

**REMEDIATION SYSTEM EVALUATION (RSE)
FOR A GROUND WATER PUMP AND TREAT SYSTEM**

**BP CARSON REFINERY
CARSON, CALIFORNIA**

SUBMITTED:
DECEMBER 22, 2005



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Office of Solid Waste
and Emergency Response
(5102G)

EPA 542-R-05-025
December 2005
www.epa.gov/tio
clu-in.org/optimization

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The U.S. Environmental Protection Agency funded the preparation of this document by GeoTrans, Inc. under EPA Contract No. 68-C-00-181 Task Order #40 to Tetra Tech EM, Inc, Chicago, Illinois.

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EXECUTIVE SUMMARY

A Remediation System Evaluation (RSE) involves a team of expert hydrogeologists and engineers, independent of the site, conducting a third-party evaluation of a ground water pump and treat system or other remedy of environmental contamination. It is a broad evaluation that considers the goals of the remedy, site conceptual model, above-ground and subsurface performance, and site exit strategy. The evaluation includes reviewing site documents, visiting the site for up to 1.5 days, and compiling a report that includes recommendations to improve the efficiency and effectiveness of the remedy. Recommendations with cost and cost savings are provided in the following four categories:

- Improvements in remedy effectiveness
- Reductions in operation and maintenance costs
- Technical improvements
- Gaining site closeout

The recommendations are intended to help the site team identify opportunities for improvements. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed prior to implementation of the recommendation. Note that the recommendations are based on an independent evaluation by the RSE team, and represent the opinions of the RSE team. These recommendations do not constitute requirements for future action, but rather are provided for the consideration of all site stakeholders.

This RSE has been conducted as a follow-up to a streamlined optimization evaluation or “RSE-lite” that was initially conducted in April 2005. The original streamlined optimization evaluation consisted of the same evaluation team reviewing site documents, conducting a conference call with the site team, and preparing a draft RSE-lite report. The draft RSE-lite report was reviewed by the site team. Based on the site team’s responses, the RSE-lite team determined that the site merited a full-scale RSE, which involved further document review, a site visit, and a more comprehensive report. This document represents that full-scale RSE report. The RSE-lite report was not finalized given that a full-scale RSE report was prepared.

The BP Carson Refinery (“BP”) is located at 1801 East Sepulveda Boulevard in Carson, California. Petroleum refining operations have been conducted at the site since 1923. From 1937 through 1945, other parcels of land were purchased and added to the refinery, and refining operations were expanded. The refinery is currently divided into various geographic areas with total area of approximately 702 acres. Ground water remediation has been ongoing at the refinery since 1977. LNAPL recovery was the focus of early remediation activities at the refinery and was emphasized in the 1990 Cleanup and Abatement Order (CAO) issued by the Los Angeles Regional Water Quality Control Board (LARWQCB). Between 1983 and 1996, approximately 17,000,000 gallons of LNAPL were recovered. A perimeter recovery system was constructed along the refinery’s western boundary between 1994 and 1997 to control potential off-site LNAPL migration, and LNAPL recovery continues to be a part of site remedial activities. In the mid-1990s, oxygenates emerged as constituents of concern for drinking water in the Carson area.

The current approach to remediation at the site consists of three parts: a collaborative regional approach to address the regional commingled plume(s), on-site LNAPL management, and on-site remedial measures to control dissolved oxygenate migration from the Northern Tank Farm (NTF), which is part of the main refinery. The collaborative regional approach involves working with the Carson Region Groundwater Group (CRGG) to develop a regional numerical model to determine if the plumes underlying the CRGG properties (including but not limited to the BP Carson Refinery) are “in control” in accordance with the Ground Water Environmental Indicator requirements of the RCRA Corrective Action Program. The onsite approach involves source elimination, source-area characterization and remediation, and ground water recovery for control of the oxygenate plume. The current remediation practices reflect a shift in focus from LNAPL recovery to also include management of the dissolved phase plume. At the request of the site team, this RSE focuses on the issues pertaining to oxygenate migration and control associated with the on-site ground water and LNAPL recovery system in the NTF area.

Based on the documents reviewed and the information gained during the site visit, the RSE team believes that the pumping provided by the ground water extraction and LNAPL recovery system is likely inadequate to provide hydraulic containment of the oxygenate plume. However, the available information is insufficient for the RSE to conclude whether or not the oxygenate plume is controlled in the horizontal and vertical directions through a combination of pumping and natural degradation. The recommendations provided in this report focus on steps that can be taken to improve the understanding of plume control in a cost-effective manner.

Recommendations are provided with respect to effectiveness, cost reduction, and technical improvements. The recommendations to improve effectiveness include the following:

- Better delineate the oxygenate plume in the Gage and Lynwood aquifers and improve the associated monitoring network
- Consider calibrating the inset model for local conditions and applying the improved version to evaluate contaminant transport and plume capture offered by the extraction network
- Enhance monitored natural attenuation (MNA) monitoring by focusing sampling on MTBE and TBA rather than MNA parameters and consider experimenting with other analytical techniques, such as stable isotope sampling, that may assist in quantifying MTBE degradation

Recommendations to reduce cost include the following:

- Proceed with the planned installation of new extraction wells in the oxygenate hot spots, but consider improving the understanding of plume delineation and site hydrogeology before installing additional extraction wells beyond those already proposed
- Maintain the weekly recovery well inspections, but reduce the frequency of operational checks from weekly to monthly since weekly measurements of mass removal do not provide an improved understanding of system performance compared to monthly measurements of mass removal

- Eliminate analysis for SVOCs and metals in ground water monitoring program where appropriate since these compounds are not contaminants of concern at the site
- Due to delays in achieving stabilization of dissolved oxygen during low-flow sampling, request revision in low-flow sampling procedure in an attempt to speed sampling effort without sacrificing the integrity of the samples
- When a remedy is completed that adequately prevents plume migration, reduce data evaluation/reporting costs to be more consistent with a long-term remedy

These cost reduction recommendations might reduce annual costs by approximately \$300,000 per year. Additional recommendations are also provided to suggest improvements in technical operation and development of an appropriate long-term remedy. A table summarizing the recommendations, including estimated costs and/or savings associated with those recommendations, is presented in Section 6.0 of this report.

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FIGURES – Prepared by the site contractor and included for reference

1.0 INTRODUCTION

1.1 PURPOSE

In 2003 and 2004, the EPA Corrective Action program and the EPA Office of Superfund Remediation and Technology Innovation (OSRTI) sponsored independent optimization evaluations called Remediation System Evaluations (RSEs) at five RCRA sites with pump and treat (P&T) systems. These RSEs involved an independent team of experts reviewing site documents, interviewing site stakeholders, and providing recommendations for improving remedy effectiveness, reducing costs, and gaining site closure.

Based on the positive results of these RSEs and the consideration that a streamlined RSE would provide a similar level of benefits to many sites for a lower cost, EPA OSRTI and the Office of Solid Waste (OSW) have commissioned a new pilot study that involves developing and piloting a streamlined RSE process. This streamlined RSE or “RSE-lite” evaluation includes reviewing site documents, conducting conference calls with the site team, and compiling a report of recommendations.

For this new pilot study, up to five RCRA Corrective Action facilities with operating remedies have been selected to receive streamlined RSEs or “RSE-lites”. Although the BP Carson Refinery is not directly part of the RCRA Corrective Action program, it is part of the Carson Region Groundwater Group (CRGG), which includes other refineries in the area, and that group is collectively working toward the RCRA Corrective Action Program Ground Water Environmental Indicator requirement for “migration under control”. The BP Carson Refinery Facility was selected to receive an RSE-lite based on its long history and ongoing ground water remedy. After conducting RSE-lites at four sites, it was determined that the BP Carson Refinery Facility would be selected to receive the full-scale RSE for the following reasons:

- Operations at the site, which is an active refinery, influence how the remedial activities are conducted to a greater degree than at the other sites that received RSE-lites.
- The hydrogeology, multiple sources of contamination, and extraction system at this site are relatively complex compared to those at other sites that received RSE-lites.
- The comments provided by the site team in response to the draft RSE-lite report included several questions, which suggested the need for further evaluation by the RSE team, including a site visit.

This report provides a brief background on the site and current operations, a summary of the observations made during the RSE-lite conference call and the RSE site visit, and recommendations for improving the effectiveness and efficiency of the remedy. The cost impacts of the recommendations are also discussed.

