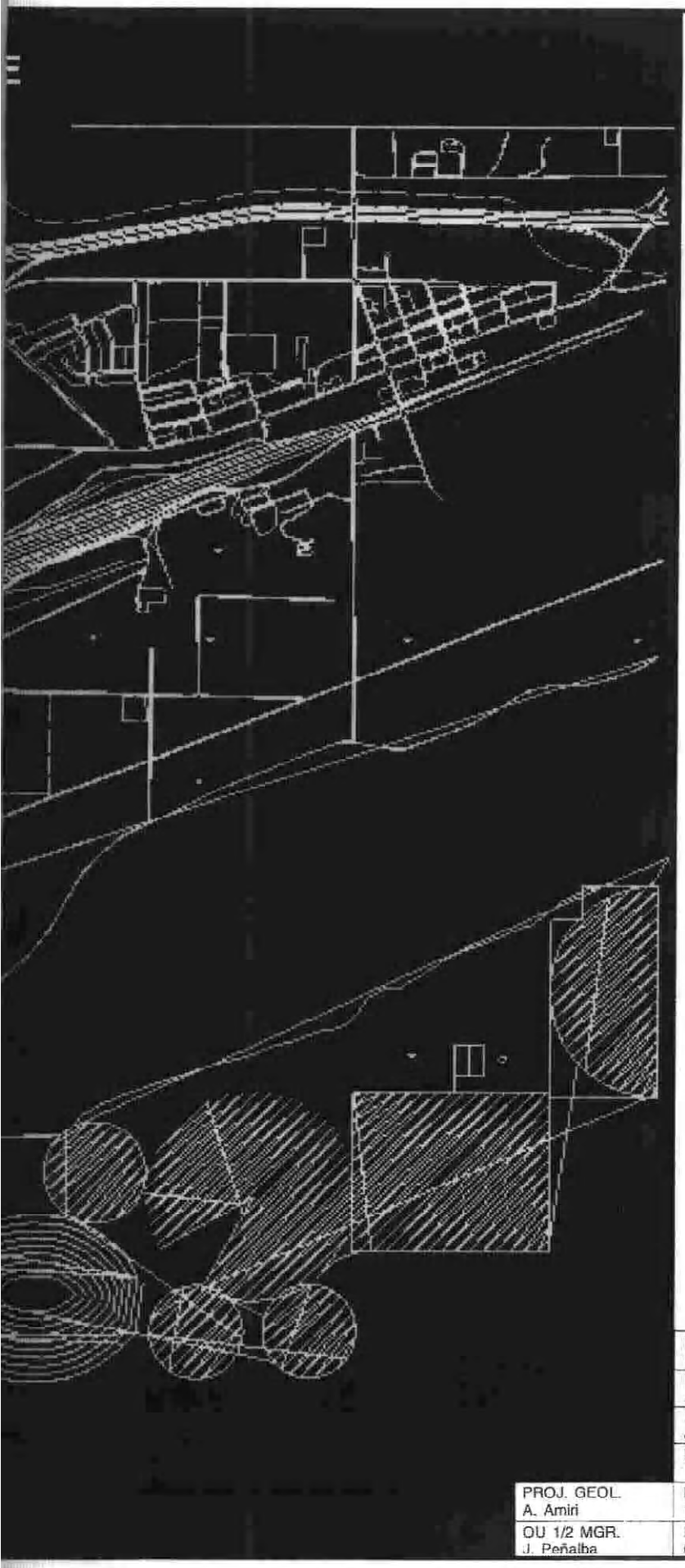
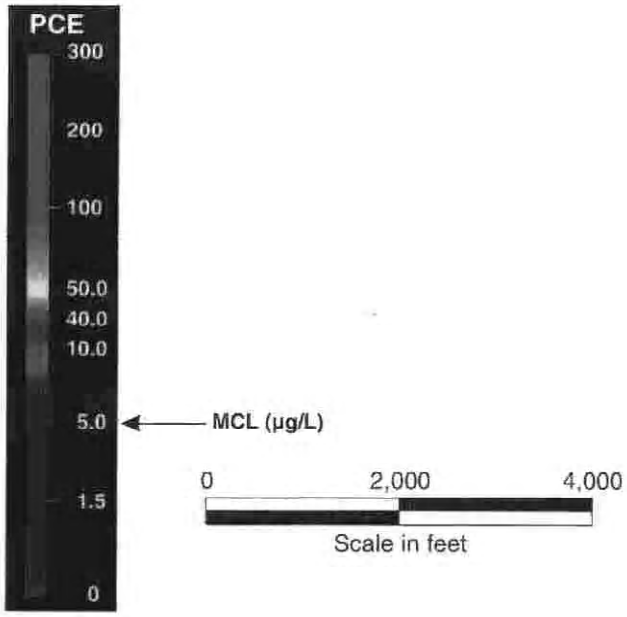


Model shows an areal view slice through PCE contaminated groundwater at approximately 150 ft. below ground surface as of October, 1995. Color variations show intensity of PCE concentration.

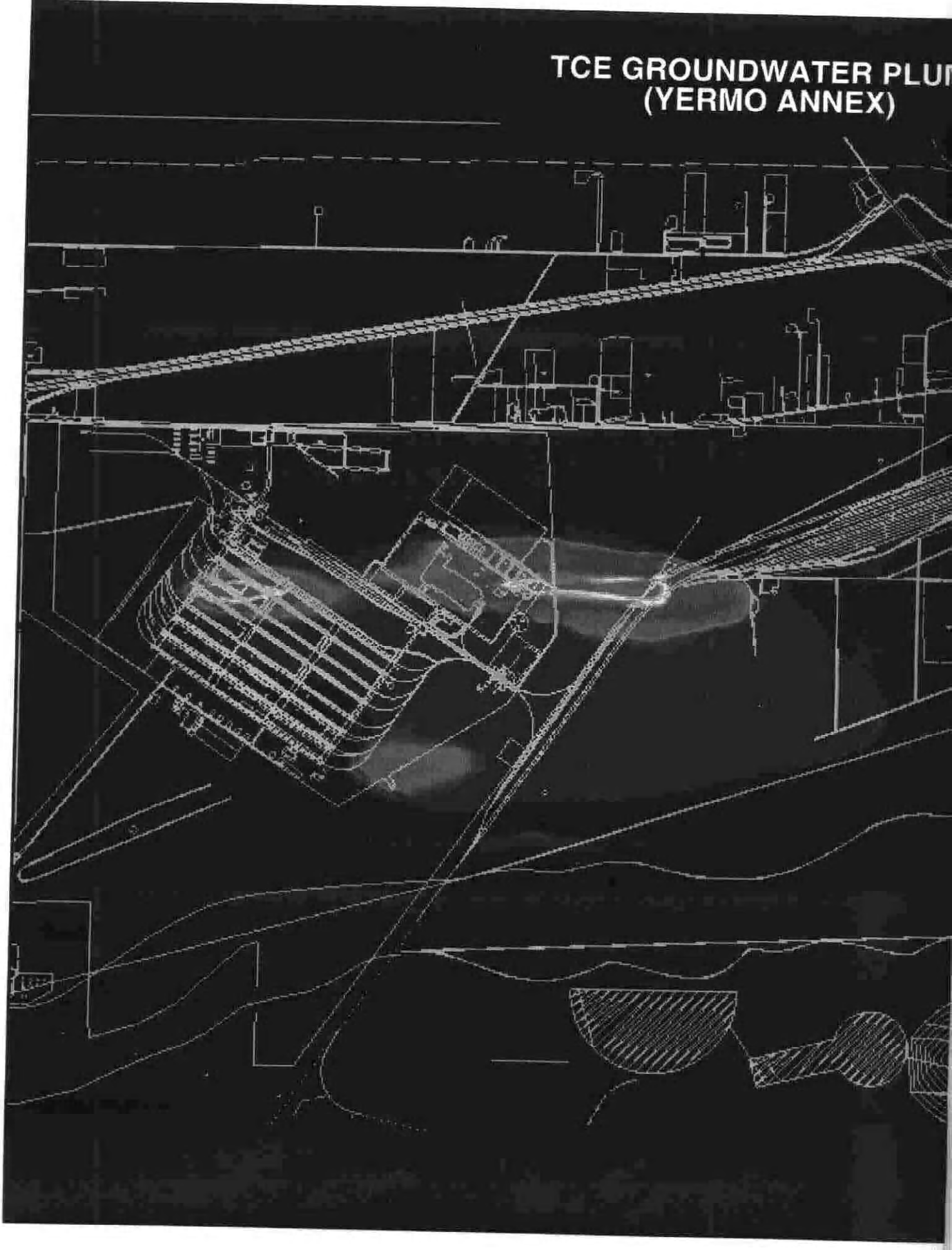
Model was produced using LYNX Geosystems to conceptualize the extent of the PCE plume. Light blue and gray areas are based on geostatistical estimations and represent values detected below MCL (5 µg/L).

