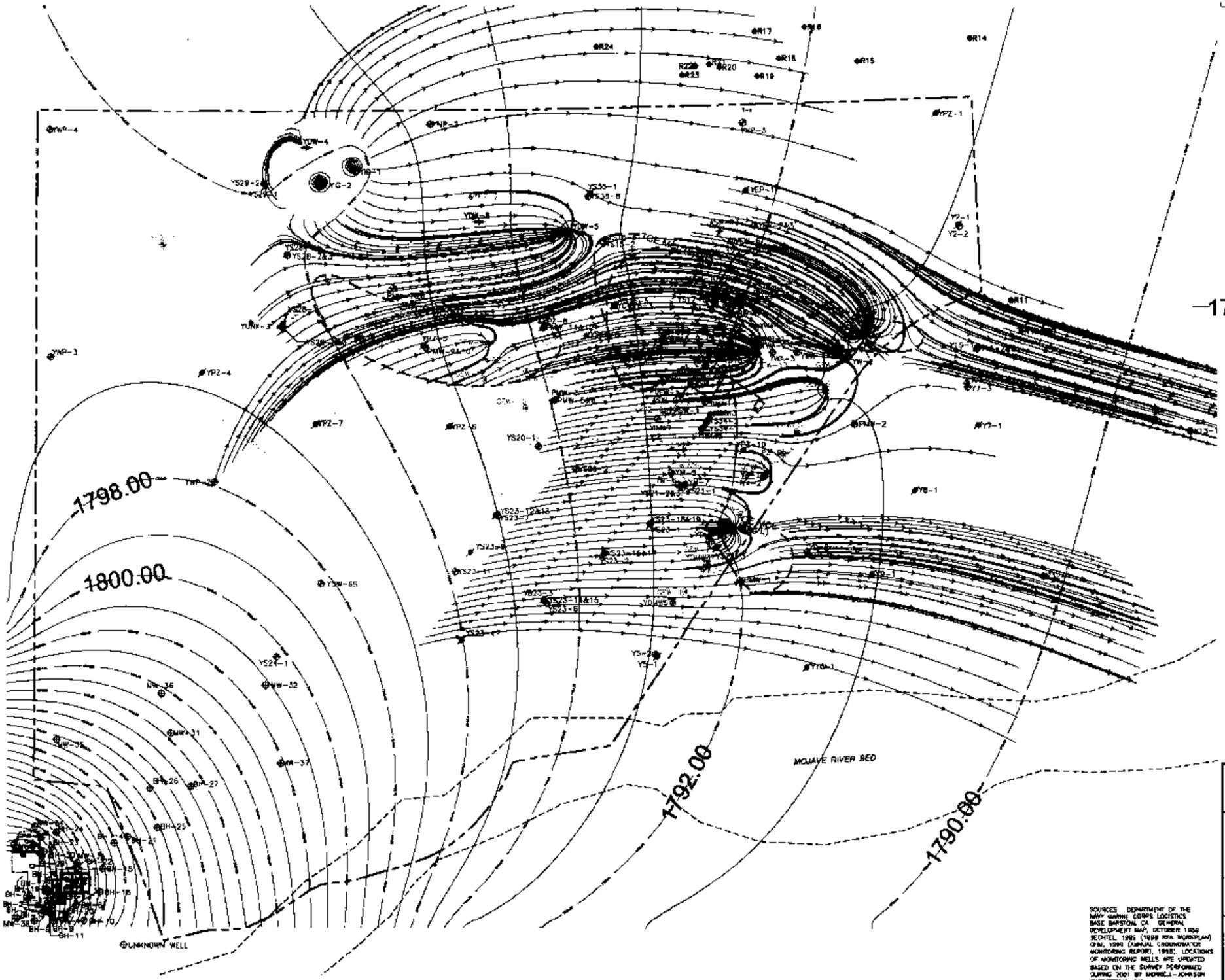

LEGEND:

- STRUCTURE
- PAVED ROAD OR AREA
- UNIMPROVED ROAD
- BRIDGE
- RAILROAD TRACKS
- FENCE
- TANKS
- UST LOCATION
- GROUNDWATER MONITORING WELL
- PIEZOMETER
- GROUNDWATER EXTRACTION WELL
- BASE GROUNDWATER SUPPLY WELL
- RESIDENTIAL WATER SUPPLY WELL
- GROUNDWATER MONITORING WELL OR PIEZOMETER (DECOMMISSIONED)
- COMBINATION WELL
- VAPOR EXTRACTION WELL
- AIR SPARGE WELL
- VAPOR MONITORING PROBE
- CALNEV WELL
- BASE BOUNDARY
- PREDICTED HYDRAULIC CAPTURE ZONE
- —1790.00— MODEL SIMULATED GROUNDWATER ELEVATION CONTOUR (ELEVATION FEET AMSL)
- MODEL SIMULATED PARTICLE PATHWAY
- PCE CONCENTRATION CONTOUR (µg/L)
- TCE CONCENTRATION CONTOUR (µg/L)

ABBREVIATIONS:

AMSL	ABOVE MEAN SEA LEVEL
MCL	MAXIMUM CONTAMINANT LEVEL
TCE	TRICHLOROETHENE
PCE	TETRACHLOROETHENE
µg/L	MICROGRAMS PER LITER

0 600 1200
FEET

SOURCES: DEPARTMENT OF THE NAVY MARINE CORPS LOGISTICS BASE BARSTOW CA GENERAL DEVELOPMENT MAP, OCTOBER 1998 SECNTEL 1999 (1998 RPA WORKPLAN) CH2M, 1999 (ANNUAL GROUNDWATER MONITORING REPORT, 1998). LOCATIONS OF MONITORING WELLS ARE UPDATED BASED ON THE SURVEY PERFORMED DURING 2001 BY MERRILL-JOHNSON ENGINEERING, INC.

DEPARTMENT OF THE NAVY

NAVFACENGCOM-SWDIV

YERMO ANNEX
MODEL-SIMULATED GROUNDWATER FLOW AND PARTICLE PATHWAYS-SCENARIO 3 (WELLS GW 4,6,7,9,13,14,15 PUMPING AT REDUCED CAPACITY)
MARINE CORPS LOGISTICS BASE
BARSTOW, CALIFORNIA

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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FOSTER WHEELER ENVIRONMENTAL CORPORATION

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