PACIFIC
ENVIRONMENTAL
GROUP, INC.

ENVIRONMENTAL
PROTECTION

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March 7, 1995
Project 330-006.3C

Ms. Amy Leech
Ms. Juliet Shin
Department of Environmental Health
Environmental Protection Division
Alameda County Health Care Services Agency
1131 Harbor Bay Parkway, Suite 250
Alameda, California 94502-6577

Re: Response to ACHCSA Letter, dated January 23, 1995
ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Dear Ms. Leech and Ms. Shin:

On behalf of ARCO Products Company (ARCO), Pacific Environmental Group, Inc. (PACIFIC) prepared this letter to respond to Alameda County Health Care Services Agency's (ACHCSA's) letter to ARCO, dated January 23, 1995. The ACHCSA letter responded to the Remedial Investigation/Feasibility Study (RI/FS) submitted by PACIFIC to ACHCSA on November 22, 1994 for the site referenced above. This response letter begins with some overall comments, then responds individually to the comments and questions raised by ACHCSA.

OVERALL COMMENTS

ARCO and PACIFIC agree with some of ACHCSA's comments and we present clarifying information where we find it appropriate. We believe that some of the issues can be resolved through consultation with Dr. Ravi Arulanantham, whose comments on the RI/FS have not yet been received. We believe that it is essential to keep Dr. Arulanantham involved in this project, as he is uniquely qualified and has provided valuable guidance for the RI/FS thus far. He also contributes considerable expertise in the fields of risk assessment and biodegradation of hydrocarbons. Therefore, before undertaking any additional field tasks to investigate areas of concern raised by ACHCSA, we propose that a meeting be held, to include Dr. Arulanantham, ACHCSA, the California Regional Water Quality Control Board (RWQCB), ARCO, and PACIFIC, to agree on what (if any) additional information is required, and what is the best way to collect that information.

RESPONSE TO SPECIFIC ISSUES

1. *Was the pump in Extraction Well EA-1 lowered as discussed during the July 8, 1994 meeting? If yes, was the capture zone for this new pump depth incorporated into the Fate and Transport Study (FTS)?*

The pump in the Extraction Well E-1A was lowered to a depth of approximately 23.5 feet in July 1994. As is standard for groundwater flow models, the FTS does not incorporate the depth of the extraction pump. Instead, it incorporates a specific volume of water removed per unit time at the extraction well location, along with other aquifer properties. The pumping rate used in the FTS was 577.5 feet^3 per day. The model used was MT3D, which is generally regarded as one the most sophisticated and widely accepted models for fate and transport studies. This model was approved for use at this site by ACHCSA.

2. *Sufficient data was not provided to prove that pumping of domestic irrigation wells is or is not affecting plume migration. PACIFIC agreed to request that the homeowners do not pump through 1995 to allow more time to determine if the pumping of domestic irrigation wells is a factor in plume migration. Furthermore, we urge ARCO to convince the remaining four homeowners who continue to pump, to stop pumping until the impact of off-site pumping is known.*

We believe that sufficient information exists to determine that the pumping of domestic irrigation wells will not affect plume migration. This was the conclusion of the FTS, wherein known maximum domestic irrigation well pumping rates for key wells were tripled, then incorporated into the FTS. The pumping rates used in the FTS for these wells were presented in Table A-1 of the RI/FS. The results of the FTS indicated that the combined pumping of Extraction Well E-1A and the key domestic irrigation wells had no appreciable affect on plume migration. The results also indicated that either non-detectable or health-protective hydrocarbon concentrations should be present in the domestic irrigation wells.

We agree with ACHCSA that a conservative approach through 1995 is prudent. Therefore, even though pumping does not pose a health concern, we are requesting all 14 domestic irrigation well owners for their cooperation in not pumping their wells and allowing PACIFIC to sample those wells quarterly through 1995. The request letters were sent to the well owners on February 27, 1995; copies of the letters were sent to ACHCSA. If any of the well owners do not respond or do not wish to cooperate, we will follow up with one additional letter or try to meet with them in person to obtain their cooperation.

3. *If domestic irrigation wells are to be used as sentinel or boundary wells, then well construction of those wells should be defined. Based on the RI/FS proposal, well 633H is intended to be used as a boundary or trigger well. If that is the case, well construction details are required for this well....*

We wish to clarify the purpose of Well 633 H and the other domestic irrigation wells. We are not proposing that any of these wells be used as boundary wells for management of the groundwater hydrocarbon plume. Instead, the domestic irrigation wells will be monitored to verify protection of human health and the environment. The results of the risk assessment indicated that the impacted groundwater does not currently pose a health concern. The monitoring data would be used to perform health risk evaluations to verify that concentrations of hydrocarbons (if any) in the domestic irrigation wells remain health protective. Therefore, construction details for these wells are not critical.

We agree with ACHCSA that well construction details are necessary for the boundary wells that are used to manage the groundwater hydrocarbon plume. Therefore, the configuration of the hydrocarbon plume in the shallow water-bearing zone will be monitored via monitoring wells constructed for that purpose, and may include Wells MW-11, MW-14, MW-15, MW-16, and possibly MW-17. We will develop the groundwater management plan in conjunction with ACHCSA following approval of the RI/FS. This plan will identify the boundary wells, their sampling requirements, and corrective actions, including possible active remediation, if certain implementation criteria are met in the boundary wells. The implementation criteria would be consistent with recently RWQCB-adopted Non-Attainment Zone policy, however, we are not proposing to specifically establish a non-attainment zone for the site. Alternative 2 proposes institutional controls consisting of a groundwater management plan that includes regular groundwater monitoring and sampling, and health risk evaluation.

4. *An assumption was made in the FTS that the half-life of 110 days for dissolved benzene is the most reasonable rate based on site lithology. A Sensitivity Study was also performed using a half-life of 250 days.*

   How do these rates compare to the biodegradation rates provided by the EPA's Toxicological Profile for Benzene? Please provide us data that relates to similar subsurface conditions of the subject site.

The biodegradation rate of 110 days used for benzene was selected based on published data cited in the RI/FS and presented at the July 8, 1994 meeting between ACHCSA, RWQCB, ARCO, and PACIFIC. The purpose of that meeting was to obtain approval of our RI/FS approach, including FTS modeling parameters like the biodegradation rate for benzene. At that meeting, no objection was raised regarding the use of the 110 day biodegradation rate for benzene. References for the published rate were submitted to ACHCSA following that meeting as requested, and until ACHCSA's January 23, 1995 letter, we did not receive any feedback that the biodegradation rate proposed and used was inappropriate. The area of biodegradation of hydrocarbons is one of those where Dr. Arulanantham's input is essential. Nevertheless, the requested information and source is given below.

> "The degradation of benzene by microorganisms has been well researched, and the conclusion reached is that benzene is biodegradable (e.g. see Haider et al. 1981, Hopper 1978, Setzkorn and Huddleston 1965, Tabak et al. 1981, Gibson 1977, Higgens et al. 1980, Smith and Rosazza 1974, Korte and Klein 1982, Unger and Claff 1985).
>
> The above-mentioned studies document the aerobic degradation of benzene, and, although far less information is available, benzene apparently is biodegraded under anaerobic conditions although probably somewhat slower than aerobically. One study that illustrates this is the research of Wilson et al. (1986). These investigators found that under anaerobic conditions in the laboratory, benzene was not significantly degraded during the first 20 weeks of incubation, but, by 40 weeks of incubation, benzene concentrations were reduced by 72%. At 120 weeks of incubation over 99% degradation had taken place. However, Batterman [1986, as reported in *Chem. Abstr.* 104(24):212909U], in investigating the in situ anoxic biological treatment of a hydrocarbon-contaminated aquifer, reported the complete removal of benzene after only 6 months. Gibson (1980) presents a proposed pathway for the anaerobic biodegradation of aromatic compounds.
>
> As discussed by Gibson (1980) and Hopper (1978), microbial metabolism of benzene proceeds through the formation of *cis*-dihydrodiols and, with further oxidation, to catechols which are the substrates for ring fission. Thus, before going to catechol, benzene biodegrades to 1,1-dihydroxoxy-1,2-dihydrobenzene (Gibson 1980).
>
> One important point must be made. The results of laboratory experiments which characterize most of the above, especially those using large numbers of organisms known to degrade benzene, must be carefully applied to field situations. An example of this is seen in the studies of Haider et al. (1981). *Nocardis* species and *Pseudomonas* species, after cultivation on benzene, effectively degraded benzene after 7 days (45 to 90%); however, when 100 g soil with a mixed bacteria population was mixed with 2 mg benzene, only 47% of the added radioactivity was recovered as CO_2 after 10 weeks. Haider et al. concluded that specific organisms which degrade benzene were present in the soil in only small numbers."
>
> Source: <u>Toxicological Profile for Benzene</u>, Oak Ridge National Laboratory for U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry, May 1989.

As indicated above, the reference cites complete degradation of benzene under anaerobic conditions after 120 weeks, or an equivalent half-life of 126 days. The reference also cites studies that indicate the aerobic biodegradation rate for benzene ranges from 7 to 70 days. Field data collected from monitoring and domestic irrigation wells show dissolved oxygen (DO) in groundwater ranges from 2 to 9 parts per million (ppm). These DO concentrations support aerobic biodegradation of benzene in groundwater.

Therefore, the selected biodegradation rate of 110 days for benzene is appropriate, and should be considered conservative.

At the July meeting, alternate biodegradation rates were suggested by Dr. Arulanantham. These rates (6 and 250 days) were suggested in order to evaluate the effects of varying biodegradation rates on the hydrocarbon plume (sensitivity analysis). The more-conservative biodegradation rate of 250 days was evaluated as requested and the results of the sensitivity analysis showed similar characteristics to results using a 110 day biodegradation rate. The less-conservative biodegradation rate was not evaluated because this rate is based on laboratory research and does not readily apply to field conditions.