1.2 RSE-LITE AND RSE PROCESSES

The RSE and RSE-lite processes involve a team of expert hydrogeologists and engineers, independent of the site, conducting a third-party evaluation of a ground water pump and treat system or other remedy of environmental contamination. They are broad evaluations that consider the goals of the remedy, site conceptual model, above-ground and subsurface performance, and site exit strategy. An RSE evaluation includes reviewing site documents, visiting the site for 1 to 1.5 days, and compiling a report that includes recommendations to improve the system. An RSE-lite is similar to an RSE but includes a conference call with the site team instead of a site visit. Recommendations are provided in the following four categories:

- Improvements in remedy effectiveness
- Reductions in operation and maintenance costs
- Technical improvements
- Gaining site closeout

Once a site is selected for an RSE or RSE-lite, a representative of the evaluation team contacts the site project manager to obtain site documents for review. The documents typically include information pertaining to site investigations, remedy design, and remedy operation and maintenance (O&M). Upon reviewing this information, the evaluation team conducts a site visit (or a conference call) with the site team to address questions that may have arisen as part of the document review or other information gaps. Based on the site documents and the information from site visit, the evaluation team prepares a report documenting recommendations for improving efficiency and effectiveness. The text of the RSE report includes a brief background of the site, series of observations and findings from the document review and site visit, site-specific recommendations, and a cost summary table summarizing estimated costs and cost savings associated with implementing each recommendation.

1.3 TEAM COMPOSITION

The team conducting the RSE included the following individuals:

- Peter Rich, Civil and Environmental Engineer, GeoTrans, Inc.
- Lindsay Swain, Hydrogeologist, GeoTrans, Inc.
- Doug Sutton, Water Resources Engineer, GeoTrans, Inc.

The RSE team was also accompanied by Ellen Rubin from EPA Headquarters who is managing the RSE/RSE-lite project for EPA.

1.4 DOCUMENTS REVIEWED

The following documents were reviewed as part of this RSE:

- California Regional Water Quality Control Board, Los Angeles Region, Cleanup and Abatement Order No. 90-121, August 22, 1990

- MTBE Investigation Report, December 18, 2001
- Carson Regional Groundwater Group 2003 Annual Progress Report, November 26, 2003
- Letter Summary of Documents Summarizing BP Carson Refinery Remedial Activities, March 5, 2004
- Refinery Subsurface Cleanup Progress Report August 2004, August 13, 2004
- Oxygenates Occurrence and LNAPL Mobility Evaluation Report, August 16, 2004
- Barrier System Evaluation, August 20, 2004
- Groundwater Model Development Report – September Data Package, October 6, 2004
- Model Output Report, Carson Regional Groundwater Group, August 2, 2005
- Conceptual Work Plan for Enhancements to the Existing Recovery System for the North Tank Farm Study Area, August 2, 2005
- Refinery Subsurface Cleanup Progress Report, August 15, 2005

1.5 PERSONS CONTACTED

The following individuals associated with the site were present for the visit:

- Greg Lovato, EPA Remedial Project Manager, EPA Region IX
- Matt Small, Hydrogeologist, EPA Region IX
- Paul Cho, California Regional Water Quality Control Board
- Wendy Phillips, California Regional Water Quality Control Board
- Kateri Luka, Environmental Business Manager, Atlantic Richfield Company (A BP Affiliated Company)
- Martin Johnson, Senior Hydrogeologist, Atlantic Richfield Company (A BP Affiliated Company)
- Greg Jirak, Senior Engineer, The RETEC Group
- Dan Baker, Senior Project Manager, The RETEC Group

2.0 SITE BACKGROUND AND SYSTEM DESCRIPTION

2.1 SITE HISTORY AND CHARACTERISTICS

2.1.1 HISTORY

The BP Carson Refinery (“BP”) is located at 1801 East Sepulveda Boulevard in Carson, California. Petroleum refining operations have been conducted at the site since 1923. From 1937 through 1945, other parcels of land were purchased and added to the refinery, and refining operations were expanded. In 2002, ownership of the refinery was transferred to BP West Coast Products LLC. As a result, the name of the refinery was changed to the BP Carson Refinery in 2002.

The refinery is divided into the following geographic areas with a total area of approximately 702 acres:

- Main Refinery
- North Property
- Northeast Property
- Southeast Property
- Southwest Property, formerly called the Southwest Tank Farm

Ground water remediation has been ongoing at the refinery since 1977. Recovery of light non-aqueous phase liquid (LNAPL) was the focus of early remediation activities at the refinery and was emphasized in the 1990 Cleanup and Abatement Order (CAO) issued by the Los Angeles Regional Water Quality Control Board (LARWQCB). Between 1983 and 1996, approximately 17,000,000 gallons of LNAPL were recovered. A perimeter recovery system was constructed along the refinery’s western boundary between 1994 and 1997 to control potential off-site LNAPL migration, and LNAPL recovery continues to be a part of site remedial activities. In the mid-1990s, oxygenates emerged as constituents of concern for drinking water in the Carson area.

The current approach to remediation at the site consists of three parts: a collaborative regional approach to address the regional commingled plume(s), on-site LNAPL management, and on-site remedial measures to control dissolved oxygenate migration from the Northern Tank Farm (NTF), which is part of the main refinery. The collaborative regional approach involves working with the CRGG to develop a regional numerical model to determine if the plumes underlying the CRGG properties are “in control” in accordance with the Ground Water Environmental Indicator requirements of the RCRA Corrective Action Program. The onsite approach involves source elimination, source-area characterization and remediation, and ground water recovery for control of the oxygenate plume. The current remediation practices reflect a shift in focus from LNAPL recovery to managing the dissolved phase plume. At the request of the site team, this RSE focuses on the issues pertaining to oxygenate migration and control associated with the on-site ground water and LNAPL recovery system in the NTF area.

2.1.2 POTENTIAL SOURCES, CONTAMINANTS OF CONCERN, AND PLUME EXTENT

Numerous potential sources exist in the Carson area including chemical plants, petroleum refineries and terminals, underground storage tanks, and a vast network of petroleum pipelines.

Chlorinated hydrocarbons, particularly 1,2-Dichloroethane (1,2-DCA), likely associated with off-site sources, have been the primary dissolved constituents of concern in the Carson area, but oxygenates were also identified as constituents of concern in the mid-1990s.

The NTF was identified as an onsite source area of oxygenates, including MTBE, which was present at the facility beginning in 1987. Based on 2003 and 2004 ground water sampling, MTBE concentrations within the NTF are as high as 800,000 ug/L (AMR 234-D) in the water table aquifer. Six NTF monitoring locations have MTBE concentrations exceeding 1,000 ug/L, and four locations have MTBE concentrations exceeding 20,000 ug/L. One monitoring location (AMR 212-G) is labeled as a Gage aquifer monitoring well but is screened at the interface between water table and Gage aquifer. AMR 212-G has a concentration of 29,000 ug/L, indicating that NTF-related contamination has likely migrated vertically. MTBE is consistently detectable above 10 ug/L in one Lynwood aquifer well (AMR 704-L).

Di-isopropyl ether (DIPE) and tert-butyl alcohol (TBA) have also been detected in the NTF vicinity. Concentrations of DIPE within the NTF are generally non-detect; however, AMR-054D has had one detection of 44 ug/L. DIPE is more prevalent in the lower aquifers, but concentrations in the NTF vicinity are less than 100 ug/L. TBA concentrations are more comparable to MTBE concentrations. Five monitoring locations within the NTF have TBA concentrations exceeding 1,000 ug/L, with a maximum concentration of 34,000 ug/L (AMR 234-D).

Based on the data from offsite wells, a regional commingled oxygenate plume is present in the water. MTBE concentrations are typically non-detect in the water table, Gage, and Lynwood aquifers downgradient of the NTF. The offsite commingled plume generally consists of DIPE and TBA, both within concentrations ranging from non-detect to less than 200 ug/L. The pattern and concentrations of 1,2-DCA in offsite wells is similar to those of DIPE and TBA (i.e., concentrations typically under 100 ug/L and present in multiple aquifers).

2.1.3 HYDROGEOLOGIC SETTING

The refinery is underlain primarily by continental and marine deposits of the Upper Pleistocene Lakewood Formation and the marine deposits of the Lower Pleistocene San Pedro Formation. Along the eastern margin of the refinery, shallow deposits are Recent Alluvium.

The uppermost ground water beneath the refinery occurs under perched, unconfined, and confined conditions. Locally, the shallow water-bearing zone may be equivalent to a semi-perched aquifer, other water-bearing zones in the Bellflower aquiclude, or possibly the Gaspar aquifer. This regionally continuous occurrence of ground water is referred to as the water table aquifer by the site team, although it is locally confined and consists of fine-grained strata.

The aquifers present beneath the refinery, from the shallowest to deepest, are as follows:

- “Water table aquifer” – denoted by a “D” in monitoring well labels
- Gage aquifer – denoted by a “G” in monitoring well labels
- Lynwood aquifer – denoted by an “L” in monitoring well labels
- Silverado aquifer – denoted by an “WS” in monitoring well labels

Beneath the northern part of the refinery, a multiple-aquifer system is present. The top of the Gage aquifer is approximately 140 feet below ground surface (bgs), and the top of the Lynwood aquifer is approximately 200 feet bgs. These aquifers are separated from the water table aquifer and from each other by aquitards. Beneath the southwest part of the Main Refinery, the Southwest Property, and the areas to the west, aquitards that separate the water table, Gage, and Lynwood aquifer may be thin or non-existent.

The Silverado aquifer is the next deepest aquifer beneath the refinery, separated from the Lynwood aquifer by an intervening aquitard. It is approximately 350 feet thick, and the top of the aquifer varies between 380 and 480 feet bgs at the refinery.

