RWQCB presentation

Weiss Associates *Environmental and Geologic Services*

5500 Shellmound Street, Emeryville, CA 94608-2411 *FAX: 510-547-5043 Phone: 510-450-6000*

TRANSMITTAL

DATE:	November 20, 1996	**PROJECT #:**	4-1129-70
TO:	Scott Seery	**PHONE:**	510 567-6700
COMPANY:	Alameda County Environmental Health Services	**FAX:**	(510) 337-9335
FROM:	Tim Utterback, (510) 450-6193		

ENCLOSED PLEASE FIND: **VAPOR SEMINAR SLIDES, CHEVRON SS 9-5607, 5269 CROW CANYON RD, CASTRO VALLEY, CA**

VIA:	FAX:	AS:	FOR:
☑ Fax	# of pages: 23 (including this cover)	☐ Per our phone call	☑ Your information
☐ 1st Class Mail		☑ You requested	☐ Return to you
☐ Overnight Delivery	☐ Hard Copy to follow	☐ Is required	☐ Your action
☐ UPS (Surface)		☐ We believe you may be interested	☐ Your review & comments
☐ Courier			

Please call (510) 450-6000 if there are any problems with transmission.

COMMENTS:

Attached are the slides for the 11/25/96 vapor pathway presentation of the case study at the above referenced site. I included more data than I will actually be presenting. Please call me at (510) 450-6193 if you want clarification of the content with respect to these slides.