5. *How do we know that contaminant attenuation observed has been due to biodegradation as opposed to adsorption and dilution? It is difficult to predict that significant biodegradation is occurring within the groundwater, capillary fringe, and vadose zone at the source and downgradient of the source of contamination.*

   A study by PACIFIC dated October 12, 1993, was made on the feasibility of in-situ bioremediation of contaminated soil at the site. The study concluded that "...characteristics favorable to bioremediation were not sufficient to warrant further study."

   Although a case comparison was made in the RI/FS to support the theory that groundwater characteristics are favorable to bioremediation at the ARCO site, we do not see enough evidence to support the assumption the Case Study groundwater characteristics are "remarkably similar" to the ARCO site.

   Because it is difficult to predict a biodegradation rate based on qualitative data, we recommend that a Fate and Transport Sensitivity Model Study be completed for a worse case scenario where biodegradation does not occur, i.e. the half-life for benzene is null.

   Furthermore, on-site specific data should be collected to support that sufficient biodegradation is occurring in the groundwater....

These comments suggest that ACHCSA is not convinced that biodegradation is taking place at the site. Considering: (1) the general observed decline in hydrocarbon concentrations in the off-site wells, (2) the excess dissolved oxygen measured in groundwater, and (3) the abundant published literature indicating that petroleum hydrocarbons, especially benzene, are biodegradable, we find it quite logical that biodegradation as well as other possible mechanisms for natural attenuation like dilution (dispersion), and adsorption, is occurring. Specific responses to the points raised by ACHCSA follow.

The FTS conducted at the site included effects of dilution, but not adsorption, in order to be more conservative. By including adsorption in the model, the hydrocarbon concentrations in groundwater should migrate downgradient at a slower rate than with biodegradation alone.

The feasibility study conducted in 1993 addressed biodegradation in soils, not groundwater. Oxygen, which is generally the limiting factor in biodegradation, is present in the groundwater in sufficient concentrations for aerobic biodegradation to occur.

ACHCSA states that insufficient evidence exists to state that the case study and the ARCO site are "remarkably similar." We found the similarities in the groundwater mineral quality and dissolved oxygen to be significant. However, the case study is less relevant than the actual hydrocarbon concentrations at the site, which have decreased markedly between 1991 and 1994. Figures 11 and 12 in the RI/FS illustrate this decrease.

To summarize, PACIFIC judges that several lines of evidence indicate that biodegradation is occurring at the site. Furthermore, previous communications with ACHCSA and the RWQCB have accepted the occurrence of biodegradation, with the recommendation that a sensitivity study with an extremely conservative biodegradation rate would be performed. The 250 day rate was suggested as acceptably conservative. This was the modeling approach that was approved by ACHCSA during the July 1994 meeting. Thus, we do not believe that conducting the FTS with a null biodegradation rate, or the collection of additional field data at this time is warranted. This is a topic we look forward to resolving at a meeting between ACHCSA, RWQCB, including Dr. Arulanantham, ARCO, and PACIFIC.

6. *The model results from Scenario 2, for which the Remedial Action Plan is supported, indicates that the plume boundaries will recede approximately 350 feet in 1 year, just two years after the benzene release to the groundwater began. The data used to produce this plume behavior is from the 1st Quarter 1994 (reported in March 1994). Data presented from the 2nd and 3rd quarterly 1994 monitoring, do not show any recessionary trend which leads us to believe that the model is inaccurate.*

   Further, we know that the plume boundaries for dissolved benzene currently extend approximately 600 feet downgradient from the site, and the benzene release to the groundwater began to occur 7 or more years ago. If the rate of biodegradation suggested by the model were occurring, it would seem that greater evidence of plume boundary recession would have been more apparent after 7 plus years of monitoring.

   It has been shown that benzene concentrations have decreased in the outlying domestic irrigation wells for the last 3 or more quarters. However to date, the plume boundaries have not appreciably receded upgradient toward the site.

> *The report states "...that groundwater from MW-10 is decreasing markedly in dissolved benzene...". Historical data presented thus far for MW-10, has exhibited sporadic fluctuations in benzene concentrations. If sufficient evidence is not provided to ensure that contaminant concentrations in MW-10 are significantly biodegrading or attenuating, a corrective action plan will be required to address containment/stabilization and, possibly, remediation of this off-site plume concentration.*

These comments suggest that we should explain more details about the FTS. First, the model does not predict 350 feet of plume recession "just two years after the benzene release...occurred." The input parameters assume a constant source of benzene to the groundwater on site, and an initial plume configuration based on March 1994 monitoring data. It is clear that the benzene source on site was formerly much greater than it is now. Significant source removal has taken place via tank replacement and extensive soil excavation concurrent with the tank replacement.

The reduction in source is an important consideration in looking for plume recession over time. The extensive plume resulted from a much more significant source than exists today. Evidence from outlying wells, including Wells MW-15, MW-16, and MW-17, as well as from various domestic irrigation wells, shows decreasing hydrocarbon concentrations. Contrary to the ACHCSA statement that plume boundaries have not receded, these wells show plume recession between 1991 and 1994. Figures 11 and 12 in the RI/FS illustrate this decrease.

We wish to clarify that the dissolved benzene plume is not approximately 600 feet in length. As of the September 1994 sampling event, benzene was detected in only three off-site wells (Wells MW-8, MW-10, and 17349 VM). Historically, these wells had the highest benzene concentrations. Data from the September 1994 sampling event showed significant decreases in the benzene concentrations in these wells since the previous quarter. Data from the December 1994 sampling event confirmed this decrease (Tables 1 and 2). Additionally, there are several monitoring wells and domestic irrigation wells that are located between these three wells and in which benzene has been detected in the past, but not recently. This indicates that the benzene in these areas has naturally attenuated to levels that meet the groundwater remedial goals, and suggests a decreasing benzene plume which extends off-site to the area just beyond Well MW-10 as well as a localized area of benzene in the area of Well 17349 VM. Historically, the higher concentrations of benzene will take more time to attenuate to levels which meet the groundwater remedial goals. This condition will be validated only through monitoring the plume through time, which is an essential element of Alternative 2 in the RI/FS.

The model is meant as a general predictive tool, and not as a predictor of exact concentrations at specific wells. The data input to the model is based whenever possible on actual field conditions, and where field measurements are not available, on reasonable assumptions. Some heterogeneities in subsurface conditions, such as variations in hydraulic conductivity or stratigraphy, are likely to exist locally. These are impossible to quantify precisely, but would cause local differences between model predictions and actual concentrations measured in monitoring wells. While it is certainly possible to calibrate the model with historic data so that it mirrors existing data, this exercise would not necessarily increase the accuracy of the model as a predictive tool. This is because any number of parameters, such as permeability, porosity, and dispersivity, can be adjusted to achieve the desired results, but we have no assurance that the adjusted parameters are the correct ones to modify to make the model more closely represent the actual subsurface conditions. The model predicts that over time, benzene concentrations should decline to non-detectable levels for most the area under consideration. This prediction will also be validated only through monitoring the plume through time, which is an essential element of Alternative 2 in the RI/FS.

We acknowledge that Well MW-10 has historically shown fluctuating benzene concentrations. In the first quarter 1993, it appears that a dissolved hydrocarbon "slug" reached Well MW-10. The concentrations peaked in the fourth quarter 1993, and since then, concentrations have declined. The fourth quarter 1994 data indicates that Well MW-10 contained 3,000 parts per billion (ppb) total petroleum hydrocarbons calculated as gasoline (TPH-g), and 150 ppb benzene (Tables 1 and 2). While this is a slight increase over the third quarter 1994, it is still less than the peak concentrations observed during 1993. As mentioned above, monitoring over time is recommended to validate the predicted decrease in hydrocarbon concentrations.

ACHCSA also comments that corrective action may be required to address hydrocarbon concentrations in Well MW-10. The RI/FS recommends that Well MW-10 be monitored as part of a groundwater management area. Possible corrective actions should be required only if certain criteria are met in the boundary wells, as would be identified in a contingency plan. Both groundwater hydrocarbon plume configuration and remaining health risk would be managed by Alternative 2.

7. *What are the current soil contaminant concentrations on site? What is the future leaching potential for these soils? How long will these soils contribute to groundwater contamination?*

   The most recent data on soil contaminant concentrations on site for the UST gasoline complex and used oil tank location is 1988; and 1992 for the oil-water separator. Per our conversation with PACIFIC, it was stated that the future leaching of on-site soil contamination was incorporated into the FTS using a general leaching rate solely for benzene. We suggest using more current, site specific data for model calibration.

Alternative 2, the recommended remedial action plan presented in the RI/FS, did not address remediation of the impacted on-site soils. However, the report indicates that the remaining soil contamination is expected to:

- *require a long period of time to naturally attenuate and*
- *will further impact the on-site groundwater.*

If residual soil contamination is in fact continuing to impact the groundwater, then as stated in Alternative 4, attempting to eliminate the ultimate source of contamination would seem warranted in this situation.

The majority of hydrocarbon mass in soil was removed during the tank replacement activities in June 1988. Based on a rough comparison of soil data for samples collected above the capillary fringe prior to and during tank replacement activities, we concluded that:

- Approximately 96 percent of the hydrocarbon mass in the area of the former underground tank complex was removed during tank replacement activities.
- Approximately 98 percent of the hydrocarbon mass in the area of the used oil tank was removed during tank replacement activities.

The most current data on hydrocarbon concentrations in soil were collected in March and April 1993, and is reported in the RI/FS in Part 2.3, Tables 5 through 9, and Figures 5 and 6. Most locations tested showed non-detectable hydrocarbon concentrations at the capillary fringe, the target area for analysis. The maximum on-site benzene concentration is located at Well SP-1/V-4, at 0.59 ppm benzene. This level is below the proposed soil cleanup goal for benzene for the site.

The leaching potential and continuing contribution of benzene from soils to groundwater was generalized for the FTS, as a constant source of 330 ppb benzene in the groundwater. This value was based on the average benzene concentration in on-site groundwater monitoring wells.