Ground water flow at the site in the water table, Gage, and Lynwood aquifers is generally to the west or southwest, particularly near the NTF. Ground water flow in the Silverado aquifer at the site is to the northeast.

2.1.4 POTENTIAL RECEPTORS

Risk-based evaluations reportedly indicate that light non-aqueous phase liquid (LNAPL) is not a direct threat to receptors given its relative immobility. In addition, the depth to the water table is roughly 40 to 75 feet bgs along the western perimeter of the refinery and is generally considered too deep to present a vapor migration risk. Recent investigations of adjacent off-site areas have shown that LNAPL has very low potential to migrate. Potential dissolved constituent migration remains an area of concern in the Carson area and has been subject to EPA’s Environmental Indicators program at adjacent facilities. The main concern is potential migration to receptor wells in the Silverado aquifer. The nearest drinking water well is located approximately 4,000 feet west of the facility in the Silverado aquifer. Although west is hydraulically downgradient for the water table, Gage, and Lynwood aquifers, it is hydraulically upgradient of the site for the Silverado aquifer.

2.2 GROUND WATER REMEDIAL SYSTEM

2.2.1 REMEDIAL SYSTEM

Extraction System

There are a total of 30 ground water and LNAPL recovery wells throughout the refinery. Of those 30 wells, 25 are located near the western (downgradient) boundary of the refinery. These 25 wells are the subject of this RSE report and are collectively referred to as the “ground water and LNAPL recovery system” in this report. The original purpose of this system was to control

potential off-site LNAPL migration in the upper portion of the water table aquifer, so the wells were installed in the upper water table aquifer in the upper 20 to 30 feet of the saturated zone. However, given the current site focus on the dissolved oxygenate plume, the recovery is now focused on ground water extraction in addition to LNAPL recovery. The site team reports that the entire system has a pumping rate of approximately 32 gpm, with pumping in the NTF accounting for approximately 10 to 15 gpm. The NTF recovery wells (all of which are installed in the water table aquifer) are as follows:

- AMR 151-12 – original recovery system well with screen interval from 58 to 93 feet bgs
- AMR 152-12 – original recovery system well with screen interval from 55 to 95 feet bgs
- AMR 208-6 – new recovery system well with screen interval from 59 to 99 feet bgs
- AMR 209-6 – new recovery system well with screen interval from 62 to 97 feet bgs
- AMR 187-6 – new recovery system well with screen interval from 90 to 130 feet bgs

The average 2005 pumping rate for each of the above-mentioned NTF recovery wells is estimated in the following table by providing the maximum extraction from a pump test conducted by the facility. As discussed in Section 4.1 of this report, this extraction rate is likely too low to provide hydraulic containment of the oxygenate plume in the NTF.

Recovery Well	Estimated Pumping Rate
AMR 151-12	1 gpm
AMR 152-12	3 gpm
AMR 208-6	1 gpm
AMR 209-6	1.5 gpm
AMR 187-6	4 gpm
Total	~10.5 gpm

Treatment System

The ground water and LNAPL recovery system effluent is pumped back to the refinery treatment system. Compared to the refinery treatment capacity, the extracted water is a minor component; however, the refinery treatment system is operating at or near capacity.

2.2.2 MONITORING PROGRAM

Ground Water Monitoring

The following four monitoring well networks are routinely sampled at the refinery.

- California Regional Water Quality Control Board, Los Angeles Region (LARWQCB) network
- Department of Toxic Substances Control (DTSC) network
- Network for monitoring oxygenates
- Network for monitoring the Southwest Area (an off-site area that is distinct from the on-site area referred to as the “Southwest Property”)

The monitoring wells in these four networks are listed in the following table.

LARWQCB	DTSC	Oxygenate	Southwest Area
AMR 702-L	AMR 608-D	AMR 054-D	AOS 538-D
AMR 704-L	AMR 611-D	AMR 083-D	AOS 539-D
ANP 703-L	AMR 613-D	AMR 186-D	AOS 540-D
AOS 541-D		AMR 190-G	
AOS 542-D		AMR 191-G	
AOS 544-D		AMR 197-G	
AOS 545-D		AOS 217-D	
AOS 560-D		AOS 705-L	
ASW 201-D		AOS 706-L	
ASW 202-D		AMR 214-D	
AM4 702-L		AOS 542-D	

Process Monitoring

Because treatment of extracted ground water is accomplished in the refinery treatment system, the process monitoring conducted as part of the remedial activities is limited to monitoring the extraction well performance and mass recovery. The following parameters are measured on a weekly basis:

- Total fluid flow as determined by totalizer
- Instantaneous flow rates
- Discharge pressure
- Air supply pressure (for those wells with pneumatic pumps)
- Fluid levels in the wells
- Percent LNAPL in the extracted total fluids
- Operational condition of wells
- Oxygenates dissolved in ground water

3.0 SYSTEM OBJECTIVES, PERFORMANCE AND CLOSURE CRITERIA

3.1 CURRENT REMEDIAL OBJECTIVES AND CLOSURE CRITERIA

The recovery system goal was LNAPL extraction in the 1990s. However, the focus of the site team expanded to include the dissolved oxygenate plume. No specific goals for plume control have been specified for the site or communicated to the RSE team. Rather, as part of determining an appropriate remedial strategy for the future of the site, the site team asked the RSE team to evaluate what the current recovery system is able to accomplish rather than compare the recovery system performance to set objectives. In the absence of the specific and documented objectives for plume control, EPA asked the RSE team to consider the property boundary as a hypothetical point of compliance for evaluating plume control. EPA notes, however, that the property boundary has not been selected or documented as an official point of compliance.

3.2 TREATMENT PLANT OPERATION STANDARDS

Extracted ground water is treated in the refinery treatment system and was not reviewed as part of this RSE.

3.3 FINDINGS PERTAINING TO REMEDY PROGRESS AND SITE CLOSURE

Specific cleanup goals have not been set for the ground water under the refinery, but the beneficial use designation for ground water in the area includes municipal and domestic uses. Therefore, the standard will likely be the maximum contaminant level (MCL) set by the State of California. For MTBE, the primary MCL is 13 ug/L, and the secondary MCL is 5 ug/L. California has also set an “action level” of 12 ug/L for TBA.

The site team is discussing the potential for a migration control remedy using a combination of hydraulic control, LNAPL recovery, and monitored natural attenuation (MNA) rather than a restoration remedy. At the time of the RSE, the site team had not selected or documented a specific target capture zone. However, for the purpose of the RSE only, EPA suggested that the RSE team refer to the property to the west as a hypothetical boundary of a target capture zone. That is, the hypothetical target capture zone would be aimed at preventing oxygenate contamination from migrating off site to the west.

4.0 FINDINGS AND OBSERVATIONS

The findings indicated below are not intended to suggest a deficiency in the remedy design or operation. These findings are not intended to suggest requirements for the site. Rather, these findings are the opinions of a third-party evaluation team and are only provided for consideration by the site team.

4.1 SUBSURFACE PERFORMANCE

- MTBE and TBA appear to be the primary contaminants of concern associated with the NTF based on concentrations exceeding 1,000 ug/L at multiple locations in the water table aquifer. The presence of DIPE onsite is very limited, and it appears likely that the DIPE that has been detected offsite primarily results from sources other than the NTF. DIPE appears to be more prevalent in the Gage and Lynwood aquifers than in the water table aquifer, and given that the recovery system extraction occurs in the water table aquifer, the recovery system is generally not contributing to the capture of DIPE, whether it derives from onsite or offsite contamination.
- The elevated MTBE and TBA concentrations (i.e., over 1,000 ug/L) in the vicinity of the NTF appear to be limited to the water table aquifer within the NTF. Only one monitoring well labeled as a Gage monitoring well (AMR 212-G) has elevated MTBE and TBA concentrations, but examination of the well construction information suggests that AMR 212-G is screened at the interface between the water table aquifer and the Gage aquifer. Monitoring well AMR 191-G is screened in the Gage aquifer immediately below AMR 212-G and has MTBE concentrations under 100 ug/L. The concentrations of MTBE and TBA in Gage monitoring wells are generally below 100 ug/L. MTBE concentrations in offsite monitoring wells are non-detect, but TBA that may or may not be site-related is present in multiple off-site wells. This might indicate relatively limited potential for off-site migration and the potential for MTBE to degrade before migrating off-site. It is unclear what role ground water extraction is playing in limiting this migration.
- The presence of MTBE in AMR 704-L indicates there may be potential for MTBE to migrate vertically to the Lynwood aquifer within the boundaries of the NTF. The presence of MTBE in AMR 704-L, however, might also be from upgradient sources (e.g., other refineries in the area), indicating that MTBE may not migrate from the water table aquifer to the Lynwood aquifer within the NTF. Therefore, an improved understanding of the oxygenate plume and hydrogeology would be needed to determine if the MTBE in the Lynwood aquifer is NTF-related.
- A preliminary evaluation of a capture zone can be conducted by comparing the amount of water flowing through a cross-sectional area of the aquifer and the amount of water that is extracted in that vicinity. To account for heterogeneities and contributions from infiltration or overlying/underlying aquifers, the amount extracted should typically be the amount of ground water flowing through the area multiplied by a safety factor of

approximately 2.0. The ground water flow rate through the NTF in the water table aquifer can be estimated using Darcy's Law. The August 2004 Barrier System Evaluation Report suggests a hydraulic conductivity of approximately 16 feet per day and a saturated thickness of 38 feet for recovery well AMR 151-12. The CRGG Model Output report suggests a hydraulic conductivity equal to or greater than 16 feet per day. Multiple site documents and potentiometric surface maps, including the CRGG Model Output report, suggest a hydraulic gradient of 0.003 to 0.004 feet per foot. Assuming a width of approximately 1,000 feet that would need to be captured, approximately 10 to 12.5 gpm is flowing through the contaminated portion of the NTF in the water table aquifer. Applying a safety factor of 2.0, approximately 20 to 25 gpm should be extracted. As a result, it is very unlikely that the 2005 extraction rate of 10.5 gpm (or more likely 6.5 gpm if extraction from AMR 187-6 is discounted due to its relative distance from the NTF) is sufficient to provide adequate capture of contamination that is migrating horizontally. Additional lack of capture might result from vertical ground water flow that is not intercepted by the recovery wells.