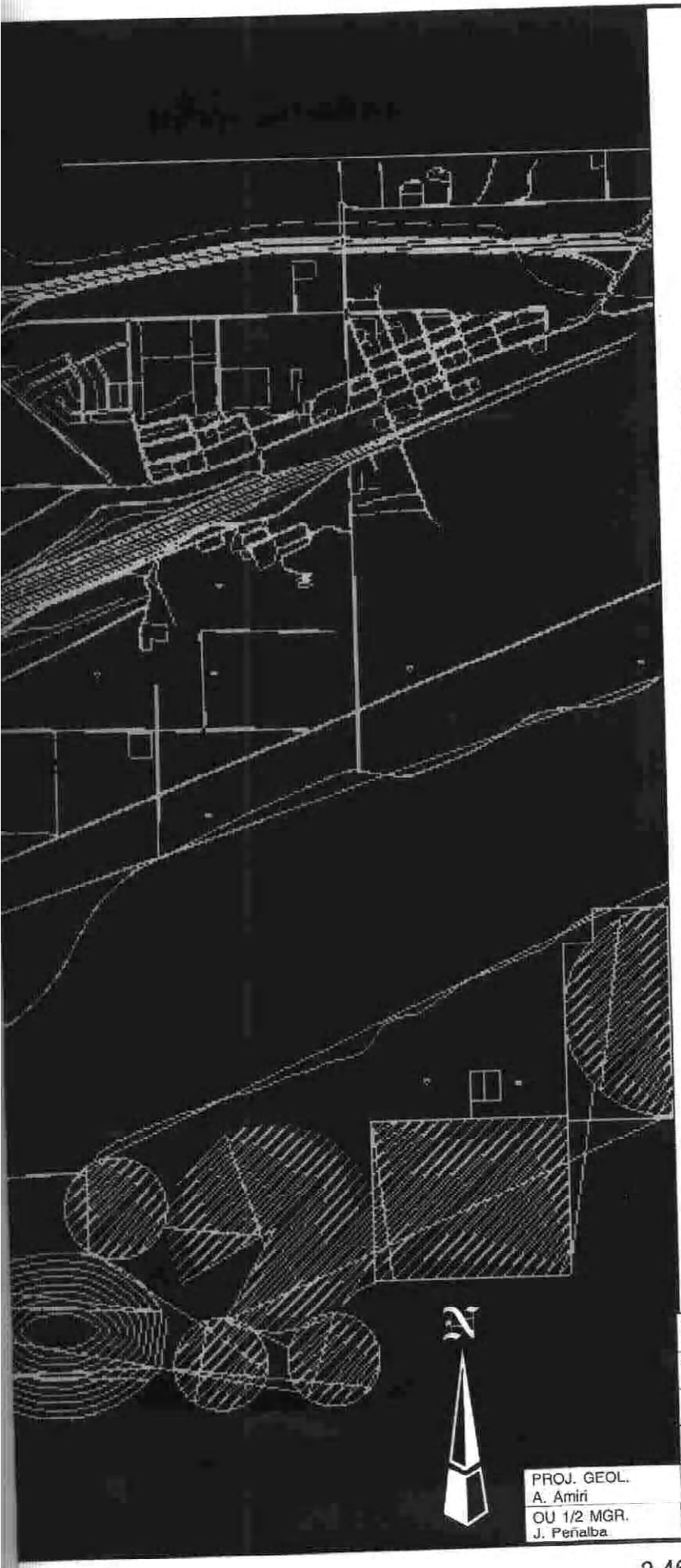
Color scale shows intensity of concentration in micrograms per liter (µg/L).



PROJ. MGR. S. Walker	JACOBS ENGINEERING GROUP INC. PASADENA, CALIFORNIA	
PROJ. ENG. A. Garrison	MARINE CORPS LOGISTICS BASE Barstow, California	
DRAWN BY J. Lawrence	**PCE Plume in Groundwater from CAOCs 15/17, 26, 35, and Bldg. 573, Yermo Annex**	
DRAWING NO. 1109\F298137A.CDR		
PROJ. GEOL. A. Amiri / MADE FROM 1109\F298-137.CDR		
OU 1/2 MGR. J. Peñalba / DATE 02/20/97	PROJ. NO. 01-F298-YB	FIGURE 3-2

TCE GROUNDWATER PLUI
(YERMO ANNEX)

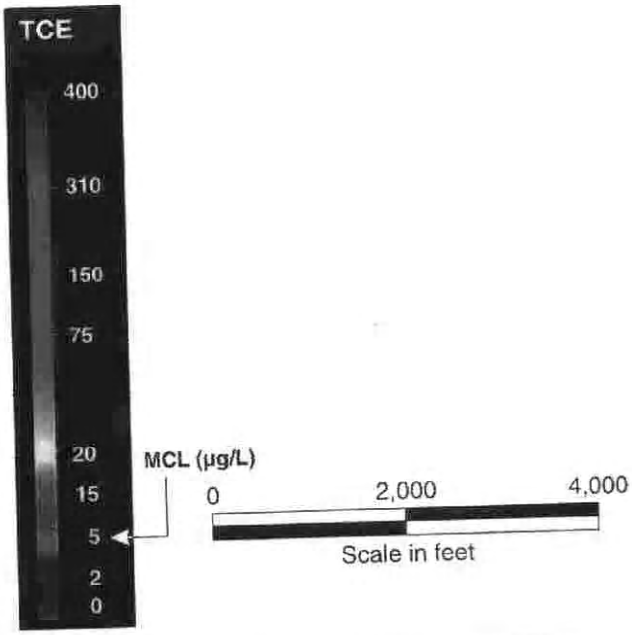




Model shows an areal view slice through TCE contaminated groundwater at approximately 150 ft. below ground surface as of October, 1995. Color variations show intensity of TCE concentration.

Model was produced using LYNX Geosystems to conceptualize the extent of the TCE plume. Light blue and gray areas are based on geostatistical estimations and represent values detected below MCL (5 µg/L).

Color scale shows intensity of concentration in micrograms per liter (µg/L).



PROJ. MGR. S. Walker	JE	JACOBS ENGINEERING GROUP INC. PASADENA, CALIFORNIA
PROJ. ENG. A. Garrison		MARINE CORPS LOGISTICS BASE Barstow, California
DRAWN BY J. Lawrence		**TCE Plume in Groundwater from CAOCs 15/17, 26, 35, and Bldg. 573, Yermo Annex**
DRAWING NO. 1109\F298138A.CDR		
PROJ. GEOL. A. Amiri	MADE FROM 1109\F298-138.CDR	
OU 1/2 MGR. J. Peñalba	DATE 02/20/97	PROJ. NO. 01-F298-YB — FIGURE 3-3

4.0 NEBO NORTH PLUME

4.1 Summary of Plume Characteristics

4.1.1 Contaminants of Concern

4.1.1.1 Organics

The results of the groundwater RI for the Nebo North plume indicated that VOCs are the primary class of chemicals affecting the groundwater in the northern Nebo Main Base area. The most prevalent contaminant is the solvent PCE, which has been detected in six groundwater monitoring wells in the area at concentrations exceeding federal and state drinking water standards. Table 4-1 shows the maximum concentrations of VOCs detected in groundwater in the North Nebo area, along with the associated MCLs. Contaminants exceeding drinking water standards are shown at the top of the table. PCE is the only contaminant found to exceed its state and federal drinking water standards, while benzene and 1,2-DCA exceeded the state standard. PCE was detected at a maximum concentration of 80 µg/L, with benzene and 1,2-DCA detected at maximum concentrations of 1.2 and 3.0 µg/L, respectively. TCE was the second most common VOC detected but it did not exceed MCLs.