We acknowledge that the remaining hydrocarbons in soil on site may require a long time to naturally biodegrade, and that prior to completion of this biodegradation they may present a continuing source to the groundwater. However, the mass of the remaining source is so low that active remediation of soils is not judged to be cost-effective. Also, the impact of this small mass source to groundwater is diminished by the existing on-site groundwater extraction system. Operation of this system until a stable plume configuration is confirmed is a primary element of Alternative 2.

8. *Although the on-site extraction system appears to have contributed to the reduction in contaminant migration since its operation began in 1991, MW-8 and MW-10, the*

> *closest monitoring wells downgradient of the site, continue to show elevated levels of TPHg and benzene. This data appears to indicate that contaminants continue to migrate off-site despite the on-site extraction system and/or that the contaminant plume in this area is not significantly biodegrading.*
>
> *Further efforts in contaminant source reduction, as presented Alternative 4 (Soil Vapor Extraction on Site, Institutional Controls for Groundwater Off Site, Air Sparging and Groundwater Extraction On Site) in the RI/FS and/or further investigations into the feasibility of off-site groundwater extraction from MW-10 should be considered as viable remediation efforts.*

The continuing presence of hydrocarbons in Wells MW-8 and MW-10 does not necessarily indicate continuing migration, or lack of biodegradation. The primary benefit of groundwater extraction is migration control of hydrocarbons. Some dissolved hydrocarbons may be "captured" by groundwater extraction. Even in the event hydrocarbons are not captured, the groundwater velocity immediately downgradient of the extraction well, beyond the capture zone, will be reduced. Thus, migration of hydrocarbons can be slowed, even without hydrocarbon "capture." This may be the case with Wells MW-8 and MW-10. Also, biodegradation would be expected to reduce hydrocarbon concentrations in these wells, but not as quickly as occurring on the fringe of the hydrocarbon plume. As the plume recedes from its most downgradient extent upgradient toward the site, Well MW-10 should continue to show decreasing benzene concentrations, and ultimately Well MW-8 should show this trend as well. Regardless, Alternative 2 proposes to manage the elevated hydrocarbon levels in Wells MW-8 and MW-10 using a groundwater management plan. We will continue to monitor the capture zone created by Well E-1A and its effect on groundwater migration in the area of Well MW-8.

As discussed above under Comment #7, further source reduction on site does not appear to be warranted, because the remaining mass source is quite small, based on 1993 data. Further, as noted under Comment #6, possible off-site corrective actions should only be considered if certain criteria are met in boundary wells (the boundary wells and the criteria will be proposed in a groundwater management plan).

Finally, ACHCSA expresses concern that contaminants may reach off-site receptors, and recommends efforts toward source reduction and plume containment. The best information which may be developed to demonstrate that off-site receptors will not be impacted, is to continue monitoring the site area. If concentrations increase in the domestic irrigation wells to levels that are not health-protective, well-specific actions can be implemented to reduce health risk to acceptable levels. These actions include discontinuing use of the well until concentrations decrease to health-protective levels. At this time, we do not judge that more aggressive remedial efforts are warranted.

We hope that we have sufficiently addressed many of the issues raised in your January 23, 1995 letter. It was our understanding that many of the issues raised had been clarified and/or approved during our July 1994 meeting, or had been presented in the RI/FS. It has been and remains our goal to work with ACHCSA to develop an RI/FS approach that is acceptable. We look forward to continuing discussion of these issues with you, Dr. Arulanantham, and the RWQCB.

Sincerely,

Pacific Environmental Group, Inc.

Keith Winemiller
Project Engineer

Debra J. Moser
Project Manager
CEG 1293

REGISTERED GEOLOGIST
DEBRA J. MOSER
No. 1293
CERTIFIED ENGINEERING GEOLOGIST
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STATE OF CALIFORNIA

Attachments:
Table 1 - Groundwater Analytical Data, Groundwater Monitoring Wells - Total Petroleum Hydrocarbons (TPH as Gasoline and BTEX Compounds)
Table 2 - Groundwater Analytical Data, Domestic Irrigation Wells - Total Petroleum Hydrocarbons (TPH as Gasoline and BTEX Compounds)

cc:
Dr. Ravi Arulanantham, Regional Water Quality Control Board
Mr. Kevin Graves, Regional Water Quality Control Board
Mr. Michael Whelan, ARCO Products Company
Mr. Chris Winsor, ARCO Products Company

Table 1

Groundwater Analytical Data

Groundwater Monitoring Wells

Total Petroleum Hydrocarbons

(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard at Hacienda Avenue
San Lorenzo, California

Well Number	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
MW-1	01/11/88	300	20	10	50	80
	06/14/88	Well Destroyed				
MW-2	07/05/85	32,000	1,000	690	NA[a]	1,500[a]
	01/11/88	3,300	804	115	168	166
	06/14/88	Well Destroyed				
MW-3	01/11/88	1,800	20	20	80	60
	03/07/89	150,000	4,600	5,200	5,600	13,000
	06/21/89	63,000	2,700	5,800	3,300	12,000
	12/12/89	Well Dry				
	03/29/90	1,100,000[b]	13,000	60,000	17,000	91,000
	06/22/90	Well Dry				
	07/18/90	Well Destroyed				
MW-4	01/11/88	62,000	2,700	7,900	850	5,200
	09/12/88	Separate-Phase Hydrocarbon Sheen				
	03/07/89	84,000	2,400	3,400	2,500	7,600
	06/21/89	31,000	400	800	200	1,500
	12/12/89	Well Dry				
	03/29/90	0.01 foot of Separate-Phase Hydrocarbon				
	06/22/90	Well Dry				
	07/18/90	Well Destroyed				
MW-5	01/11/88	31,000	4,000	2,700	3,800	5,500
	03/07/89	1,300	340	ND	140	50
	06/21/89	1,100	200	ND	130	40
	12/12/89	Well Dry				
	03/29/90	Well Dry				
	06/22/90	Well Dry				
	09/19/90	Well Dry				
	12/27/90	Well Dry				
	03/21/91	Well Dry				
	06/26/91	Well Dry				
	09/24/91	Well Dry				
	12/19/91	Well Dry				
	03/18/92	11,000	110	2.0	410	150
	06/15/92	Well Dry				
	09/16/92	Well Dry				
	12/22/92	960	220	6.5	4.0	2.0
	03/17/93	2,600	180	1.4	28	1.2
	06/17/93	2,500	450	7.5	55	<5

Table 1 (continued)

Groundwater Analytical Data
Groundwater Monitoring Wells
Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard at Hacienda Avenue
San Lorenzo, California

Well Number	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
MW-5 (cont.)	09/17/93	1,400	230	<5.0	6.7	<5.0
	12/29/93	690	38	2.1	2.7	3.8
	03/30/94	1,400	30	<5	<5	<5
	06/14/94	1,700	42	<5	<5	<5
	09/20/94	500	18	<0.5	<0.5	0.52
	12/20/94	840	19	2.2	1.1	2.3
MW-6 (E-1)	06/21/89	1,700	170	170	85	290
	12/12/89	500	26	7	8	18
	03/29/90	130	14	9	4	11
	06/22/90	150	15	5	4	13
	07/18/90	---------- Well Destroyed ----------				
MW-7	04/13/90	<50	<0.3	<0.3	<0.3	<0.3
	06/22/90	<50	0.5	1	0.6	3
	09/19/90	<50	<0.3	<0.3	<0.3	<0.3
	12/27/90	69	<0.3	0.3	0.4	2
	03/21/91	<30	<0.3	<0.3	<0.3	<0.3
	06/26/91	<30	<0.3	<0.3	<0.3	<0.3
	09/24/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/17/92	<30	<0.3	<0.3	<0.3	<0.3
	06/17/92	<30	<0.3	<0.3	<0.3	<0.3
	09/16/92	<50	<0.5	<0.5	<0.5	<0.5
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/17/93	<50	<0.5	<0.5	<0.5	<0.5
	06/15/93	<50	<0.5	<0.5	<0.5	<0.5
	09/14/93	<50	<0.5	<0.5	<0.5	<0.5
	12/29/93	<50	<0.5	<0.5	<0.5	<0.5
	03/30/94	<50	<0.5	<0.5	<0.5	<0.5
	06/14/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5
MW-8	04/13/90	4,900	350	16	450	33
	06/22/90	3,700	370	12	330	28
	09/19/90	140	4	3	3	3
	12/27/90	1,200	7	0.3	53	<0.3
	03/21/91	540	8.8	<6.0	21	9.6
	06/26/91	2,100	290	<6.0	56	<6.0
	09/24/91	260	51	0.34	7.9	<0.3
	12/19/91	5,300	300	<3.0	21	4.8
	03/17/92	9,200	370	3.0	48	4.9

Table 1 (continued)

Groundwater Analytical Data
Groundwater Monitoring Wells

Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard at Hacienda Avenue
San Lorenzo, California

Well Number	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
MW-8	06/17/92	3,300	460	2.7	63	6.9
(cont.)	09/16/92	1,500	58	<0.5	6.1	4.5
	12/22/92	3,600	410	56	62	4.4
	03/18/93	3,800	61	<0.5	11	1.2
	06/17/93	2,400	430	<5	11	<5
	09/14/93	1,900	36	1.4	32	8.6
	12/29/93	2,100	50	0.65	2.9	4.7
	03/29/94	1,900	220	<10	<10	<10
	06/14/94	2,800	340	<5	<5	<5
	09/20/94	2,100	46	<1.0	<1.0	<1.0
	12/20/94	1,800	120	<2.5	<2.5	<2.5
MW-9	04/13/90	<50	<0.3	<0.3	<0.3	2
	06/22/90	12,000	200	3	250	180
	09/19/90	<50	<0.3	<0.3	<0.3	0.6
	12/27/90	<50	<0.3	<0.3	<0.3	<0.3
	03/21/91	<30	<0.3	<0.3	<0.3	<0.3
	06/26/91	<30	<0.3	<0.3	<0.3	<0.3
	09/24/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/17/92	<30	<0.3	<0.3	<0.3	<0.3
	06/16/92	<30	<0.3	<0.3	<0.3	<0.3
	09/16/92	<50	<0.5	<0.5	<0.5	<0.5
	12/21/92	75[c]	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/15/93	<50	<0.5	<0.5	<0.5	<0.5
	09/14/93	<50	<0.5	<0.5	<0.5	<0.5
	12/29/93	<50	<0.5	<0.5	<0.5	<0.5
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/14/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5
MW-10	04/13/90	10,000	150	4	280	200
	06/22/90	9,700	28	<0.3	131	210
	09/19/90	1,800	<0.3	4	0.8	10
	12/27/90	5,700	7	3	95	61
	03/21/91	6,900	22	<15	92	33
	06/26/91	9,300	51	<0.3	59	34
	09/24/91	360	8.6	5.2	14	6.2
	12/19/91	3,300	9.2	8.4	11	17
	03/18/92	4,700	14	<6.0	29	10
	06/16/92	4,800	0.46	0.34	7.4	3.8

