PACIFIC
ENVIRONMENTAL
GROUP, INC.

93 OCT -7 PM 12: 18

October 5, 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 results of a modified health risk assessment (RA) for the off-site groundwater associated with the site referenced above. On behalf of ARCO Products Company (ARCO), Pacific Environmental Group, Inc. (PACIFIC) completed the RA based on the methodology described in PACIFIC's July 27, 1993 proposal, which Alameda County Health Care Services Agency (ACHCSA) approved on August 3, 1993. The results of this assessment are summarized below. Additionally, all results are tabulated and example calculations for each health risk scenario identified by ACHCSA are presented as:

Attachment A - Scenario 1: Children Playing in Irrigating Groundwater
Attachment B - Scenario 2: Adults Working or Resting Adjacent to Irrigating Groundwater
Attachment C - Scenario 3: Soil Vapor Transport through Soil
Attachment D - Non-Carcinogenic Risk

SUMMARY

The results of the modified health risk assessment for children indicate that the total potential carcinogenic risk ranges from 4.3×10^{-7} to 8.5×10^{-7} and the total potential non-carcinogenic risk hazard quotient is less than 1 (Table 1). The results of the modified health risk assessment for adults indicate that the total potential carcinogenic risk ranges from 8.9×10^{-7} to 9.1×10^{-7} and the total potential non-carcinogenic hazard quotient is less than 1 (Table 2). With ACHCSA

A 453-7300

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PACIFIC
ENVIRONMENTAL
GROUP, INC.

93 OCT -7 PM 12:37

October 5, 1993
Project 330-06.14

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Hazardous Materials Division
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80 Swan Way, Room 200
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SUMMARY

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acceptance of this summary letter, PACIFIC will incorporate these results into the Remedial Investigation and Feasibility Study.

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

Sincerely,

Pacific Environmental Group, Inc.

Keith Winemiller
Senior Staff Engineer

Debra Moser
Project Manager

Attachments: Table 1 - Summary of Potential Health Risk to Children
Table 2 - Summary of Potential Health Risk to Adults
Attachment A - Scenario 1: Children Playing in Irrigating Groundwater
Attachment B - Scenario 2: Adults Working or Resting Adjacent to Irrigating Groundwater
Attachment C - Scenario 3: Soil Vapor Transport through Soil
Attachment D - Non-Carcinogenic Risk

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
Summary of Potential Health Risk to Childern

ARCO Service Station
17601 Hesperian Boulevard
San Lorenzo, California

Well Number	Carcinogenic Risk					Non-Carcinogenic Risk				
			Inhalation					Inhalation		
	Dermal Contact	Ingestion	Volatilized Groundwater	Soil Vapor	Cumulative Risk	Dermal Contact	Ingestion	Volatilized Groundwater	Soil Vapor	Cumulative Risk
590	NA	NA	NA	4.3E-07	4.3E-07	NA	NA	NA	7.4E-01	7.4E-01
633	NA	NA	NA	4.3E-07	4.3E-07	NA	NA	NA	7.4E-01	7.4E-01
634	NA	NA	NA	4.3E-07	4.3E-07	NA	NA	NA	7.4E-01	7.4E-01
642	NA	NA	NA	4.3E-07	4.3E-07	NA	NA	NA	7.4E-01	7.4E-01
675	NA	NA	NA	4.3E-07	4.3E-07	NA	NA	NA	7.4E-01	7.4E-01
17197	NA	NA	NA	4.3E-07	4.3E-07	NA	NA	NA	7.4E-01	7.4E-01
17200	NA	NA	NA	4.3E-07	4.3E-07	NA	8.4E-06	1.6E-04	7.4E-01	7.4E-01
17203	NA	NA	NA	4.3E-07	4.3E-07	4.8E-06	9.1E-07	NA	7.4E-01	7.4E-01
17302	4.2E-08	1.4E-09	4.6E-10	4.3E-07	4.8E-07	4.4E-07	6.2E-06	8.2E-06	7.4E-01	7.4E-01
17348	NA	NA	NA	4.3E-07	4.3E-07	NA	NA	NA	7.4E-01	7.4E-01
17349	3.5E-07	5.9E-08	1.4E-08	4.3E-07	8.5E-07	2.7E-04	2.1E-04	5.4E-03	7.4E-01	7.5E-01
17371	3.6E-08	3.1E-09	9.5E-10	4.3E-07	4.7E-07	2.4E-05	6.5E-05	4.3E-04	7.4E-01	7.4E-01
17372	2.4E-07	2.0E-08	3.13E-09	4.3E-07	7.0E-07	6.7E-06	2.5E-05	8.7E-05	7.4E-01	7.4E-01
17393	NA	NA	NA	4.3E-07	4.3E-07	NA	NA	NA	7.4E-01	7.4E-01

NA = Not applicable

Table 2
Summary of Potential Health Risk to Adults

ARCO Service Station
17601 Hesperian Boulevard
San Lorenzo, California

Well Number	Carcinogenic Risk Inhalation			Non-Carcinogenic Risk Inhalation		
	Volatilized Groundwater	Soil Vapor	Cumulative Risk	Volatilized Groundwater	Soil Vapor	Cumulative Risk
590	NA	8.9E-07	8.9E-07	NA	5.6E-01	5.6E-01
633	NA	8.9E-07	8.9E-07	NA	5.6E-01	5.6E-01
634	NA	8.9E-07	8.9E-07	NA	5.6E-01	5.6E-01
642	NA	8.9E-07	8.9E-07	NA	5.6E-01	5.6E-01
675	NA	8.9E-07	8.9E-07	NA	5.6E-01	5.6E-01
17197	NA	8.9E-07	8.9E-07	NA	5.6E-01	5.6E-01
17200	NA	8.9E-07	8.9E-07	1.2E-04	5.6E-01	5.6E-01
17203	NA	8.9E-07	8.9E-07	NA	5.6E-01	5.6E-01
17302	1.3E-09	8.9E-07	9.0E-07	6.2E-06	5.6E-01	5.6E-01
17348	NA	8.9E-07	8.9E-07	NA	5.6E-01	5.6E-01
17349	4.0E-08	8.9E-07	9.3E-07	4.0E-03	5.6E-01	5.6E-01
17371	2.7E-09	8.9E-07	9.0E-07	3.2E-04	5.6E-01	5.6E-01
17372	9.0E-09	8.9E-07	9.1E-07	6.5E-05	5.6E-01	5.6E-01
17393	NA	8.9E-07	8.9E-07	NA	5.6E-01	5.6E-01

NA = Not applicable

ATTACHMENT A

SCENARIO 1: CHILDREN PLAYING IN IRRIGATING GROUNDWATER

Table A–1
Dermal Contact with Groundwater: Children Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

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

WHERE:

CW = Benzene Concentration in Water (Historical Maximum) [milligrams/liter]
SA = Skin Surface Area Available for Contact [square centimeters]
DP = Dermal Permeability Constant [centimeters/hour]
ED = Exposure Duration [years]
EF = Exposure Frequency [days/year]
ET = Exposure Time [hours/day]
CF = Volumetric Conversion Factor for Water [1 liter/1,000 cubic centimeters]
SF = Slope Factor [kilograms–day/milligram]
PC = Partitioning Coefficient [fraction]
BW = Body Weight [kilograms]
AT = Averaging Time [days]

APPROVED VALUES:

CW =	See Below	
SA =	4,970	sq.cm
DP =	0.410	cm/hr
ED =	9	yr
EF =	See Below	
ET =	See Below	
CF =	0.001	L/cu.cm
SF =	0.029	kg–day/mg
BW =	25	kg
AT =	25,550	day
PC =	0.10	

WELL SPECIFIC VARIABLES:

WELL I.D.	CW (mg/L)	ET (hr/day)	EF (day/yr)	RISK
590	ND	6.5	52	NA
633	ND	NA	NA	NA
634	NS	NA	NA	NA
642	ND	1.3	260	NA
675	NS	NA	NA	NA
17197	ND	NA	52	NA
17200	0.0027	NA	NA	NA
17203	ND	1.5	24	NA
17302	0.00064	5.0	156	4.2E–08
17348	ND	NA	NA	NA
17349	0.0160	1.0	260	3.5E–07
17371	0.0090	2.0	24	3.6E–08
17372	0.0055	2.0	260	2.4E–07
17393	ND	NA	NA	NA

ND = Not detected above method detection limit
NA = Not available or not applicable
NS = Not sampled

EQUATION: $$RISK = \frac{CW \times SA \times DP \times ED \times EF \times ET \times CF \times SF \times PC}{BW \times AT}$$

WHERE:

- CW = BENZENE CONCENTRATION IN WATER (HISTORICAL MAXIMUM) [mg/L]
- SA = SKIN SURFACE AREA AVAILABLE FOR CONTACT [cm^2]
- DP = DERMAL PERMEABILITY CONSTANT [cm/h]
- ET = EXPOSURE TIME [h/d]
- EF = EXPOSURE FREQUENCY [d/y]
- ED = EXPOSURE DURATION [y]
- CF = VOLUMETRIC CONVERSION FACTOR FOR WATER [L/1000 cm^3]
- SF = SLOPE FACTOR [kg-d/mg]
- BW = BODY WEIGHT [Kg]
- AT = AVERAGING TIME [d]
- PC = PARTITIONING COEFFICIENT [FRACTION]

APPROVED VALUES:

- CW = 0.016 mg/L
- SA = 4,970 cm^2
- DP = 0.410 cm/h
- ET = 1.0 h/d
- EF = 260 d/y
- ED = 9 yr
- CF = 0.001 L/m^3
- SF = 0.029 kg-d/mg
- BW = 25 kg
- AT = 25,550 d
- PC = 0.10

CALCULATIONS:

$$RISK = \frac{(0.016\ mg/L \times 4,970\ cm^2 \times 0.410\ cm/h \times 1.0\ h/d \times 260\ d/y \times 9\ y \times 0.001\ L/m^3 \times 0.10 \times 0.029\ kg\text{-}d/mg}{(25\ kg)(25,550\ d)}$$

$$= 3.46 \times 10^{-7}$$

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/13/93
			Drawn By: ~~Tom Nott~~

Title: CALCULATIONS FOR DERMAL CONTACT WITH GROUNDWATER / CHILD EXPOSURE

Table A–2
Ingestion of Groundwater: Children Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$RISK = \frac{CW \times IR \times ED \times EF \times SF \times PC}{BW \times AT}$$

WHERE:

CW = Benzene Concentration in Water (Historical Maximum) [milligrams/liter]
IR = Ingestion Rate (liters/day)
ED = Exposure Duration [years]
EF = Exposure Frequency [days/year]
SF = Slope Factor [kilograms–day/milligram]
PC = Partitioning Coefficient [fraction]
BW = Body Weight [kilograms]
AT = Averaging Time [days]

APPROVED VALUES:

CW =	See Below	
IR =	0.35	L/day
ED =	9	yr
EF =	See Below	
SF =	0.029	kg–day/mg
PC =	0.10	
BW =	25	kg
AT =	25,550	day

WELL SPECIFIC VARIABLES:

WELL I.D.	CW (mg/L)	EF (day/yr)	RISK
590	ND	52	**NA**
633	ND	NA	**NA**
634	NS	NA	**NA**
642	ND	260	**NA**
675	NS	NA	**NA**
17197	ND	52	**NA**
17200	0.0027	NA	**NA**
17203	ND	24	**NA**
17302	0.00064	156	**1.4E–09**
17348	ND	NA	**NA**
17349	0.0160	260	**5.9E–08**
17371	0.0090	24	**3.1E–09**
17372	0.0055	260	**2.0E–08**
17393	ND	NA	**NA**

ND = Not detected above method detection limit
NA = Not available or not applicable
NS = Not sampled

EQUATION: $$RISK = \frac{CW \times IR \times ED \times EF \times SF \times PC}{BW \times AT}$$

WHERE:

CW	=	BENZEE CONCENTRATION IN WATER (HISTORICAL MAXIMUM) [mg/L]
IR	=	INGESTION RATE [L/d]
EF	=	EXPOSURE FREQUENCY [d/y]
ED	=	EXPOSURE DURATION [y]
SF	=	SLOPE FACTOR [kg-d/mg]
BW	=	BODY WEIGHT [kg]
AT	=	PARTITIONING COEFFICIENT [FUNCTION]

APPROVED VALUES:

CW	=	0.016 mg/L
IR	=	0.35 L/d
EF	=	260 d/y
ED	=	9 y
SF	=	0.029 kg-d/mg
BW	=	25 kg
AT	=	25,550 d
PC	=	0.10

CALCULATIONS:

$$RISK = \frac{(0.016\ mg/L)(0.35\ m^3/h)(260\ d/y)(9\ y)(0.029\ kg\text{-}d/mg)(0.1)}{(25\ kg)(25{,}550\ d)}$$

$$= 5.95 \times 10^{-8}$$

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/13/93
			Drawn By: Jam Nell

Title: CALCULATIONS FOR INGESTION OF GROUNDWATER
CHILDRER EXPOSURE

Table A–3
Inhalation of Volatilized Groundwater: Children Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$CA = \frac{CW \times Q \times T \times PC}{V + (v \times H \times W \times T)}$$

WHERE:

CA = Benzene Concentration in Air [milligrams/cubic meter]
CW = Benzene Concentration in Water [milligrams/Liter]
Q = Flow Rate of Extracted Groundwater [liters/second]
T = Time (Normalized to Hourly–basis) [seconds]
PC = Partitioning Coefficient [fraction]
V = Volume of Air Surrounding the Irrigation Well [cubic meters]
v = Wind Velocity [meters/second]
H = Dispersion Height [meters]
W = Width of Backyard [meters]

APPROVED VALUES:

CW =	See Below
Q =	0.63 L/s
T =	3,600 s
PC =	0.9
V =	See Below
v =	2.0 m/s
H =	1.5 m
W =	See Below

WELL SPECIFIC VARIABLES:

WELL I.D.	CW (mg/L)	V (cu.m)	W (m)	CA (mg/cu.m)
590	ND	NA	NA	NA
633	ND	NA	NA	NA
634	NS	NA	NA	NA
642	ND	NA	NA	NA
675	NS	NA	NA	NA
17197	ND	NA	NA	NA
17200	0.0027	3,554	48.7	1.0E–05
17203	ND	NA	NA	NA
17302	0.00064	153	10.1	1.2E–05
17348	ND	NA	NA	NA
17349	0.0160	293	14.0	2.2E–04
17371	0.0090	167	10.5	1.6E–04
17372	0.0055	669	21.1	4.9E–05
17393	ND	NA	NA	NA

Table A-3 (continued)
Inhalation of Volatilized Groundwater: Children Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$RISK = \frac{CA \times IR \times ED \times EF \times SF}{BW \times AT}$$

WHERE:

CA = Benzene Concentration in Air (Calculated Above) [milligrams/cubic meter]
IR = Inhaltion Rate [cubic meters/hour]
ED = Exposure Duration [years]
EF = Exposure Frequency [days/year]
SF = Slope Factor [kilograms-day/milligram]
BW = Body Weight [kilograms]
AT = Averaging Time [days]

APPROVED VALUES:

CA =	See Below	
IR =	0.60	cu.m/hr
ED =	9	yr
EF =	See Below	
SF =	0.029	kg-day/mg
BW =	25	kg
AT =	25,550	day

WELL SPECIFIC VARIABLES:

WELL I.D.	CA (mg/cu.m)	EF (day/yr)	RISK
590	NA	52	**NA**
633	NA	NA	**NA**
634	NA	NA	**NA**
642	NA	260	**NA**
675	NA	NA	**NA**
17197	NA	52	**NA**
17200	1.04E-05	NA	**NA**
17203	NA	24	**NA**
17302	1.20E-05	156	**4.6E-10**
17348	NA	NA	**NA**
17349	2.16E-04	260	**1.4E-08**
17371	1.61E-04	24	**9.5E-10**
17372	4.91E-05	260	**3.1E-09**
17393	NA	NA	**NA**

ND = Not detected above method detection limit
NA = Not available or not applicable
NS = Not sampled

EQUATIONS:

$$RISK = \frac{CA \times IR \times SF \times ED \times EF}{BW \times AT}$$

$$CA = \frac{CW \times Q \times T \times PC}{\forall + (V \times H \times W \times T)}$$

WHERE:

CA	=	BENZENE CONCENTRATION IN AIR [mg/m³]
IR	=	INHALATION RATE [m³/h]
EF	=	EXPOSURE FREQUENCY [d/y]
ED	=	EXPOSURE DURATION [y]
SF	=	SLOPE FACTOR [kg-d/mg]
BW	=	BODY WEIGHT [kg]
AT	=	AVERAGING TIME [d]
CW	=	BENZENE CONCENTRATION IN WATER [mg/L]
Q	=	FLOW RATE OF EXTRACTED GROUNDWATER [L/s]
T	=	TIME (NORMALIZED TO HOURLY-BASIS) [s]
PC	=	PARTITIONING COEFFICIENT [FRACTION]
$\forall$	=	VOLUME OF AIR SURROUNDING THE IRRIGATION WELL [m³]
V	=	WIND VELOCITY [m/s]
H	=	DISPERSION HEIGHT [m]
W	=	WIDTH OF BACKYARD [m]
(V x H x W x T)	=	VOLUMETRIC WIND EFFECTS ON EXPOSED AREA [m³]

APPROVED VALUES:

CA	=	CALCULATION
IR	=	0.60 m³/h
EF	=	260 d/y
ED	=	9 y
SF	=	0.029 kg-d/mg
BW	=	25 kg
AT	=	25,550 d
CW	=	0.016 mg/L
Q	=	0.63 L/s
T	=	3,600 s
PC	=	0.50
$\forall$	=	293 m³
V	=	2.0 m/s
H	=	1.5 m
W	=	14.0 m

NOTE: Q IS THE FLOW RATE OF EXTRACTED GROUNDWATER DETERMINED TO BE 10.0 GALLONS PER MINUTE FROM FIELD WELL STUDIES.

#1

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.19	Figure No: WELL # 17349	Date: 9/13/93
			Drawn By: Jason Nash

Title: CALCULATIONS FOR INHALATION OF VOLATILIZED GROUNDWATER CHILDREN EXPOSURE

1/2

CALCULATIONS:

$$CA = \frac{(0.016\ mg/L \times 0.63\ L/s \times 3{,}600\ s)(0.9)}{\left(293\ m^3 + (2.0\ m/s \times 1.5\ m \times 14\ m \times 3600\ s)\right)}$$

$$= 2.16 \times 10^{-4}\ mg/m^3$$

$$Risk = \frac{(2.16 \times 10^{-4}\ mg/m^3 \times 0.6\ m^3/h \times 0.029\ kg \cdot d/mg \times 9\ y \times 260\ d/y)}{(25\ kg \times 25{,}550\ d)}$$

$$= 1.37 \times 10^{-8}$$

#2

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/13/93
			Drawn By: [illegible]

Title: CALCULATIONS FOR INHALATION OF VOLATILIZED GROUNDWATER CHILDREN EXPOSURE

2/2

ATTACHMENT B

SCENARIO 2: ADULTS WORKING OR RESTING ADJACENT TO IRRIGATING GROUNDWATER

Table B-1
Inhalation of Volatilized Groundwater: Adult Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$CA = \frac{CW \times Q \times T \times PC}{V + (v \times H \times W \times T)}$$

WHERE:

CA = Benzene Concentration in Air [milligrams/cubic meter]
CW = Benzene Concentration in Water [milligrams/Liter]
Q = Flow Rate of Extracted Groundwater [liters/second]
T = Time (Normalized to Hourly-basis) [seconds]
PC = Partitioning Coefficient [fraction]
V = Volume of Air Surrounding the Irrigation Well [cubic meters]
v = Wind Velocity [meters/second]
H = Dispersion Height [meters]
W = Width of Backyard [meters]

APPROVED VALUES:

CW =	See Below	
Q =	0.63	L/s
T =	3,600	s
PC =	0.9	
V =	See Below	
v =	2.0	m/s
H =	2.0	m
W =	See Below	

WELL SPECIFIC VARIABLES:

WELL I.D.	CW (mg/L)	V (cu.m)	W (m)	CA (mg/cu.m)
590	ND	NA	NA	NA
633	ND	NA	NA	NA
634	NS	NA	NA	NA
642	ND	NA	NA	NA
675	NS	NA	NA	NA
17197	ND	NA	NA	NA
17200	0.0027	4,738	48.7	7.8E-06
17203	ND	NA	NA	NA
17302	0.00064	204	10.1	9.0E-06
17348	ND	NA	NA	NA
17349	0.0160	390	14.0	1.6E-04
17371	0.0090	222	10.5	1.2E-04
17372	0.0055	892	21.1	3.7E-05
17393	ND	NA	NA	NA

Table B–1 (continued)
Inhalation of Volatilized Groundwater: Adult Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$RISK = \frac{CA \times IR \times ED \times EF \times SF}{BW \times AT}$$

WHERE:

CA = Benzene Concentration in Air (Calculated Above) [milligrams/cubic meter]
IR = Inhaltion Rate [cubic meters/hour]
ED = Exposure Duration [years]
EF = Exposure Frequency [days/year]
SF = Slope Factor [kilograms–day/milligram]
BW = Body Weight [kilograms]
AT = Averaging Time [days]

APPROVED VALUES:

CA =	See Below	
IR =	0.83	cu.m/hr
ED =	70	yr
EF =	See Below	
SF =	0.029	kg–day/mg
BW =	70	kg
AT =	25,550	day

WELL SPECIFIC VARIABLES:

WELL I.D.	CA (mg/cu.m)	EF (day/yr)	RISK
590	NA	52	NA
633	NA	NA	NA
634	NA	NA	NA
642	NA	260	NA
675	NA	NA	NA
17197	NA	52	NA
17200	7.82E–06	NA	NA
17203	NA	24	NA
17302	8.98E–06	156	1.3E–09
17348	NA	NA	NA
17349	1.62E–04	260	4.0E–08
17371	1.21E–04	24	2.7E–09
17372	3.69E–05	260	9.0E–09
17393	NA	NA	NA

ND = Not detected above method detection limit
NA = Not available or not applicable
NS = Not sampled

EQUATIONS: $RISK = \frac{CA \times IR \times ED \times EF \times SF}{BW \times AT}$

$$CA = \frac{CW \times Q \times T \times PC}{\forall + (V \times H \times W \times T)}$$

WHERE:

- CA = BENZENE CONCENTRATION IN AIR [mg/m³]
- IR = INHALATION RATE [m³/h]
- FF = EXPOSURE FREQUENCY [d/y]
- ED = EXPOSURE DURATION [y]
- SF = SLOPE FACTOR [Kg-d/mg]
- BW = BODY WEIGHT [kg]
- AT = AVERAGING TIME [d]
- CW = BENZENE CONCENTRATION IN WATER [mg/L]
- Q = FLOW RATE OF EXTRACTED GROUNDWATER [L/S]
- T = TIME (NORMALIZED TO HOURLY-BASIS) [S]
- PC = PARTITIONING COEFFICIENT [FRACTION]
- $\forall$ = VOLUME OF AIR SURROUNDING THE IRRIGATION WELL [m³]
- V = WIND VELOCITY [m/s]
- H = DISPERSION HEIGHT [m]
- W = WIDTH OF BACKYARD [m]
- (VxHxWxT) = VOLUMETRIC WIND EFFECTS ON EXPOSED AREA [m³]

APPROVED VALUES:

- CA = CALCULATION
- IR = 0.83 m³/h
- EF = 260 d/y
- ED = 70 y
- SF = 0.029 kg-d/mg
- BW = 70 kg
- AT = 25,550 d
- CW = 0.016 mg/L
- Q = 0.63 L/S
- T = 3,600 s
- PC = 0.9
- $\forall$ = 390 m³
- V = 2.0 m/s
- H = 20 m
- W = 14.0 m

NOTE: Q IS THE FLOWRATE OF EXTRACTED GROUNDWATER DETERMINED TO BE 10.0 GALLONS PER MINUTE FROM FIELD WELL STUDIES.