- Because the recovery wells were originally installed to recover LNAPL rather than control a dissolved plume, the wells may not be located in the most appropriate areas to prevent horizontal and/or vertical migration. For example, AMR 231-D had an MTBE concentration of 550,000 ug/L in Spring 2004, but it is located over 300 feet from the nearest recovery well in what is likely a sidegradient direction. On the other hand, some of the extraction wells are likely effective at mitigating contaminant migration. AMR 152-12 and AMR 209-6 may prevent contamination from AMR 233-D and AMR 234-D from migrating west toward AMR 083-D and Wilmington Avenue. Extraction at these two wells may be responsible for the declining concentrations in AMR 083-D, where MTBE concentrations have decreased over the past three sampling events.
- The ground water flow velocity in the water table aquifer is relatively slow. Based on the parameters stated above and an estimated effective porosity of 0.4, the seepage velocity is approximately 0.16 feet per day. Therefore, for MTBE to migrate 300 feet (e.g., from AMR 083-D where the MTBE concentration was 1,500 ug/L in 2003 to AOS 217-D where MTBE is still non-detect) would take approximately 5 years. It is interesting to note that benzene has higher concentrations than MTBE offsite in the water table aquifer. For example, at AOS 217-D (approximately 150 feet downgradient of the NTF), the benzene concentration has typically been approximately 10,000 ug/L whereas the MTBE concentrations have been non-detect. This might be due to historical contaminant migration that preceded MTBE usage and the operation of the recovery system, but, as indicated by the facility, it could also be due to an off-site release from a pipeline rather than from the NTF. If the off-site benzene contamination results from an old NTF source, it would suggest relatively slow biodegradation for benzene and might also suggest that biodegradation would be relatively slow for MTBE. However, if the off-site benzene is from a pipeline release rather than the NTF, then these benzene concentrations provide little or no information with respect to biodegradation rates for MTBE.
- Well gaging data from AMR 193-D and AMR 190-G suggest a downward vertical gradient of 0.014 feet per foot. In addition, well gaging data from AMR 213-D to AMR 212-G suggest a downward gradient of 0.033 feet per foot. These downward gradients

can drive vertical migration from the water table aquifer to the Gage aquifer and are likely responsible for the MTBE concentration of 29,000 ug/L that was detected at AMR 212-G in the Gage aquifer. The actual vertical flow (velocity or flux) would be determined by the hydraulic gradient and the vertical hydraulic conductivity, which likely varies across the site due to lenses of silt, sand, gravel, and clay. The CRGG Model Output Report suggests a vertical hydraulic conductivity range of 0.001 to 0.1 feet per day for the confining layer between the water table aquifer and the Gage aquifer and references a value of 0.1 feet per day from a previous modeling effort. Assuming an average vertical hydraulic conductivity of 0.1 feet per day in the NTF area, the vertical Darcy velocity is approximately 0.0024 feet per day and the seepage velocity is approximately 0.006 feet per day. Ground water flow from the water table aquifer to the Gage aquifer in the NTF (approximately 800,000 square feet) would be approximately 10 gpm if this assumed hydraulic conductivity is correct. The downward ground water flow could be lower if the average hydraulic conductivity is lower, but it could also be higher if the average hydraulic conductivity is higher or there are gaps in the aquitard. This simple calculation indicates that the NTF extraction system pumping rate may be comparable to the volume of water that is migrating downward in the NTF from the water table aquifer to the Gage aquifer but that the ability of the extraction network to prevent downward migration may be dependent on extraction well locations.

- A comparison of the vertical flow rate from the water table aquifer to the Gage aquifer with the horizontal flow rate in the Gage aquifer can provide an estimate of how much the contamination is diluted as it enters the Gage aquifer from the water table aquifer. The above discussion suggests that the flow rate from the water table aquifer to the Gage aquifer is approximately 10 gpm, which could be higher or lower due to the actual vs. estimated hydraulic conductivity. The flow rate in the Gage aquifer can also be calculated using Darcy's Law. The CRGG Model Output Report suggests that the hydraulic conductivity of the Gage aquifer in the vicinity of the NTF is approximately 50 feet per day and that the hydraulic gradient is approximately 0.0025 feet per foot in a westerly direction. The horizontal Darcy velocity in the Gage aquifer based on these values is therefore approximately 0.125 feet per day. Assuming a 1,000-foot width of the NTF and limiting this exercise to the upper 20 feet of the Gage aquifer provides a cross-sectional area of approximately 20,000 square feet. Therefore, the total flow rate through the upper 20 feet of the Gage aquifer is approximately 2,500 cubic feet per day. This translates to approximately 15 gpm. Therefore, the flow from the water table aquifer and from upgradient in the Gage aquifer are of similar magnitudes suggesting that contamination might be diluted by approximately 50% (e.g., concentrations of 100,000 ug/L in the water table aquifer might be diluted to 50,000 ug/L in the Gage aquifer in the absence of degradation. However, MTBE and TBA concentrations in the Gage aquifer monitoring wells seem to be several orders of magnitude lower than the concentrations in the water table aquifer. This suggests one or more of the following:
 - The MTBE detected in the Gage aquifer to date may only be the leading edge of the MTBE plume, and higher concentrations will be detected in the Gage aquifer in the future.

- The hydraulic and contaminant transport parameters of the water table aquifer, Gage aquifer, and the aquitard have different hydraulic properties than used in these preliminary calculations.
 - Sampling is not occurring in the appropriate locations of the Gage aquifer to detect the maximum oxygenate concentrations in that aquifer.
 - Degradation and dispersion could be occurring to substantially reduce the oxygenate concentration before it reaches the Gage aquifer.
- In general, plume control can be provided by a combination of ground water extraction and natural degradation. Ground water extraction provides containment of the plume or a portion of the plume, and natural degradation reduces concentrations before migration allows the plume to expand. Typically, plume control can be established by confirming a plume is not expanding beyond a point of compliance. Within the scope of an RSE, the RSE team can only preliminarily evaluate plume control. More rigorous evaluation would likely be required by the site team. With regard to hydraulic containment, the RSE team notes the following:
 - A water budget for the site (see above) suggests that more water is flowing through the site than is being extracted by the ground water and LNAPL recovery system. In addition, the recovery wells are not necessarily located in the appropriate locations to provide hydraulic containment because they were originally installed to recover LNAPL. Together, these points suggest that the recovery system is not providing full hydraulic containment of the dissolved plume.
 - As with many sites, the potentiometric surface map lacks sufficient detail to accurately trace the capture zone. This does not mean that the RSE team suggests the installation of additional piezometers. It simply means that this line of evidence will not likely be helpful in evaluating capture. It is often not cost-effective to install enough piezometers to be able to evaluate a capture zone based on a potentiometric surface map alone.
 - Water quality monitoring is inconclusive. Typically, concentrations downgradient of an extraction system should be non-detect or should decrease to background concentrations. TBA is present off site at concentrations that are low relative to on site concentrations, but it is difficult to determine if the TBA is from other sources in the area or if it is from the NTF. MTBE appears to be non-detect in existing off site monitoring wells, but this could be due to insufficient coverage of monitoring wells along the western property boundary. Finally, oxygenates are detectable at or below 100 ug/L in existing Gage and Lynwood aquifer monitoring wells, but is unclear if oxygenate concentrations are higher in other parts of these aquifers under the NTF or if oxygenates are migrating off site in these aquifers.

- For a site with complex hydrogeology such as this one, numerical ground water flow modeling with particle tracking may be the strongest line of evidence for evaluating capture. However, the model should be appropriately calibrated under pumping and non-pumping conditions for the specific area being evaluated. The inset ground water model developed by the facility, may be appropriate for evaluating capture in the future, but, in the opinion of the RSE team, would not be very effective in the form discussed during the RSE meeting. At the time of the RSE meeting, the inset model was using the regional scale calibration and had not been calibrated to pumping and non-pumping scenarios that are local to the NTF.