Table 1 (continued)

Groundwater Analytical Data

Groundwater Monitoring Wells

Total Petroleum Hydrocarbons

(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard at Hacienda Avenue
San Lorenzo, California

Well Number	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
MW-10 (cont.)	09/16/92	2,000	8.3	3.0	3.3	5.5
	12/22/92	2,700^{c}	6.2	<1.0	7.5	2.8
	03/16/93	4,100	340	2.4	58	54
	06/17/93	4,900	860	<10	540	92
	09/17/93	4,500	670	<10.0	240	7.2
	12/28/93	5,000	1,200^{d}	12	46	31
	03/29/94	4,700	470	<10	29	45
	06/14/94	3,700	370	<1.0	<1.0	<1.0
	09/20/94	2,600	79	<2.5	7.4	2.7
	12/20/94	3,000	150	<5.0	<5.0	<5.0
MW-11	04/13/90	<50	<0.3	<0.3	<0.3	<0.3
	06/22/90	63	0.4	0.9	0.7	3
	09/19/90	<50	<0.3	<0.3	<0.3	<0.3
	12/27/90	<50	<0.3	<0.3	<0.3	<0.3
	03/21/91	<30	<0.3	<0.3	<0.3	<0.3
	06/26/91	<30	<0.3	<0.3	<0.3	<0.3
	09/24/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/17/92	<30	<0.3	<0.3	<0.3	<0.3
	06/16/92	<30	<0.3	<0.3	<0.3	<0.3
	09/16/92	<50	<0.5	<0.5	<0.5	<0.5
	12/22/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/16/93	<50	<0.5	<0.5	<0.5	<0.5
	09/14/93	<50	<0.5	<0.5	<0.5	<0.5
	12/29/93	<50	<0.5	<0.5	<0.5	<0.5
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5
E-1A (MW-12)	09/19/90	<50	7	0.9	1	2
	12/27/90	<50	3	0.5	1	1
	03/21/91	<30	4.2	<0.3	1.1	0.89
	06/26/91	41	6.3	<0.3	1.2	0.59
		-------------------------- Converted to Extraction Well 8/91 --------------------------				
	03/28/94	120	4.8	<0.50	5.7	4.1
	06/14/94*	230	12	<0.5	16	1.5
	09/20/94*	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	2.4	<0.5	1.9	<0.5
MW-13	07/03/91	<30	<0.3	<0.3	<0.3	<0.3
	09/24/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3

Table 1 (continued)

Groundwater Analytical Data
Groundwater Monitoring Wells

Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard at Hacienda Avenue
San Lorenzo, California

Well Number	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
MW-13 (cont.)	03/17/92	<30	<0.3	<0.3	<0.3	<0.3
	06/17/92	<30	<0.3	<0.3	<0.3	<0.3
	09/16/92	<50	<0.5	<0.5	<0.5	<0.5
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/17/93	<50	<0.5	<0.5	<0.5	<0.5
	06/15/93	<50	<0.5	<0.5	<0.5	<0.5
	09/14/93	<50	<0.5	<0.5	<0.5	<0.5
	12/29/93	<50	<0.5	<0.5	<0.5	<0.5
	03/30/94	<50	<0.5	<0.5	<0.5	<0.5
	06/14/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5
MW-14	07/03/91	<30	<0.3	<0.3	<0.3	<0.3
	09/24/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/17/92	<30	<0.3	<0.3	<0.3	<0.3
	06/16/92	<30	<0.3	<0.3	<0.3	<0.3
	09/16/92	<50	<0.5	<0.5	<0.5	<0.5
	12/22/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/15/93	<50	<0.5	<0.5	<0.5	<0.5
	09/15/93	<50	<0.5	<0.5	<0.5	<0.5
	12/28/93	<50	<0.5	<0.5	<0.5	<0.5
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5
MW-15	07/03/91	570	1.8	1.0	1.0	2.2
	09/24/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	360	<0.6	<0.6	0.64	<0.6
	03/18/92	730	0.74	0.98	1.8	0.68
	06/16/92	310	0.54	0.34	0.96	2.5
	09/16/92	100	1.0	<0.5	<0.5	<0.5
	12/22/92	130[c]	<0.5	<0.5	<0.5	<0.5
	03/18/93	130[c]	<0.5	<0.5	<0.5	<0.5
	06/17/93	<50	<0.5	<0.5	<0.5	<0.5
	09/17/93	<50	<0.5	<0.5	<0.5	<0.5
	12/29/93	52	<0.5	<0.5	<0.5	1.5
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5

Table 1 (continued)

Groundwater Analytical Data
Groundwater Monitoring Wells

Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard at Hacienda Avenue
San Lorenzo, California

Well Number	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
MW-16	07/03/91	2,700	31	6.9	4.6	3.1
	09/24/91	430	1.8	1.3	1.9	1.5
	12/19/91	75	<0.3	<0.3	<0.3	<0.3
	03/18/92	1,500	4.0	0.73	2.2	1.3
	06/16/92	80	<0.3	<0.3	<0.3	<0.3
	09/16/92	<50	<0.5	<0.5	<0.5	<0.5
	12/22/92	<50	<0.5	<0.5	<0.5	<0.5
	03/18/93	380[c]	<0.5	<0.5	<0.5	<0.5
	06/17/93	<50	<0.5	<0.5	<0.5	<0.5
	09/17/93	<50	<0.5	<0.5	<0.5	<0.5
	12/28/93	<50	<0.5	<0.5	0.72	<0.5
	03/28/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	52	<0.5	<0.5	<0.5	<0.5
MW-17	07/03/91	1,200	12	1.9	28	40
	09/24/91	150	2.7	0.5	3.9	0.59
	12/19/91	370	2.6	<0.3	7.2	6.5
	03/18/92	470	3.1	<0.3	9.1	8.6
	06/16/92	310	1.7	0.56	12	9.6
	09/16/92	77	1.5	<0.5	1.2	1.0
	12/21/92	220	1.2	<0.5	9.8	9.4
	03/17/93	250	<0.5	<0.5	7.8	3.3
	06/17/93	90	0.92	<0.5	2.7	2.4
	09/16/93	140	<0.5	<0.5	5.4	3.9
	12/29/93	<50	<0.5	<0.5	<0.5	<0.5
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/15/94	62	<0.5	<0.5	1.2	<0.90
	09/19/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	77	<0.5	<0.5	1.6	0.67
MW-18	10/04/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/18/92	<30	<0.3	<0.3	<0.3	<0.3
	06/15/92	<30	<0.3	<0.3	<0.3	<0.3
	09/15/92	<50	<0.5	<0.5	<0.5	<0.5
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/17/93	<50	<0.5	<0.5	<0.5	<0.5
	06/16/93	<50	<0.5	<0.5	<0.5	<0.5
	09/16/93	<50	<0.5	<0.5	<0.5	<0.5
	12/28/93	<50	<0.5	<0.5	<0.5	<0.5
	03/28/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5

Table 1 (continued)

Groundwater Analytical Data

Groundwater Monitoring Wells

Total Petroleum Hydrocarbons

(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard at Hacienda Avenue
San Lorenzo, California

Well Number	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
MW-19	10/04/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/18/92	<30	<0.3	<0.3	<0.3	<0.3
	06/15/92	<30	<0.3	<0.3	<0.3	<0.3
	09/15/92	<50	<0.5	<0.5	<0.5	<0.5
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/17/93	<50	<0.5	<0.5	<0.5	<0.5
	06/16/93	<50	<0.5	<0.5	<0.5	<0.5
	09/16/93	<50	<0.5	<0.5	<0.5	<0.5
	12/28/93	<50	<0.5	<0.5	<0.5	<0.5
	03/28/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/19/94	<50	<0.5	<0.5	<0.5	<0.5
	12/19/94	<50	<0.5	<0.5	<0.5	<0.5
MW-20	10/04/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/18/92	<30	<0.3	<0.3	<0.3	<0.3
	06/15/92	<30	<0.3	<0.3	<0.3	<0.3
	09/15/92	<50	<0.5	<0.5	<0.5	<0.5
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/17/93	<50	<0.5	<0.5	<0.5	<0.5
	06/16/93	<50	<0.5	<0.5	<0.5	<0.5
	10/11/93	------------------------------------ Well Destroyed ------------------------------------				
MW-21	10/04/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/18/92	<30	<0.3	<0.3	<0.3	<0.3
	06/15/92	<30	<0.3	<0.3	<0.3	<0.3
	09/15/92	<50	<0.5	<0.5	<0.5	<0.5
	12/22/92	<50	<0.5	<0.5	<0.5	<0.5
	03/17/93	<50	<0.5	<0.5	<0.5	<0.5
	06/16/93	<50	<0.5	<0.5	<0.5	<0.5
	09/16/93	<50	<0.5	<0.5	<0.5	<0.5
	12/28/93	<50	<0.5	<0.5	<0.5	<0.5
	03/28/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/19/94	<50	<0.5	<0.5	<0.5	<0.5
	12/19/94	<50	<0.5	<0.5	<0.5	<0.5
MW-22	10/04/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/17/92	<30	<0.3	<0.3	<0.3	<0.3
	06/15/92	<30	<0.3	<0.3	<0.3	<0.3