#1

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/14/93
			Drawn By: Jam

Title: CALCULATION FOR INHALATION OF VOLATILIZED GROUNDWATER ADULT EXPOSURE

CALCULATIONS:

$$CA = \frac{(0.016 mg/L)(0.63 L/s)(3600 s)(0.9)}{\left(390 m^3 + (2.0 m/s)(2.0 m)(14.0 m)(3600 s)\right)}$$

$$= \underline{\underline{1.62 \times 10^{-9}}} \ mg/m^3$$

$$RISK = \frac{(1.62 \times 10^{-9} mg/m^3)(0.83 m^3/h)(260 d/y)(70 y)(0.029 kg\text{-}d/mg)}{(70 kg)(25,550 d)}$$

$$\boxed{= 3.96 \times 10^{-8}}$$

#2

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/14/93
			Drawn By: Tam Nou

Title: CALCULATIONS FOR INHALATION OF VOLATILIZED GROUNDWATER
ADULT EXPOSURE

2/2

ATTACHMENT C

SCENARIO 3: SOIL VAPOR TRANSPORT THROUGH SOIL

Table C-1
Inhalation of Soil Vapor: Children Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Determine Benzene Concentration in Air At Groundwater-Air Interface Based on Groundwater Concentration

Using Henry's Law:

$$CSV = \frac{[HB \times ((CWB / MWB) / (CWW / MWW)) / PT] \times D \times MWB \times CF}{MWA}$$

Where:
- CSV = Benzene Concentration in Air at the Water-Air Interface [micrograms/milliliter]
- HB = Henry's Law Coefficient (Benzene) [atmospheres]
- CWB = Benzene Concentration in Water (Site-Wide Historical Maximum) [milligrams/liter]
- MWB = Molecular Weight of Benzene [grams/mole]
- CWW = Water Concentration in Water [milligrams/liter]
- MWW = Molecular Weight of Water [grams/mole]
- PT = Total Pressure [atmospheres]
- D = Density of Subsurface Air (50 degrees F) [grams/liter]
- CF = Conversion Factor [1,000 micrograms-milliliter/gram-liter]
- MWA = Molecular Weight of Air [grams/liter]

Values:

HB =	240.0	atm
CWB =	3.40E-04	g/L
MWB =	78.12	g/mole
CWW =	1,000.0	g/L
MWW =	18.00	g/mole
PT =	1.0	atm
D =	1.2	g/L
CF =	1,000.0	ug/g
MWA =	29.0	g/mole

Solution: CSV = 6.08E-02 ug/mL

Determine Benzene Concentration in Air at Groundsurface Based on Diffusion

Using SEASOIL and Farmer's Equations:

$$CA = \frac{-[DA \times (((n - ms)^{10/3}) / n^2)] \times [(CATM - CSV) / L] \times T] \times CF}{H}$$

Where:
- CA = Benzene Concentration in Air at Groundsurface [milligrams/cubic meter]
- DA = Steady State Diffusion Coefficient in Air (Benzene) [square centimeters/second]
- n = Soil Porosity [fraction]
- ms = Soil Moisture [fraction]
- CATM = Benzene Concentration in Background Surface Air [micrograms/milliliter]
- CSV = Benzene Concentration in Air at the Water-Air Interface [micrograms/milliliter]
- L = Depth of Soil Cover [centimeters]
- T = Time (Normalized to Hour-basis) [seconds]
- CF = Conversion Factor [10 square centimeters-milligrams/square meter-microgram]
- H = Dispersion Height [meters]

Values:

DA =	0.077	sq.cm/s
n =	0.25	
ms =	0.20	
CATM =	1.98E-03	ug/mL
CSV =	6.08E-02	ug/mL
L =	357.2	cm
T =	3,600	s
CF =	10.0	sq.cm-mg/sq.m-ug
H =	1.5	m

Solution: CA = 2.24E-04 mg/cu.m

Table C–1 (continued)
Inhalation of Soil Vapor: Children Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

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

WHERE:

CA =	Benzene Concentration in Air (Calculated Above) [milligrams/cubic meter]
IR =	Inhalation Rate [cubic meters/hour]
ET =	Exposure Time [hours/day]
ED =	Exposure Duration [years]
EF =	Exposure Frequency [days/year]
SF =	Slope Factor [kilograms–day/milligram]
BW =	Body Weight [kilograms]
AT =	Averaging Time [days]

APPROVED VALUES:

CA =	2.24E–04	mg/cu.m
IR =	0.83	cu.m/hr
ET =	15.36	hr/day
EF =	365	day/yr
ED =	9	yr
SF =	0.029	kg–day/mg
BW =	25	kg
AT =	25,550	day

SOLUTION:

RISK = 4.3E–07

Table C-2
Inhalation of Soil Vapor: Adult Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Determine Benzene Concentration in Air At Groundwater-Air Interface Based on Groundwater Concentration

Using Henry's Law:

$$CSV = \frac{[\,HB \times ((CWB / MWB) / (CWW / MWW)) / PT\,] \times D \times MWB \times CF}{MWA}$$

Where:	CSV =	Benzene Concentration in Air at the Water-Air Interface [micrograms/milliliter]
	HB =	Henry's Law Coefficient (Benzene) [atmospheres]
	CWB =	Benzene Concentration in Water (Site-Wide Historical Maximum) [milligrams/liter]
	MWB =	Molecular Weight of Benzene [grams/mole]
	CWW =	Water Concentration in Water [milligrams/liter]
	MWW =	Molecular Weight of Water [grams/mole]
	PT =	Total Pressure [atmospheres]
	D =	Density of Subsurface Air (50 degrees F) [grams/liter]
	CF =	Conversion Factor [1,000 micrograms-milliliter/gram-liter]
	MWA =	Molecular Weight of Air [grams/liter]

Values:	HB =	240.0	atm
	CWB =	3.40E-04	g/L
	MWB =	78.12	g/mole
	CWW =	1,000.0	g/L
	MWW =	18.00	g/mole
	PT =	1.0	atm
	D =	1.2	g/L
	CF =	1,000.0	ug/g
	MWA =	29.0	g/mole
Solution:	**CSV =**	**6.08E-02**	**ug/mL**

Determine Benzene Concentration in Air at Groundsurface Based on Diffusion

Using SEASOIL and Farmer's Equations:

$$CA = \frac{-[\,DA \times (((n - ms)^{10/3} / n^2)\,] \times [\,(CATM - CSV) / L\,] \times T\,] \times CF}{H}$$

Where:	CA =	Benzene Concentration in Air at Groundsurface [micrograms/cubic meter]
	DA =	Steady State Diffusion Coefficient in Air (Benzene) [square centimeters/second]
	n =	Soil Porosity [fraction]
	ms =	Soil Moisture [fraction]
	CATM =	Benzene Concentration in Background Surface Air [micrograms/milliliter]
	CSV =	Benzene Concentration in Air at the Water-Air Interface [micrograms/milliliter]
	L =	Depth of Soil Cover [centimeters]
	T =	Time (Normalized to Hour-basis) [seconds]
	CF =	Conversion Factor [10 square centimeters-milligrams/sqaure meter-microgram]
	H =	Dispersion Height [meters]

Values:	DA =	0.077	sq.cm/s
	n =	0.25	
	ms =	0.20	
	CATM =	1.98E-03	ug/mL
	CSV =	6.08E-02	ug/mL
	L =	357.2	cm
	T =	3,600	s
	CF =	10.0	sq.cm-mg/sq.m-ug
	H =	2.0	m
Solution:	**CA =**	**1.68E-04**	**mg/cu.m**

Table C–2 (continued)
Inhalation of Soil Vapor: Adult Exposure

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

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

WHERE:

CA =	Benzene Concentration In Air (Calculated Above)	[milligrams/cubic meter]
IR =	Inhalation Rate	(cubic meters/hour)
ET =	Exposure Time	[hours/day]
EF =	Exposure Frequency	[days/year]
ED =	Exposure Duration	[years]
SF =	Slope Facter	[kilograms–day/milligram]
BW =	Body Weight	[kilograms]
AT =	Averaging Time	[days]

APPROVED VALUES:

CA =	1.68E–04	mg/cu.m
IR =	0.83	cu.m/hr
ET =	15.36	hr/day
EF =	365	day/yr
ED =	70	yr
SF =	0.029	kg–day/mg
BW =	70	kg
AT =	25,550	day

SOLUTION:

RISK = 8.9E–07

EQUATION: $$RISK = \frac{CA \times IR \times ET \times ED \times EF \times SF}{BW \times AT}$$

WHERE:
- CA = BENZENE CONCENTRATION IN AIR [mg/m³]
- IR = INHALATION RATE [m³/h]
- ET = EXPOSURE TIME [h/d]
- EF = EXPOSURE FREQUENCY [d/y]
- ED = EXPOSURE DURATION [d]
- SF = SLOPE FACTOR [kg·d/mg]
- BW = BODY WEIGHT [kg]
- AT = AVERAGING TIME [d]

APPROVED VALUES:
- CA = CALCULATIONS
- IR = 0.83 m³/h
- ET = 15.26 h/d
- EF = 265 d/y
- ED = 9 y
- SF = 0.029 kg·d/mg
- BW = 25 kg
- AT = 25,550 d

CALCULATIONS:

NOTE: FOR SIMPLICITY WE WILL BREAK DOWN THE CALCULATION FOR THE BENZENE CONCENTRATION IN AIR. FOR EACH EQUATION A BRIEF DESCRIPTION OF THE VARIABLE WILL FOLLOW.

- DETERMINE THE MOLE FRACTION OF BENZENE IN WATER BASED ON THE MAXIMUM HISTORICAL BENZENE CONCENTRATION IN WATER RECORDED ON SITE.

$$X_B = \frac{\frac{CW_B}{MW_B}}{\frac{CW_W}{MW_W}}$$

WHERE:
- CW_B = BENZENE CONCENTRATION IN WATER (MAXIMUM HISTORICAL RECORDED VALUE) [g/L]
- MW_B = MOLAR WEIGHT OF BENZENE [g/mol B]
- CW_W = CONCENTRATION OF WATER [g/L]
- MW_W = MOLAR WEIGHT OF WATER [g/mol W]
- X_B = MOLE FRACTION OF BENZENE IN WATER [FRACTION]

#1

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By: [illegible]

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR CHILDREN AND ADULT EXPOSURE

APPROVED VALUES:

$CW_B = 3.40 \times 10^{-4}$ g/L

$MW_B = 78.12$ g/mol$_B$

$CW_W = 1000.00$ g/L

$MW_W = 18.00$ g/mol$_W$

$$\therefore X_B = \frac{\left(\frac{3.40 \times 10^{-4}\ g/L}{78.12\ g/mol_B}\right)}{\left(\frac{1000.00\ g/L}{18.00\ g/mol_W}\right)}$$

$$= 7.83 \times 10^{-8}\ mol_B/mol_W$$

* DETERMINE THE MOLE FRACTION OF BENZENE IN AIR.

$$Y_B = \frac{(H_B \times X_B)}{P_T}$$

WHERE: H_B = HENRY'S LAW COEFFICIENT FOR BENZENE [atm]

P_T = TOTAL PARTIAL PRESSURE [atm]

Y_B = MOLE FRACTION OF BENZENE IN AIR [mol$_B$/mol$_W$]

APPROVED VALUES:

$H_B = 240$ atm

$P_T = 1.0$ atm

$$\therefore Y_B = \frac{(240\ atm)(7.83 \times 10^{-8}\ mol_B/mol_W)}{(1.0\ atm)}$$

$$= 1.88 \times 10^{-5}\ mol_B/mol_W$$

#2

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By:

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR CHLOREN AND ADULT EXPOSURE.

