PACIFIC
ENVIRONMENTAL
GROUP, INC.

93 JUL 28 AM 9:24

July 27, 1993
Project 330-06.14

Dr. Ravi Arulanantham
Department of Environmental Health
Hazardous Materials Division
Alameda County Health Care Services Division
80 Swan Way, Room 200
Oakland, California 94621

Re: ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Dear Dr. Arulanantham:

This letter presents the proposed methodology and variable values to complete a modified health risk assessment (RA) for the off-site groundwater associated with the site referenced above. The RA will evaluate three health risk scenarios defined by Alameda County Health Care Services Agency (ACHCSA), in a meeting with ARCO Products Company (ARCO) and Pacific Environmental Group, Inc. (PACIFIC) on February 24, 1993. The minutes of this meeting, prepared by PACIFIC in a memorandum to ARCO and ACHCSA on March 4, 1993, are included as Attachment A.

HEALTH RISK SCENARIOS

ARCO will determine the health risk associated with the off-site shallow groundwater for the following three scenarios defined by ACHCSA:

- **Scenario 1 - Children Playing in Irrigating Groundwater:** This scenario assumes that children could play in extracted groundwater potentially containing dissolved petroleum hydrocarbons. As a consequence, children could be exposed to petroleum hydrocarbons via the inhalation, dermal contact, and ingestion exposure route pathways.
- **Scenario 2 - Adults Working or Resting Adjacent to Irrigating Groundwater:** This scenario assumes that adults will work or rest adjacent to extracted groundwater potentially containing

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

dissolved petroleum hydrocarbons. As a consequence, adults could be exposed to petroleum hydrocarbons via the inhalation exposure route pathway. During the February 24, 1993 meeting, ACHCSA agreed that the ingestion and dermal contact exposure route pathways should not be considered for adults.

- **Scenario 3 - Benzene Vapor Transport Through Soil:** This scenario assumes that dissolved petroleum hydrocarbons will volatilize from the groundwater, and that the vapor will migrate through the soil to the ground surface. As a consequence, children and adults could potentially be exposed to soil vapors containing petroleum hydrocarbons via the inhalation exposure route pathway.

Contaminants of concern have been identified in the off-site shallow groundwater, including benzene, toluene, ethylbenzene, and xylenes. Benzene is a known human carcinogen. Toluene, ethylbenzene, and xylenes are not classified as carcinogens, but have subchronic effects. Both carcinogenic (benzene) and non-carcinogenic (toluene, ethylbenzene, and xylenes) health risk will be determined for these three scenarios using established United States Environmental Protection Agency (EPA) and site-specific risk assessment parameter values (Tables 1 and 2). A detailed methodology to determine health risk for each scenario is described below.

SCENARIO 1 - Children Playing in Irrigating Groundwater

Carcinogenic Risk

Carcinogenic health risk associated with inhalation of benzene will be determined using the variable values and the equation presented in Table 3. The concentration of benzene in air will be estimated based on the following assumptions:

1. Dissolved benzene, if present in the extracted groundwater, will partially volatilize at a constant rate during irrigation regardless of temperature, pressure, and other factors. This assumption represents a maximum exposure estimate and will provide a benzene vapor mass for each irrigation well, based on the concentration of benzene in groundwater, volume of groundwater extracted, and partitioning coefficient. The following equation will be used to estimate the maximum benzene vapor mass at each irrigation well location:

$$M = CW * Q * CF * T * PC$$

where:

M = Mass of Benzene [grams]
CW = Highest Historical Concentration of Benzene in Irrigation Well Groundwater [micrograms per liter]
Q = Flow of Extracted Groundwater [liters per second] Flow will be estimated using on- and off-site aquifer testing data and irrigation well-specific operational data, and will be normalized to an hourly basis.
CF = Unit Conversion Factor
T = Time (normalized to an hourly basis) [second]
PC = Partitioning Coefficient [fraction]

2. The partitioning coefficient is estimated to be 0.5, which suggests that 50 percent of the benzene in water will volatilize during irrigation. The partitioning coefficient is being used to more accurately estimate health risk by differentiating the benzene mass to each exposure route pathway; 50 percent of the benzene mass will be available to the inhalation route, and 50 percent will be available for the dermal contact and ingestion route pathways. The proposed value of the partitioning coefficient is not fixed, and could be adjusted. However, the partitioning coefficient is necessary to prevent an unrealistic overestimation of health risk.