4.1.1.2 Inorganics

The evaluation of the nature and extent of metal concentrations at the Nebo Main Base indicates that no metals are present above naturally occurring levels in groundwater. The RI concluded that there is no evidence that discharge of wastes from the Base has resulted in metal concentrations above background levels in the underlying groundwater in the northern Nebo Main Base area.

4.1.2 VOC Contaminant Sources

VOCs are the only confirmed class of groundwater contaminants in the northern Nebo North plume area. The areal extent of the VOC plume and location of

contaminant sources are shown in Figure 4-1. The Nebo North plume appears to be the result of disposal activities originating as long ago as 1943 when major industrial operations took place at Warehouse 2 (the Old Repair Facility) and adjacent buildings. Warehouse 2 was constructed in 1942 and operated as a repair facility until 1961 when operations were suspended and transferred to Building 573 in the Yermo Annex. The operations at Warehouse 2 included engine repair, rebuilding, and testing; and metal parts cleaning, etc., similar to the present operations at Building 573. The Warehouse 2 building is currently used as a general warehouse. Residual vadose zone VOC contamination in the area of Warehouse 2 has been detected at the location of three former UST sites (SWMU 10.43) identified as Solid Waste Management Units. Other potential sources have been identified in the northern Nebo Main Base area under the RCRA Facility Assessment (RFA) program, including SWMUs 10.1, 10.4, 10.5, 10.12, and 10.13. Although an analysis of the available soil data from these sources indicates they do not pose a threat to groundwater, these data points are generally from shallow soil samples (0 to 5 feet bgs) and there is some uncertainty regarding the representativeness of these results for vadose zone contamination.

4.1.3 Location of Vadose Zone Contamination

VLEACH modeling conducted with the soil data from SWMU 10.43, the three UST sites at Warehouse 2, indicated that VOCs present in the vadose zone soils may pose a continuing, long-term source of VOCs to groundwater. Groundwater contamination by VOCs has been confirmed to exist at this site. On the basis of these results, Warehouse 2 was included in the FS for evaluation of vadose zone and groundwater remedial alternatives.

The three USTs were removed in 1992 under the RFA program. The results of soil samples collected during the removal of the USTs indicated elevated VOC levels in two of the three UST locations. Other SWMUs in the vicinity of Warehouse 2 were also found to be contaminated with VOCs; however, the results of the human health evaluations found no significant health risk.

4.1.4 Location of Groundwater Contamination

Groundwater contamination with VOCs was detected in and downgradient of the source area, Warehouse 2, discussed in Section 4.1.3. Figures 4-2 and 4-3 show the distribution of PCE and TCE in groundwater in the area of the northern Nebo Main Base plume. These maps, contoured using the Lynx Geosystem, show the location of the source area and the extent of the dissolved VOC plume. The Nebo North plume extends approximately 4,000 by 1,500 feet and appears to be limited to the upper 20 feet of the aquifer.

In addition to the identified PCE and TCE plumes, various low-level VOC detections have been reported in monitoring wells throughout the Nebo Main Base. These detections are sporadic and essentially occur over the entire Nebo Main Base. The results from multiple sampling events between March 1992 to September 1995 indicate that no discernible plumes exist in these areas. Since these areas are 1) generally below MCLs and health risk levels, and 2) have no discernible sources, no further remedial action is necessary for these areas.

4.1.5 Contaminant Migration Routes

The following potential routes of contaminants migration were identified for the Nebo North plume area:

1) **Vadose Zone Contaminant Transport:**

   a) Vertical transport through the soil by desorption of chemicals bonded to the surface of the soil particles and percolation of infiltrated water through the contaminated soil column, and

   b) Vertical and horizontal transport of contaminant vapors through soil pore space from either residual or re-vaporization of material adsorbed/absorbed onto the soil particles. Vapors can potentially recontaminate the groundwater or be emitted to the surface.

2) **Groundwater Contaminant Transport:** Vertical and horizontal transport of contaminants through the groundwater matrix.

4.1.5.1 Vadose Zone Contaminant Transport

In general, VOCs have a high vertical mobility in soils. The data gathered from the Nebo North plume area indicate that VOCs have percolated into the shallow groundwater, and that PCE is the predominant constituent of groundwater contamination.

Source leaching modeling was performed using VLEACH 2.0 (Turin 1990) to assess the future impact to groundwater from vadose zone contaminants in the northern Nebo Main Base area. The VLEACH results indicate that Warehouse 2 may continue to release contaminants to the groundwater for the next 28 years. However, this is based on a conservative model with limited data. VLEACH results for other potential contaminant sources in the area indicate no continuous threat to groundwater.

4.1.5.2 Groundwater Contaminant Transport

As shown in Figure 4-3, the VOC plume extends from Warehouse 2 on the western side of the Nebo Main Base to the current leading edge of the plume at the eastern Base perimeter. Based on the hydrogeological characteristics of the aquifer and the estimated date of which the releases originated (1943), groundwater modeling indicates that the plume should have migrated about 10,000 feet. However, the plume has remained very stable and has not been observed to increase its size, volume, or mass over the course of 12 quarterly sampling events conducted since 1992. Fate and transport modeling data generated for the site indicate that shallow groundwater (approximately 20 to 30 feet), high fluctuation in water table elevations, and predominantly sandy soil may be contributing to the natural degradation of this plume. As shown in Figure 4-3, the plume appears to be contained within the Base boundary. The nearest known water supply well is about 3,000 feet downgradient of the leading edge of the plume.

Groundwater samples from intermediate depth monitoring wells (screened from 40 to 60 feet below the groundwater table), resulted in mostly non-detect concentrations of VOCs below detection limits throughout the Nebo Main Base.

A vertical extent of 40 feet was conservatively assumed to be the average depth of groundwater VOC contamination.

4.2 Summary of Nebo North Plume Risks

The major risk currently associated with the Nebo North plume is the ingestion of the contaminated groundwater underlying the affected on-Base area. Actual or threatened releases of hazardous substances from the Nebo North plume, if not addressed by implementing the response action selected in this ROD, may present a threat to public health and the environment.

4.2.1 Chemicals of Concern

The majority of the waste and residues generated by mission operations at the Nebo Main Base have been managed, treated, and disposed of on site throughout the Base history. By application of screening criteria, the chemicals detected in the vadose zone and groundwater during the RI were evaluated for inclusion as chemicals of potential concern in the risk assessment. Contaminants of concern identified in groundwater at the northern Nebo Main Base area are listed in Table 4-1.

4.2.2 Summary of Toxicity Values

Summaries of the carcinogenic and noncarcinogenic toxicity values for contaminants of concern in groundwater at the Nebo North plume area are provided in Tables 3-3 and 3-4, respectively.

4.2.3 Human Health Risk

To evaluate the groundwater at the Nebo North plume under OU 2, the BLRA used a hypothetical on-Base residential scenario.

The BLRA showed that under this scenario for cancer risk, as many as three additional persons in 10,000 (3×10^{-4}) could develop cancer during their

lifetimes. Excluding the contribution from naturally occurring background metals, the incremental cancer index is approximately 1×10^{-4} (one in ten thousand). The majority of the risk results are from PCE. As discussed in Section 3.2.3, the exposure assumptions used to estimate the risk are extremely conservative and tend to overestimate risk.

For noncancer health effects, the hazard index for the Nebo North plume is estimated to be 2.9, which exceeds the EPA's acceptable criterion of 1. Approximately 1.4 is attributed to naturally occurring background metals, with the remainder resulting primarily from PCE.

Hypothetical receptors were also evaluated, assuming exposure at the MCL and background levels (analytical quantitation limit). At the MCL, the incremental risk from both PCE and 1,2-DCA was estimated to be approximately 1×10^{-5} (one in one hundred thousand). The corresponding incremental risk at the background level is approximately 5×10^{-6}. The noncarcinogenic hazard index is less than 1.0 from both chemicals.

Based on the above results, on-Base groundwater containing VOC contamination above drinking water standards is a medium of concern for remedial action. In addition, the subsurface soil is a medium of concern because of potential cross-media chemical transport from subsurface soil to groundwater.