Table 1 (continued)

Groundwater Analytical Data
Groundwater Monitoring Wells

Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard at Hacienda Avenue
San Lorenzo, California

Well Number	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
MW-22 (cont.)	09/15/92	<50	<0.5	<0.5	<0.5	<0.5
	12/22/92	<50	<0.5	<0.5	<0.5	<0.5
	03/17/93	<50	<0.5	<0.5	<0.5	<0.5
	06/16/93	<50	<0.5	<0.5	<0.5	<0.5
	09/16/93	<50	<0.5	<0.5	<0.5	<0.5
	12/28/93	<50	<0.5	<0.5	<0.5	<0.5
	03/28/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/19/94	<50	<0.5	<0.5	<0.5	<0.5
	12/19/94	<50	<0.5	<0.5	<0.5	<0.5
MW-23	10/04/91	<30	<0.3	<0.3	<0.3	<0.3
	12/19/91	<30	<0.3	<0.3	<0.3	<0.3
	03/17/92	<30	<0.3	<0.3	<0.3	<0.3
	06/15/92	<30	<0.3	<0.3	<0.3	<0.3
	09/15/92	<50	<0.5	<0.5	<0.5	<0.5
	12/22/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/16/93	<50	<0.5	<0.5	<0.5	<0.5
	09/15/93	<50	<0.5	<0.5	<0.5	<0.5
	12/28/93	<50	<0.5	<0.5	<0.5	<0.5
	03/28/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/19/94	<50	<0.5	<0.5	<0.5	<0.5
	12/19/94	<50	<0.5	<0.5	<0.5	<0.5
MW-24	03/29/93	<50	<0.5	<0.5	<0.5	<0.5
	06/15/93	<50	<0.5	<0.5	<0.5	<0.5
	09/14/93	<50	<0.5	<0.5	<0.5	<0.5
	12/29/93	<50	<0.5	<0.5	<0.5	<0.5
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5
MW-25	03/29/93	<50	0.69	<0.5	<0.5	<0.5
	06/15/93	<50	<0.5	<0.5	<0.5	<0.5
	09/14/93	<50	<0.5	<0.5	<0.5	<0.5
	12/29/93	<50	<0.5	<0.5	<0.5	<0.5
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5

Table 1 (continued)

Groundwater Analytical Data

Groundwater Monitoring Wells

Total Petroleum Hydrocarbons

(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard at Hacienda Avenue
San Lorenzo, California

Well Number	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
MW-26	03/29/93	<50	<0.5	<0.5	<0.5	<0.5
	06/15/93	<50	<0.5	<0.5	<0.5	<0.5
	09/14/93	<50	<0.5	<0.5	<0.5	<0.5
	12/29/93	<50	<0.5	<0.5	<0.5	<0.5
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/13/94	<50	<0.5	<0.5	<0.5	<0.5
	09/20/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5

ppb = Parts per billion
NA = Not available
a. Ethylbenzene and xylenes given as a combined value.
b. Well contained slight product sheen.
c. Non-typical gasoline chromatograph pattern.
d. Anomalous data point.
< = Denotes minimum laboratory detection limits. See attached certified analytical reports.
* = Value taken from system influent sampling.
MW-1 and MW-2 destroyed prior to March 7, 1989 sampling event.
MW-3, MW-4, and MW-6 (E-1) destroyed June 18, 1990.

Table 2

Groundwater Analytical Data
Domestic Irrigation Wells

Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

Hacienda Avenue and Via Magdalena
San Lorenzo, California

Well Address	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
590 H	11/13/91	<30	<0.3	<0.3	<0.3	<0.3
	10/14/92	<50	<0.5	<0.5	<0.5	<0.5
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/17/93	<50	<0.5	<0.5	<0.5	<0.5
	09/16/93	<50	<0.5	<0.5	<0.5	<0.5
	12/30/93[a]	NS	NS	NS	NS	NS
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/16/94	<50	<0.5	<0.5	<0.5	<0.5
	09/21/94	<50	<0.5	<0.5	<0.5	<0.5
	12/21/94	<50	<0.5	<0.5	<0.5	<0.5
633 H	09/11/91[b,d]	NS	NS	NS	NS	NS
	10/14/92[a]	NS	NS	NS	NS	NS
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/17/93	<50	<0.5	<0.5	<0.5	<0.5
	09/15/93[b,d]	NS	NS	NS	NS	NS
	12/30/93[b,d]	NS	NS	NS	NS	NS
	03/29/94[b,d]	NS	NS	NS	NS	NS
	06/15/94[b,d]	NS	NS	NS	NS	NS
	09/21/94[b,d]	NS	NS	NS	NS	NS
	10/07/94	<50	<0.5	<0.5	<0.5	<0.5
	12/21/94	<50	<0.5	<0.5	<0.5	<0.5
634 H	09/11/91[b,d]	NS	NS	NS	NS	NS
	10/14/92[a]	NS	NS	NS	NS	NS
	12/21/92[b,d]	NS	NS	NS	NS	NS
	03/16/93[b,d]	NS	NS	NS	NS	NS
	06/17/93[b,d]	NS	NS	NS	NS	NS
	09/15/93[a]	NS	NS	NS	NS	NS
	12/30/93[b,d]	NS	NS	NS	NS	NS
	03/29/94[b,d]	NS	NS	NS	NS	NS
	06/15/94	NS	NS	NS	NS	NS
	09/21/94[b,d]	NS	NS	NS	NS	NS
	12/21/94[b,d]	NS	NS	NS	NS	NS
642 H	11/13/91	<30	<0.3	<0.3	<0.3	<0.3
	10/16/92	<50	<0.5	<0.5	<0.5	<0.5
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/17/93	<50	<0.5	<0.5	<0.5	<0.5
	09/16/93	<50	<0.5	<0.5	<0.5	<0.5
	12/30/93[a]	NS	NS	NS	NS	NS
	03/30/94	<50	<0.5	<0.5	<0.5	<0.5

Table 2 (continued)
Groundwater Analytical Data
Domestic Irrigation Wells
Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

Hacienda Avenue and Via Magdalena
San Lorenzo, California

Well Address	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
642 H (cont.)	06/15/94	NS	NS	NS	NS	NS
	09/21/94[b,d]	NS	NS	NS	NS	NS
	12/21/94[b,d]	NS	NS	NS	NS	NS
675 H	09/11/91[b,d]	NS	NS	NS	NS	NS
	10/14/92[a]	NS	NS	NS	NS	NS
	12/21/92[b,d]	NS	NS	NS	NS	NS
	03/16/93[b,d]	NS	NS	NS	NS	NS
	06/17/93[b,d]	NS	NS	NS	NS	NS
	09/15/93[a]	NS	NS	NS	NS	NS
	12/30/93[a]	NS	NS	NS	NS	NS
	03/29/94[a]	NS	NS	NS	NS	NS
	06/15/94[a]	NS	NS	NS	NS	NS
	09/22/94	<50	<0.5	<0.5	<0.5	<0.5
	12/21/94[b,d]	NS	NS	NS	NS	NS
17197 VM	11/13/91	<30	<0.3	<0.3	<0.3	<0.3
	10/14/92	<50	<0.5	<0.5	<0.5	<0.5
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/17/93	<50	<0.5	<0.5	<0.5	<0.5
	09/16/93	<50	<0.5	<0.5	<0.5	<0.5
	12/30/93	<50	<0.5	<0.5	<0.5	<0.5
	03/30/94	<50	<0.5	<0.5	<0.5	<0.5
	06/15/94	<50	<0.5	<0.5	<0.5	<0.5
	09/21/94[a]	NS	NS	NS	NS	NS
	12/21/94	<50	<0.5	<0.5	<0.5	<0.5
17200 VM	11/13/91	440	2.7	<0.3	<0.3	12
	10/14/92[a]	NS	NS	NS	NS	NS
	12/18/92	160	1.4	<0.5	<0.5	3.4
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/16/93	<50	<0.5	<0.5	<0.5	<0.5
	09/15/93	<50	<0.5	<0.5	<0.5	<0.5
	12/30/93	<50	<0.5	<0.5	<0.5	<0.5
	03/29/94	<50	<0.5	<0.5	<0.5	<0.5
	06/15/94	<50	<0.5	<0.5	<0.5	<0.5
	09/21/94	<50	<0.5	<0.5	<0.5	<0.5
	12/20/94	<50	<0.5	<0.5	<0.5	<0.5
17203 VM	11/13/91	<30	<0.3	<0.3	<0.3	<0.3
	10/16/92[a]	NS	NS	NS	NS	NS
	12/21/92	<50	<0.5	<0.5	<0.5	1.3
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5

Table 2 (continued)