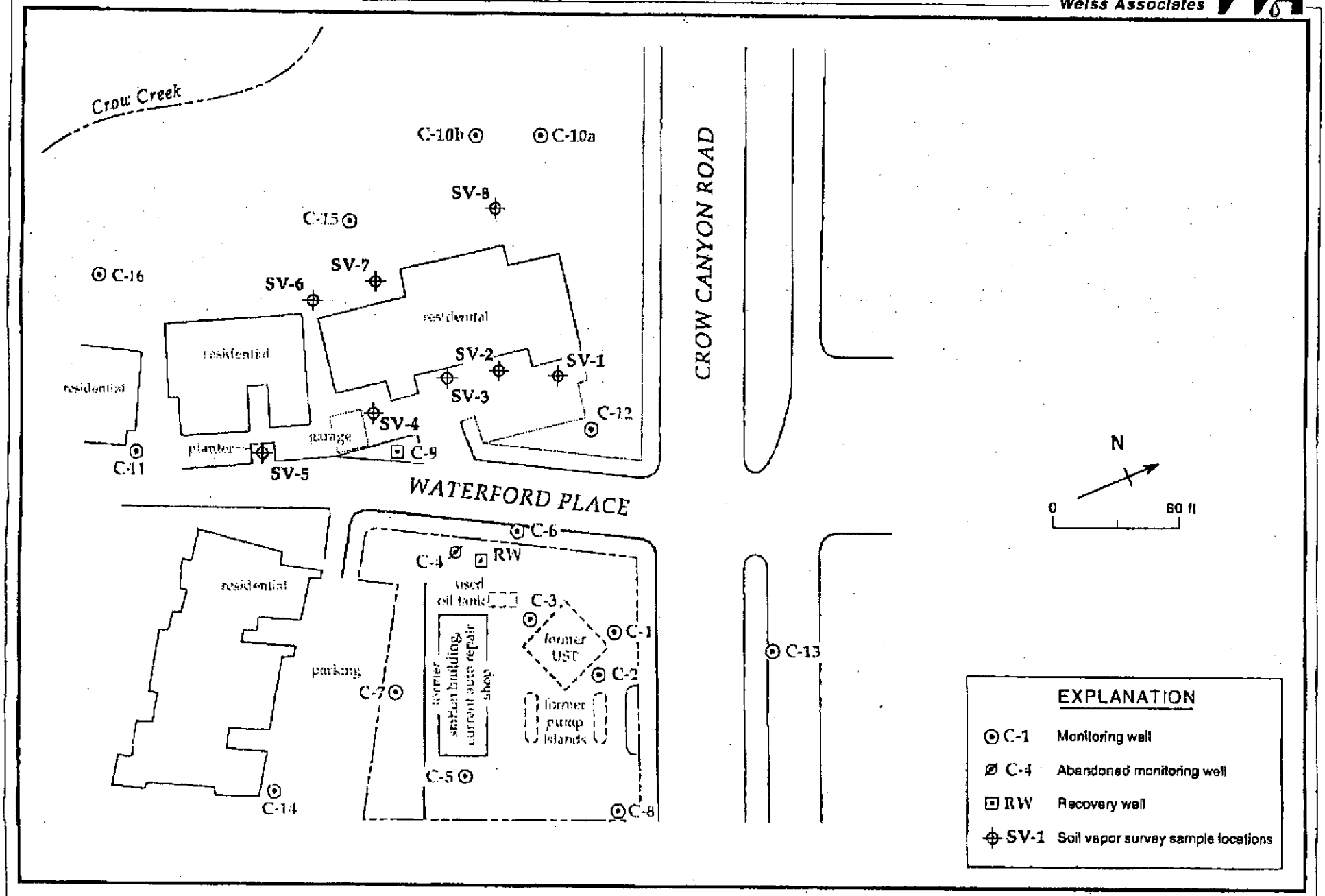


Figure 2. Site Plan - Chevron Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

Table 1. **Residential Receptors** - Comparison of Representative Concentrations to Tier 1 Risk-Based Screening Levels - Former Chevron Service Station, 9-5607, 5269 Crow Canyon Road, Castro Valley, California

Source Medium	Exposure Pathway	Potentially Complete Pathway?	Benzene		Ethylbenzene		Toluene		Xylenes	
			Representative Concentration[a]	RBSL[b]	Representative Concentration[a]	RBSL[c]	Representative Concentration[a]	RBSL[c]	Representative Concentration[a]	RBSL[c]
Soil (mg/kg)	Volatilization to Outdoor Air	Y	2.3	0.79	9.3	RES	2.7	RES	40	RES
	Vapor Intrusion to Buildings	Y	2.3	0.015	9.3	427	2.7	20.6	40	RES
	Surficial Soil (0-3 ft depth): Ingestion/Dermal/Inhalation	N	N/A	16.8	N/A	7,830	N/A	13,300	N/A	145,000
	Leachate to Ground Water for Ingestion	Y	2.3	0.05	9.3	575	2.7	129	40	RES
Ground Water (mg/l)	Volatilization to Outdoor Air	Y	8.2	31.9	2.5	>S	0.70	>S	2.1	>S
	Vapor Intrusion to Buildings	Y	8.2	0.069	2.5	77.5	0.70	32.8	2.1	>S
	Ingestion	Y	8.2	0.0085	2.5	3.65	0.70	7.30	2.1	73.0

Notes:

RBSL = ASTM RBCA Tier 1 Risk-Based Screening Level
RES = Selected risk level is not exceeded for pure compound presene at any concentration in soil.
>S = At pure compound solubility (mg/l), selected risk level is not exceeded.
a = Representative concentration in residential area soil are the maximum concentrations detected in soil boring samples. The representative soil sample was collected on 8/20/96 from 25 ft depth in soil boring SV-7. The representative concentration in ground water is from well C-9 containing the maximum dissolved hydrocarbon concentrations in the downgradient residential area. The representative concentrations in well C-9 are from the ground water sample collected on January16, 1996.
b = The RBSLs used for benzene are based on a carcinogenic risk of 1 in 100,000 (10^{-5}) and California's standard cancer slope factor of 0.1 mg/kg-day.
c = The RBSLs used for non-carcinogenic compounds are based on a chronic hazard quotient of 1.0.