4.2.4 Ecological Risk

An ecological risk assessment was independently performed by EPA Region IX to evaluate potential effects on plants and animals from groundwater contaminants at MCLB Barstow. An area of potential concern evaluated by the EPA is the riparian habitat on the northeast corner of the Nebo Main Base. Groundwater in this area surfaces and pools near the Mojave River, creating the potential for a complete exposure pathway to ecological receptors. The riparian habitat was investigated to assess the potential for contaminated groundwater to have affected this area. However, an evaluation of surface waters and

associated sediments in this area found that they do not pose an ecological threat.

4.3 Rationale for Remedial Action Decisions

This section discusses the rationale used to make groundwater and vadose zone cleanup decisions for the Nebo North plume.

4.3.1 Groundwater Cleanup

The areal extent of VOC contamination at the Nebo North plume was determined during the RI/FS. As discussed in Section 4.1.5, the Nebo North plume is very stable and does not appear to be increasing in size. In contrast with the Yermo Annex plume, the MCL and background contour areas for the Nebo North plume are relatively close together and contained on Base. Site characterization and fate and transport modeling data generated for the site support indications that the shallow groundwater, high fluctuation in water table elevations, and predominantly sandy soil conditions in the northern Nebo Main Base area may be resulting in the natural degradation of this plume. The remediation strategy for this plume is to prevent the VOC contamination from migrating off-Base. Two groundwater cleanup options were considered in the FS under this remediation strategy.

1) Remediation of groundwater contamination at the MCL boundary by institutional controls coupled with vadose zone source reduction and natural contaminant degradation processes. Based on the evidence that exists in support of plume degradation by natural processes, the Marine Corps decided to include this process option in the remedial alternatives evaluated for this plume. Because the RI/FS data collection program was not designed with natural processes considered as a possible remedy, the existing data are not sufficient to quantitatively demonstrate how natural processes are actually occurring. However, 5 years of groundwater sampling since 1992 demonstrate that the plume is at "steady state" (i.e., plume is not growing and VOC concentrations in groundwater are stable). The data indicate that the plume is self-contained. However, source reduction at Warehouse 2 will be implemented under this strategy to enhance the cost-effective containment and natural degradation of the plume. There are no downgradient receptors at risk within 3,000 feet of the leading edge of the plume.

2) Containment of groundwater contamination at the MCL boundary by active extraction and treatment technology. This process option was evaluated to determine if extraction and treatment is a cost-effective remedy to prevent plume migration and provide a permanent solution. A pilot study consisting of eight extraction wells (four in the center of the plume near the more highly contaminated area, and four at the leading edge of the plume to provide containment) was conducted to analyze mass removal rates and evaluate plume behavior. The pilot study results indicate that the system removed ten times more VOC mass than was predicted and can effectively remove VOC contamination from groundwater. The results also support the assessment that the plume is not migrating. As predicted, most of the VOC contamination was removed at the upgradient wells. VOC concentrations decrease significantly by the time they reach the downgradient wells and at least two of these wells have consistently shown concentrations below detection limits. Furthermore, there are no obvious upward or downward trends in mass removal rates or VOC concentrations, which supports earlier conclusions that the plume has reached a steady state condition.

The pilot study has proven that extraction and treatment can effectively contain and remove VOC contamination from groundwater and could significantly shorten cleanup duration. However, existing evidence also supports conclusions that natural contaminant degradation processes are taking place at an effective rate (e.g., stable plume) to prevent adverse health effects to potential receptors. Because extraction and treatment would quadruple the cost of cleanup compared to natural processes without commensurate benefits in risk reduction to receptors, the Marine Corps prefers the source reduction and natural attenuation option. However, based on the uncertainties associated with natural attenuation at this time (e.g., limited source characterization and definition/relative contribution of processes at work and rates of reduction), the Marine Corps has decided to keep the existing extraction and treatment system in place, fully maintained and on standby for startup as a fail-safe containment option in case source reduction and natural attenuation fail to effectively contain the plume. This decision is consistent with the intent of CERCLA and the NCP that the final remedy be cost-effective and use permanent solutions and alternative treatment technologies to the maximum extent practicable.

Selection of the appropriate remedial goal for the Nebo North plume was made based on an evaluation of the technical and economic feasibility of achieving MCL and background levels, the residual risk remaining in groundwater after

achieving each cleanup goal, and the costs/benefits of incremental risk reduction. The following summarizes the TEF analysis results and conclusions.

1) Cleanup of contaminated groundwater to MCLs would reduce baseline risks by 91 percent, resulting in a residual risk of 1×10^{-5}. Cleanup to background levels would reduce baseline risks by 95 percent, resulting in a residual risk of 5×10^{-6} (an incremental 4 percent reduction over MCLs). Both cleanup levels are within EPA's risk management range and are considered protective of human health and the environment.

2) Cleanup of contaminated groundwater to MCLs would remove 75 percent of the total estimated VOC mass, and take from 12 to 45 years depending on the alternative selected. Cleanup to background levels would remove 100 percent of the total estimated VOC mass (an incremental 25 percent mass reduction over MCLs), but would take from 30 to 120 years for the same alternatives (an incremental 150 percent duration over MCLs).

3) The estimated present worth costs of all alternatives evaluated range from $1.0 to $5.8 million for cleanup to MCL, versus $1.1 to $7.3 million for cleanup to background levels, a cost increase of 14 to 30 percent for background over MCLs.

In summary, remediating to background levels rather than to MCLs would result in only a minimal incremental difference in risk reduction and mass removal while increasing cleanup duration by two- to three-fold and cleanup costs by approximately 20 percent. Based on the proven technical difficulties of restoring aquifer quality to background levels with existing technology discussed in Section 3.3, and the fact that both MCLs and background cleanup goals are considered protective of human health and the environment, the TEF analysis concluded that cleanup to background levels is technically and economically impracticable. Therefore, the Marine Corps selected MCLs as the cleanup goal for the Nebo North plume.

4.3.2 Source Reduction

Vadose zone contamination that may pose a continuing, long-term source of VOCs to groundwater has been determined to exist in the area around Warehouse 2, the Old Repair Facility. Continued releases to groundwater from this area could reduce the effectiveness of the remediation and extend the duration of cleanup.

The following cleanup options for the Warehouse 2 area were evaluated in the FS.

1) **Soil excavation.** This option is not feasible to remove the residual contamination in the soil because of the presence of physical improvements (i.e., buildings, structures) around Warehouse 2.

2) **In Situ Vertical AS/SVE.** This option involves installing and operating a full-scale SVE system (four AS and five SVE wells) to provide adequate coverage of the vadose zone in the area of Warehouse 2. The relatively sandy soils and shallow groundwater at this site provide ideal conditions for AS/SVE. Such a system is readily implementable and could conceivably shorten the remediation time for natural processes to degrade the groundwater VOC plume by 30 years (from 45 to 15), at an approximate cost of $700 K.

Based on the FS results, the Marine Corps has determined that source removal in the northern Nebo Main Base area would be a cost-effective enhancement to significantly reduce the estimated cleanup duration from 45 to 15 years and accelerate the natural degradation processes. Therefore, the Marine Corps has decided to implement source reduction (i.e., AS/SVE) in the northern Nebo Main Base area as part of the selected final remedy.

Additional vadose zone characterization of Warehouse 2 is needed to delineate the vadose zone source area sufficiently to design the AS/SVE system. The characterization will be performed as part of the remedial design for this remedy.

Vadose Zone Modeling to Determine AS/SVE System "Shut Off"

Performance parameters for vadose zone modeling to support AS/SVE shut off decisions will be measured in a similar fashion to CAOC 26, using the criteria described in Sections 2.8.4 to 2.8.6 and 3.3.2.2 of this ROD.

4.4 Description of Remedial Action Alternatives, Nebo North Plume

Five alternatives are presented in this ROD for remediating groundwater and vadose zone soil in the Nebo Main North plume area. These alternatives are discussed in

detail in the Draft Final FS for OUs 1 and 2 (Jacobs 1996) and summarized in this section.

4.4.1 Alternative 1 – No Action

Under this alternative, no further action would be taken to clean up or control contamination from vadose zone soils or groundwater. The existing site conditions would not change. No costs are associated with this alternative. The no action alternative provides a baseline for comparing the other alternatives.