- DETERMINE BENZENE CONCENTRATION IN AIR AT THE GROUNDWATER – AIR INTERFACE BASED ON GROUNDWATER CONCENTRATION.

$$C_{SV} = \frac{Y_B \times D \times MW_B \times CF}{MW_A}$$

WHERE: C_{SV} = BENZENE CONCENTRATION IN AIR AT THE WATER – AIR INTERFACE [µg/mL]

Y_B = MOLE FRACTION OF BENZENE IN AIR [mol$_B$/mol$_A$]

D = DENSITY OF SUBSURFACE AIR (50°F) [g/L]

MW_B = MOLECULAR WEIGHT OF BENZENE [g/mol$_B$]

CF = CONVERSION FACTOR [1000 µg·mL/g·L]

MW_A = MOLECULAR WEIGHT OF AIR [g/L]

APPROVED VALUES:

C_{SV} = CALCULATION

Y_B = 1.88×10^{-5} mol$_B$ / mol$_A$

D = 1.2 g/L

MW_B = 78.12 g/mol$_B$

CF = 1000 µg/g

MW_A = 29.0 g/mol

$$\therefore C_{SV} = \frac{(1.88 \times 10^{-5} \text{ mol}_B/\text{mol}_A)(1.2 \text{ g/L})(78.12 \text{ g/mol}_B)(1000 \text{ µg/g})}{(29.0 \text{ g/mol})}$$

$$= 6.08 \times 10^{-2} \text{ µg/mL}$$

#3

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By: Jason Noack

Title: CALCULATION FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR CHILDREN AND ADULT EXPOSURE

- DETERMINE THE APPARENT STEADY STATE DIFFUSION COEFFICIENT IN SOIL VAPOR.

$$D_{SV} = \frac{D_A \times (n - m_S)^{(10/3)}}{n^2}$$

WHERE: D_{SV} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN SOIL VAPOR [cm^2/s]
D_A = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN AIR [cm^2/s]
n = SOIL POROSITY [FRACTION]
m_S = SOIL MOISTURE [FRACTION]

APPROVED VALUES:
D_{SV} = CALCULATION
D_A = 0.077 cm^2/s
n = 0.25
m_S = 0.20

$$\therefore D_{SV} = \frac{(0.077\ cm^2/s)(0.25 - 0.20)^{(10/3)}}{(0.25)^2}$$

$$= 5.67 \times 10^{-5}\ cm^2/s$$

- DETERMINE THE BENZENE FLUX ACROSS SOIL SURFACE

$$P = \frac{-D_{SV} \times (C_{Atm} - C_{SV}) \times T}{L}$$

WHERE: P = BENZENE FLUX ACROSS SOIL SURFACE [$\mu g/cm^2$]
D_{SV} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN AIR [cm^2/s]
C_{Atm} = BENZENE CONCENTRATION AT GROUND SURFACE [$\mu g/mL$]
C_{SV} = BENZENE CONCENTRATION IN AIR AT THE WATER-AIR INTERFACE [$\mu g/mL$]
T = TIME (NORMALIZED TO HOUR-BASIS) [s]
L = DEPTH OF SOIL COVER [cm]

#4

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By:

Title: CALCULATION FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR CHILDREN AND ADULT EXPOSURE

APPROVED VALUES:

P = CALCULATION
D_{SV} = 5.67×10^{-5} cm²/s
C_{ATM} = 1.98×10^{-3} µg/mL
C_{SV} = 6.08×10^{-2} µg/mL
T = 3,600 s
L = 357.2 cm

$$\therefore P = -\frac{(5.67 \times 10^{-5}\ cm^2/s)(1.98 \times 10^{-3}\ \mu g/mL - 6.08 \times 10^{-2}\ \mu g/mL)(3600\ s)}{(357.2\ cm)}$$

$$= 3.36 \times 10^{-5}\ \mu g/cm^2$$

- DETERMINE THE BENZENE CONCENTRATION IN AIR AT GROUNDSURFACE BASED ON DIFFUSION

$$CA = \frac{P \times CF}{H}$$

WHERE: P = BENZENE FLUX ACROSS SOIL SURFACE [µg/cm²]
CF = CONVERSION FACTOR
H = DISPERSION HEIGHT [m]

APPROVED VALUES:

P = 3.36×10^{-5} µg/cm²
CF = 10.0 cm²-mg/m²-µg
H = 1.5 m (CHILDREN)
2.0 m (ADULTS)

$$\therefore CA_C = \frac{(3.36 \times 10^{-5}\ \mu g/cm^2)(10.0\ cm^2 \cdot mg/m^2 \cdot \mu g)}{(1.5\ m)}$$

$$= 2.24 \times 10^{-4}\ mg/m^3 \quad \text{(CHILDREN)}$$

$$\therefore CA_A = \frac{(3.36 \times 10^{-5}\ \mu g/cm^2)(10.0\ cm^2 \cdot mg/m^2 \cdot \mu g)}{(2.0\ m)}$$

$$= 1.68 \times 10^{-4}\ mg/m^3 \quad \text{(ADULTS)}$$

#5

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By:

Title: CALCULATION FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR: CHILDREN AND ADULT EXPOSURE

- DETERMINE THE RISK DUE TO THE INHALATION OF SOIL VAPOR.

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

WHERE:
- CA = BENZENE CONCENTRATION IN AIR [mg/m³]
- IR = INHALATION RATE [m³/h]
- ET = EXPOSURE TIME [h/d]
- ED = EXPOSURE DURATION [d]
- EF = EXPOSURE FREQUENCY [d/y]
- SF = SLOPE FACTOR [kg-d/mg]
- BW = BODY WEIGHT [kg]
- AT = AVERAGING TIME [d]

APPROVED VALUES:
- CA_c = 2.24×10^{-4} mg/m³ (CHILDREN)
- CA_A = 1.68×10^{-4} mg/m³ (ADULTS)
- IR = 0.83 m³/h
- ET = 15.36 h/d
- ED = 9y (CHILDREN)
  70y (ADULTS)
- EF = 365 d/y
- SF = 0.029 kg·d/mg
- BW = 25kg (CHILDREN)
  70 kg (ADULTS)
- AT = 25,550 d

$$\therefore \text{RISK}_c = \frac{(2.24 \times 10^{-4}\ mg/m^3)(0.83\ m^3/h)(15.36\ h/d)(9y)(365\ d/y)(0.029\ kg\cdot d/mg)}{(25kg)(25,550\ d)}$$

$$= 4.26 \times 10^{-7} \quad \text{(CHILDREN)}$$

$$\therefore \text{RISK}_A = \frac{(1.68 \times 10^{-4}\ mg/m^3)(0.83\ m^3/h)(15.36\ h/d)(70y)(365\ d/y)(0.029\ kg\cdot d/mg)}{(70kg)(25,550\ d)}$$

$$= 8.87 \times 10^{-7} \quad \text{(ADULTS)}$$

#6

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-006 14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By: [illegible]

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR CHILDREN AND ADULT EXPOSURE

6/6

ATTACHMENT D

NON-CARCINOGENIC RISK

Table D-1
Ingestion of Groundwater: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$RISK = \frac{\frac{CW \times IR \times PC}{BW}}{RfD}$$

WHERE:

CW = Compound-Specific Concentration in Water (Historical Maximum) [milligrams/liter]
IR = Ingestion Rate (liters/day)
PC = Partitioning Coefficient [fraction]
BW = Body Weight [kilograms]
RfD = Reference Dose [milligram/kilogram/day]

APPROVED VALUES:

CW =	See Below	
IR =	0.35	L/day
PC =	0.10	
BW =	25	kg
RfD =	0.10	mg/kg/day (Ethylbenzene)
	0.20	mg/kg/day (Toluene)
	2.00	mg/kg/day (Xylene)

Table D-1 (continued)
Ingestion of Groundwater: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

WELL SPECIFIC VARIABLES:

WELL I.D.	CW Ethylbenzene (mg/L)	CW Toluene (mg/L)	CW Xylene (mg/L)	RISK Ethlybenzene	RISK Toluene	RISK Xylene
590	ND	ND	ND	NA	NA	NA
633	ND	ND	ND	NA	NA	NA
634	NS	NS	NS	NA	NA	NA
642	ND	ND	ND	NA	NA	NA
675	NS	NS	NS	NA	NA	NA
17197	ND	ND	ND	NA	NA	NA
17200	ND	ND	0.0120	NA	NA	8.4E-06
17203	ND	ND	0.0013	NA	NA	9.1E-07
17302	0.00044	ND	ND	6.2E-06	NA	NA
17348	ND	ND	ND	NA	NA	NA
17349	0.0071	0.0042	0.1100	9.9E-05	2.9E-05	7.7E-05
17371	0.0039	0.0010	0.0045	5.5E-05	7.0E-06	3.2E-06
17372	0.0013	0.0009	0.0012	1.8E-05	6.3E-06	8.4E-07
17393	ND	ND	ND	NA	NA	NA

ND = Not detected above method detection limit
NA = Not available or not applicable
NS = Not sampled

EQUATION: $$RISK = \frac{CW \times IR \times PC}{\frac{BW}{RFD}}$$

WHERE:
- CW_E = ETHYLBENZENE CONCENTRATION IN WATER [mg/L]
- CW_T = TOLUENE CONCENTRATION IN WATER [mg/L]
- CW_X = XYLENE CONCENTRATION IN WATER [mg/L]
- IR = INGESTION RATE [L/d]
- PC = PARTITIONING COEFFICIENT
- BW = BODY WEIGHT [kg]
- RFD_E = REFERENCE DOSE FOR ETHYLBENZENE [mg/kg/d]
- RFD_T = REFERENCE DOSE FOR TOLUENE [mg/kg/d]
- RFD_X = REFERENCE DOSE FOR XYLENE [mg/kg/d]

APPROVED VALUES:
- CW_E = 0.0071 mg/L
- CW_T = 0.0042 mg/L
- CW_X = 0.11 mg/L
- IR = 0.35 L/d
- PC = 0.1
- BW = 25 kg
- RFD_E = 0.1 mg/kg/d
- RFD_T = 0.2 mg/kg/d
- RFD_X = 2.0 mg/kg/d

CALCULATIONS:

$$RISK_E = \frac{(0.0071\ mg/L)(0.35\ L/d)(0.1)}{\frac{(25\ kg)}{(0.1\ mg/kg/d)}} = 9.94 \times 10^{-5}\ (\text{ETHYLBENZENE})$$

$$RISK_T = \frac{(0.0042\ mg/L)(0.35\ L/d)(0.1)}{\frac{(25\ kg)}{(0.2\ mg/kg/d)}} = 2.94 \times 10^{-5}\ (\text{TOLUENE})$$

$$RISK_X = \frac{(0.1100\ mg/L)(0.35\ l/d)(0.1)}{\frac{(25\ kg)}{(2.0\ mg/kg/d)}} = 7.7 \times 10^{-5}\ (\text{XYLENE})$$

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06-14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By:

Title: CALCULATIONS FOR THE RISK ASSOCIATED WITH THE INGESTION OF VOLATILIZED GROUNDWATER ⇒ NON-CARCINOGENIC CHILDREN EXPOSURE

1/1

Table D-2
Dermal Contact with Groundwater: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$RISK = \frac{\frac{CW \times SA \times DP \times ET \times PC}{BW \times CF}}{RfD}$$

WHERE:

CW = Compound-Specific Concentration in Water (Historical Maximum) [milligrams/liter]
SA = Skin Surface Area Available for Contact [square centimeters]
DP = Dermal Permeability Constant [centimeters/hour]
ET = Exposure Time [hours/day]
PC = Partitioning Coefficient [fraction]
BW = Body Weight [kilograms]
CF = Conversion Factor [1,000 cubic centimeters/liter]
RfD = Compound-Specific Reference Dosage [milligrams/kilogram/day]