Therefore, based on the information provided, the degree of hydraulic containment is uncertain but is likely insufficient to hydraulically contain the plume due to the extraction well locations and overall extraction rate. This finding does not mean that the plume is not adequately controlled. Insufficient information is available to evaluate the role of natural degradation and overall plume control.

- Site monitoring data presented by BP suggest that microbial degradation is occurring. There is uncertainty, however, in the degree of that degradation and its role in preventing plume migration. The data show decreases in MTBE concentrations with time and distance, a relatively low MTBE vs. TBA ratio, an increase in dissolved iron in several locations, and relatively high methane concentrations. The degradation of BTEX may affect some of these observed parameters. The wells where increases in dissolved iron were identified are generally located in areas where benzene concentrations are higher than MTBE concentrations, and it is generally understood that BTEX degrades more readily than MTBE. A decrease in dissolved iron would generally not serve as direct evidence of anaerobic oxidation of MTBE with iron since iron (III) would serve as the electron acceptor and form iron (II), which is more soluble than iron (III). The elevated methane concentrations (e.g., on the order of 10 mg/L) may indicate fermentation of either MTBE or BTEX compounds.

4.2 COMPONENT PERFORMANCE

4.2.1 RECOVERY SYSTEM

The “uptime” of the recovery system has been approximately 80%, but maintaining this efficiency has required a substantial level of effort due to iron fouling and biological growth. Routine activities have included instrumentation and downhole equipment cleaning (10 of 30 wells per year), well redevelopment (6 of 30 wells per year), recovery well line flushing (three times per year). In addition, the facility is upgrading the extraction system by replacing the carbon steel manifold with fiberglass and replacing pneumatic pumps (used in some wells) with piston pumps. Although the piston pumps require more maintenance than the pneumatic pumps, they have been chosen by the facility and its contractor to avoid the need for permitting and treating the air discharged from the pneumatic pumps.

4.2.2 TREATMENT SYSTEM

Treatment is provided by the refinery treatment system and was not considered during the RSE effort.

4.3 COSTS

The O&M costs are approximately \$945,000 per year for the remedial activities across the whole refinery system as summarized in the following table. This cost appears relatively high compared to the costs of operating and maintaining P&T systems at other facilities; however, the level of effort is likely higher for certain remedial work at this site compared to others due to health and safety requirements and other activities associated with an active refinery.

Cost Category	Approximate Annual Cost
Project management	
• Project management for recovery system	\$70,000
• Additional, site-wide project management	\$66,000
Recovery system O&M	
• Labor for O&M of recovery system	\$270,000
• Equipment for O&M of recovery system	\$60,000
• Acid and chemicals for O&M of recovery system	\$3,000
Vacuum truck operation	\$30,000
Ground water monitoring (28 wells sampled and 284 wells gaged, semi-annually)	\$186,000
Data analysis and evaluation management	\$160,000
Reporting (monthly and semi-annual reports)	\$100,000
Utilities and disposal costs included in refinery operation	N/A
Total	\$945,000

Additional cost information for three of the most significant cost categories is provided below.

- PM/reporting/data analysis – Labor for this category is approximately \$330,000 per year. Assuming an average, competitive billing rate of \$100 per hour, this annual cost is equivalent to approximately 1.5 full-time equivalent (FTE) employees dedicated to management, reporting, and data analysis of remedial activities across the entire refinery.
- Recovery system O&M – Labor for this category is approximately \$270,000 per year, and the facility reports that this is equivalent to 2.7 FTE employees (at a lower billing rate than that assumed for the above labor category). The following table provides the facility’s summary of labor hours for O&M.

Activity	Units	Quantity	Units/Yr	Hours/Yr	FTE*
Inspections and operational checks	Hr/wk	22	52	1144	0.61
Troubleshooting and repairs	Hr/well	8	100	800	0.43
Instrumentation/downhole equip. cleaning	Hr/well	40	10	400	0.21
Well redevelopment	Hr/well	60	6	360	0.19
Evaluations by the O&M engineer	Hr/mth	16	12	192	0.10
Recovery well manifold replacement	Hr/mnfld	80	4	320	0.17
Recovery well line flushing	Hr/flush	120	3	360	0.19
Mobile LNAPL recovery	Hr/mnth	24	12	288	0.15
Pipeline checks	Hr/chk	48	1	48	0.03
Pipeline valve checks	Hr/well	4	30	120	0.06
Maint. of downhole sampling equipment	Hr/well	10	18	180	0.10
Health and safety	Hr/wk	14	52	728	0.39
Preventative maintenance	Hr/mtg	20	2	40	0.02
Total				4980	2.66

* Assumes one full-time equivalent is 1,880 hours per year.

The above table indicates that the weekly inspections and operational checks, followed by repairs and health and safety, require the largest level of effort relative to other O&M activities.

- Ground water sampling – The total cost for ground water sampling is approximately \$186,000 per year, including approximately \$10,000 for planning and coordination, approximately \$45,000 for analytical costs, and approximately \$121,000 for sampling (labor and equipment). Activities include the following:
 - Planning, coordination, etc.
 - Gaging (and associated maintenance) 300 on-site wells twice a year
 - Gaging (and associated maintenance) 36 off-site wells four times a year
 - Sampling up to 28 wells twice a year with low-flow sampling
 - Analysis for VOCs, oxygenates, ethanol, methanol, SVOCs, dissolved metals, and MNA parameters for each sample (approximately \$500 per sample) and associated field/equipment blanks

4.4 REGULATORY COMPLIANCE

The site team did not report any non-compliance issues to the RSE team.

5.0 SYSTEM EFFECTIVENESS IN PROTECTING HUMAN HEALTH AND ENVIRONMENT

5.1 GROUND WATER

It is the RSE team's understanding that, to date, the potential receptors associated with the site (i.e., supply wells in the Silverado aquifer) have not been affected by site-related contamination. However, it is uncertain as to whether or not the current remedial actions taken in the NTF will be successful at preventing site-related contamination from reaching those receptors in the future. There is evidence that NTF-related contamination has migrated from the water table aquifer to the Gage aquifer, but it is unclear to what extent NTF-related contamination has migrated deeper to the Lynwood aquifer or offsite. Contaminant detections in the Lynwood aquifer may be NTF-related or may be due to impacts from off-site sources (e.g., other refineries).

5.2 SURFACE WATER, AIR, SOIL, AND SEDIMENT

At the site team's request, the RSE focused on the ability of the NTF recovery system to prevent migration of oxygenates. Therefore, potential surface water, air, soil, and sediment were not evaluated as part of the RSE.

6.0 RECOMMENDATIONS

6.1 RECOMMENDATIONS TO IMPROVE SYSTEM PROTECTIVENESS

6.1.1 BETTER DELINEATE OXYGENATE PLUME AND ENHANCE MONITORING NETWORK FOR THE NTF

To date, the majority of the monitoring wells associated with the NTF are screened in the water table aquifer. Monitoring wells in the Gage aquifer have oxygenate concentrations that are several orders of magnitude lower than the concentrations in the water table monitoring wells, but this could be due to a relative lack of monitoring well coverage in the Gage aquifer.

It is recommended that the site team consider further delineation in the Gage aquifer, and possibly the Lynwood aquifer. Seven proposed locations for collecting samples are as follows:

On-site

- Near AMR 204-D and AMR 231-D
- Near AMR 233-D and AMR 234-D

Off-site

- midway between AOS 536-D and AOS 217-D
- co-located with AOS 217-D
- approximately 400 feet northeast of AOS-217-D and 300 feet west of AMR 231-D

Samples should be taken at several vertical intervals in the Gage aquifer, and possibly Lynwood aquifer, at these locations. Efforts should be taken to avoid compromising the integrity of the aquitards that are present between the various aquifers. Based on the results from these (or similar) sampling locations, sampling at additional locations, particularly off-site, may be merited. The site team might consider using the TRIAD approach developed by the U.S. EPA Office of Superfund Remediation and Technology Innovation, which incorporates systematic planning, dynamic work plans, and real-time (or quick-turn) monitoring. More information can be found at www.cluin.org/triad. Technical support from EPA or EPA contractors may be available. Permanent monitoring wells at the outer edges of the plume (both horizontally and vertically) will likely be appropriate to monitor plume stability over time. Nested or multi-port wells may be appropriate in some locations. The cost of the field effort will depend heavily on the number of locations and depths sampled. The RSE team defers to the site team for the cost of this effort.

6.1.2 CONSIDERATIONS FOR FURTHER DEVELOPMENT AND APPLICATION OF THE INSET GROUND WATER FLOW MODEL

The facility has developed an inset numerical ground water flow model based on the regional model developed in association with CRGG. The inset model uses the hydraulic parameters used for the NTF area in the regional model and has boundary conditions determined from

simulations with the regional model. The discretization for the inset model is finer than that used in the regional model, so the main benefit of the inset model is to provide a more refined view of ground water flow in the NTF as modeled by the regional model.