3. The benzene vapor mass will instantaneously disperse during irrigation into a fixed volume of air surrounding the irrigation well. This volume will be conservatively based on the area of the homeowners backyard multiplied by a dispersion height. The area of each backyard will be based on review of aerial photographs, and will include only the landscaped area behind the residence; other buildings, like sheds, side yards, and the frontyard will not be included in this value. The area of each backyard will then be multiplied by 1.5 meters to obtain a volume. This value conservatively represents the maximum height in which the benzene mass will volatilize. Wind effects will be incorporated into the calculation using a simplified model. Wind will be estimated at 4.5 miles per hour, or 2 meters per second. These assumptions should provide a realistic maximum exposure estimate. The following equation will be used to calculate the concentration of benzene in the air volume surrounding the irrigation well:

$$CA = (M / (V_y + (v_s * H * W * T)) * CF$$

where:

CA = Concentration of Benzene in Air [milligrams per cubic meter]
M = Mass of Benzene [grams]
V_y = Volume of Air Surrounding the Irrigation Well (based on area of backyard multiplied by dispersion height) [cubic meters]
v_s = Wind Velocity (Normalized to an hourly basis) [meters per second]
H = Dispersion Height [meter]
W = Width of Backyard [meter]
T = Time (normalized to an hourly basis) [second]
CF = Unit Conversion Factor

and where the expression:

(v_s * H * W * T) represents the volume of air in the backyard due to wind effects [cubic meters]

The concentration of benzene in the air volume surrounding the irrigation well will be determined for each irrigation well location and used in the equation shown on Table 3.

Carcinogenic health risk associated with dermal contact and ingesting benzene-impacted groundwater will be determined using the variable values and the equations presented in Tables 4 and 5, respectively. As suggested by ACHCSA during the February 24, 1993 meeting, the contact rate associated with swimming will serve as the basis for determining the ingestion rate of groundwater.

Non-Carcinogenic Health Risk

Non-carcinogenic risk associated with inhalation, dermal contact, and ingestion exposure to extracted groundwater containing dissolved petroleum hydrocarbons will be calculated using the variable values and equations presented in Table 6.

SCENARIO 2 - Adults Working or Resting Adjacent to Irrigating Groundwater

Carcinogenic Risk

Carcinogenic health risk associated with inhalation of benzene will be determined using the variables and the equation presented in Table 7. The concentration of benzene in air will be estimated based on the equations and assumptions used in Scenario 1. However, the air volume surrounding the irrigation well for adults will be determined using the area of the backyard multiplied by a height of 2 meters.

Non-Carcinogenic Health Risk

Non-carcinogenic risk associated with inhalation exposure to extracted groundwater containing dissolved petroleum hydrocarbons will be calculated using the variable values and equations presented in Table 6.

SCENARIO 3 - Benzene Vapor Transport Through Soil

Carcinogenic Risk

Carcinogenic health risk associated with inhalation of benzene will be determined for children and adults using the variable values and the equations presented in Tables 8 and 9, respectively. The concentration of benzene in air will be estimated based on the following assumptions:

1. The highest concentration of benzene in the off-site groundwater (MW-10, March 16, 1993) will be used to determine the concentration of benzene in soil vapor. This assumption overestimates the potential health risk to homeowners across the site.

2. Volatilization of dissolved benzene will be determined using Henry's Law. The value obtained will provide a maximum benzene concentration in air at the groundwater-air interface. Henry's Law is:

$$Y_b = (H_b * X_b) / P_t$$

where:

Y_b = Mole Fraction of Benzene in Air [fraction]
H_b = Henry's Law Coefficient for Benzene [atmosphere]
X_b = Mole Fraction of Benzene in Water [fraction]
P_t = Total Partial Pressure [atmosphere]

3. Farmer's equations will be used to determine the benzene flux from the groundwater-air interface through the soil cover, and was verbally approved for application by ACHCSA. Farmer's equations are:

$$P = -D_{sv} * (C_{atm} - C_{sv}) / L$$

and

$$P_o = P * dT$$

where:

P = Pollutant Flux Across Soil Surface [micrograms per square centimeter per second]
D_{sv} = Apparent Steady State Diffusion Coefficient in Soil Vapor [square centimeters per second]

C_{atm} = Concentration of Benzene at Ground Surface [micrograms per milliliter]
C_{sv} = Concentration of Benzene in Soil Vapor [micrograms per milliliter]
L = Depth of Soil Cover [centimeter]
P_o = Total Pollutant Flux Across Soil Surface [micrograms per square centimeter]
dT = Length of Simulation Time [second]

4. The soil diffusion coefficient for benzene will be related to the air diffusion coefficient for benzene using the following Farmer equation:

$$D_{sv} = D_a * ((n-m_s)^{10/3} / n^2)$$

where:

D_{sv} = Apparent Steady State Diffusion Coefficient in Soil Vapor [square centimeters per second]
D_a = Apparent Steady State Diffusion Coefficient in Air [square centimeters per second]
n = Soil Porosity [fraction]
m_s = Soil Moisture [fraction]

5. Based on soil lithology data collected during soil boring and groundwater monitoring well installation, soil porosity is estimated at 25 percent, and soil moisture is estimated at 20 percent.

6. The background concentration of benzene in air is estimated to be 1.98 micrograms per liter (ug/L). This value represents the 4-year average (1987 through 1990) background benzene concentration at the Bay Area Air Quality Management District's (BAAQMD's) sampling location in San Leandro, California. According to a BAAQMD official, the sampling data were collected in a light commercial area near residential homes, and the background concentration of benzene in air results from the operation of automobiles.

7. Depth of soil cover varies with cyclical fluctuations in the piezometric groundwater elevation surface. Based on quarterly monitoring data since 1988, the depth of soil cover varies from approximately 13.62 to 9.83 feet. The average of these values (11.72 feet) will be used in Farmer's equation.

8. The pollutant flux across the soil surface will remain constant and will instantaneously disperse into a 2-meter high volume for

adults, and a 1.5-meter high volume for children (which represent the dispersion height). Additionally, pollutant flux will be determined on an hourly basis in order to correspond with the units of inhalation rate (m^3/hour). These assumptions should provide a realistic maximum exposure estimate.

Non-Carcinogenic Health Risk

Non-carcinogenic risk associated with inhalation exposure to soil vapor containing dissolved petroleum hydrocarbons will be calculated using the variable values and the equations presented in Table 6.

SUMMARY

This letter presents the proposed methodology to perform a modified health risk assessment for the referenced site. The modified health risk assessment will evaluate the three health risk scenarios defined by ACHCSA during a February 24, 1993 meeting with ARCO and PACIFIC. Several assumptions, with justification, are presented in this letter. Based on these conservative assumptions, this methodology will be used to determine the potential health risk to the residential homeowners. Once this methodology is approved by ACHCSA, PACIFIC will prepare a letter summarizing the potential health risk associated with the off-site groundwater. This summary letter will be submitted to ACHCSA thirty days following verbal approval of this methodology.

If you have any questions regarding this methodology, please do not hesitate to call.

Sincerely,

Pacific Environmental Group, Inc.

Keith Winemiller
Senior Staff Engineer

Debra Moser
Project Manager

3300614\RAMETHOD

REFERENCES

United States Environmental Protection Agency, *A Seasonal Soil Compartment Model*, Bonazountas, M. and Wagner, J., May 1984.

United States Environmental Protection Agency, *Health Effects Assessment Summary Tables*, Annual FY 1992; March 1992.

United States Environmental Protection Agency, *Exposure Factors Handbook*: July 1989.

United States Environmental Protection Agency, *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part A.*: December 1989.