4.4.2 Alternative 2 – Institutional Controls/Groundwater Monitoring with Fail-Safe Extraction and Treatment Containment

This alternative includes implementing institutional controls and initiating a long-term groundwater monitoring program. This alternative relies on natural processes such as dispersion, degradation, sorption, and volatilization to reduce VOC concentrations. Institutional controls will ensure that the affected groundwater will not be used in the future, thereby maintaining the current lack of exposure to, and risks from, chemicals in groundwater.

Institutional controls will include restrictions on the use of untreated groundwater for domestic use and provisions for wellhead treatment of affected water supply wells within the Nebo North plume area. The institutional controls to restrict access to contaminated groundwater in this area will be documented in the Base Master Plan.

This alternative also includes a long-term monitoring program to monitor vadose zone and groundwater beneath and downgradient of contaminant sources. Groundwater monitoring involves sampling existing monitoring wells to: 1) fully understand the relative contribution and rates of reduction of the different natural processes that have stabilized and are passively remediating the plume(s); 2) monitor trends in contaminant concentrations; 3) evaluate remediation progress and contaminant migration patterns; and 4) provide early warning to turn on the existing fail-safe extraction and treatment system to

prevent contaminant exposure to potentially affected downgradient users. Vadose zone monitoring involves sampling of soil vapor probes to 1) monitor trend in contaminant concentrations and 2) assess the effect of the vadose zone contaminant on the effectiveness of the selected remedy.

A Post-ROD vadose zone and groundwater Remedial Action Monitoring Plan for the Nebo North plume remedial action will be prepared under the authority of this ROD, outlining the monitoring well network, sampling and analytical methods, sampling frequency and major decision points during monitoring (e.g., adding/removing monitoring wells from the network, changing sampling frequency or analytical parameters, etc.). The Post-ROD Monitoring Plan will be a primary FFA deliverable to be submitted to the agencies within one year of the signing of the ROD.

This alternative relies on the natural processes that appear to be occurring on the Nebo North plume to passively remediate VOC contaminated groundwater to meet federal and state drinking water standards (MCLs). The effectiveness of natural degradation processes will be demonstrated through long-term monitoring.

The cost for Alternative 2 includes approximately $1.22 million in capital costs (including the cost of the existing pilot pump-and-treat system), and $55,000 in yearly O&M costs to put in place institutional controls and install and monitor groundwater monitoring wells, for a total present worth cost of $2.2 million. Groundwater modeling indicates that it would take this alternative about 45 years for the VOC plume to naturally degrade to levels below drinking water standards (MCLs). Except for the no action alternative, all alternatives include institutional controls and long-term groundwater monitoring.

4.4.3 Alternative 3 – Groundwater Removal, Ex Situ Treatment, and Discharge

This alternative involves operating the existing groundwater pump-and-treat pilot study system, which includes eight existing extraction wells designed to fully

capture the portion of the plume above federal and state drinking water standards (MCLs). The extracted groundwater is passed through an activated carbon filtration system, which will remove contaminants to meet regulatory discharge requirements. The treated water is then recharged back into the aquifer via two percolation ponds downgradient of the contaminant plume. This system is estimated to extract and treat 300 to 400 gallons per minute (gpm) from the plume. This alternative would actively remediate VOC-contaminated groundwater to meet MCLs. The portion of the plume currently above MCLs represents about 95 percent of the total VOC contamination in the Nebo North area.

The approximate volume of groundwater requiring remediation is estimated to be 0.65 billion gallons. The cost of Alternative 3 includes $2.4 million in capital costs to construct the treatment system (all of which has already been constructed as part of the extraction and treatment pilot study), and $234,000 in yearly O&M costs to operate the system. The total present worth cost of this alternative is estimated at $7.1 million, ($2.4 million of which has already been spent). Groundwater modeling indicates that it would take this alternative about 42 years to clean up the groundwater to levels below MCLs.

4.4.4 Alternative 4 – Groundwater Removal, Ex Situ Treatment, and Discharge with Source Reduction (AS/SVE) at Warehouse 2

This alternative combines the pilot study system from Alternative 3 with AS/SVE at Warehouse 2. This alternative is designed to significantly reduce the time to clean up the groundwater VOC contamination by removing the contaminants trapped in the vadose zone soils directly underneath the original source. Contaminants trapped in the vadose zone can provide a continuous source of contaminants to groundwater for many years, thus prolonging the cleanup efforts. This alternative is estimated to reduce the time to clean up the plume to below MCLs by 30 years, from 42 to 12 years. The cost for Alternative 4 includes $3.2 million in capital costs to construct the treatment system (of which $2.4 million have already been constructed as part of the pilot study), and

$345,000 in yearly O&M costs to operate the system, for an estimated total present worth cost of $5.8 million.

4.4.5 Alternative 5 – Source Reduction (AS/SVE) at Warehouse 2

This alternative is a variation of Alternative 2 and involves adding AS/SVE source reduction at Warehouse 2 to enhance natural contaminant degradation processes. This alternative significantly reduces the total time required to passively remediate the groundwater VOC contamination to below MCLs from 45 to 15 years. The cost for Alternative 5 includes capital costs of $773,000 to construct the AS/SVE system, $1.2 million for the existing pilot pump-and-treat system, and $166,000 in yearly O&M costs to operate the system and implement institutional controls for an estimated total present worth cost of $ 3.0 million.

4.5 Summary of Comparative Analysis of Alternatives.

This section summarizes the evaluation of alternatives conducted to determine which alternative provides the best balance with respect to statutory balancing criteria in Section 121 of CERCLA and Section 300.430 of NCP. The NCP categorizes the nine evaluation criteria into three groups as discussed in Section 2.9.

The following analysis summarizes the evaluation of remedial alternatives under these three categories. Table 4-2 assesses each of the alternatives for achievement of a specific criterion.

The selected alternative for addressing the groundwater contamination at the Nebo North plume is Alternative 5 – Source Reduction (AS/SVE) at Warehouse 2 combined with Institutional Controls/Groundwater Monitoring and fail-safe Extraction and Treatment Containment. This alternative remediates the contaminant plume through natural attenuation enhanced by AS/SVE at the source. The groundwater and vadose zone monitoring program will provide an adequate understanding of these processes and early warning triggers to start up the existing fail-safe extraction and treatment system to prevent exposure to potential receptors. The practicality of the proposed

remedy is supported by the results of the extraction and treatment pilot study recently completed. Based on the current information, this alternative provides the best balance of trade-offs among the alternatives with respect to the EPA's nine evaluation criteria.

4.5.1 Threshold Criteria

4.5.1.1 Overall Protection of Human Health and the Environment

The calculated human health risk for all alternatives is within the EPA's risk management range. However, without institutional controls, the no action alternative is at the upper bound of the risk range (10^{-4}) and may not provide adequate protection of human health and the environment if the groundwater were to be used for domestic use in the future. The institutional controls alternative provides protection by restricting future use and maintaining a fail-rate extraction and treatment system. The calculated human health risk for Alternatives 3, 4, and 5 is well within EPA's target risk range (1×10^{-5}). Assuming that institutional controls are effective, all alternatives except the no action alternative are considered to be protective of human health and the environment. However, only Alternatives 3, 4, and 5 use active measures to reduce contamination, reduce the future threat to human health and the environment, and more quickly remediate to cleanup levels.

4.5.1.2 Compliance with ARARs

A summary of the potentially applicable ARARs for groundwater protection at MCLB Barstow is provided in Section 2.10. All alternatives comply with location-specific ARARs because no ecological or cultural resources are threatened by the groundwater contamination. All alternatives also comply with action-specific ARARs; specifically, state antidegradation ARARs for treated groundwater discharges, VOC emissions control, and groundwater monitoring requirements.

The Lahontan RWQCB has classified the aquifer underlying the Nebo Main Base as a potential drinking water source. Based on the natural degradation processes that appears to be occurring at the site, all other alternatives,

including the no action and institutional controls alternatives, provide passive or active remedies that will comply with the chemical-specific federal and state ARARs for drinking water standards (i.e., MCLs).

4.5.2 Primary Balancing Criteria

4.5.2.1 Long-term Effectiveness and Permanence

All alternatives except Alternative 1 provide moderate to high long-term effectiveness and permanence in a relatively short time frame (i.e., 12 to 45 years). Institutional controls (Alternative 2) can effectively reduce risk by restricting the use of untreated groundwater for drinking water and providing wellhead treatment fail-safe when warranted. Alternative 2 will meet cleanup levels through natural contaminant degradation processes in approximately 45 years. As mentioned previously, the calculated human health risks are within the protective range.