APPROVED VALUES:

CW =	See Below	
SA =	4,970	sq.cm
DP =	0.001	cm/hr (Ethylbenzene)
	0.0009	cm/hr (Toluene)
	0.25	cm/hr (Xylene)
ET =	See Below	
PC =	0.10	
BW =	25	kg
CF =	1,000	cu.cm/L
RfD =	0.10	mg/kg/d (Ethylbenzene)
	0.20	mg/kg/d (Toluene)
	2.00	mg/kg/d (Xylene)

Table D-2 (continued)
Dermal Contact with Groundwater: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

WELL SPECIFIC VARIABLES:

WELL I.D.	CW Ethylbenzene (mg/L)	CW Toluene (mg/L)	CW Xylene (mg/L)	ET (hr/day)	RISK Ethylbenzene	RISK Toluene	RISK Xylene
590	ND	ND	ND	6.5	NA	NA	NA
633	ND	ND	ND	NA	NA	NA	NA
634	NS	NS	NS	NA	NA	NA	NA
642	ND	ND	ND	1.3	NA	NA	NA
675	NS	NS	NS	NA	NA	NA	NA
17197	ND	ND	ND	NA	NA	NA	NA
17200	ND	ND	0.0120	NA	NA	NA	NA
17203	ND	ND	0.0013	1.5	NA	NA	4.8E-06
17302	0.0004	ND	ND	5.0	4.4E-07	NA	NA
17348	ND	ND	ND	NA	NA	NA	NA
17349	0.0071	0.0042	0.1100	1.0	1.4E-06	3.8E-07	2.7E-04
17371	0.0039	0.0010	0.0045	2.0	1.6E-06	1.8E-07	2.2E-05
17372	0.0013	0.0009	0.0012	2.0	5.2E-07	1.6E-07	6.0E-06
17393	ND	ND	ND	NA	NA	NA	NA

ND = Not detected above method detection limit
NA = Not available or not applicable
NS = Not sampled

EQUATION: $$RISK = \frac{CW \times SA \times DP \times ET \times PC}{\frac{BW \times CF}{RfD}}$$

WHERE:

- CW_E = ETHYLBENZENE CONCENTRATION IN WATER [mg/L]
- CW_T = TOLUENE CONCENTRATION IN WATER [mg/L]
- CW_X = XYLENE CONCENTRATION IN WATER [mg/L]
- SA = SKIN SURFACE AREA AVAILABLE FOR CONTACT [cm^2]
- DP = DERMAL PERMEABILITY CONSTANT [cm/h] (COMPOUND SPECIFIC)
- ET = EXPOSURE TIME [h/d]
- PC = PARTITIONING COEFFICIENT
- BW = BODY WEIGHT [kg]
- CF = CONVERSION FACTOR
- RfD_E = REFERENCE DOSAGE FOR ETHYLBENZENE [mg/kg/d]
- RfD_T = REFERENCE DOSAGE FOR TOLUENE [mg/kg/d]
- RfD_X = REFERENCE DOSAGE FOR XYLENE [mg/kg/d]

APPROVED VALUES:

- CW_E = 0.0071 mg/L
- CW_T = 0.0042 mg/L
- CW_X = 0.1100 mg/L
- SA = 4,990 cm^2
- DP_E = 0.001 cm/h
- DP_T = 0.0009 cm/h
- DP_X = 0.25 cm/h
- ET = 1.0 h/d
- PC = 0.1
- BW = 25 kg
- CF = 1,000 cm^3/L
- RfD_E = 0.1 mg/kg/d
- RfD_T = 0.2 mg/kg/d
- RfD_X = 2.0 mg/kg/d

CALCULATIONS:

$$RISK_E = \frac{(0.0071\ mg/L)(4,990\ cm^2)(0.001\ cm/h)(1.0\ h/d)(0.1)}{\frac{(25\ kg)(1,000\ cm^3/L)}{(0.1\ mg/kg/d)}}$$

$$= 1.41 \times 10^{-6} \quad \text{(ETHYLBENZENE)}$$

#1

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06-14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By: Jean Nash

Title: CALCULATIONS FOR RISK ASSOCIATED WITH DERMAL CONTACT TO GROUNDWATER => NON-CARCINOGENIC CHILDREN EXPOSURE

$$Risk_T = \frac{(0.0042\ mg/L)(4,970\ cm^2)(0.0009\ cm/h)(1.0\ h/d)(0.1)}{\frac{(25\ kg)(1000\ cm^3/L)}{(0.2\ mg/kg/d)}}$$

$$= 3.76 \times 10^{-7} \quad \text{(TOLUENE)}$$

$$Risk_X = \frac{(0.1100\ mg/L)(4,970\ cm^2)(0.25\ cm/h)(1.0\ h/d)(0.1)}{\frac{(25\ kg)(1000\ cm^3/L)}{(2.0\ mg/kg/L)}}$$

$$= 273 \times 10^{-9} \quad \text{(XYLENE)}$$

2

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By:

Title: CALCULATIONS FOR RISK ASSOCIATED WITH DERMAL CONTACT TO GROUNDWATER => NON-CARCINOGENIC CHILDREN EXPOSURE

2/2

Table D-3
Inhalation of Volatilized Groundwater: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$CA = \frac{CW \times Q \times T \times PC}{V + (v \times H \times W \times T)}$$

WHERE:

CA = Compound-Specific Concentration in Air [milligrams/cubic meter]
CW = Compound-Specific Concentration in Water [milligrams/Liter]
Q = Flow Rate of Extracted Groundwater [liters/second]
T = Time (Normalized to Hourly-basis) [seconds]
PC = Partitioning Coefficient [fraction]
V = Volume of Air Surrounding the Irrigation Well [cubic meters]
v = Wind Velocity [meters/second]
H = Dispersion Height [meters]
W = Width of Backyard [meters]

APPROVED VALUES:

CW =	See Below	
Q =	0.63	L/s
T =	3,600	s
PC =	0.9	
V =	See Below	
v =	2.0	m/s
H =	1.5	m
W =	See Below	

Table D-3 (continued)
Inhalation of Volatilized Groundwater: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

WELL SPECIFIC VARIABLES:

WELL I.D.	CW Ethylbenzene (mg/L)	CW Toluene (mg/L)	CW Xylene (mg/L)	V (cu.m)	W (m)	CA Ethlybenzene (mg/cu.m)	CA Toluene (mg/cu.m)	CA Xylene (mg/cu.m)
590	ND	ND	ND	NA	NA	NA	NA	NA
633	ND	ND	ND	NA	NA	NA	NA	NA
634	NS	NS	NS	NA	NA	NA	NA	NA
642	ND	ND	ND	NA	NA	NA	NA	NA
675	NS	NS	NS	NA	NA	NA	NA	NA
17197	ND	ND	ND	NA	NA	NA	NA	NA
17200	ND	ND	0.0120	3,554	48.7	NA	NA	4.6E-05
17203	ND	ND	0.0013	NA	NA	NA	NA	NA
17302	0.00044	ND	ND	153	10.1	8.2E-06	NA	NA
17348	ND	ND	ND	NA	NA	NA	NA	NA
17349	0.0071	0.0042	0.1100	293	14.0	9.6E-05	5.7E-05	1.5E-03
17371	0.0039	0.0010	0.0045	167	10.5	7.0E-05	1.8E-05	8.1E-05
17372	0.0013	0.0009	0.0012	669	21.1	1.2E-05	7.9E-06	1.1E-05
17393	ND	ND	ND	NA	NA	NA	NA	NA

Table D-3 (continued)
Inhalation of Volatilized Groundwater: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$RISK = \frac{CA}{RfC}$$

WHERE:

CA = Compound-Specific Concentration in Air (Calculated Above) [milligrams/cubic meter]
RfC = Reference Concentration [milligrams/cubic meter]

APPROVED VALUES:

CA = See Below
RfC = 1.0 mg/cu.m (Ethylbenzene)
0.2 mg/cu.m (Toluene)
0.3 mg/cu.m (Xylene)

WELL SPECIFIC VARIABLES:

WELL I.D.	CA Ethylbenzene (mg/cu.m)	CA Toluene (mg/cu.m)	CA Xylene (mg/cu.m)	RISK Ethylbenzene	RISK Toluene	RISK Xylene
590	NA	NA	NA	NA	NA	NA
633	NA	NA	NA	NA	NA	NA
634	NA	NA	NA	NA	NA	NA
642	NA	NA	NA	NA	NA	NA
675	NA	NA	NA	NA	NA	NA
17197	NA	NA	NA	NA	NA	NA
17200	NA	NA	4.67E-05	NA	NA	1.6E-04
17203	NA	NA	NA	NA	NA	NA
17302	8.23E-06	NA	NA	8.2E-06	NA	NA
17348	NA	NA	NA	NA	NA	NA
17349	9.60E-05	5.69E-05	1.49E-03	9.6E-05	2.8E-04	5.0E-03
17371	7.00E-05	1.80E-05	8.08E-05	7.0E-05	9.0E-05	2.7E-04
17372	1.16E-05	7.89E-06	1.08E-05	1.2E-05	3.9E-05	3.6E-05
17393	NA	NA	NA	NA	NA	NA

ND = Not detected above method detection limit
NS = Not sampled
NA = Not available or not applicable

EQUATION: $RISK = \frac{CA}{RFC}$

$$CA = \frac{CW \times Q \times T \times PC}{\forall + (V \times H \times W \times T)}$$

WHERE:

- CA = BENZENE CONCENTRATION IN AIR [mg/m^3]
- RFC = REFERENCE CONCENTRATION [mg/m^3]
- CW = BENZENE CONCENTRATION IN WATER [mg/L]
- Q = FLOW RATE OF EXTRACTED GROUNDWATER [L/s]
- T = TIME (NORMALIZED TO HOURLY-BASIS) [s]
- PC = PARTITIONING COEFFICIENT [FRACTION]
- $\forall$ = VOLUME OF AIR SURROUNDING THE IRRIGATION WELL [m^3]
- V = WIND VELOCITY [m/s]
- H = DISPERSION HEIGHT [m]
- W = WIDTH OF BACKYARD [m]

APPROVED VALUES:

- CA = CALCULATED
- RFC_E = 1.0 mg/m^3 (ETHYLBENZENE)
- RFC_T = 0.2 mg/m^3 (TOLUENE)
- RFC_X = 0.3 mg/m^3 (XYLENE)
- CW_E = 0.0071 mg/L (ETHYLBENZENE)
- CW_T = 0.0042 mg/L (TOLUENE)
- CW_X = 0.1100 mg/L (XYLENE)
- Q = 0.63 L/s
- T = 3,600 s
- PC = 0.9
- $\forall$ = 293 m^3
- V = 2.0 m/s
- H = 1.5 m
- W = 14.0 m

CALCULATION:

- DETERMINE THE CONCENTRATION IN AIR OF ALL COMPOUNDS.

$$CA_E = \frac{(0.0071\ mg/L)(0.63\ L/s)(3600\ s)(0.9)}{(293\ m^3) + (2.0\ m/s)(1.5\ m)(14\ m)(3,600\ s)}$$

$$= 9.57 \times 10^{-5}\ mg/m^3 \quad \text{(ETHYLBENZENE)}$$

II 1

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By:

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF VOLATILIZED GROUNDWATER ⇒ NON-CARCINOGENIC CHILDREN EXPOSURE

1/2

$$CA_T = \frac{(0.0042\ mg/L)(0.63\ L/s)(3600\ s)(0.9)}{(293\ m^3) + (2.0\ m/s)(1.5\ m)(14\ m)(3600\ s)}$$

$$= 5.66 \times 10^{-5}\ mg/m^3 \quad (\text{TOLUENE})$$

$$CA_X = \frac{(0.1100\ mg/L)(0.63\ L/s)(3600\ s)(0.9)}{(293\ m^3) + (2.0\ m/s)(1.5\ m)(14\ m)(3600\ s)}$$

$$= 1.48 \times 10^{-3}\ mg/m^3 \quad (\text{XYLENE})$$

- DETERMINE THE RISK FOR NON-CARCINOGENIC INHALATION

$$Risk_E = \frac{(9.57 \times 10^{-5}\ mg/m^3)}{(1.0\ mg/m^3)}$$

$$= 9.57 \times 10^{-5} \quad (\text{ETHYLBENZENE})$$

$$Risk_T = \frac{(5.66 \times 10^{-5}\ mg/m^3)}{(0.2\ mg/m^3)}$$

$$= 2.83 \times 10^{-4} \quad (\text{TOLUENE})$$

$$Risk_X = \frac{(1.48 \times 10^{-3}\ mg/m^3)}{(0.3\ mg/m^3)}$$

$$= 4.93 \times 10^{-3} \quad (\text{XYLENE})$$

#2

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-00.14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By:

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF VOLATILIZED GROUNDWATER ⇒ NON-CARCINOGENIC CHILDREN EXPOSURE

2/2

Table D-4
Inhalation of Soil Vapor: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Determine Benzene Concentration In Air At Groundwater-Air Interface Based on Groundwater Concentration

Using Henry's Law:

$$CSV = \frac{[H \times ((CW / MW) / (CWW / MWW)) / PT] \times D \times MW \times CF}{MWA}$$

Where:
- CSV = Compound-Specific Concentration in Air at the Water-Air Interface [micrograms/milliliter]
- H = Henry's Law Coefficient (Compound-Specific, Approximate) [atmospheres]
- CW = Compound-Specific Concentration in Water (Site-Wide Historical Maximum) [milligrams/liter]
- MW = Molecular Weight (Compound-Specific) [grams/mole]
- CWW = Water Concentration in Water [milligrams/liter]
- MWW = Molecular Weight of Water [grams/mole]
- PT = Total Pressure [atmospheres]
- D = Density of Subsurface Air (50 degrees F) [grams/liter]
- CF = Conversion Factor [1,000 micrograms-milliliter/gram-liter]
- MWA = Molecular Weight of Air [grams/liter]

Values:

H =	376.0	atm (Ethylbenzene)
	291.0	atm (Toluene)
	225.0	atm (Xylene)
CW =	0.2800	g/L (Ethylbenzene)
	0.0082	g/L (Toluene)
	0.2100	g/L (Xylene)
MW =	106.17	g/mole (Ethylbenzene)
	92.15	g/mole (Toluene)
	106.17	g/mole (Xylene)
CWW =	1,000.0	g/L
MWW =	18.00	g/mole
PT =	1.0	atm
D =	1.2	g/L
CF =	1,000.0	ug/g
MWA =	29.0	g/mole

Solution:

CSV =	**78.42**	**ug/mL (Ethylbenzene)**
	1.78	**ug/mL (Toluene)**
	35.19	**ug/mL (Xylene)**

Table D-4 (continued)
Inhalation of Soil Vapor: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Determine Benzene Concentration in Air at Groundsurface Based on Diffusion
Using SEASOIL and Farmer's Equations:

$$CA = \frac{-[DA \times (((n - ms)^{(10/3)}) / n^2)] \times [(CATM - CSV) / L] \times T] \times CF}{H}$$

Where:
- CA = Compound-Specific Concentration in Air at Groundsurface [milligrams/cubic meter]
- DA = Steady State Diffusion Coefficient in Air (Compound-Specific) [sqaure centimeters/second]
- n = Soil Porosity [fraction]
- ms = Soil Moisture [fraction]
- CATM = Compound-Specific Concentration in Background Surface Air [micrograms/milliliter]
- CSV = Compound-Specific Concentration in Air at the Water-Air Interface [micrograms/milliliter]
- L = Depth of Soil Cover [centimeters]
- T = Time (Normalized to Hour-basis) [seconds]
- CF = Conversion Factor [10 square centimeters-milligrams/square meter-microgram]
- H = Dispersion Height [meters]

Values:

DA =	0.0658	sq.cm/s (Ethylbenzene)
	0.0770	sq.cm/s (Toluene, Data Not Available - Assumed to Equal Benzene)
	0.0770	sq.cm/s (Xylene, Data Not Available - Assumed to Equal Benzene)
n =	0.25	
ms =	0.20	
CATM =		(Data Not Available - Assumed to Equal Zero for Ethylbenzene, Toluene, and Xylene)
CSV =	78.42	ug/mL (Ethylbenzene)
	1.78	ug/mL (Toluene)
	35.19	ug/mL (Xylene)
L =	357.2	cm
T =	3,600	s
CF =	10.0	sq.cm-mg/sq.m-ug
H =	1.5	m

Solution:

CA =	**2.55E-01**	**mg/cu.m**
	6.77E-03	**mg/cu.m**
	1.34E-01	**mg/cu.m**

Table D-4 (continued)
Inhalation of Soil Vapor: Children Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$RISK = \frac{CA}{RfC}$$

WHERE:

CA = Compound-Specific Concentration in Air (Calculated Above) [milligrams/cubic meter]
RfC = Reference Concentration (Compound-Specific) [milligrams/cubic meter]

APPROVED VALUES:

CA =	2.55E-01	mg/cu.m (Ethylbenzene)
	6.77E-03	mg/cu.m (Toluene)
	1.34E-01	mg/cu.m (Xylene)
RfC =	1.0	mg/cu.m (Ethylbenzene)
	0.2	mg/cu.m (Toluene)
	0.3	mg/cu.m (Xylene)

SOLUTION:

RISK =	**2.6E-01**	**Ethylbenzene**
	3.4E-02	**Toluene**
	4.5E-01	**Xylene**

EQUATION: $RISK = \frac{CA}{RfC}$

WHERE: CA = COMPOUND CONCENTRATION IN AIR [mg/m³]
RfC = REFERENCE CONCENTRATION [mg/m³]

APPROVED VALUES:

CA_E = } CALCULATIONS
CA_T = }
CA_X = }

$RfC_E = 1.0\ mg/m^3$
$RfC_T = 0.2\ mg/m^3$
$RfC_X = 0.3\ mg/m^3$

CALCULATIONS:

NOTE: FOR SIMPLICITY WE WILL BREAK DOWN THE CALCULATION FOR THE COMPOUND CONCENTRATIONS IN AIR. EACH EQUATION WILL BE ACCOMPANIED BY A BRIEF DESCRIPTION OF THE VARIABLES PRESENTED.

- DETERMINE THE MOLE FRACTION OF EACH COMPOUND BASED ON MAXIMUM RECORDED CONCENTRATION.

$$X_E = \frac{\frac{CW_E}{MW_E}}{\frac{CW_W}{MW_W}} \qquad X_T = \frac{\frac{CW_T}{MW_T}}{\frac{CW_W}{MW_W}} \qquad X_X = \frac{\frac{CW_X}{MW_X}}{\frac{CW_W}{MW_W}}$$

WHERE:
CW_E = ETHYLBENZENE CONCENTRATION IN WATER [mg/L]
CW_T = TOLUENE CONCENTRATION IN WATER [mg/L]
CW_X = XYLENE CONCENTRATION IN WATER [mg/L]
CW_W = WATER [mg/L]
MW_E = MOLECULAR WEIGHT OF ETHYLBENZENE [g/mol$_E$]
MW_T = MOLECULAR WEIGHT OF TOLUENE [g/mol$_T$]
MW_X = MOLECULAR WEIGHT OF XYLENE [g/mol$_X$]
MW_W = MOLECULAR WEIGHT OF WATER [g/mol$_W$]
X_E = MOLE FRACTION OF ETHYLBENZENE IN WATER
X_T = MOLE FRACTION OF TOLUENE IN WATER
X_X = MOLE FRACTION OF XYLENE IN WATER

#1

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/16/93
			Drawn By: [illegible]

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR
=> NON-CARCINOGENIC — CHILDREN AND ADULT EXPOSURE

APPROVED VALUES:

CW_E = 0.2800 g/L
CW_T = 0.0082 g/L
CW_X = 0.2100 g/L
CW_W = 1000 g/L
MW_E = 106.17 g/mole
MW_T = 92.15 g/mol T
MW_X = 106.17 g/mole X
MW_W = 18.00 g/mol W

$$X_E = \frac{\frac{(0.2800\ g/L)}{(106.17\ g/mole)}}{\frac{(1000\ g/L)}{(18.00\ g/mol_W)}} = 4.75 \times 10^{-5}\ mole/mol_W$$

$$X_T = \frac{\frac{(0.0082\ g/L)}{(92.15\ g/mol_T)}}{\frac{(1000\ g/L)}{(18.00\ g/mol_W)}} = 1.60 \times 10^{-6}\ mol_T/mol_W$$

$$X_X = \frac{\frac{(0.2100\ g/L)}{(106.17\ g/mol_X)}}{\frac{(1000\ g/L)}{(18.00\ g/mol_W)}} = 3.56 \times 10^{-5}\ mol_X/mol_W$$

- DETERMINE THE MOLE FRACTION OF THE COMPOUNDS IN AIR.

$$Y_E = \frac{H_E \times X_E}{P_T} \qquad Y_T = \frac{H_T \times X_T}{P_T} \qquad Y_X = \frac{H_X \times X_X}{P_T}$$

WHERE:

Y_E = MOLE FRACTION OF ETHYLBENZENE IN AIR
Y_T = MOLE FRACTION OF TOLUENE IN AIR
Y_X = MOLE FRACTION OF XYLENE IN AIR
H_E = HENRY'S LAW COEFFICIENT FOR ETHYLBENZENE
H_T = HENRY'S LAW COEFFICIENT FOR TOLUENE
H_X = HENRY'S LAW COEFFICIENT FOR XYLENE
X_E = MOLE FRACTION OF ETHYL BENZENE IN WATER
X_T = MOLE FRACTION OF TOLUENE IN WATER
X_X = MOLE FRACTION OF XYLENE IN WATER
P_T = TOTAL PRESSURE

#2

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/16/93
			Drawn By: [illegible]

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR
⇒ NON-CARCINOGENIC
CHILDREN AND ADULT EXPOSURE

APPROVED VALUES:

H_E = 376.0 atm
H_T = 291.0 atm
H_X = 225.0 atm
X_E = 4.75×10^{-5} mole/molw
X_T = 1.60×10^{-6} molT/molw
X_X = 3.56×10^{-5} molx/molw
P_T = 1.0 atm

$$\therefore \quad Y_E = \frac{(376.0\ atm)(4.75 \times 10^{-5}\ mole/molw)}{1.0\ atm} = 1.79 \times 10^{-2}\ mole/mol.$$

$$Y_T = \frac{(291.0\ atm)(1.60 \times 10^{-6}\ molT/molw)}{1.0\ atm} = 4.66 \times 10^{-4}\ molT/molw$$

$$Y_X = \frac{(225.0\ atm)(3.56 \times 10^{-5}\ molx/molw)}{1.0\ atm} = 8.01 \times 10^{-3}\ molx/molw$$

- DETERMINE COMPOUND CONCENTRATIONS IN AIR AT THE GROUNDWATER-AIR INTERFACE BASED ON GROUNDWATER CONCENTRATIONS.

$$C_{SV_E} = \frac{Y_E \times D \times MW_E \times CF}{MW_A}$$

$$C_{SV_T} = \frac{Y_T \times D \times MW_T \times CF}{MW_A}$$

$$C_{SV_X} = \frac{Y_X \times D \times MW_X \times CF}{MW_A}$$

#3

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06-K	Figure No: WELL # 17349	Date: 9/16/93
			Drawn By:

Title: CALCULATION FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR
⇒ NON-CARCINOGENIC CHILDREN AND ADULT EXPOSURE

APPROVED VALUES:

C_{SV_E} = C_{SV_T} = C_{SV_X} = } CALCULATED

$Y_E = 1.79 \times 10^{-2}$ mole/mole$_W$

$Y_T = 4.66 \times 10^{-4}$ mole$_T$/mole$_W$

$Y_X = 8.01 \times 10^{-3}$ mole$_X$/mole$_W$

$MW_E = 106.17$ g/mole$_E$

$MW_T = 92.15$ g/mole$_T$

$MW_X = 106.17$ g/mole$_X$

$CF = 1000$ µg/g

$MW_A = 29.0$ g/mole$_A$

$D = 1.2$ g/L

WHERE:

C_{SV_E} = ETHYLBENZENE CONCENTRATION IN AIR AT THE WATER-AIR INTERFACE

C_{SV_T} = TOLUENE CONCENTRATION IN AIR AT THE WATER-AIR INTERFACE

C_{SV_X} = XYLENE CONCENTRATION IN AIR AT THE WATER-AIR INTERFACE

Y_E = MOLE FRACTION OF ETHYLBENZENE IN AIR

Y_T = MOLE FRACTION OF TOLUENE IN AIR

Y_X = MOLE FRACTION OF XYLENE IN AIR

MW_E = MOLECULAR WEIGHT OF ETHYLBENZENE

MW_T = MOLECULAR WEIGHT OF TOLUENE

MW_X = MOLECULAR WEIGHT OF XYLENE

CF = CONVERSION FACTOR

MW_A = MOLECULAR WEIGHT OF AIR

D = DENSITY OF SUBSURFACE AIR

$$\therefore C_{SV_E} = \frac{(1.79 \times 10^{-2}\ \text{mole}_E/\text{mole}_W)(1.2\ \text{g/L})(106.17\ \text{g/mole}_E)(1000\ \mu\text{g/g})}{29.0\ \text{g/mole}_A}$$

$$= \underline{\underline{78.64\ \mu\text{g/mL}}}$$

$$\therefore C_{SV_T} = \frac{(4.66 \times 10^{-4}\ \text{mole}_T/\text{mole}_W)(1.2\ \text{g/L})(92.15\ \text{g/mole}_T)(1000\ \mu\text{g/g})}{29.0\ \text{g/mole}_A}$$

$$= \underline{\underline{1.78\ \mu\text{g/mL}}}$$

$$\therefore C_{SV_X} = \frac{(8.01 \times 10^{-3}\ \text{mole}_X/\text{mole}_W)(1.2\ \text{g/L})(106.17\ \text{g/mole}_T)(1000\ \mu\text{g/g})}{29.0\ \text{g/mole}_A}$$

$$= \underline{\underline{35.19\ \mu\text{g/mL}}}$$

#4

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/16/93
			Drawn By: [illegible]

Title: CALCULATION FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR

⇒ NON-CARCINOGENIC — CHILDREN AND ADULT EXPOSURE

- DETERMINE THE APPARENT STEADY STATE DIFFUSION COEFFICIENT IN SOIL VAPOR FOR EACH COMPOUND.

$$D_{SV_E} = \frac{D_{A_E} \times (n - m_s)^{(10/3)}}{n^2}$$

$$D_{SV_T} = \frac{D_{A_T} \times (n - m_s)^{(10/3)}}{n^2}$$

$$D_{SV_X} = \frac{D_{A_X} \times (n - m_s)^{(10/3)}}{n^2}$$

WHERE:

D_{SV_E} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN SOIL VAPOR FOR ETHYLBENZENE

D_{SV_T} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN SOIL VAPOR FOR TOLUENE

D_{SV_X} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN SOIL VAPOR FOR XYLENE

D_{A_E} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN AIR FOR ETHYLBENZENE

D_{A_T} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN AIR FOR TOLUENE

D_{A_X} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN AIR FOR XYLENE

n = SOIL POROSITY

m_s = SOIL MOISTURE

APPARENT VALUES:

$D_{A_E} = 0.0658 \text{ cm}^2/\text{s}$

$D_{A_T} = 0.0770 \text{ cm}^2/\text{s}$

$D_{A_X} = 0.0770 \text{ cm}^2/\text{s}$

$n = 0.25$

$m_s = 0.20$

#5

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17399	Date: 9/16/93
			Drawn By:

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR
⇒ NON-CARCINOGENIC CHILDREN AND ADULT EXPOSURE

5/9

$$\therefore D_{SV_E} = \frac{(0.0658\ cm^2/s \times 0.25 - 0.20)^{(10/3)}}{(0.25)^2}$$

$$= \underline{4.85 \times 10^{-5}\ cm^2/s}$$

$$\therefore D_{SV_T} = D_{SV_X} = \frac{(0.0770\ cm^2/s \times 0.25 - 0.20)^{(10/3)}}{(0.25)^2}$$

$$= \underline{5.67 \times 10^{-5}\ cm^2/s}$$

- DETERMINE THE COMPOUND FLUX ACROSS THE SOIL SURFACE

$$P_E = -\frac{D_{SV_E} \times (C_{ATM} - C_{SV_E}) \times T}{L}$$

$$P_T = -\frac{D_{SV_T} \times (C_{ATM} - C_{SV_T}) \times T}{L}$$

$$P_X = -\frac{D_{SV_X} \times (C_{ATM} - C_{SV_X}) \times T}{L}$$

WHERE:

- D_{SV_E} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN SOIL VAPOR FOR ETHYLBENZENE
- D_{SV_T} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN SOIL VAPOR FOR TOLUENE
- D_{SV_X} = APPARENT STEADY STATE DIFFUSION COEFFICIENT IN SOIL VAPOR FOR XYLENE
- C_{SV_E} = ETHYLBENZENE CONCENTRATION IN AIR AT AIR-WATER INTERFACE
- C_{SV_T} = TOLUENE CONCENTRATION IN AIR AT AIR-WATER INTERFACE
- C_{SV_X} = XYLENE CONCENTRATION IN AIR AT AIR-WATER INTERFACE
- C_{ATM} = COMPOUND CONCENTRATION IN BACKGROUND SURFACE AIR
- T = TIME
- L = DEPTH OF SOIL COVER
- P = COMPOUND FLUX ACROSS SOIL SURFACE

N 6

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No:	Figure No:	Date:
			Drawn By:

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR
⇒ NON-CARCINOGENIC — CHILDREN AND ADULT EXPOSURE

APPARENT VALUES:

$D_{SV_E} = 4.85 \times 10^{-5}\ cm^2/s$
$D_{SV_T} = 5.67 \times 10^{-5}\ cm^2/s$
$D_{SV_X} = 5.67 \times 10^{-5}\ cm^2/s$
$C_{SV_E} = 78.69\ \mu g/mL$
$C_{SV_T} = 1.78\ \mu g/mL$
$C_{SV_X} = 35.19\ \mu g/mL$
$C_{Amb} = 0.00$
$T = 3,600\ s$
$L = 357.2\ cm$

$$\therefore P_E = \frac{-(4.85 \times 10^{-5}\ cm^2/s \times 0 - 78.69\ \mu g/mL \times 3600\ s)}{357.2\ cm}$$

$$= 3.84 \times 10^{-2}\ \mu g/cm^2$$

$$\therefore P_T = \frac{-(5.67 \times 10^{-5}\ cm^2/s \times 0 - 1.78\ \mu g/mL \times 3600\ s)}{357.2\ cm}$$

$$= 1.02 \times 10^{-3}\ \mu g/cm^2$$

$$\therefore P_X = \frac{-(5.67 \times 10^{-5}\ cm^2/s \times 0 - 35.19\ \mu g/mL \times 3600\ s)}{357.2\ cm}$$

$$= 2.01 \times 10^{-2}\ \mu g/cm^2$$

- DETERMINE THE COMPOUND CONCENTRATION IN AIR AT THE GROUNDSURFACE BASE ON DIFFUSION.

$$CA_E = \frac{P_E \times CF}{H} \qquad CA_T = \frac{P_T \times CF}{H} \qquad CA_X = \frac{P_X \times CF}{H}$$

WHERE: P = COMPOUND FLUX ACROSS SOIL SURFACE
CF = CONVERSION FACTOR
H = DISPERSION HEIGHT

#7

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-006.14	Figure No: WELL # 17349	Date: 9/16/13
			Drawn By: [illegible]

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR
⇒ NON-CARCINOGENIC CHILDREN AND ADULT EXPOSURE

APPROVED VALUES:

$P_E = 3.84 \times 10^{-2}$ ug/cm²
$P_T = 1.02 \times 10^{-3}$ ug/cm²
$P_x = 2.01 \times 10^{-2}$ ug/cm²
CF = 10.0 cm²-mg/m²-ug
H_C = 1.5m
H_A = 2.0m

$\therefore CA_E = \frac{(3.84 \times 10^{-2} \text{ ug/cm}^2 \times 10.0 \text{ cm}^2\text{-mg/m}^2\text{-ug})}{H_C \text{ \& } H_A}$

$= 2.56 \times 10^{-1}$ mg/m³ (CHILDREN)

$= 1.92 \times 10^{-1}$ mg/m³ (ADULTS)

$\therefore CA_T = \frac{(1.02 \times 10^{-3} \text{ ug/cm}^2 \times 10.0 \text{ cm}^2\text{-mg/m}^2\text{-ug})}{H_C \text{ \& } H_A}$

$= 6.80 \times 10^{-3}$ mg/m³ (CHILDREN)

$= 5.10 \times 10^{-3}$ mg/m³ (ADULTS)

$\therefore CA_x = \frac{(2.01 \times 10^{-2} \text{ ug/cm}^2)(10.0 \text{ cm}^2\text{-mg/m}^2\text{-ug})}{H_C \text{ \& } H_A}$

$= 1.34 \times 10^{-1}$ mg/m³ (CHILDREN)

$= 1.01 \times 10^{-1}$ mg/m³ (ADULTS)

#8

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/16/93
			Drawn By: [illegible]

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR ⇒ NON-CARCINOGENIC CHILDREN AND ADULT EXPOSURE

- DETERMINE THE RISK DUE TO THE INHALATION OF SOIL VAPOR NON-CARCINOGENIC RISK.

$$\text{RISK} = \frac{CA}{RfC}$$

WHERE: RfC_E = ETHYLBENZENE REFERENCE CONCENTRATION
RfC_T = TOLUENE REFERENCE CONCENTRATION
RfC_X = XYLENE REFERENCE CONCENTRATION

APPROVED VALUES:
RfC_E : 1.0 mg/m³
RfC_T : 0.2 mg/m³
RfC_X : 0.3 mg/m³

	CHILDREN	ADULTS
$RISK_E$	$= \frac{2.56 \times 10^{-1}\ mg/m^3}{1.0\ mg/m^3}$	$= \frac{1.92 \times 10^{-1}\ mg/m^3}{1.0\ mg/m^3}$
	$= 2.56 \times 10^{-1}$ (ETHYLBENZENE)	$= 1.92 \times 10^{-1}$ (ETHYLBENZENE)
$RISK_T$	$= \frac{6.80 \times 10^{-3}\ mg/m^3}{0.2\ mg/m^3}$	$= \frac{5.10 \times 10^{-3}\ mg/m^3}{0.2\ mg/m^3}$
	3.40×10^{-2} (TOLUENE)	$= 2.55 \times 10^{-2}$ (TOLUENE)
$RISK_X$	$= \frac{1.34 \times 10^{-1}\ mg/m^3}{0.3\ mg/m^3}$	$= \frac{1.01 \times 10^{-1}\ mg/m^3}{0.3\ mg/m^3}$
	$= 4.47 \times 10^{-1}$ (XYLENE)	$= 3.37 \times 10^{-1}$ (XYLENE)

#9

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/16/93
			Drawn By:

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF SOIL VAPOR
⇒ NON-CARCINOGENIC CHILDREN AND ADULT EXPOSURE

9

Table D-5
Inhalation of Volatilized Groundwater: Adult Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$CA = \frac{CW \times Q \times T \times PC}{V + (v \times H \times W \times T)}$$