Attachments: Table 1 - Domestic Irrigation Well Analytical Data - Total Petroleum Hydrocarbons (TPH as Gasoline and BTEX Compounds)
Table 2 - Domestic Irrigation Well Operational Data
Table 3 - Inhalation of Volatilized Groundwater: Children Exposure
Table 4 - Dermal Contact with Groundwater: Children Exposure
Table 5 - Ingestion of Groundwater: Children Exposure
Table 6 - Non-Carcinogenic Risk Determination: Children and Adult Exposure
Table 7 - Inhalation of Volatilized Groundwater: Adult Exposure
Table 8 - Inhalation of Soil Vapor: Children Exposure
Table 9 - Inhalation of Soil Vapor: Adult Exposure
Attachment A - Alameda County Health Care Services Agency February 24, 1993 Meeting Minutes Memorandum

cc: Mr. Mike Whelan ARCO Products Company
Mr. Chris Winsor, ARCO Products Company
Dr. Charles Lapin, ARCO Products Company
Mr. Rich Hiett, Regional Water Quality Control Board - S.F. Bay Region
Ms. Juliett Shin, Alameda County Health Care Services Agency

Table 1
Domestic Irrigation Well Analytical Data
Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Well Address	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
590	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
633	09-11/91	NS	NS	NS	NS	NS
	10/92	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
634	09-11/91	NS	NS	NS	NS	NS
	10/92	NS	NS	NS	NS	NS
	12/92	NS	NS	NS	NS	NS
	03/16/93	NS	NS	NS	NS	NS
642	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
675	09-11/91	NS	NS	NS	NS	NS
	10/92	NS	NS	NS	NS	NS
	12/92	NS	NS	NS	NS	NS
	03/16/93	NS	NS	NS	NS	NS
17197	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
17200	11/13/91	440	2.7	<0.3	<0.3	12
	10/92	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
17203	11/13/91	<30	<0.3	<0.3	<0.3	<0.3
	10/92	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 1 (continued)
Domestic Irrigation Well Analytical Data
Total Petroleum Hydrocarbons
(TPH as Gasoline and BTEX Compounds)

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Well Address	Date Sampled	TPH as Gasoline (ppb)	Benzene (ppb)	Toluene (ppb)	Ethylbenzene (ppb)	Xylenes (ppb)
17302	10/21/91	72	0.64	<0.3	0.44	<0.3
	10/92	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
17348	09-11/91	NS	NS	NS	NS	NS
	10/92	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
17349	09/27/91	780	13.0	<3.0	<3.0	<3.0
	10/14/92	2,200	<5.0	<5.0	<5.0	110
	12/18/92	1,500	14.0	1.8	7.1	56
	03/16/93	1,100	16.0	4.2	1.8	1.8
17371	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
17372	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
17393	11/13/91	31	<0.3	<0.3	<0.3	<0.3
	10/92	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

ppb = Parts per billion
< = Not detected at or above laboratory detection limit
NS = Not sampled
* = Non-typical chromatograph pattern.

Table 2
Domestic Irrigation Well Operational Data

ARCO Service Station 608
17601 Hesperian Boulevard
San Lorenzo, California

Well Identification	Frequency of Operation (days/year)	Duration of Operation (hours/day)	Estimated Area of Backyard (m^2)
590	52	6 to 7	NA
633	NA	NA	NA
634	NA	NA	NA
642	260	1 to 1.5	NA
675	NA	NA	NA
17197	52	NA	NA
17200	NA	NA	2,369
17203	24	1.5	NA
17302	156	5	102
17348	NA	NA	NA
17349	260	1	195
17371	24	2	111
17372	260	2	446
17393	NA	NA	NA

m^2 = Square meters
NA = Not available or not applicable

Table 3
Inhalation of Volatilized Groundwater: Children Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Equation:

$$\text{Risk} = \frac{CA \times IR \times ET \times EF \times ED \times SF}{BW \times AT}$$

Where:

CA	= Benzene Concentration in Air [mg/cubic meter]
IR	= Inhalation Rate [cubic meters/hour]
ET	= Exposure Time [hours/day]
EF	= Exposure Frequency [days/year]
ED	= Exposure Duration [years]
SF	= Slope Factor [mg/kg−day]
BW	= Body Weight [kg]
AT	= Averaging Time [days]

Proposed Variable Values:

CA = Irrigation Well−Specific Concentration
Determined for each location using method described in text

IR = 0.6 cubic meters/hour (Showering, all age group; EPA, 1989)
Assumes children will play in irrigation spray

ET = Irrigation Well−Specific Value (Homeowner Liaison)

EF = Irrigation Well−Specific Value (Homeowner Liaison)

ED = 9 years (by convention; EPA, 1989)

SF = 0.029 mg/kg−day (EPA IRIS Database)