Although the inset model, as currently developed, can be a useful tool, it is unclear how accurate the model is for modeling ground water flow in the NTF. Subsurface characteristics and ground water flow are highly scale dependent. Therefore, what may be appropriate on a regional basis may not be appropriate at the local scale, particularly if the model will be used for evaluating the capture zone of a local extraction network. If the site team is considering use of the model and particle tracking to determine the extent of hydraulic containment offered by the NTF extraction network, the model should likely be calibrated under both pumping and non-pumping conditions using water levels from NTF monitoring wells. This calibration might consider the influence of pumping on water levels in both water table aquifer monitoring wells and Gage aquifer monitoring wells. This might help the site team better understand influences on local NTF flow such as the extraction network, possible local variations hydraulic conductivity, and possible variations in aquitard thickness or presence. The effort to calibrate the model, assuming the appropriate water level data is available or easily collected during a subsequent sampling round, might be \$25,000. Running model simulations with particle tracking to evaluate the affect of pumping, might be an additional \$15,000, including documentation. Given the complexity of the site hydrogeology and the presence of significant vertical gradients, numerical modeling with particle tracking will likely be an important component in evaluating the effectiveness of the extraction system.

6.1.3 ENHANCE MNA MONITORING

Even if the extraction network does not provide adequate hydraulic containment of the oxygenate plume, plume migration may be adequately prevented by a combination of extraction and natural attenuation. The facility has been collecting and analyzing data to determine the extent of oxygenate degradation. As mentioned in Section 4.1 of this report, the extent of degradation and its role in preventing oxygenate migration is unclear. Further sampling of iron, sulfate, and methane will not likely provide sufficient evidence to incorporate MNA as a primary remedial component. Recent EPA guidance titled *Monitored Natural Attenuation of MTBE as a Risk Management Option at Leaking Underground Storage Tank Sites* (EPA/600/R-04/179, January 2005), notes the uncertainty associated with sampling these traditional MNA parameters.

The site team should consider focusing sampling on the oxygenates themselves and might consider experimenting with more specific sampling and analysis for MTBE degradation, such as stable isotope sampling. The EPA document mentioned above discusses the use of stable isotope sampling as a means for evaluating and potentially quantifying MTBE degradation. MTBE is composed of carbon atoms with a fairly predictable distribution between the ^{13}C isotope and ^{12}C isotope. The ^{12}C isotope is much more prevalent, but biodegradation distinctively favors degradation of MTBE containing the ^{12}C isotope. Therefore, as degradation progresses, the relative fraction of MTBE with the ^{13}C isotope increases relative to the total amount of MTBE. The favoring of the ^{12}C isotope in degradation is even stronger for anaerobic degradation processes, which means that this type of sampling and analysis may be particularly effective at this site, which is clearly depleted of oxygen. The EPA document suggests that as of

January 2005, this type of stable isotope analysis was available commercially from a few university laboratories for approximately \$250 per sample. The site team might consider this type of sampling and analysis at multiple locations in and near the NTF in both the water table and Gage aquifers. The site team may be able to establish a relationship between the distance the MTBE has migrated and the degree of degradation, which might ultimately help the site team establish a theoretical maximum extent of the MTBE plume. Continuing these analyses may also be worthwhile over time to determine if the rate of degradation is changing. It is notable that MTBE degradation generally requires some time to reach a noticeable rate because the microbes that degrade MTBE reproduce at a slower rate than microbes associated with biodegradation of BTEX compounds.

Assuming that this analytical technique is applied to samples collected from the oxygenate network of 11 monitoring wells plus a few additional wells on an annual basis and that the analytical costs reported in EPA documentation are accurate, the additional cost to the site might be under \$5,000 per year.

6.2 RECOMMENDATIONS TO REDUCE SYSTEM COSTS

6.2.1 INSTALLATION OF NEW EXTRACTION WELLS IN OXYGENATE HOT SPOTS

The facility is considering the voluntary installation of two new extraction wells in the NTF. Those wells would be located in basins 69 and 91 near AMR 200-D and AMR 204-D, respectively. These two wells have LNAPL with MTBE concentrations that are over 4,000 ug/L and are located in areas where the facility believes LNAPL recovery will be effective. The RSE team agrees with the installation of these wells from a remedy effectiveness perspective given that there is less oxygenate contamination that can migrate from the site if a greater amount is removed by extraction. The RSE team also notes, however, that while this action is pro-active, the installation and maintenance of additional extraction wells without a further understanding of plume delineation and NTF hydrogeology may not be the most cost-effective remedial approach. In addition, the RSE team places higher emphasis on either demonstrating or achieving plume control (via a combination of pumping and degradation) versus emphasis on increasing mass removal. Due to the cost of maintaining extraction wells and a current lack of understanding of the role of extraction in preventing plume migration, the RSE team discourages the installation of additional wells beyond those already proposed until the plume and NTF hydrogeology are better understood.

6.2.2 REDUCE FREQUENCY OF OPERATIONAL CHECKS

The facility currently conducts weekly inspections and operational checks of the extraction network. The inspections generally consist of a simple visual inspection conducted at the beginning of every week to check for running status, leaks, and abnormal operational conditions. Minor maintenance and trouble shooting is also included. In addition, the facility also conducts a weekly operational check of each well that includes collection of totalizer readings, calculation of instantaneous flow rates, discharge pressure, air supply pressure (for wells with pneumatic pumps), fluid levels in the wells, percent LNAPL, and operational condition of the wells. In all of the 40+ P&T systems that the RSE team has reviewed, this is the one site that the RSE team

remembers seeing weekly operational checks of these types of parameters. The RSE team suspects that the primary driver for the frequent operational checks is to calculate mass removal because visual inspections, coupled with less frequent operational checks, should be more than sufficient to operate the recovery system and maintain satisfactory system uptime. Although measuring mass removal provides a feeling of measuring progress, the mass removal will likely continue at this site for a number of decades (if not indefinitely), and weekly measurements of mass removal will not provide the site team with any more useful information about remedy performance, progress toward restoration, or plume capture. Furthermore, the mass removal data that the facility shared with the RSE team during the site visit indicated variable results and no discernible trend. The RSE team therefore recommends reducing the frequency of the operational checks from weekly to monthly and calculation of mass removal on a monthly basis rather than a weekly basis. The inspections, which are less intensive than the operational checks, should continue at frequency of once per week. Implementing this change should reduce operator labor by approximately 0.4 FTEs. Assuming that the replacement of the recovery well manifolds will also be completed soon, another 0.17 FTEs should be eliminated. Furthermore, other preventative measures, such as replacing strainers and flow meters should result in a further reduction in trouble shooting and repairs, perhaps a reduction of up to 0.2 FTEs. As a result, future labor cost for O&M should be less than 75% of the current cost (e.g., 2.0/2.66), representing a savings of approximately \$70,000 per year.

6.2.3 ELIMINATE ANALYSIS FOR SVOCs AND METALS WHERE APPROPRIATE

Annual ground water monitoring laboratory costs are approximately \$45,000, and a significant portion of this expense (estimated at \$25,000) is for analysis of SVOCs and metals at about 25 of approximately 35 wells. This analysis has continued for multiple events even though SVOCs and metals are not contaminants of concern at the site. The RSE team recommends eliminating these parameters, or at a minimum, reducing the frequency of analysis. If select metals are of interest, analysis of individual parameters could be proposed.

6.2.4 REQUEST REVISION IN LOW-FLOW SAMPLING PROCEDURE

The site sampling team interviewed during the RSE site visit stated that dissolved oxygen stability measurements are slowing well sampling by about one well per day. The RSE team has seen this difficulty at many sites. The site team should consider requesting that dissolved oxygen not be included in the sampling stability parameters as the problem typically is related to instrument reliability and use rather than ground water inconsistency. This should decrease the sampling level of effort by approximately 10% to 20%, representing a potential savings of approximately \$6,000 to \$12,000 per year without sacrificing the quality of the samples.

6.2.5 REDUCE DATA EVALUATION/REPORTING COSTS WHEN SYSTEM IS OPTIMIZED

Data analysis costs are reportedly \$160,000 per year on top of project management and reporting costs. Although this cost may be appropriate given the current state of evaluating the remedy and developing a numerical model, it is significantly higher than what would be appropriate once the extraction system is optimized and a remedy (likely a combination of P&T and MNA) has been demonstrated to prevent plume migration. An appropriate cost for data evaluation and reporting for the NTF portion of the site might be \$60,000 per year once the remedy is

optimized. With consistent effort at conducting the above recommendations and implementing an appropriate remedy, the RSE team envisions that this level of reduced expenditure could likely be realized within two years.

6.3 RECOMMENDATIONS FOR TECHNICAL IMPROVEMENT

6.3.1 CONSIDER NTF-SPECIFIC ANNUAL REPORTING

The site team should consider NTF-specific reporting. This reporting may occur as a section of a broader annual report, or it may be a separate annual report. The reporting should include the following:

- Construction details of the recovery wells
- Extraction rates for each of the recovery wells
- Ground water monitoring (sampling and gaging) directly associated with the NTF
- Potentiometric surface maps for the relevant aquifers
- Plume maps for the relevant aquifers
- An evaluation of capture based on model simulations and concentration trends

The RSE team estimates that this reporting might add approximately \$5,000 per year to the current reporting costs.