WHERE:

CA = Compound-Specific Concentration in Air [milligrams/cubic meter]
CW = Compound-Specific Concentration in Water [milligrams/Liter]
Q = Flow Rate of Extracted Groundwater [liters/second]
T = Time (Normalized to Hourly-basis) [seconds]
PC = Partitioning Coefficient [fraction]
V = Volume of Air Surrounding the Irrigation Well [cubic meters]
v = Wind Velocity [meters/second]
H = Dispersion Height [meters]
W = Width of Backyard [meters]

APPROVED VALUES:

CW =	See Below	
Q =	0.63	L/s
T =	3,600	s
PC =	0.9	
V =	See Below	
v =	2.0	m/s
H =	2.0	m
W =	See Below	

Table D–5 (continued)
Inhalation of Volatilized Groundwater: Adult Exposure
Non–Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

WELL SPECIFIC VARIABLES:

WELL I.D.	CW Ethylbenzene (mg/L)	CW Toluene (mg/L)	CW Xylene (mg/L)	V (cu.m)	W (m)	CA Ethlybenzene (mg/cu.m)	CA Toluene (mg/cu.m)	CA Xylene (mg/cu.m)
590	ND	ND	ND	NA	NA	NA	NA	NA
633	ND	ND	ND	NA	NA	NA	NA	NA
634	NS	NS	NS	NA	NA	NA	NA	NA
642	ND	ND	ND	NA	NA	NA	NA	NA
675	NS	NS	NS	NA	NA	NA	NA	NA
17197	ND	ND	ND	NA	NA	NA	NA	NA
17200	ND	ND	0.0120	4,738	48.7	NA	NA	3.5E–05
17203	ND	ND	0.0013	NA	NA	NA	NA	NA
17302	0.00044	ND	ND	204	10.1	6.2E–06	NA	NA
17348	ND	ND	ND	NA	NA	NA	NA	NA
17349	0.0071	0.0042	0.1100	390	14.0	7.2E–05	4.3E–05	1.1E–03
17371	0.0039	0.0010	0.0045	222	10.5	5.2E–05	1.3E–05	6.1E–05
17372	0.0013	0.0009	0.0012	892	21.1	8.7E–06	5.9E–06	8.0E–06
17393	ND	ND	ND	NA	NA	NA	NA	NA

Table D-5 (continued)
Inhalation of Volatilized Groundwater: Adult Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

EQUATION:

$$RISK = \frac{CA}{RfC}$$

WHERE:

CA = Compound-Specific Concentration in Air (Calculated Above) [milligrams/cubic meter]
RfC = Reference Concentration [milligrams/cubic meter]

APPROVED VALUES:

CA = See Below
RfC = 1.0 mg/cu.m (Ethylbenzene)\
0.2 mg/cu.m (Toluene)
0.3 mg/cu.m (Xylene)

WELL SPECIFIC VARIABLES:

WELL I.D.	CA Ethylbenzene (mg/cu.m)	CA Toluene (mg/cu.m)	CA Xylene (mg/cu.m)	RISK Ethylbenzene	RISK Toluene	RISK Xylene
590	NA	NA	NA	NA	NA	NA
633	NA	NA	NA	NA	NA	NA
634	NA	NA	NA	NA	NA	NA
642	NA	NA	NA	NA	NA	NA
675	NA	NA	NA	NA	NA	NA
17197	NA	NA	NA	NA	NA	NA
17200	NA	NA	3.48E-05	NA	NA	1.2E-04
17203	NA	NA	NA	NA	NA	NA
17302	6.18E-06	NA	NA	6.2E-06	NA	NA
17348	NA	NA	NA	NA	NA	NA
17349	7.20E-05	4.26E-05	1.12E-03	7.2E-05	2.1E-04	3.7E-03
17371	5.25E-05	1.35E-05	6.05E-05	5.2E-05	6.7E-05	2.0E-04
17372	8.71E-06	5.90E-06	8.04E-06	8.7E-06	2.9E-05	2.7E-05
17393	NA	NA	NA	NA	NA	NA

ND = Not detected above method detection limit
NS = Not sampled
NA = Not available or not applicable

EQUATION: $RISK = \frac{CA}{RfC}$

$$CA = \frac{C_W \times Q \times T \times PC}{\forall + (V \times H \times T \times W)}$$

WHERE:

- CA = BENZENE CONCENTRATION IN AIR [mg/m³]
- RfC = REFERENCE CONCENTRATION [mg/m³]
- C_W = BENZENE CONCENTRATION IN WATER [mg/L]
- Q = FLOW RATE OF EXTRACTED GROUNDWATER [m/s]
- T = TIME (NORMALIZED TO HOURLY BASIS) [s]
- PC = PARTITIONING COEFFICIENT
- $\forall$ = VOLUME OF AIR SURROUNDING IRRIGATION WELL [m³]
- V = WIND VELOCITY [m/s]
- H = DISPERSION HEIGHT [m]
- W = WIDTH OF BACKYARD [m]

APPROVED VALUES:

CA_E, CA_T, CA_X = CALCULATED

RfC_E	1.0 mg/m³	(ETHYLBENZENE)
RfC_T	0.2 mg/m³	(TOLUENE)
RfC_X	0.3 mg/m³	(XYLENE)
C_{W_E}	0.0071 mg/L	(ETHYLBENZENE)
C_{W_T}	0.0042 mg/L	(TOLUENE)
C_{W_X}	0.1100 mg/L	(XYLENE)
Q	0.63 L/s	
T	3600 s	
PC	0.9	
$\forall$	293 m³	
V	20 m/s	
H	2.0 m	
W	14.0 m	

CALCULATIONS:

- DETERMINE COMPOUND CONCENTRATIONS IN AIR.

#1

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06-14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By: [illegible]

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF VOLATILIZED GROUNDWATER ⇒ NON-CARCINOGENIC ADULT EXPOSURE

1/2

$$CA_E = \frac{(0.0071\ mg/L)(0.63\ L/s)(3600\ s)(0.9)}{(293\ m^3) + (2.0\ m/s)(7.0\ m)(19.0\ m)(3600\ s)}$$

$$= 7.18 \times 10^{-5}\ mg/m^3 \quad \text{(ETHYLBENZENE)}$$

$$CA_T = \frac{(0.0042\ mg/L)(0.63\ L/s)(3600\ s)(0.9)}{(293\ m^3) + (2.0\ m/s)(2.0\ m)(14.0\ m)(3600\ s)}$$

$$= 4.25 \times 10^{-5}\ mg/m^3 \quad \text{(TOLUENE)}$$

$$CA_X = \frac{(0.1100\ mg/L)(0.63\ L/s)(3600\ s)(0.9)}{(293\ m^3) + (2.0\ m/s)(2.0\ m)(14.0\ m)(3600\ s)}$$

$$= 1.11 \times 10^{-3}\ mg/m^3 \quad \text{(XYLENE)}$$

- DETERMINE RISK FOR NON-CARCINOGENIC INHALATION

$$Risk_E = \frac{(7.18 \times 10^{-5}\ mg/m^3)}{(1.0\ mg/m^3)}$$

$$= 7.18 \times 10^{-5} \quad \text{(ETHYLBENZENE)}$$

$$Risk_T = \frac{(4.25 \times 10^{-5}\ mg/m^3)}{(0.2\ mg/m^3)}$$

$$= 2.13 \times 10^{-4} \quad \text{(TOLUENE)}$$

$$Risk_X = \frac{(1.11 \times 10^{-3}\ mg/m^3)}{(0.3\ mg/m^3)}$$

$$= 3.70 \times 10^{-3} \quad \text{(XYLENE)}$$

#2

PACIFIC ENVIRONMENTAL GROUP, INC.	Project No: 330-06.14	Figure No: WELL # 17349	Date: 9/15/93
			Drawn By: NJ

Title: CALCULATIONS FOR RISK ASSOCIATED WITH THE INHALATION OF VOLATILIZED GROUNDWATER ⇒ NON-CARCINOGENIC ADULT EXPOSURE

2-2

Table D-6
Inhalation of Soil Vapor: Adult Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Determine Benzene Concentration in Air At Groundwater-Air Interface Based on Groundwater Concentration

Using Henry's Law:

$$CSV = \frac{[H \times ((CW / MW) / (CWW / MWW)) / PT] \times D \times MW \times CF}{MWA}$$

Where:
- CSV = Compound-Specific Concentration in Air at the Water-Air Interface [micrograms/milliliter]
- H = Henry's Law Coefficient (Compound-Specific, Approximate) [atmospheres]
- CW = Compound-Specific Concentration in Water (Site-Wide Historical Maximum) [milligrams/liter]
- MW = Molecular Weight (Compound-Specific) [grams/mole]
- CWW = Water Concentration in Water [milligrams/liter]
- MWW = Molecular Weight of Water [grams/mole]
- PT = Total Pressure [atmospheres]
- D = Density of Subsurface Air (50 degrees F) [grams/liter]
- CF = Conversion Factor [1,000 micrograms-milliliter/gram-liter]
- MWA = Molecular Weight of Air [grams/liter]

Values:

H =	376.0	atm (Ethylbenzene)
	291.0	atm (Toluene)
	225.0	atm (Xylene)
CW =	0.2800	g/L (Ethylbenzene)
	0.0082	g/L (Toluene)
	0.2100	g/L (Xylene)
MW =	106.17	g/mole (Ethylbenzene)
	92.15	g/mole (Toluene)
	106.17	g/mole (Xylene)
CWW =	1,000.0	g/L
MWW =	18.00	g/mole
PT =	1.0	atm
D =	1.2	g/L
CF =	1,000.0	ug/g
MWA =	29.0	g/mole

Solution:

CSV =	**78.42**	**ug/mL (Ethylbenzene)**
	1.76	**ug/mL (Toluene)**
	35.19	**ug/mL (Xylene)**

Table D-6 (continued)
Inhalation of Soil Vapor: Adult Exposure
Non-Carcinogenic Risk

ARCO Service Station 0608
17601 Hesperian Boulevard
San Lorenzo, California

Determine Benzene Concentration in Air at Groundsurface Based on Diffusion
Using SEASOIL and Farmer's Equations:

$$CA = \frac{-[DA \times (((n - ms)^{(10/3)}) / n^2)] \times [(CATM - CSV) / L] \times T] \times CF}{H}$$

Where:
- CA = Compound-Specific Concentration in Air at Groundsurface [milligrams/cubic meter]
- DA = Steady State Diffusion Coefficient in Air (Compound-Specific) [sqaure centimeters/second]
- n = Soil Porosity [fraction]
- ms = Soil Moisture [fraction]
- CATM = Compound-Specific Concentration in Background Surface Air [micrograms/milliliter]
- CSV = Compound-Specific Concentration in Air at the Water-Air Interface [micrograms/milliliter]
- L = Depth of Soil Cover [centimeters]
- T = Time (Normalized to Hour-basis) [seconds]
- CF = Conversion Factor [10 square centimeters-milligrams/square meter-microgram]
- H = Dispersion Height [meters]

Values:

DA =	0.0658	sq.cm/s (Ethylbenzene)
	0.0770	sq.cm/s (Toluene, Data Not Available - Assumed to Equal Benzene)
	0.0770	sq.cm/s (Xylene, Data Not Available - Assumed to Equal Benzene)
n =	0.25	
ms =	0.20	
CATM =		(Data Not Available - Assumed to Equal Zero for Ethylbenzene, Toluene, and Xylene)
CSV =	78.42	ug/mL (Ethylbenzene)
	1.78	ug/mL (Toluene)
	35.19	ug/mL (Xylene)
L =	357.2	cm
T =	3,600	s
CF =	10.0	sq.cm-mg/sq.m-ug
H =	2.0	m

Solution:

CA =	**1.92E-01**	**mg/cu.m**
	5.08E-03	**mg/cu.m**
	1.01E-01	**mg/cu.m**