BW = 25 kg (6<9 year old boys and girls; EPA, 1989)

AT = 25,550 days (EPA, 1989)
Assumes 70 year lifetime for carcinogenic effects

Table 4
Dermal Contact with Groundwater: Children Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Equation:

$$\text{Risk} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF \times SF}{BW \times AT}$$

Where:

CW	= Benzene Concentration in Air [mg/L]
SA	= Skin Surface Area Available for Contact [square centimeters]
PC	= Dermal Permeability Constant [cm/hour]
ET	= Exposure Time [hours/day]
EF	= Exposure Frequency [days/year]
ED	= Exposure Duration [years]
CF	= Volumetric Conversion Factor for Water [1 liter/1,000 cubic centimeters]
SF	= Slope Factor [mg/kg−day]
BW	= Body Weight [kg]
AT	= Averaging Time [days]

Proposed Variable Values:

CW	= Irrigation Well−Specific Concentration Maximum groundwater benzene concentration detected in each irrigation well will be used
SA	= 4,970 square centimeters (Hands, arms, legs, 9<10 year olds; EPA, 1989)
PC	= 0.41 centimeters/hour
ET	= Irrigation Well−Specific Value (Homeowner Liaison)
EF	= Irrigation Well−Specific Value (Homeowner Liaison)
ED	= 9 years (by convention; EPA, 1989)
CF	= 0.001 liters/cubic centimeter
SF	= 0.029 mg/kg−day (EPA IRIS Database)
BW	= 25 kg (6<9 year old boys and girls; EPA, 1989)
AT	= 25,550 days (EPA, 1989) Assumes 70 year lifetime for carcinogenic effects

Table 5
Ingestion of Groundwater: Children Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Equation:

$$\text{Risk} = \frac{CW \times IR \times EF \times ED \times SF}{BW \times AT}$$

Where:

CW	=	Benzene Concentration in Water [mg/liter]
IR	=	Ingestion Rate [liters/day]
EF	=	Exposure Frequency [days/year]
ED	=	Exposure Duration [years]
SF	=	Slope Factor [mg/kg−day]
BW	=	Body Weight [kg]
AT	=	Averaging Time [days]

Proposed Variable Values:

CW = Irrigation Well−Specific Concentration
Maximum groundwater benzene concentration detected in each irrigation well will be used

IR = 0.35 liters/day (EPA, 1989 and Homeowner Liaison)
Based on 7 hour contact time and 50 mL/hour contact rate

ET = Irrigation Well−Specific Value (Homeowner Liaison)

EF = Irrigation Well−Specific Value (Homeowner Liaison)

ED = 9 years (by convention; EPA 1989)

SF = 0.029 mg/kg−day (EPA IRIS Database)

BW = 25 kg (6<9 year old boys and girls; EPA, 1989)

AT = 25,550 days (EPA, 1989)
Assumes 70 year lifetime for carcinogenic effects

Table 6
Non–Carcinogenic Risk Determination: Children and Adult Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Equations:	Ingestion	Inhalation	Dermal Contact
Risk =	$\frac{CW * IR}{BW}$ / RfD	$\frac{CA}{RfC}$	$\frac{CW * SA * PC * ET}{BW}$ / RfD

Where:

CW = Toluene, Ethylbenzene, Xylene Concentration in Water [mg/L]
CA = Toluene, Ethylbenzene, Xylene Concentration in Air [mg/cubic meter]
IR = Ingestion Rate [liters/day]
SA = Skin Surface Area [square centimeters]
PC = Dermal Permeability Constant [cm/hour]
ET = Exposure Time [hours/day]
BW = Body Weight [kg]
RfD = Reference Dose [mg/kg–day]
RfC = Reference Concentration [mg/cubic meter]

Proposed Variable Values:

CW = Irrigation Well–Specific Concentration
Maximum groundwater concentration of each component detected in each well will be used

CA = Irrigation Well–Specific Concentration
Determined for each location using method described in text

IR = (Water) 0.35 L/day (ACHCSA)
= (Air) 20 cubic meters/day (Adult, average; EPA, 1989)
= (Air) 20 cubic meters/day (Children, assumed)

ET = Irrigation Well–Specific Value (Homeowner Liaison)