4.5.2.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

The no action alternative would not reduce toxicity, mobility, or volume through treatment because it is not a treatment option. All other alternatives would achieve moderate to high reduction of toxicity, mobility, or volume through extraction and treatment and AS/SVE remediation, and satisfy the statutory preference for treatment. Alternative 2 can achieve this criterion through natural contaminant degradation processes and contingent fail-safe extraction and treatment.

4.5.2.3 Short-Term Effectiveness

Due to the length of remediation, short-term risks are the same as current risks. All alternatives, except the no action alternative, rely on institutional controls for short-term effectiveness of community protection.

The no action and institutional control alternatives would have the least immediate harmful effect on human health and the environment, but would also provide less protection in the short term. The active remediation alternatives would slightly increase the short-term risk of exposure by pumping groundwater and handling contaminated soil. However, use of proper worker protection and safety measures would reduce these risks to safe levels.

4.5.2.4 Implementability

The no action alternative is the easiest to implement because there is nothing to implement. Imposing institutional controls off-Base will require state, local, and community involvement.

Extraction and treatment and AS/SVE are proven, commercially available, readily implementable, and simple to operate technologies. A full-scale extraction and treatment system already has been constructed and is operating at the Nebo North plume. No constructibility issues that could affect installation of an AS/SVE system at Warehouse 2 have been identified. All alternatives involve reasonable cleanup durations.

4.5.2.5 Cost Effectiveness

The selected Alternative 5 is the second least costly alternative, not including the no action alternative. The estimated present worth value for Alternative 5 is $3.0 million. The estimated present worth value of Alternatives 4 and 2 are $5.8 million and $2.2 million, respectively. The selected alternative will meet the threshold criteria for protection of human health and the environment, and will comply with ARARs in about 15 years.

4.5.3 Modifying Criteria

4.5.3.1 State Acceptance

The California State DTSC and RWQCB have reviewed the approved FS and Proposed Plan, and agree with the selected final remedy for the Nebo North plume.

4.5.3.2 Community Acceptance

Minor verbal comments were received from the public concerning the proposed actions for OUs 1 and 2. These comments are included on Page 27 of the public meeting transcripts provided in Appendix C, and in Section 6, "Responsiveness Summary."

4.6 Summary of Selected Remedy For the Nebo North Plume

As required by CERCLA and the NCP, and based on the results of the detailed analysis of alternatives presented in the FS, MCLB Barstow selected Alternative 5 as the final remedy to address groundwater and vadose zone contamination at the Nebo North plume.

For the contaminated vadose zone and groundwater on site, the selected remedy includes source reduction using an AS/SVE system at Warehouse 2 to enhance remediation. In the implementation of this remedy, the DON shall perform sufficient source characterization of the vadose zone to delineate the source at Warehouse 2, by which to design the AS/SVE system. To ensure that human health and the environment are protected in the future, institutional controls will be implemented that include access restrictions to prevent the on-Base use of untreated groundwater for domestic use. Wellhead treatment will be provided for any existing water supply wells that fall within the area of the plume exceeding MCLs. The DON will provide necessary information to appropriate county agencies identifying off-Base areas impacted by groundwater contamination exceeding MCLs. The DON will support county agencies with any

technical information needed for the county to implement restrictions on construction and use of wells in the affected areas.

All requirements, procedures and restrictions established in Section 3.6 for development and implementation of institutional controls, pursuant to Base Master Plan amendment language, shall apply equally to this section.

Natural attenuation processes and source reduction at Warehouse 2 will be relied upon to remediate VOC-contaminated soil and groundwater to met the cleanup goals (performance standards) established in Table 2-1 of this ROD. A sampling protocol will be developed and incorporated in the Nebo Main Base Remedial Action Groundwater Monitoring Plan to periodically determine VOC degradation rates and monitor VOC mass reduction in the vadose zone and groundwater plume to demonstrate the effectiveness of the selected remedy.

The four downgradient extraction wells from the existing groundwater extraction and treatment pilot study system will be activated if VOC concentrations in downgradient monitoring wells exceed MCLs as established in the approved post-ROD groundwater monitoring plan. The monitoring plan will contain a statistical approach for triggering activation and deactivation of the system in accordance with US and California EPA guidance developed for determining statistically significant changes in indicator parameter values. The regulatory agencies will be notified when the pump and treat system is activated. The system will extract contaminated groundwater from the aquifer at a depth of 50 feet, treat it on site through a carbon filtration system, and recharge it back into the aquifer through two percolation ponds downgradient of the plume. Spent carbon filters will be taken off site for regeneration and will be reused. Extraction and treatment of the groundwater will continue until the VOC concentrations in downgradient monitoring wells no longer exceed MCLs, as established in the approved groundwater monitoring plan.

The post-ROD monitoring plan, which will be a primary FFA document to be submitted to the regulatory agencies within one year of the signing of this ROD, will specify the wells that will be monitored to determine if an MCL has been exceeded, and the

schedule and procedures for confirming that this excess is statistically significant as described above.

The selected remedy includes periodic groundwater and vadose zone monitoring to track changes in the concentrations and extent of contamination. The major components of the remedy consist of:

- Implementing institutional controls
- Designing and implementing a sampling protocol to monitor and evaluate the progress of natural processes in achieving performance standards
- Designing and constructing groundwater monitoring wells and SVE wells as necessary
- Designing, installing and operating an AS/SVE system in the area of Warehouse 2, and conducting vadose zone monitoring to assess the effectiveness of the system
- Starting, operating, and shutting down the groundwater extraction and treatment pilot study system on a contingency basis
- Transporting, regenerating, recycling, and/or disposal of the spent carbon filters
- Operating and maintaining a long-term groundwater monitoring plan, which includes quarterly, semiannual or annual monitoring of selected COCs in the monitoring and extraction wells to be specified in a post-ROD OU 2 Remedial Action Groundwater Monitoring Plan
- Closure criteria.

The groundwater remedy for the Nebo North plume (OU 2) is consistent with the requirements of Section 121 of CERCLA and the NCP. The remedy will reduce the mobility, toxicity, and volume of contaminated groundwater at the Nebo North plume. In addition, the remedy is protective of human health and the environment, will attain all federal and state ARARs, is cost-effective, and uses permanent solutions to the maximum extent practicable. Based on the information available at this time, the selected remedy represents the best balance among the criteria used to evaluate remedies.

4.6.1 Performance Standards for Groundwater and Source Reduction

Groundwater from the aquifer shall be monitored until the cleanup goals (performance standards) set forth in Table 2-1 are achieved as agreed upon between the DON and the regulatory agencies. See Sections 2.8 and 4.3.2 for discussion of source reduction performance standards.

4.6.2 Infiltration Standards

Treated groundwater that will be recharged back into the aquifer through the percolation ponds shall comply with the substantive general waste discharge requirements for land disposal of treated groundwater, set forth in Lahontan RWQCB Board Order No. 6-93-106 as TBCs. These requirements are listed in Table 3-6. Meeting these requirements shall ensure compliance with SWRCB Resolution 68-16 and the Basin Plan ARARs. The general discharge requirements of Board Order No. 6-93-106 have monitoring requirements that verify compliance. A schedule of compliance appropriate for this monitoring shall be established in the OU 2 Nebo Main Base Remedial Action Groundwater Monitoring Plan.

4.6.3 Groundwater and Vadose Zone Monitoring

Groundwater and vadose zone monitoring shall be conducted for the Nebo North plume during the remedial action in accordance with the Nebo Main Base Remedial Action Groundwater Monitoring Plan (see Section 4.4.2) to verify that the remedial action is being effective towards achieving RAOs. The DON will monitor the groundwater and vadose zone as specified in the groundwater monitoring plan until it is demonstrated that the remedial action has effectively and permanently reduced the VOC contamination to within the RGs set out in Table 2-1. The criteria for assessing the effectiveness of the remedial action shall also be included in the remedial action groundwater monitoring plan. If monitoring indicates that RGs have not been met in accordance with these criteria, the groundwater and vadose zone remedial action will continue until the RGs are achieved. The results of the groundwater and vadose zone monitoring

will be evaluated every five years, and the duration and frequency of the groundwater monitoring modified as appropriate and with the concurrence of the FFA signatories, until it is determined that the remedial action has been completed.