Groundwater Analytical Data
Domestic Irrigation Wells

Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

Hacienda Avenue and
Via Magdalena
San Lorenzo, California

Well Address	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
17203 VM (cont.)	06/17/93	<50	<0.5	<0.5	<0.5	<0.5
	09/16/93	<50	<0.5	<0.5	<0.5	<0.5
	12/30/93	<50	<0.5	<0.5	<0.5	<0.5
	03/30/94	<50	<0.5	<0.5	<0.5	<0.5
	06/15/94	<50	<0.5	<0.5	<0.5	<0.5
	09/21/94[a]	NS	NS	NS	NS	NS
	12/21/94	<50	<0.5	<0.5	<0.5	<0.5
17302 VM	10/21/91	72	0.64	<0.3	0.44	<0.3
	10/14/92[a]	NS	NS	NS	NS	NS
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/17/93[b,d]	NS	NS	NS	NS	NS
	09/16/93	66	<0.5	<0.5	<0.5	<0.5
	12/30/93	<50	<0.5	<0.5	<0.5	<0.5
	03/30/94	<50	<0.5	<0.5	<0.5	<0.5
	06/15/94	<50	<0.5	<0.5	<0.5	<0.5
	03/30/94	<50	<0.5	<0.5	<0.5	<0.5
	06/15/94	<50	<0.5	<0.5	<0.5	<0.5
	09/21/94[a]	NS	NS	NS	NS	NS
	12/21/94	<50	<0.5	<0.5	<0.5	<0.5
17348 VM	11/13/91[b,d]	NS	NS	NS	NS	NS
	10/14/92[a]	NS	NS	NS	NS	NS
	12/21/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/16/93	<50	<0.5	<0.5	<0.5	<0.5
	09/15/93	<50	<0.5	<0.5	<0.5	<0.5
	12/30/93[b,d]	NS	NS	NS	NS	NS
	03/30/94	<50	<0.5	<0.5	<0.5	<0.5
	06/15/94	<50	<0.5	<0.5	<0.5	<0.5
	09/21/94[a]	NS	NS	NS	NS	NS
	12/21/94	<50	<0.5	<0.5	<0.5	<0.5
17349 VM	09/27/91	780	13	<3.0	<3.0	<3.0
	10/14/92	2,200	<50	<50	<50	110
	12/18/92	1,500	14	1.8	7.1	56
	03/16/93	1,100	16	4.2	1.8	1.8
	06/17/93	1,100	1.5	6.7	2.9	7.9
	09/16/93	1,200	13	21	3.0	10
	12/30/93[a]	NS	NS	NS	NS	NS
	03/30/94	420	<1	<1	<1	5.3

Table 2 (continued)

Groundwater Analytical Data

Domestic Irrigation Wells

Total Petroleum Hydrocarbons

(TPH as Gasoline and BTEX Compounds)

Hacienda Avenue and
Via Magdalena
San Lorenzo, California

Well Address	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
17349 VM	06/15/94	460	<0.5	<0.5	<0.5	1.8
	09/21/94	590	1.8	<0.5	1.1	7.6
	12/21/94	670	<0.5	<0.5	<0.5	1.8
17371 VM	11/13/91	870	9.0	1.0	2.1	4.5
	10/14/92	<50	<0.5	<0.5	<0.5	<0.5
	12/18/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	500	8.7	<0.5	3.9	3.1
	06/17/93[c]	NS	NS	NS	NS	NS
	09/16/93[c]	NS	NS	NS	NS	NS
	12/30/93[c]	NS	NS	NS	NS	NS
	03/30/94[c]	NS	NS	NS	NS	NS
	06/15/94[c]	NS	NS	NS	NS	NS
	09/21/94[c]	NS	NS	NS	NS	NS
	12/21/94[c]	NS	NS	NS	NS	NS
17372 VM	09/27/91	300	5.5	<0.60	1.3	0.72
	10/14/92	220	<1.0	<1.0	<1.0	<1.0
	12/18/92	290	3.8	0.88	0.99	1.2
	03/16/93	110*	<0.5	<0.5	<0.5	<0.5
	06/17/93	140	<0.5	1.3	0.63	1.1
	09/15/93	120	<0.5	1.1	0.62	1.2
	12/30/93	<50	<0.5	<0.5	<0.5	<0.5
	03/30/94	<50	<0.5	<0.5	<0.5	<0.5
	06/15/94	110	<0.5	<0.5	<0.5	<0.5
	09/21/94	55	<0.5	<0.5	<0.5	<0.5
	12/21/94	<50	<0.5	<0.5	<0.5	<0.5
17393 VM	11/13/91	31	<0.3	<0.3	<0.3	<0.3
	10/14/92[a]	NS	NS	NS	NS	NS
	12/18/92	<50	<0.5	<0.5	<0.5	<0.5
	03/16/93	<50	<0.5	<0.5	<0.5	<0.5
	06/17/93	<50	<0.5	<0.5	<0.5	<0.5
	09/15/93	<50	<0.5	<0.5	<0.5	<0.5
	12/30/93[a]	NS	NS	NS	NS	NS
	12/30/93	<50	<0.5	<0.5	<0.5	<0.5
	03/30/94	50	<0.5	<0.5	<0.5	<0.5
	06/15/94	<50	<0.5	<0.5	<0.5	<0.5

Table 2 (continued)

Groundwater Analytical Data

Domestic Irrigation Wells

Total Petroleum Hydrocarbons

(TPH as Gasoline and BTEX Compounds)

Hacienda Avenue and
Via Magdalena
San Lorenzo, California

Well Address	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
17393 VM	09/21/94[a]	NS	NS	NS	NS	NS
(cont.)	12/21/94	<50	<0.5	<0.5	<0.5	<0.5

ppb = Parts per billion
H = Hacienda Avenue
VM = Via Magdalena
< = Denotes laboratory detection limit
NS = Not sampled
* = Non-typical chromatogram pattern, did not sample.
a. Owner not available to approve sampling access, well not sampled.
b. Pump not functioning, well not sampled.
c. Access denied by owner, well not sampled.
d. Pumping equipment obstructing sampling access, well not sampled.
Homeowners are contacted 1 week prior to sampling event.

PACIFIC
ENVIRONMENTAL
GROUP INC.

FACSIMILE TRANSMITTAL

DATE: 4-6-95

PROJ. # 330-006.3C

TO: KEVIN GRAVES
RWQCB

FAX: 510-286-1380

FROM: KEITH WINGMILLER

IF YOU HAVE ANY PROBLEMS RECEIVING THIS FACSIMILE, PLEASE CALL (408) 441-7500

SHEETS TO FOLLOW COVER PAGE

11

COMMENTS: I WILL TRANSMIT THE BACK-UP TABLES (14 PAGES) AFTER THE TEXT IS FAX'D. THAT WAY YOU CAN BEGIN YOUR REVIEW SOONER, OR DISREGARD IF UNNECESSARY.

THANKS

KEITH.

P.S. ~~BE~~ I'LL BE OUT-~~OF~~ THE OFFICE 10:40 - NOON. TODAY

Keith's

PACIFIC
ENVIRONMENTAL
GROUP INC.

March 7, 1995
Project 330-006.3C

Ms. Amy Leech
Ms. Juliet Shin
Department of Environmental Health
Environmental Protection Division
Alameda County Health Care Services Agency
1131 Harbor Bay Parkway, Suite 250
Alameda, California 94502-6577

Re: Response to ACHCSA Letter, dated January 23, 1995
ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Dear Ms. Leech and Ms. Shin:

On behalf of ARCO Products Company (ARCO), Pacific Environmental Group, Inc. (PACIFIC) prepared this letter to respond to Alameda County Health Care Services Agency's (ACHCSA's) letter to ARCO, dated January 23, 1995. The ACHCSA letter responded to the Remedial Investigation/Feasibility Study (RI/FS) submitted by PACIFIC to ACHCSA on November 22, 1994 for the site referenced above. This response letter begins with some overall comments, then responds individually to the comments and questions raised by ACHCSA.

OVERALL COMMENTS

ARCO and PACIFIC agree with some of ACHCSA's comments and we present clarifying information where we find it appropriate. We believe that some of the issues can be resolved through consultation with Dr. Ravi Arulanantham, whose comments on the RI/FS have not yet been received. We believe that it is essential to keep Dr. Arulanantham involved in this project, as he is uniquely qualified and has provided valuable guidance for the RI/FS thus far. He also contributes considerable expertise in the fields of risk assessment and biodegradation of hydrocarbons. Therefore, before undertaking any additional field tasks to investigate areas of concern raised by ACHCSA, we propose that a meeting be held, to include Dr. Arulanantham, ACHCSA,

2025 Gateway Place, Suite 440, San Jose, California 95110 (408) 441-7500 FAX (408) 441-7539

the California Regional Water Quality Control Board (RWQCB), ARCO, and PACIFIC, to agree on what (if any) additional information is required, and what is the best way to collect that information.

RESPONSE TO SPECIFIC ISSUES

1. *Was the pump in Extraction Well EA-1 lowered as discussed during the July 8, 1994 meeting? If yes, was the capture zone for this new pump depth incorporated into the Fate and Transport Study (FTS)?*

The pump in the Extraction Well E-1A was lowered to a depth of approximately 23.5 feet in July 1994. As is standard for groundwater flow models, the FTS does not incorporate the depth of the extraction pump. Instead, it incorporates a specific volume of water removed per unit time at the extraction well location, along with other aquifer properties. The pumping rate used in the FTS was 577.5 feet^3 per day. The model used was MT3D, which is generally regarded as one the most sophisticated and widely accepted models for fate and transport studies. This model was approved for use at this site by ACHCSA.

2. *Sufficient data was not provided to prove that pumping of domestic irrigation wells is or is not affecting plume migration. PACIFIC agreed to request that the home-owners do not pump through 1995 to allow more time to determine if the pumping of domestic irrigation wells is a factor in plume migration. Furthermore, we urge ARCO to convince the remaining four homeowners who continue to pump, to stop pumping until the impact of off-site pumping is known.*

We believe that sufficient information exists to determine that the pumping of domestic irrigation wells will not affect plume migration. This was the conclusion of the FTS, wherein known maximum domestic irrigation well pumping rates for key wells were tripled, then incorporated into the FTS. The pumping rates used in the FTS for these wells were presented in Table A-1 of the RI/FS. The results of the FTS indicated that the combined pumping of Extraction Well E-1A and the key domestic irrigation wells had no appreciable affect on plume migration. The results also indicated that either non-detectable or health-protective hydrocarbon concentrations should be present in the domestic irrigation wells.

We agree with ACHCSA that a conservative approach through 1995 is prudent. Therefore, even though pumping does not pose a health concern, we are requesting all 14 domestic irrigation well owners for their cooperation in not pumping their wells and allowing PACIFIC to sample those wells quarterly through 1995. The request letters were sent to the well owners on February 27, 1995; copies of the letters were sent to ACHCSA. If any of the well owners do not respond or do not wish to cooperate, we will follow up with one additional letter or try to meet with them in person to obtain their cooperation.