SA = 4,970 square centimeters (Hands, arms, legs, 9<10 year olds; EPA, 1989)

PC = 0.41 centimeters/hour

BW = 70 kg (Adult, average; EPA, 1989)
= 25 kg (6>9 year old boys and girls; EPA, 1989)

RfD = (Ethylbenzene) 0.1 mg/kg/day (EPA IRIS Database)
= (Toluene) 0.2 mg/kg/day (EPA IRIS Database)
= (Xylene) 2 mg/kg/day (EPA IRIS Database)

RfC = (Ethylbenzene) 1 mg/cubic meter (EPA IRIS Database)
= (Toluene) 0.2 mg/cubic meter (EPA IRIS Database)
= (Xylene) 0.3 mg/cubic meter (EPA IRIS Database)

Table 7
Inhalation of Volatilized Groundwater: Adult Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Equation:

$$\text{Risk} = \frac{CA \times IR \times ET \times EF \times ED \times SF}{BW \times AT}$$

Where:

CA	= Benzene Concentration in Air [mg/cubic meter]
IR	= Inhalation Rate [cubic meters/hour]
ET	= Exposure Time [hours/day]
EF	= Exposure Frequency [days/year]
ED	= Exposure Duration [years]
SF	= Slope Factor [mg/kg−day]
BW	= Body Weight [kg]
AT	= Averaging Time [days]

Proposed Variable Values:

CA	= Irrigation Well−Specific Concentration Determined for each location using method described in text
IR	= 20 cubic meters/day (Adult, average; EPA, 1989)
ET	= Irrigation Well−Specific Value (Homeowner Liaison)
EF	= Irrigation Well−Specific Value (Homeowner Liaison)
ED	= 70 years (Lifetime, by convention; EPA, 1989)
SF	= 0.029 mg/kg−day (EPA IRIS Database)
BW	= 70 kg (Adult, average; EPA, 1989)
AT	= 25,550 days (EPA, 1989) Assumes 70 year lifetime for carcinogenic effects

Table 8
Inhalation of Soil Vapor: Children Exposure

ARCO Service Station 0606
17601 Hesperian Boulevard
San Lorenzo, California

Equation:

$$\text{Risk} = \frac{CA \times IR \times ET \times EF \times ED \times SF}{BW \times AT}$$

Where:

CA	= Benzene Concentration in Air [mg/cubic meter]
IR	= Inhalation Rate [cubic meters/hour]
ET	= Exposure Time [hours/day]
EF	= Exposure Frequency [days/year]
ED	= Exposure Duration [years]
SF	= Slope Factor [mg/kg-day]
BW	= Body Weight [kg]
AT	= Averaging Time [days]

Proposed Variable Values:

CA	= To be determined using methodology described in text
IR	= 0.6 cubic meters/hour (Showering, all age groups; EPA, 1989) Assumes children will play within the irrigation spray
ET	= 15.36 hours/day (EPA, 1989)
EF	= 365 days/year Assumes continuous daily exposure
ED	= 9 years (by convention; EPA, 1989)
SF	= 0.029 mg/kg-day (EPA IRIS Database)
BW	= 25 kg (6<9 year old boys and girls; EPA, 1989)
AT	= 25,550 days (EPA, 1989) Assumes 70 year lifetime for carcinogenic effects

Table 9
Inhalation of Soil Vapor: Adult Exposure

ARCO Service Station 0606
17601 Hesperian Boulevard
San Lorenzo, California

Equation:

$$\text{Risk} = \frac{CA \times IR \times ET \times EF \times ED \times SF}{BW \times AT}$$

Where:

CA	= Benzene Concentration in Air [mg/cubic meter]
IR	= Inhalation Rate [cubic meters/hour]
ET	= Exposure Time [hours/day]
EF	= Exposure Frequency [days/year]
ED	= Exposure Duration [years]
SF	= Slope Factor [mg/kg−day]
BW	= Body Weight [kg]
AT	= Averaging Time [days]

Proposed Variable Values:

CA	= To be determined using proposed methodology described in text
IR	= 0.83 cubic meters/hour (Adult, average; EPA, 1989) Based on EPA Guidance
ET	= 15.36 hours/day (EPA, 1989)
EF	= 365 days/year Assumes continuous daily exposure
ED	= 70 years (Lifetime, by convention; EPA, 1989)
SF	= 0.029 mg/kg−day (EPA IRIS Database)
BW	= 70 kg (Adult, average; EPA, 1989)
AT	= 25,550 days (EPA, 1989) Assumes 70 year lifetime for carcinogenic effects

ATTACHMENT A

ALAMEDA COUNTY HEALTH CARE SERVICES AGENCY
FEBRUARY 24, 1993 MEETING MINUTES
MEMORANDUM

PACIFIC
ENVIRONMENTAL
GROUP, INC.