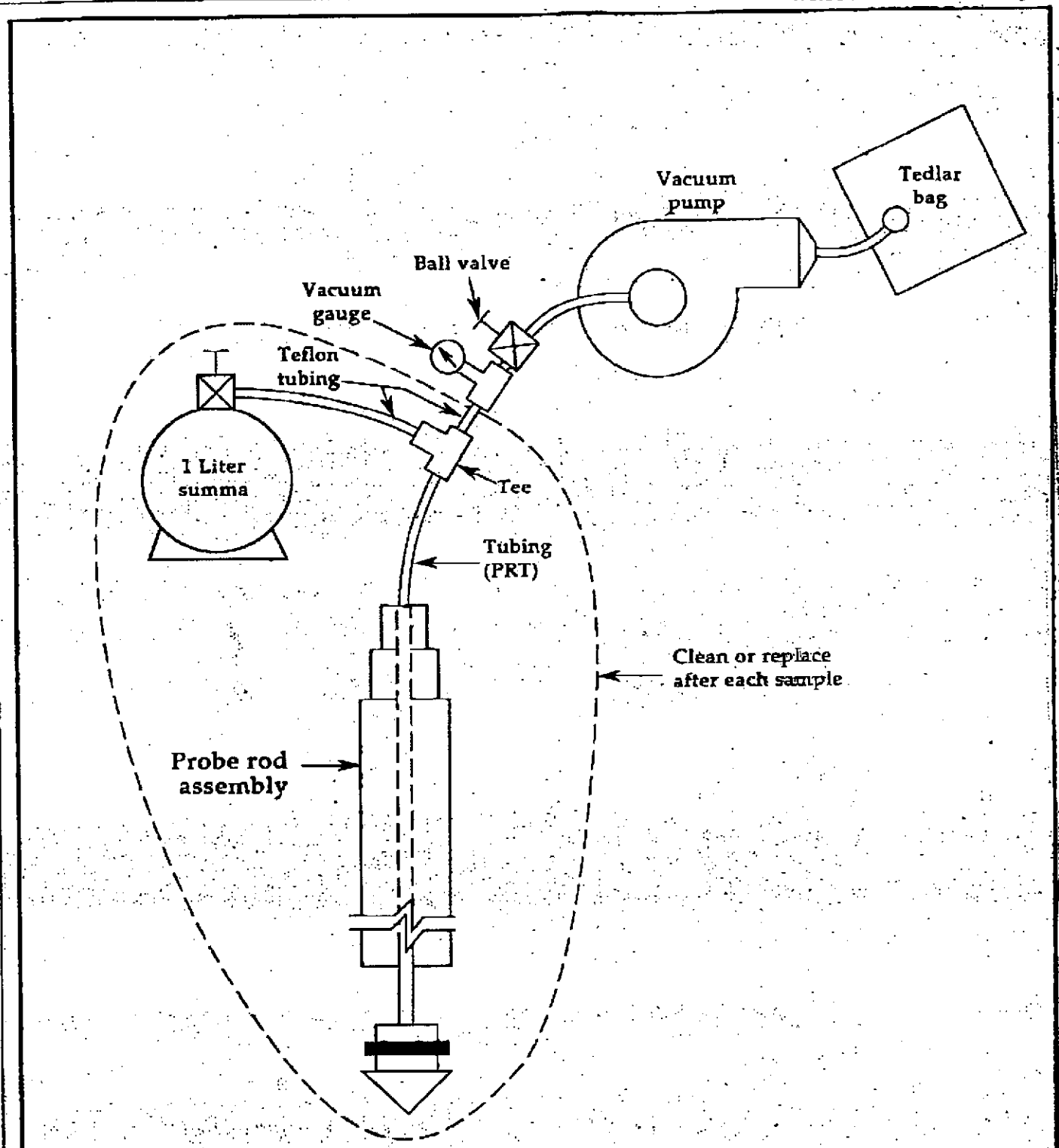


Figure 3. Vapor Sample Collection Configuration - Former Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California

Table 1. Analytic Results for Vapor Samples - Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California.