3. *If domestic irrigation wells are to be used as sentinel or boundary wells, then well construction of those wells should be defined. Based on the RI/FS proposal, well 633H is intended to be used as a boundary or trigger well. If that is the case, well construction details are required for this well....*

We wish to clarify the purpose of Well 633 H and the other domestic irrigation wells. We are not proposing that any of these wells be used as boundary wells for management of the groundwater hydrocarbon plume. Instead, the domestic irrigation wells will be monitored to verify protection of human health and the environment. The results of the risk assessment indicated that the impacted groundwater does not currently pose a health concern. The monitoring data would be used to perform health risk evaluations to verify that concentrations of hydrocarbons (if any) in the domestic irrigation wells remain health protective. Therefore, construction details for these wells are not critical.

We agree with ACHCSA that well construction details are necessary for the boundary wells that are used to manage the groundwater hydrocarbon plume. Therefore, the configuration of the hydrocarbon plume in the shallow water-bearing zone will be monitored via monitoring wells constructed for that purpose, and may include Wells MW-11, MW-14, MW-15, MW-16, and possibly MW-17. We will develop the groundwater management plan in conjunction with ACHCSA following approval of the RI/FS. This plan will identify the boundary wells, their sampling requirements, and corrective actions, including possible active remediation, if certain implementation criteria are met in the boundary wells. The implementation criteria would be consistent with recently RWQCB-adopted Non-Attainment Zone policy, however, we are not proposing to specifically establish a non-attainment zone for the site. Alternative 2 proposes institutional controls consisting of a groundwater management plan that includes regular groundwater monitoring and sampling, and health risk evaluation.

4. *An assumption was made in the FTS that the half-life of 110 days for dissolved benzene is the most reasonable rate based on site lithology. A Sensitivity Study was also performed using a half-life of 250 days.*

   How do these rates compare to the biodegradation rates provided by the EPA's Toxicological Profile for Benzene? Please provide us data that relates to similar subsurface conditions of the subject site.

The biodegradation rate of 110 days used for benzene was selected based on published data cited in the RI/FS and presented at the July 8, 1994 meeting between ACHCSA, RWQCB, ARCO, and PACIFIC. The purpose of that meeting was to obtain approval of our RI/FS approach, including FTS modeling parameters like the biodegradation rate for benzene. At that meeting, no objection was raised regarding the use of the 110 day biodegradation rate for benzene. References for the published rate were submitted to ACHCSA following that meeting as requested, and until ACHCSA's January 23, 1995 letter, we did not receive any feedback that the biodegradation rate proposed and used was inappropriate. The area of biodegradation of hydrocarbons is one of those where Dr. Arulanantham's input is essential. Nevertheless, the requested information and source is given below.

> "The degradation of benzene by microorganisms has been well researched, and the conclusion reached is that benzene is biodegradable (e.g. see Haider et al. 1981, Hopper 1978, Setzkorn and Huddleston 1965, Tabak et al. 1981, Gibson 1977, Higgens et al. 1980, Smith and Rosazza 1974, Korte and Klein 1982, Unger and Claff 1985).
>
> The above-mentioned studies document the aerobic degradation of benzene, and, although far less information is available, benzene apparently is biodegraded under anaerobic conditions although probably somewhat slower than aerobically. One study that illustrates this is the research of Wilson et al. (1986). These investigators found that under anaerobic conditions in the laboratory, benzene was not significantly degraded during the first 20 weeks of incubation, but, by 40 weeks of incubation, benzene concentrations were reduced by 72%. At 120 weeks of incubation over 99% degradation had taken place. However, Batterman [1986, as reported in *Chem. Abstr.* 104(24):212909U], in investigating the in situ anoxic biological treatment of a hydrocarbon-contaminated aquifer, reported the complete removal of benzene after only 6 months. Gibson (1980) presents a proposed pathway for the anaerobic biodegradation of aromatic compounds.
>
> As discussed by Gibson (1980) and Hopper (1978), microbial metabolism of benzene proceeds through the formation of *cis*-dihydrodiols and, with further oxidation, to catechols which are the substrates for ring fission. Thus, before going to catechol, benzene biodegrades to 1,1-dihydroxoxy-1,2-dihydrobenzene (Gibson 1980).
>
> One important point must be made. The results of laboratory experiments which characterize most of the above, especially those using large numbers of organisms known to degrade benzene, must be carefully applied to field situations. An example of this is seen in the studies of Haider et al. (1981). *Nocardis* species and *Pseudomonas* species, after cultivation on benzene, effectively degraded benzene after 7 days (45 to 90%); however, when 100 g soil with a mixed bacteria population was mixed with 2 mg benzene, only 47% of the added radioactivity was recovered as CO_2 after 10 weeks. Haider et al. concluded that specific organisms which degrade benzene were present in the soil in only small numbers."
>
> Source: Toxicological Profile for Benzene, Oak Ridge National Laboratory for U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry, May 1989.

As indicated above, the reference cites complete degradation of benzene under anaerobic conditions after 120 weeks, or an equivalent half-life of 126 days. The reference also cites studies that indicate the aerobic biodegradation rate for benzene ranges from 7 to 70 days. Field data collected from monitoring and domestic irrigation wells show dissolved oxygen (DO) in groundwater ranges from 2 to 9 parts per million (ppm). These DO concentrations support aerobic biodegradation of benzene in groundwater.

Therefore, the selected biodegradation rate of 110 days for benzene is appropriate, and should be considered conservative.

At the July meeting, alternate biodegradation rates were suggested by Dr. Arulanantham. These rates (6 and 250 days) were suggested in order to evaluate the effects of varying biodegradation rates on the hydrocarbon plume (sensitivity analysis). The more-conservative biodegradation rate of 250 days was evaluated as requested and the results of the sensitivity analysis showed similar characteristics to results using a 110 day biodegradation rate. The less-conservative biodegradation rate was not evaluated because this rate is based on laboratory research and does not readily apply to field conditions.

5. *How do we know that contaminant attenuation observed has been due to biodegradation as opposed to adsorption and dilution? It is difficult to predict that significant biodegradation is occurring within the groundwater, capillary fringe, and vadose zone at the source and downgradient of the source of contamination.*

   A study by PACIFIC dated October 12, 1993, was made on the feasibility of in-situ bioremediation of contaminated soil at the site. The study concluded that "...characteristics favorable to bioremediation were not sufficient to warrant further study."

   Although a case comparison was made in the RI/FS to support the theory that groundwater characteristics are favorable to bioremediation at the ARCO site, we do not see enough evidence to support the assumption the Case Study groundwater characteristics are "remarkably similar" to the ARCO site.

   Because it is difficult to predict a biodegradation rate based on qualitative data, we recommend that a Fate and Transport Sensitivity Model Study be completed for a worse case scenario where biodegradation does not occur, i.e. the half-life for benzene is null.

   Furthermore, on-site specific data should be collected to support that sufficient biodegradation is occurring in the groundwater....

These comments suggest that ACHCSA is not convinced that biodegradation is taking place at the site. Considering: (1) the general observed decline in hydrocarbon concentrations in the off-site wells, (2) the excess dissolved oxygen measured in groundwater, and (3) the abundant published literature indicating that petroleum hydrocarbons, especially benzene, are biodegradable, we find it quite logical that biodegradation as well as other possible mechanisms for natural attenuation like dilution (dispersion), and adsorption, is occurring. Specific responses to the points raised by ACHCSA follow.

The FTS conducted at the site included effects of dilution, but not adsorption, in order to be more conservative. By including adsorption in the model, the hydrocarbon concentrations in groundwater should migrate downgradient at a slower rate than with biodegradation alone.

The feasibility study conducted in 1993 addressed biodegradation in soils, not groundwater. Oxygen, which is generally the limiting factor in biodegradation, is present in the groundwater in sufficient concentrations for aerobic biodegradation to occur.

ACHCSA states that insufficient evidence exists to state that the case study and the ARCO site are "remarkably similar." We found the similarities in the groundwater mineral quality and dissolved oxygen to be significant. However, the case study is less relevant than the actual hydrocarbon concentrations at the site, which have decreased markedly between 1991 and 1994. Figures 11 and 12 in the RI/FS illustrate this decrease.

To summarize, PACIFIC judges that several lines of evidence indicate that biodegradation is occurring at the site. Furthermore, previous communications with ACHCSA and the RWQCB have accepted the occurrence of biodegradation, with the recommendation that a sensitivity study with an extremely conservative biodegradation rate would be performed. The 250 day rate was suggested as acceptably conservative. This was the modeling approach that was approved by ACHCSA during the July 1994 meeting. Thus, we do not believe that conducting the FTS with a null biodegradation rate, or the collection of additional field data at this time is warranted. This is a topic we look forward to resolving at a meeting between ACHCSA, RWQCB, including Dr. Arulanantham, ARCO, and PACIFIC.

6. *The model results from Scenario 2, for which the Remedial Action Plan is supported, indicates that the plume boundaries will recede approximately 350 feet in 1 year, just two years after the benzene release to the groundwater began. The data used to produce this plume behavior is from the 1st Quarter 1994 (reported in March 1994). Data presented from the 2nd and 3rd quarterly 1994 monitoring, do not show any recessionary trend which leads us to believe that the model is inaccurate.*

   Further, we know that the plume boundaries for dissolved benzene currently extend approximately 600 feet downgradient from the site, and the benzene release to the groundwater began to occur 7 or more years ago. If the rate of biodegradation suggested by the model were occurring, it would seem that greater evidence of plume boundary recession would have been more apparent after 7 plus years of monitoring.

   It has been shown that benzene concentrations have decreased in the outlying domestic irrigation wells for the last 3 or more quarters. However to date, the plume boundaries have not appreciably receded upgradient toward the site.