March 4, 1993
Project 330-06.14

SENT
☑ MAILED ☐ BY HAND
☐ FED EX ☐ COURIER
☐ FAXED ☐ FINAL
☐ UPS ☐ DRAFT
Date 3-4-93 Init. SD

MEMORANDUM

To: Mr. Michael Whelan
ARCO Products Company
P.O. Box 5811
San Mateo, California 94402

cc: Dr. Charles Lapin, ARCO
Dr. Ravi Arulanantham, ACHCSA
Mr. Chris Winsor, ARCO

From: Mr. Keith Winemiller
Pacific Environmental Group, Inc.
2025 Gateway Place, Suite 440
San Jose, California 95110

Subject: ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

This memorandum presents the minutes of the meeting between Alameda County Health Care Services Agency (ACHCSA), ARCO Products Company (ARCO), and Pacific Environmental Group, Inc. (PACIFIC) conducted on February 24, 1993 regarding the above referenced site. Meeting attendees included: ACHCSA - Dr. Ravi Arulanantham, ARCO - Dr. Charles Lapin (via telephone), and PACIFIC - Mr. Keith Winemiller. The purpose of this meeting was to discuss the risk assessment parameter values proposed in PACIFIC's letter to ACHCSA, dated December 8, 1992. The main discussion topics and subsequent action items are summarized below:

- Dr. Arulanantham indicated that he supports the utilization of site-specific risk assessment parameters to more closely determine site-specific health risk. However, Dr. Arulanantham indicated that, due

to the nature of the impact, specifically the proximity to, and impact of residential irrigation wells, more conservative risk assessment parameters are appropriate.

- Dr. Arulanantham outlined three scenarios which the risk assessment must evaluate. These scenarios are:

  1. **Children playing in irrigating groundwater.** Health risk to children playing in benzene-affected, irrigating groundwater will be determined for the inhalation, ingestion, and dermal contact exposure pathways.

  2. **Adults adjacent to irrigating groundwater.** Health risk to adults as a result of working, or resting adjacent to, irrigating groundwater will be determined for the inhalation exposure pathway.

  3. **Benzene vapor transport through soil.** Health risk to adults and children due to inhalation of benzene, which has migrated through the soil from the groundwater surface into the homes of well owners.

- Dr. Arulanantham indicated that these scenarios can be effectively modeled, and that additional air sampling will be unnecessary. PACIFIC will prepare a summary of the models which will be used to determine inhalation exposure and soil vapor transport parameters, and will outline the procedure for conducting the risk assessment. This outline should be submitted to ACHCSA for approval.

- Dr. Arulanantham indicated that the benzene concentration in groundwater used for the first and second scenarios may be well-specific. ARCO may also use the highest benzene concentration detected in any irrigation well to determine health risk for these two scenarios. Additionally, the maximum benzene concentration in groundwater detected off site should be used for the third scenario.

- Dr. Arulanantham agreed that the adults should not ingest groundwater; therefore, ARCO will not calculate health risk associated with groundwater ingestion for adults. Furthermore, he indicated that children will ingest groundwater during play-activities. He suggested that the ingestion rate associated with swimming may be appropriate for this activity.

- Dr. Arulanantham indicated that exposure duration should be based on lifetime exposure.
- Dr. Arulanantham indicated that the well operation data used for exposure time and exposure frequency should not be averaged. He indicated that the maximum values observed for exposure frequency and exposure time may be used in place of worst case scenario values (24 hours per day and 365 days per year, respectively).
- Dr. Arulanantham agreed that if well use is discontinued all exposure routes, except for benzene vapor transport through soil, will be eliminated.
- ARCO indicated that no data exists to determine past health risk; however, data is available to determine current health risk.