Boring Location	Sample ID/ Depth (ft)	B	E	T	X	O_2	CO_2	CH_4
		←parts per billion by volume (ppbv)→				←percent by volume→		
SV-1	SV-1 @ 3'	<4.3	<4.3	<4.3	<8.6	22	0.076	<0.002
SV-2	SV-2 @ 8'	<6.1	<6.1	<6.1	<12.2	1.4	28	0.010
SV-3	SV-3 @ 8'	<4.4	7.6	<4.4	6.7	21	0.25	<0.002
SV-3	SV-3 @ 25'	2,100	3,800	680	2,300	21	0.58	0.004
SV-4	SV-4 @ 3'	<4.3	<4.3	<4.3	<4.6	14	9.3	<0.002
SV-4	SV-4 @ 8	<4.2	<4.2	<4.2	5.7	21	0.35	<0.002
SV-4	SV-4 @ 11	<4.2	6.0	<4.2	<8.4	21	0.80	0.007
SV-4	SV-4 @ 25	38,000	140,000	20,000	83,000	21	0.37	0.002
SV-4	SV-4 @ 25' dup	39,000	140,000	22,000	87,000	21	0.35	0.002
SV-5	SV-5 @ 12'	6.2	32	11	39	22	0.091	<0.002
SV-6	SV-6 @ 3'	29	42	6.4	25.4	0.51	0.054	0.005
SV-7	SV-7 @ 3'	<4.2	5.1	<4.2	6.8	21	0.47	<0.002
SV-8	SV-8 @ 3'	40	83	9.5	59	19	3.6	<0.002

Abbreviations:

B = Benzene by EPA Method 8020
E = Ethylbenzene by EPA Method 8020
T = Toluene by EPA Method 8020
X = Xylenes by EPA Method 8020
O_2 = Oxygen by ASTM Method D3416
CO_2 = Carbon dioxide by ASTM Method D3416
CH_4 = Methane by ASTM Method D3416
<n = Not detected at detection limits of n ppbv

Notes:

Samples collected on 8/19/96 and 8/20/96 by Weiss Associates and analyzed by Air Toxics, Folsom, California.

Table 2. Analytic Results for Soil Boring Samples - Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California.

Boring Location	Sample ID/Depth Below Ground Surface (ft)	TPH-G	B	E	T	X
		← parts per million (mg/kg) →				
SV-1	SS-1 @ 5'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-1	SS-1 @ 10'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-1	SS-1 @ 21'	<1.0	<0.005	<0.005	<0.005	0.014
SV-2	SS-2 @ 3'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-2	SS-2 @ 8'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-2	SS-2 @ 10'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-2	SS-2 @ 21'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-3	SS-3 @ 5'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-3	SS-3 @ 10'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-3	SS-3 @ 21'	17	0.67	0.74	0.38	1.2
SV-4	SS-4 @ 6'	<1.0	<0.005	<0.005	<0.005	0.012
SV-4	SS-4 @ 9.5'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-4	SS-4 @ 23.5'	97	0.59	<0.010	1.0	2.9
SV-5	SS-5 @ 5'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-5	SS-5 @ 10'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-5	SS-5 @ 24.5'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-6	SS-6 @ 5'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-6	SS-6 @ 10'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-6	SS-6 @ 25'	61	0.85	0.65	1.2	3.6
SV-7	SS-7 @ 5'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-7	SS-7 @ 10'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-7	SS-7 @ 25'	400	2.3	2.7	9.3	40

Table 2. Analytic Results for Soil Boring Samples - Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California.