6.3.2 RECONSIDER PUMPING FROM RECOVERY WELL 187-6

Recovery well 187-6 is located downgradient of the NTF where oxygenate concentrations are low or non-detect and the extraction rate of approximately 4 gpm accounts for approximately one third of the overall NTF extraction rate. After the delineation event and use of an improved inset model, the site team might consider the value of pumping from this well (and perhaps other non-NTF wells at the site), particularly given the substantial cost associated with maintaining the recovery wells and the potential to use the excess treatment capacity for ground water that may be extracted from other locations.

6.4 RECOMMENDATIONS TO SPEED SITE CLOSEOUT

6.4.1 DETERMINE AN EFFECTIVE STRATEGY FOR CONTROLLING PLUME MIGRATION

The presence of wide-spread LNAPL at the site, the relatively fine/impermeable nature of the water table aquifer, and the potential for future releases suggests that aquifer restoration within the NTF will require a number of decades or an indefinite time period. As such, the RSE team suggests that the site team focus on controlling the migration of the plume as a primary objective and potentially considering mass removal as a secondary objective once plume control has been achieved/demonstrated. The RSE team believes that appropriate plume control could likely be provided by a combination of both pumping and natural attenuation, but the contribution of either of these components requires further evaluation.

The additional sampling from the Gage aquifer (6.1.1), a more refined inset model (6.1.2), and stable isotope analysis (6.1.3) should provide valuable information in determining an appropriate strategy for plume control. The strategy will likely include determining a target area for plume control, with appropriate horizontal and vertical boundaries for the furthest extent that oxygenates can migrate and remain above standards. The horizontal boundaries might be the property boundary or a designated distance from the property boundary, and the vertical boundary might be the Lynwood aquifer. These are only provided as examples because the RSE team is not in the position of determining an appropriate target control area. The strategy may be heavily dependent on biodegradation with only minor contributions from ground water extraction. On the other hand, the strategy might include pumping from the water table aquifer or perhaps even pumping from the Gage aquifer if monitoring and modeling suggest that pumping from the water table aquifer is inadequate at preventing downward migration. Although pumping from the Gage aquifer would likely involve higher flow rates, the MTBE concentrations would likely be lower and there would likely be fewer maintenance issues.

Table 6-1. Cost Summary Table

Recommendation	Reason	Estimated Additional Capital Costs (\$)	Estimated Change in Annual Costs (\$/yr)
6.1.1 Better Delineate Oxygenate Plume and Enhance Monitoring Network for the NTF	Effectiveness	Not Quantified	Not Quantified
6.1.2 Considerations for Further Development and Application of the Inset Ground Water Flow Model	Effectiveness	\$40,000	(included in future reporting/data evaluation costs)
6.1.3 Enhance MNA Monitoring	Effectiveness	\$0	\$5,000
6.1.4 Installation of New Extraction Wells in Oxygenate Hot Spots	Effectiveness	\$0	\$0
6.2.1 Reduce Frequency of Operational Checks	Cost Reduction	\$0	(\$70,000)
6.2.2 Eliminate Analysis for SVOCs and Metals where Appropriate	Cost Reduction	\$0	(\$25,000)
6.2.3 Request Revision in Low-Flow Sampling Procedure	Cost Reduction	\$0	(\$6,000) to (\$12,000)
6.2.4 Reduce Data Evaluation/Reporting Costs when System is Optimized	Cost Reduction	\$0	(\$200,000) (to be realized in ~ 2 years)
6.3.1 Consider NTF-Specific Annual Reporting	Technical Improvement	\$0	\$5,000
6.3.2 Reconsider Pumping from Recovery Well 187-6	Technical Improvement	\$0	\$0
6.4.1 Determine an Effective Strategy for Controlling Plume Migration	Site Closure	Not quantified	Not quantified

Costs in parentheses imply cost reductions.

FIGURES*

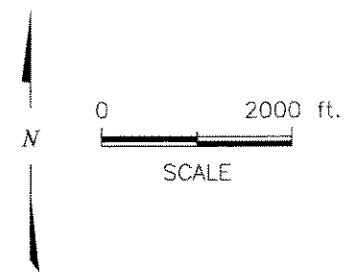
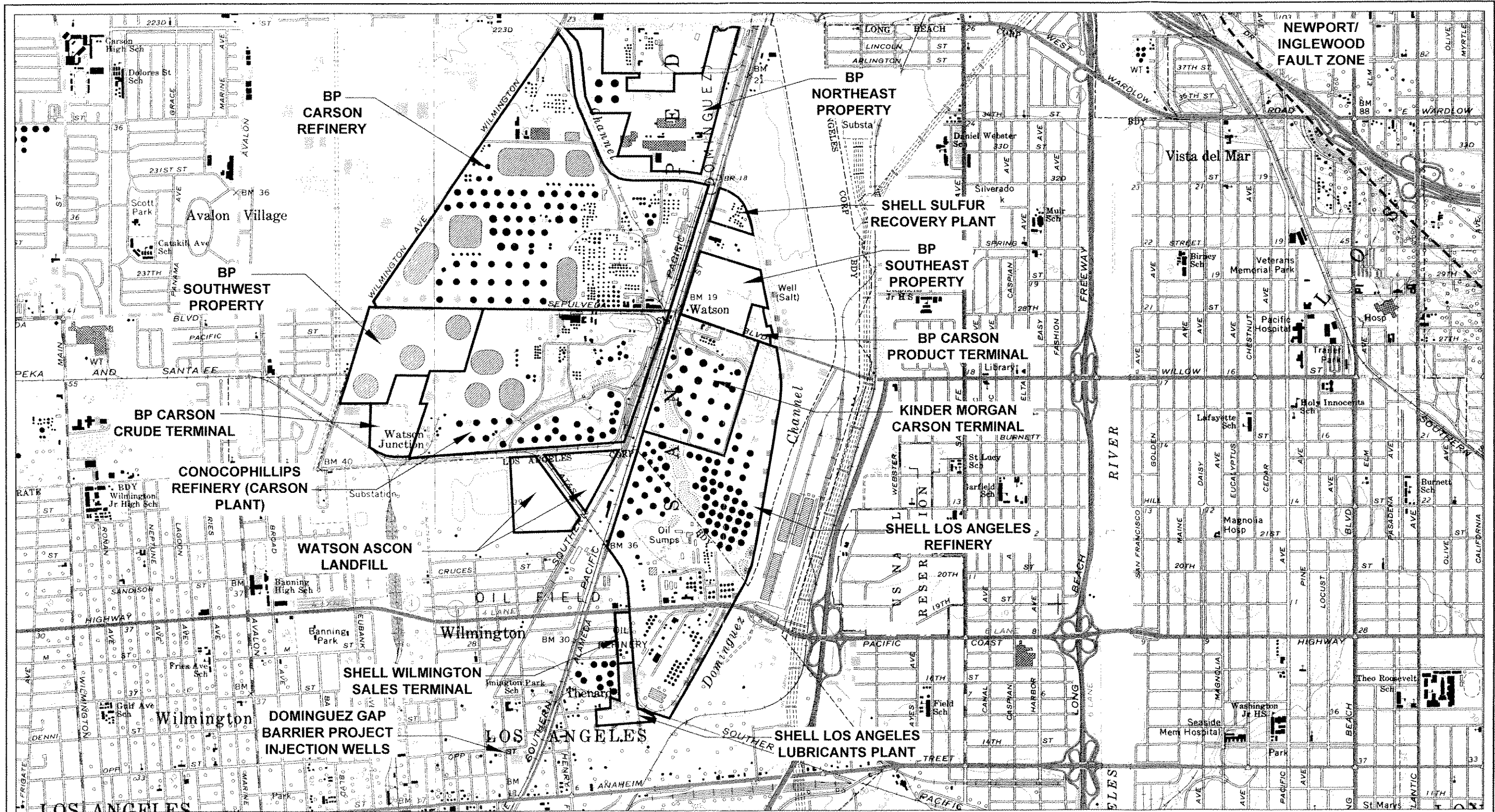
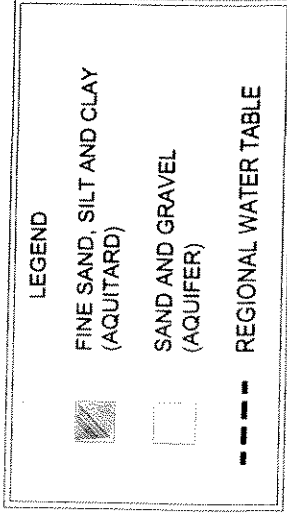
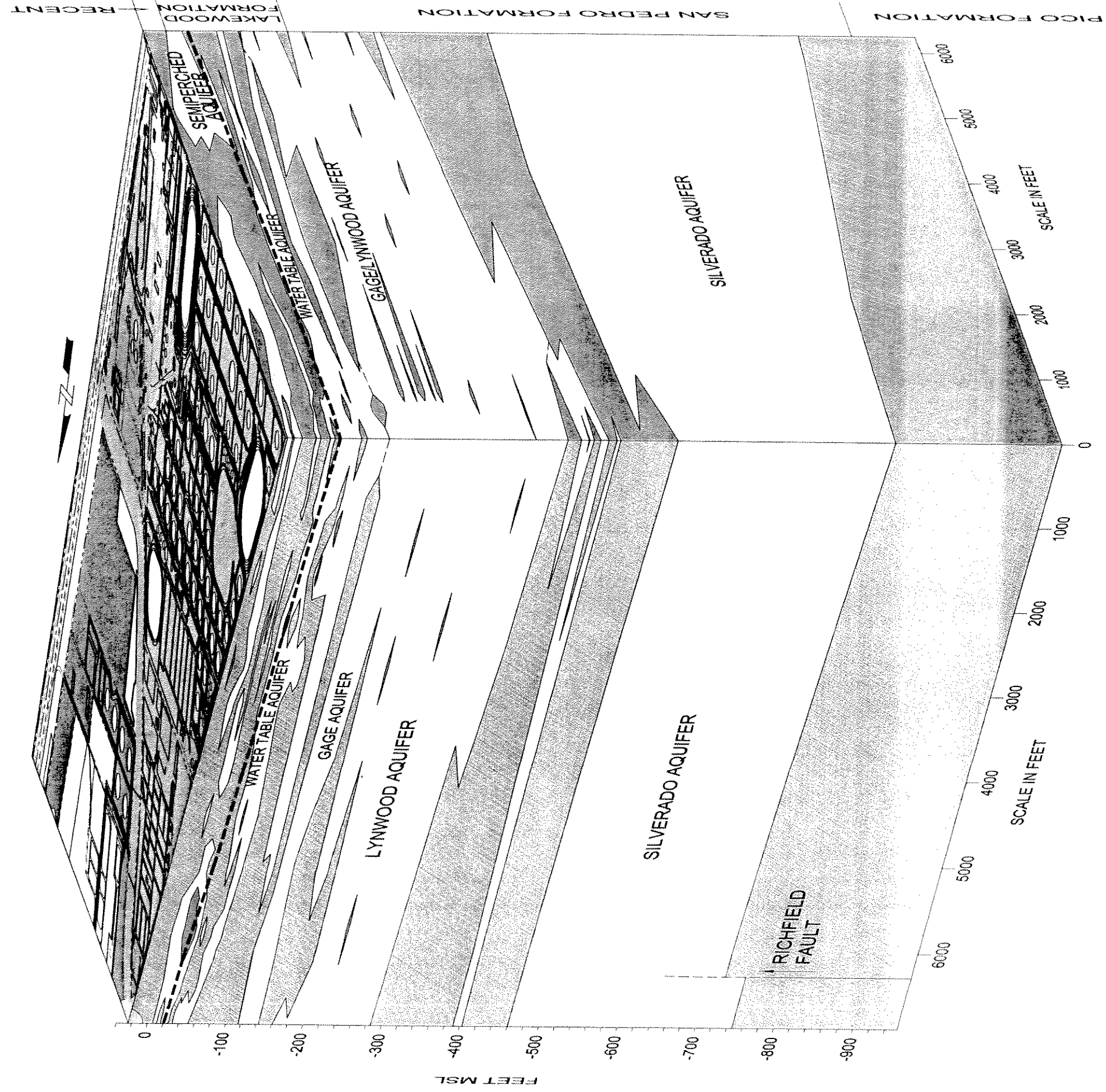