4.7 Statutory Determination

Under its legal authorities, the Marine Corps' primary responsibility at Superfund sites is to undertake remedial actions that adequately protect human health and the environment. In addition, Section 121 of CERCLA established several other statutory requirements and preferences. These specify that, when complete, the selected remedial action for this site must comply with applicable or relevant and appropriate environmental standards as established under federal and state environmental laws unless a statutory waiver is justified. The selected remedy also must be cost effective and use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. Finally, the statute includes a preference for remedies that, as their principal element, employ treatment that permanently and significantly reduce the volume, toxicity, or mobility of hazardous wastes. The following sections discuss how the selected remedy meets these statutory requirements.

4.7.1 Protection of Human Health and the Environment

The selected remedy protects human health and the environment by remediating the contaminant plume through natural processes and AS/SVE source reduction at the Nebo North plume. The selected remedy provides protection to human health and the environment by eliminating, reducing, and controlling risk through source reduction, natural processes and institutional controls. The contaminated groundwater in the Nebo North plume will be treated by natural processes to cleanup levels. In addition, institutional controls and fail-safe extraction and treatment containment will be used if necessary throughout the remediation process to protect human health and the environment.

4.7.2 Compliance with ARARs

As stated in Section 2.10, remedial actions performed under CERCLA must comply with all ARARs. All alternatives considered for the Nebo North groundwater plume were evaluated on the basis of the degree to which they comply with these requirements. The selected alternative was found to comply with all ARARs presented in Tables 2-2 through 2-7.

4.7.3 Cost Effectiveness

Cost effectiveness is determined by comparing the cost of all alternatives being considered with their overall effectiveness to determine whether the costs are proportional to the effectiveness achieved. The Marine Corps evaluates the incremental cost of each alternative as compared to the increased effectiveness of the remedy. The selected remedy for groundwater and vadose zone is source reduction, institutional controls, and remediation by natural degradation processes and through fail-safe pump-and-treat. Based on the information obtained, this selected remedy will provide the best balance of trade-offs among the alternatives with respect to the nine criteria provided by the NCP to evaluate the alternatives. The selected remedy is the second least costly of the alternatives considered that meets the threshold criteria for protection of human health and the environment and compliance with ARARs for groundwater contamination removal.

4.7.4 Use of Permanent Solutions to the Maximum Extent Practicable

MCLB Barstow, EPA, DTSC, and CRWQCB believe that the selected remedy is the most appropriate remedial approach for Nebo North groundwater and vadose zone cleanup, and provides the best balance among the evaluation criteria for the remedial alternatives considered. The source reduction/natural processes remedy for groundwater and vadose zone is a permanent remedy. The selected remedy meets the statutory requirement to use permanent solutions and innovative treatment technologies to the maximum extent practicable.

4.7.5 Preference for Treatment as a Principal Element

The statutory preference for treatment at the Nebo North plume will be met through passive treatment of contaminated groundwater by natural processes and removal of VOCs from the vadose zone by AS/SVE.

4.8 Documentation of Significant Change

The final remedy for Nebo North plume, Alternative 5, has not been changed or refined from the Proposed Plan.

Table 4-1
Nebo North Plume
Maximum Groundwater Concentrations of VOCs and Associated MCLs

VOCs	Maximum Groundwater Concentration (µg/L)	Federal MCL (µg/L)	California MCL (µg/L)	PRG (µg/L)
Contaminants Exceeding Drinking Water Standards (MCLs)				
1,2-Dichloroethane (1,2-DCA)	3	5.0	0.5	-
Benzene	1.2	5.0	1.0	-
Tetrachloroethene (PCE)	80	5.0	5.0	-
Contaminants Not Exceeding Drinking Water Standards (MCLs)				
1,1-Dichloroethane	0.7	-	5.0	-
1,1,1-TCA	2	200	200	-
2-Hexanone	13	-	-	Not available
1,2-Dichloroethene, Total (1,2- DCE)	2	70.0	6.0	-
2-Butanone (methyl ethyl ketone)	5	-	-	1900
Acetone[1]	7	-	-	610
Carbon Disulfide	3	-	-	21
Chloroform	2	100 [2]	-	-
Chloromethane[2]	8.9	-	-	1.5
Methylene Chloride[1]	2	5.0	-	-
Toluene	0.2	1,000	150	-
Trichloroethene (TCE)	4	5.0	5.0	-
				-

[1] This chemical is a suspected laboratory contaminant and is not considered representative of plume conditions.

[2] MCL is for total trihalomethanes.

Note: Data also include most recent groundwater monitoring conducted by OHM Remediation Services, Inc. (OHM 1994, 1995, 1996).

TABLE 4-2
Summary of Comparative Analysis - Nebo North Plume, NRF-1
MCLB Barstow

Criteria	Alternatives				
	NRF1-GW-1	NRF1-GW-2	NRF1-GW-3	NRF1-GW-4	NRF1-GW-5
Overall Protection of Human Health and the Environment	No	Within Risk Management Range**			
Compliance with ARARs	* No	* No	Yes	Yes	Yes
Long-Term Effectiveness and Permanence	Low	Mod	Mod	High	High
Reduction of Toxicity, Mobility, or Volume	Low	Low	Mod	High	High
Short-Term Effectiveness	Low	Mod	Mod	High	High
Implementability	High	High	High	High	High
Duration of Remedy					
Time to MCLs (years)	45	45	42	12	15
Time to Background (years)	120	120	110	30	38
Present Cost ($ millions) 20 Years Duration	0	1.9	5.3	6.6	3.1
Remediation to MCLs	0	2.2	7.1	5.8	3.0
Remediation to Background	0	2.3	7.9	7.3	3.6

* ARARs achieved over time only through natural groundwater attenuation.

** Alternatives NRF1-GW-2 through NRF1-GW-5 all result in residual risks that fall within EPA's risk management range of 10^{-6} to 10^{-4}. Clean up to MCLs would result in an upper-bound incremental risk of approximately 1×10^{-5} while clean up to background (0.5 µg/L) would result in a risk of approximately 5×10^{-6}.

Alternative NRF1-GW-1: No Action

Alternative NRF1-GW-2: Institutional Controls and Groundwater Monitoring with fail-safe pump-and treat