Boring Location	Sample ID/Depth Below Ground Surface (ft)	TPH-G	B	E	T	X
		← parts per million (mg/kg) →				
SV-8	SS-8 @ 5'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-8	SS-8 @ 10'	<1.0	<0.005	<0.005	<0.005	<0.005
SV-8	SS-8 @ 25'	<1.0	<0.005	<0.005	<0.005	<0.005

Abbreviations:

TPH-G = Total petroleum hydrocarbons as gasoline by Modified EPA Method 8015
B = Benzene by EPA Method 8020
E = Ethylbenzene by EPA Method 8020
T = Toluene by EPA Method 8020
X = Xylenes by EPA Method 8020
<n = Not detected at detection limits of n ppb

Notes:

Samples collected on 8/19/96 and 8/20/96 by Weiss Associates and analyzed by Sequoia Analytical, Redwood City, California.

Table 3. Physical Property Measurements for Soil Samples - Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California.

Sample ID	Depth Collected Below Ground Surface (ft)	foc %	Dry Density (g/cc)	Natural Density (g/cc)	Grain Density (g/cc)	Porosity (cc/cc)
SV-1	6	---	1.94	2.21	2.68	0.277
SV-1	10	---	1.84	2.16	2.69	0.315
SV-2	3	0.30	---	---	---	---
SV-2	15	0.23	---	---	---	---
SV-3	3	0.20	---	---	---	---
SV-3	21.5	0.14	---	---	---	---
SV-4	5	0.29	---	---	---	---
SV-4	23	0.14	---	---	---	---

Abbreviations:

foc = Fraction of Organic Carbon by Walley-Black Method
g/cc = grams per cubic centimeter
cc/cc = porous volume/total volume of soil
Dry density by American Petroleum Institute RP-40
Natural density by American Petroleum Institute RP-40
Grain density by American Petroleum Institute RP-40
Porosity by American Petroleum Institute RP-40

Notes:

Samples collected on 8/19/96 and 8/20/96 by Weiss Associates and analyzed by Sequoia Analytical, Redwood City, California and Core Laboratories, Bakersfield, California.

Table 4. Analytic Results for Ground Water Sample - Chevron Service Station #9-5607, 5269 Crow Canyon Road, Castro Valley, California.

Boring Location	Sample ID	TPH-G	B	E	T	X
		← parts per million (mg/L) →				
SV-1	WS-1	0.610	0.028	0.0082	0.025	0.10

Abbreviations:

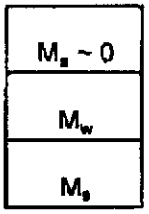
TPH-G = Total petroleum hydrocarbons as gasoline by Modified EPA Method 8015
B = Benzene by EPA Method 8020
E = Ethylbenzene by EPA Method 8020
T = Toluene by EPA Method 8020
X = Xylenes by EPA Method 8020

Notes:

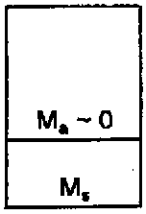
Sample collected on 8/19/96 by Weiss Associates and analyzed by Sequoia Analytical, Redwood City, California.

Calculation of Air Content and Water Content

Former Chevron SS # 9-5607, 5269 Crow Canyon Road, Castro Valley, CA



$\rho_{natural} = (M_s + M_w) / V_t$



$\rho_{dry} = M_s / V_t$

Sample: SS-1 @ 6'

$\rho_{solids} = M_s / V_s = 2.68$ g/cc

Let $V_t = 1$cc

$\rho_{dry} = M_s / V_t = 1.94$ g/cc

$M_s = 1.94$g/cc x 1cc = 1.94 g

$\rho_{natural} = (M_s + M_w) / V_t = 2.21$ g/cc

$M_w = 2.21$ g/cc x 1cc - 1.94g = 0.27g

$M_w / V_w = 1$ g/cc

$V_w = 0.27$g / (1g/cc) = 0.27cc

$\theta_t = (V_a + V_w) / V_t = 0.28$ cc/cc

$V_a = 0.28$ cc/cc x 1 cc - 0.27 cc = 0.01 cc

$\theta_w = V_w / V_t$
$\theta_a = V_a / V_t$

Results
$\theta_t = 0.28$
$\theta_w = 0.27$
$\theta_a = 0.01$

Sample: SS-1 @ 10'