> *The report states "...that groundwater from MW-10 is decreasing markedly in dissolved benzene...". Historical data presented thus far for MW-10, has exhibited sporadic fluctuations in benzene concentrations. If sufficient evidence is not provided to ensure that contaminant concentrations in MW-10 are significantly biodegrading or attenuating, a corrective action plan will be required to address containment/stabilization and, possibly, remediation of this off-site plume concentration.*

These comments suggest that we should explain more details about the FTS. First, the model does not predict 350 feet of plume recession "just two years after the benzene release...occurred." The input parameters assume a constant source of benzene to the groundwater on site, and an initial plume configuration based on March 1994 monitoring data. It is clear that the benzene source on site was formerly much greater than it is now. Significant source removal has taken place via tank replacement and extensive soil excavation concurrent with the tank replacement.

The reduction in source is an important consideration in looking for plume recession over time. The extensive plume resulted from a much more significant source than exists today. Evidence from outlying wells, including Wells MW-15, MW-16, and MW-17, as well as from various domestic irrigation wells, shows decreasing hydrocarbon concentrations. Contrary to the ACHCSA statement that plume boundaries have not receded, these wells show plume recession between 1991 and 1994. Figures 11 and 12 in the RI/FS illustrate this decrease.

We wish to clarify that the dissolved benzene plume is not approximately 600 feet in length. As of the September 1994 sampling event, benzene was detected in only three off-site wells (Wells MW-8, MW-10, and 17349 VM). Historically, these wells had the highest benzene concentrations. Data from the September 1994 sampling event showed significant decreases in the benzene concentrations in these wells since the previous quarter. Data from the December 1994 sampling event confirmed this decrease (Tables 1 and 2). Additionally, there are several monitoring wells and domestic irrigation wells that are located between these three wells and in which benzene has been detected in the past, but not recently. This indicates that the benzene in these areas has naturally attenuated to levels that meet the groundwater remedial goals, and suggests a decreasing benzene plume which extends off-site to the area just beyond Well MW-10 as well as a localized area of benzene in the area of Well 17349 VM. Historically, the higher concentrations of benzene will take more time to attenuate to levels which meet the groundwater remedial goals. This condition will be validated only through monitoring the plume through time, which is an essential element of Alternative 2 in the RI/FS.

The model is meant as a general predictive tool, and not as a predictor of exact concentrations at specific wells. The data input to the model is based whenever possible on actual field conditions, and where field measurements are not available, on reasonable assumptions. Some heterogeneities in subsurface conditions, such as variations in hydraulic conductivity or stratigraphy, are likely to exist locally. These are impossible to quantify precisely, but would cause local differences between model predictions and actual concentrations measured in monitoring wells. While it is certainly possible to calibrate the model with historic data so that it mirrors existing data, this exercise would not necessarily increase the accuracy of the model as a predictive tool. This is because any number of parameters, such as permeability, porosity, and dispersivity, can be adjusted to achieve the desired results, but we have no assurance that the adjusted parameters are the correct ones to modify to make the model more closely represent the actual subsurface conditions. The model predicts that over time, benzene concentrations should decline to non-detectable levels for most the area under consideration. This prediction will also be validated only through monitoring the plume through time, which is an essential element of Alternative 2 in the RI/FS.

We acknowledge that Well MW-10 has historically shown fluctuating benzene concentrations. In the first quarter 1993, it appears that a dissolved hydrocarbon "slug" reached Well MW-10. The concentrations peaked in the fourth quarter 1993, and since then, concentrations have declined. The fourth quarter 1994 data indicates that Well MW-10 contained 3,000 parts per billion (ppb) total petroleum hydrocarbons calculated as gasoline (TPH-g), and 150 ppb benzene (Tables 1 and 2). While this is a slight increase over the third quarter 1994, it is still less than the peak concentrations observed during 1993. As mentioned above, monitoring over time is recommended to validate the predicted decrease in hydrocarbon concentrations.

ACHCSA also comments that corrective action may be required to address hydrocarbon concentrations in Well MW-10. The RI/FS recommends that Well MW-10 be monitored as part of a groundwater management area. Possible corrective actions should be required only if certain criteria are met in the boundary wells, as would be identified in a contingency plan. Both groundwater hydrocarbon plume configuration and remaining health risk would be managed by Alternative 2.

7. *What are the current soil contaminant concentrations on site? What is the future leaching potential for these soils? How long will these soils contribute to groundwater contamination?*

   The most recent data on soil contaminant concentrations on site for the UST gasoline complex and used oil tank location is 1988; and 1992 for the oil-water separator. Per our conversation with PACIFIC, it was stated that the future leaching of on-site soil contamination was incorporated into the FTS using a general leaching rate solely for benzene. We suggest using more current, site specific data for model calibration.

> *Alternative 2, the recommended remedial action plan presented in the RI/FS, did not address remediation of the impacted on-site soils. However, the report indicates that the remaining soil contamination is expected to:*
>
> - *require a long period of time to naturally attenuate and*
> - *will further impact the on-site groundwater.*
>
> *If residual soil contamination is in fact continuing to impact the groundwater, then as stated in Alternative 4, attempting to eliminate the ultimate source of contamination would seem warranted in this situation.*

The majority of hydrocarbon mass in soil was removed during the tank replacement activities in June 1988. Based on a rough comparison of soil data for samples collected above the capillary fringe prior to and during tank replacement activities, we concluded that:

- Approximately 96 percent of the hydrocarbon mass in the area of the former underground tank complex was removed during tank replacement activities.
- Approximately 98 percent of the hydrocarbon mass in the area of the used oil tank was removed during tank replacement activities.

The most current data on hydrocarbon concentrations in soil were collected in March and April 1993, and is reported in the RI/FS in Part 2.3, Tables 5 through 9, and Figures 5 and 6. Most locations tested showed non-detectable hydrocarbon concentrations at the capillary fringe, the target area for analysis. The maximum on-site benzene concentration is located at Well SP-1/V-4, at 0.59 ppm benzene. This level is below the proposed soil cleanup goal for benzene for the site.

The leaching potential and continuing contribution of benzene from soils to groundwater was generalized for the FTS, as a constant source of 330 ppb benzene in the groundwater. This value was based on the average benzene concentration in on-site groundwater monitoring wells.

We acknowledge that the remaining hydrocarbons in soil on site may require a long time to naturally biodegrade, and that prior to completion of this biodegradation they may present a continuing source to the groundwater. However, the mass of the remaining source is so low that active remediation of soils is not judged to be cost-effective. Also, the impact of this small mass source to groundwater is diminished by the existing on-site groundwater extraction system. Operation of this system until a stable plume configuration is confirmed is a primary element of Alternative 2.

8. *Although the on-site extraction system appears to have contributed to the reduction in contaminant migration since its operation began in 1991, MW-8 and MW-10, the*

> *closest monitoring wells downgradient of the site, continue to show elevated levels of TPHg and benzene. This data appears to indicate that contaminants continue to migrate off-site despite the on-site extraction system and/or that the contaminant plume in this area is not significantly biodegrading.*
>
> *Further efforts in contaminant source reduction, as presented Alternative 4 (Soil Vapor Extraction on Site, Institutional Controls for Groundwater Off Site, Air Sparging and Groundwater Extraction On Site) in the RI/FS and/or further investigations into the feasibility of off-site groundwater extraction from MW-10 should be considered as viable remediation efforts.*

The continuing presence of hydrocarbons in Wells MW-8 and MW-10 does not necessarily indicate continuing migration, or lack of biodegradation. The primary benefit of groundwater extraction is migration control of hydrocarbons. Some dissolved hydrocarbons may be "captured" by groundwater extraction. Even in the event hydrocarbons are not captured, the groundwater velocity immediately downgradient of the extraction well, beyond the capture zone, will be reduced. Thus, migration of hydrocarbons can be slowed, even without hydrocarbon "capture." This may be the case with Wells MW-8 and MW-10. Also, biodegradation would be expected to reduce hydrocarbon concentrations in these wells, but not as quickly as occurring on the fringe of the hydrocarbon plume. As the plume recedes from its most downgradient extent upgradient toward the site, Well MW-10 should continue to show decreasing benzene concentrations, and ultimately Well MW-8 should show this trend as well. Regardless, Alternative 2 proposes to manage the elevated hydrocarbon levels in Wells MW-8 and MW-10 using a groundwater management plan. We will continue to monitor the capture zone created by Well E-1A and its effect on groundwater migration in the area of Well MW-8.

As discussed above under Comment #7, further source reduction on site does not appear to be warranted, because the remaining mass source is quite small, based on 1993 data. Further, as noted under Comment #6, possible off-site corrective actions should only be considered if certain criteria are met in boundary wells (the boundary wells and the criteria will be proposed in a groundwater management plan).

Finally, ACHCSA expresses concern that contaminants may reach off-site receptors, and recommends efforts toward source reduction and plume containment. The best information which may be developed to demonstrate that off-site receptors will not be impacted, is to continue monitoring the site area. If concentrations increase in the domestic irrigation wells to levels that are not health-protective, well-specific actions can be implemented to reduce health risk to acceptable levels. These actions include discontinuing use of the well until concentrations decrease to health-protective levels. At this time, we do not judge that more aggressive remedial efforts are warranted.

We hope that we have sufficiently addressed many of the issues raised in your January 23, 1995 letter. It was our understanding that many of the issues raised had been clarified and/or approved during our July 1994 meeting, or had been presented in the RI/FS. It has been and remains our goal to work with ACHCSA to develop an RI/FS approach that is acceptable. We look forward to continuing discussion of these issues with you, Dr. Arulanantham, and the RWQCB.

Sincerely,

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Attachments: Table 1 - Groundwater Analytical Data, Groundwater Monitoring Wells - Total Petroleum Hydrocarbons (TPH as Gasoline and BTEX Compounds)
Table 2 - Groundwater Analytical Data, Domestic Irrigation Wells - Total Petroleum Hydrocarbons (TPH as Gasoline and BTEX Compounds)

cc: Dr. Ravi Arulanantham, Regional Water Quality Control Board
Mr. Kevin Graves, Regional Water Quality Control Board
Mr. Michael Whelan, ARCO Products Company
Mr. Chris Winsor, ARCO Products Company