FIGURE 1
LOCATION OF CRGG FACILITIES, 2003 CRGG ANNUAL PROGRESS REPORT



AOS/542-D	Fall '03 (Dup)	Spring '04
MTBE	<0.0010UJ (<0.0010)	<0.0010
DIPE	0.088J (0.82)	0.093
TBA	<0.010UJ (<0.010)	<0.010
1,2-DCA	0.029J (0.028)	0.029
Benzene	<0.00050UJ (<0.00050)	<0.00050

AOS/705-L	Spring '03	Fall '03	Spring '04
MTBE	<0.0010	<0.0010	<0.0010
DIPE	0.023	0.016	0.012
TBA	0.034	0.022	0.020
1,2-DCA	0.057	0.042	0.043
Benzene	<0.00050	<0.00050	<0.00050

AMR/190-G	Spring '03	Fall '03	Spring '04
MTBE	0.0060	<0.0010	<0.0010
DIPE	0.040	0.037	0.059
TBA	0.031	0.022	0.027
1,2-DCA	0.0031	0.0022	0.0029
Benzene	0.0021	0.0011	<0.00050

AMR/704-L	Spring '03	Fall '03	Spring '04
MTBE	0.062	0.062	0.017
DIPE	0.0041	0.0027J	0.0048
TBA	<0.010	<0.10	0.0062J
1,2-DCA	0.0069	0.0054	0.0074
Benzene	0.0060	0.02	0.0075

AMR/083-D	Spring '03	Fall '03	Spring '04
MTBE	1.5	0.52	0.33
DIPE	<0.010	<0.020	<0.040
TBA	0.27	0.29	0.28J
1,2-DCA	0.016	0.014	0.024
Benzene	10	9.8	12

AOS/217-D	Spring '03	Fall '03	Spring '04
MTBE	<0.020	<0.020	<0.040
DIPE	<0.020	<0.020	<0.040
TBA	0.17J	0.14J	<0.40
1,2-DCA	0.072	0.070	0.071
Benzene	11	9.6	10

AMR/232-D	Spring '04
MTBE	<0.025
DIPE	<0.025
TBA	0.23J
1,2-DCA	0.13
Benzene	7.8

AMR/213-D	Spring '03	Fall '03	Spring '04
MTBE	<0.040	<0.0020	<0.040
DIPE	<0.040	<0.0020	<0.040
TBA	<0.40	0.15	<0.40
1,2-DCA	0.057	0.034	0.029
Benzene	2.9	2.7	2.4

AMR/192-D	Spring '03
MTBE	1.3
DIPE	<0.010
TBA	0.46
1,2-DCA	<0.0050
Benzene	1.6

AOS/706-L	Spring '03	Fall '03	Spring '04
MTBE	<0.0010	<0.0010	<0.0010
DIPE	0.050	0.040	0.023
TBA	0.12	0.074	0.049
1,2-DCA	0.028	0.035	0.036
Benzene	<0.00050	0.00034J	<0.00050

AOS/538-D	Spring '04
MTBE	<0.0010
DIPE	<0.0010
TBA	<0.010
1,2-DCA	<0.00050
Benzene	0.050

AMR/186-D	Spring '04
MTBE	<0.0010
DIPE	<0.0010
TBA	0.051
1,2-DCA	<0.00050
Benzene	0.020

AMR/191-G	Spring '03	Fall '03	Spring '04
MTBE	0.086	0.027	0.24
DIPE	0.057	0.047	0.083
TBA	0.035	0.030	<0.10
1,2-DCA	<0.00050	<0.00050	<0.0050
Benzene	2.3	2.7	2.3

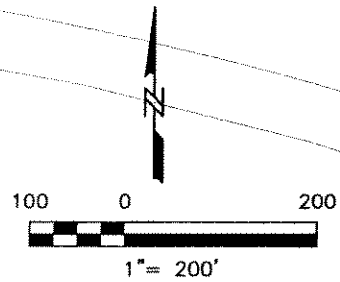
AMR/197-G	Spring '03	Fall '03	Spring '04
MTBE	<0.0010	<0.0010	<0.0010
DIPE	0.035	0.025	0.025
TBA	0.045	0.037	0.022
1,2-DCA	0.038	0.031	0.028
Benzene	0.0012	0.00073	0.00060

AMR/054-D	Spring '03	Fall '03	Spring '04
MTBE	400	240	180
DIPE	0.080J	0.044	<0.40
TBA	14	22J	<4.0
1,2-DCA	0.36	0.19	0.51
Benzene	12	11J	8.4

AMR/234-D	Spring '04
MTBE	800
DIPE	<0.20
TBA	34
1,2-DCA	<0.10
Benzene	21

AMR/233-D	Spring '04
MTBE	25
DIPE	<0.040
TBA	1.3
1,2-DCA	0.018J
Benzene	15

NOTES:
 1-ALL UNITS ARE IN MG/L
 2-WELL DESIGNATIONS:
 D = WELL IS SCREENED IN THE WATER TABLE AQUIFER
 G = WELL IS SCREENED IN THE GAGE AQUIFER
 L = WELL IS SCREENED IN THE LYNWOOD AQUIFER



LEGEND	
—	STUDY AREA
●	MONITORING WELL WITH LNAPL
●	MONITORING WELL WITHOUT LNAPL
□	WATER TABLE AQUIFER RECOVERY WELL
▨	WATER TABLE AQUIFER WELL
▩	GAGE AQUIFER WELL
▧	LYNWOOD AQUIFER WELL