Alternative NRF1-GW-3: Groundwater Removal, Ex Situ Treatment, and Discharge

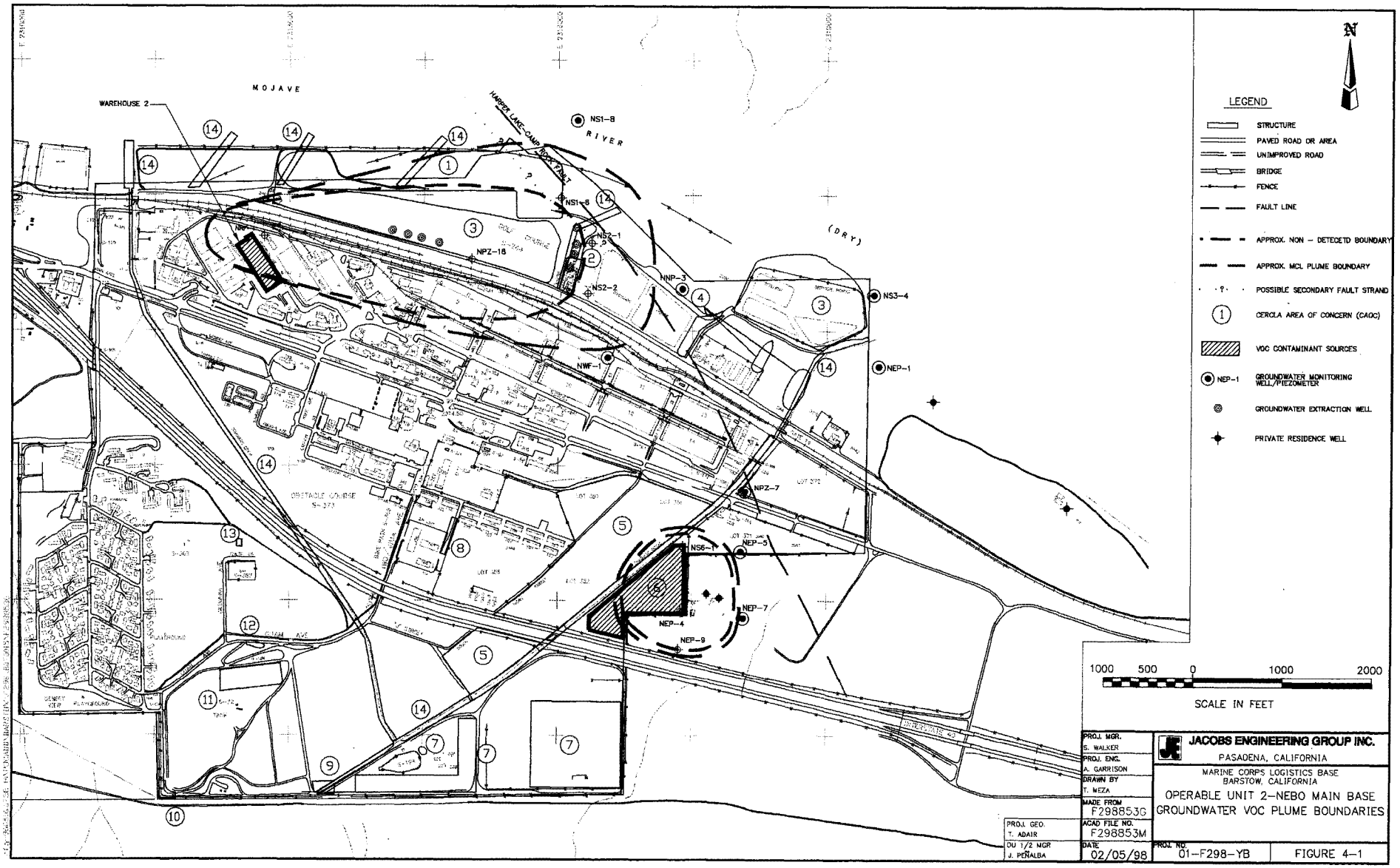
Alternative NRF1-GW-4: Groundwater Removal, Ex Situ Treatment, and Discharge with Source Reduction (Air Sparging/Soil Vapor Extraction)

Alternative NRF1-GW-5: Source Reduction (Air Sparging/Soil Vapor Extraction)

ARARs - Applicable or relevant and appropriate requirements.

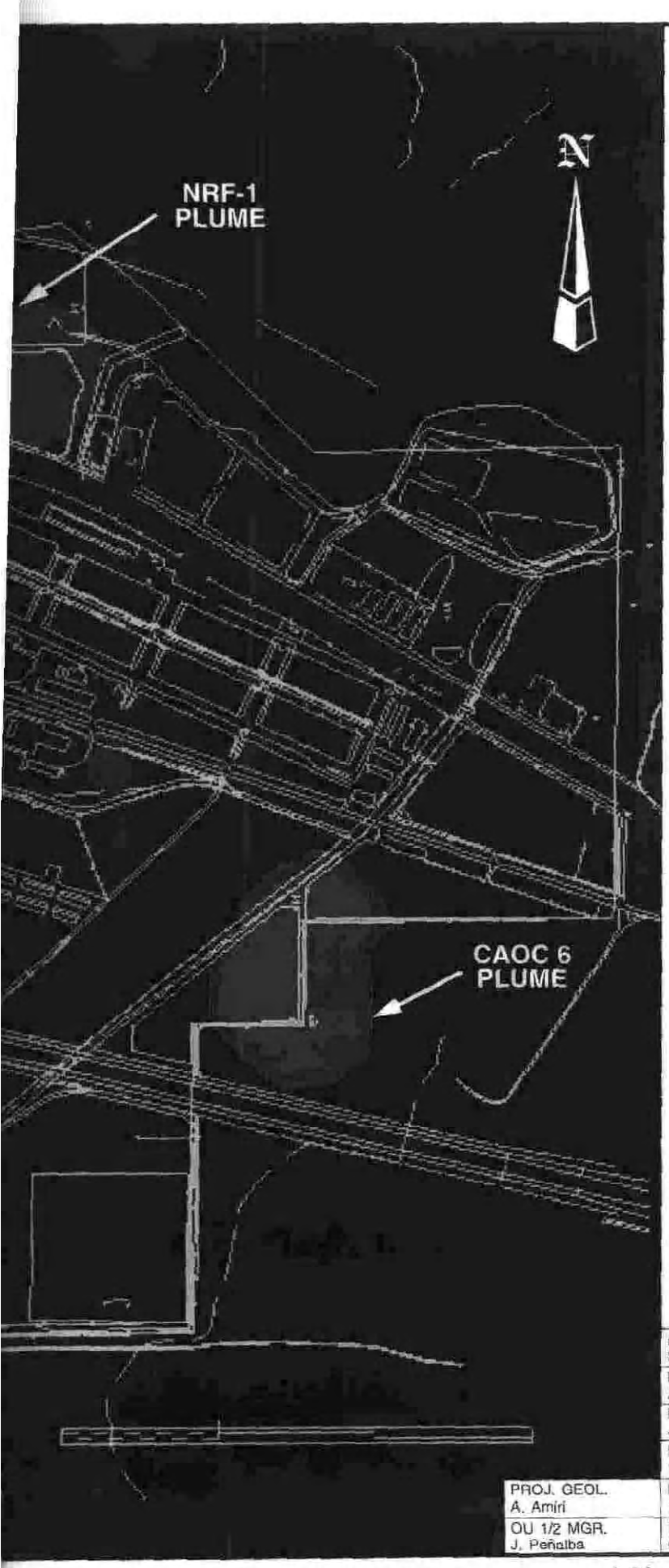
Mod - Moderate.

NA - Not applicable.



GLE-J02-01F298-B7-0026

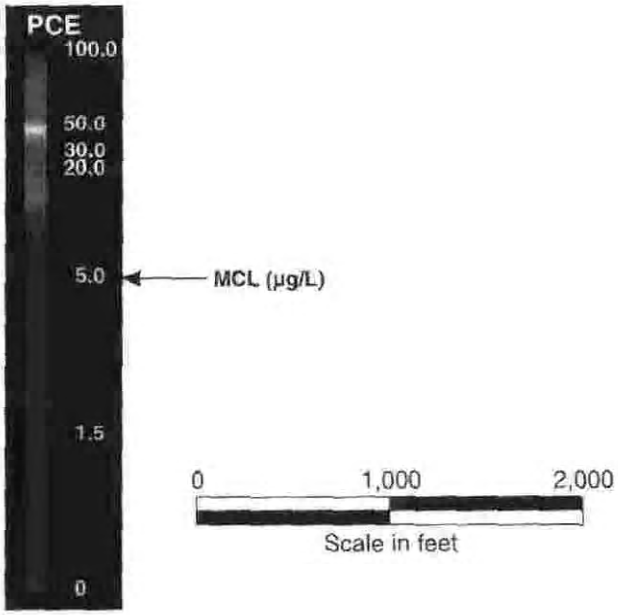
PCE GROUNDWATER PLUM
(NEBO MAIN BASE)



Model shows an areal view slice through PCE contaminated groundwater at approximately 40 ft. below ground surface at NRF-1 and 100 ft. below ground surface at CAOC 6 as of October, 1995. Color variations show intensity of PCE concentration.

Model was produced using LYNX Geosystems to conceptualize the extent of the PCE plume. Light blue and gray areas are based on geostatistical estimations and represent values detected below MCL (5 µg/L).

Color scale shows intensity of concentration in micrograms per liter (µg/L).



PROJ. MGR. S. Walker	JACOBS ENGINEERING GROUP INC. PASADENA, CALIFORNIA	
PROJ. ENG. A. Garrison	MARINE CORPS LOGISTICS BASE Barstow, California	
DRAWN BY J. Lawrence	**PCE Plumes in Groundwater from NRF-1 and CAOC 6 Nebo Main Base**	
DRAWING NO. 1109\F298135A.CDR		
PROJ. GEOL. A. Amiri / MADE FROM 1109\F298-135.CDR		
OU 1/2 MGR. J. Peñalba / DATE 02/20/97	PROJ. NO. 01-F298-YB	FIGURE 4-2

TCE GROUNDWATER PLUME (NEBO MAIN BASE)