$\rho_{solids} = M_s / V_s = 2.69$ g/cc

Let $V_t = 1$cc

$\rho_{dry} = M_s / V_t = 1.84$ g/cc

$M_s = 1.84$g/cc x 1cc = 1.84 g

$\rho_{natural} = (M_s + M_w) / V_t = 2.16$ g/cc

$M_w = 2.16$ g/cc x 1cc - 1.84g = 0.32g

$M_w / V_w = 1$ g/cc

$V_w = 0.27$g / (1g/cc) = 0.32cc

$\theta_t = (V_a + V_w) / V_t = 0.32$ cc/cc

$V_a = 0.32$ cc/cc x 1 cc - 0.32 cc = 0.00 cc

$\theta_w = V_w / V_t$
$\theta_a = V_a / V_t$

Results
$\theta_t = 0.32$
$\theta_w = 0.32$
$\theta_a = 0.00$

VAPOR PATHWAY ANALYSIS CASE STUDY - CHEVRON CASTRO VALLEY (CONTINUED)

Indoor Air Risk Predicted by Soil Vapor Data

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
ASTM 96	ρ_b	1.7	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_T	0.28	Porosity (v/v)
Site Spec	d	91	Depth to detected benzene (cm)
	Diffusivity Parameters		
ASTM 96	H	0.22	Henry's Constant for Benzene
ASTM 96	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 96	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient soil (cm^2/s)
	Prediction of Flux From Benzene Concentration in Soil Vapor		
Lab Data	$C_{v,measured}$	40	Measured Benzene Concentration in Vapor (ppbv)
Unit Conv	$C_{v,measured}$	0.13	Measured Benzene Concentration in Vapor (ug/L)
Calculated	F_{max}	1.19E-11	Maximum Diffusive Vapor Flux Predicted by Benzene Concentration in Soil Vapor (ug/cm^2-sec)
	Indoor Air Concentration		
ASTM 96	Lb	200	Enclosed Space Volume/Infiltration Area Ratio (cm)
ASTM 96	ER_{air}-indoor	0.00014	Enclosed Space Air Exchange Rate (sec^{-1})
Calculated	C_{indoor}	4.26E-10	Enclosed Space Air Concentration (ug/cm^3)
	Dose		
ASTM 96	IR_{air}-indoor	15	Daily Indoor Inhalation Rate (m^3/day)
ASTM 96	EF	350	Exposure Frequency (days/year)
ASTM 96	ED	30	Exposure Duration (years)
Calculated	Dose	0.067091	Dose (mg)
	Risk		
CAL EPA	SF_i	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
ASTM 96	BW	70	Adult Body Weight (kg)
ASTM 96	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	Risk	3.75E-09	Risk (positives/population)

Formulas

$$D_i^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

$$F_{max} = D_i^{eff}\frac{C_{v,measured}}{d}$$

$$C_{indoor} = \frac{F_{max}}{ER_{air-indoor} \times L_b}$$

$$Dose = C_{indoor} \times IR_{air-indoor} \times EF \times ED$$

$$Risk = \frac{Dose \times SF_i}{BW \times AT}$$

Notes:

ASTM 96 = American Society for Testing and Materials, March 5, 1996. Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

Site Spec: Depth to detected benzene in the soil vapor sample from boring location SV-8.

Lab Data: Porosity determined by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs). Benzene concentration in Soil Vapor determined by laboratory analysis of pore space vapor from soil boring SV-8 at 3 feet bgs.

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, enclosed space air concentration, dose and risk calculations from ASTM 96 guidance. Formulas presented above.

Outdoor Air Risk Predicted by Soil Vapor Data

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

	Soil Specific Parameters		
ASTM 96	ρ_s	1.7	Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01	Air Content (v/v)
Calculated	θ_{ws}	0.27	Water Content (v/v)
Lab Data	θ_t	0.28	Porosity (v/v)
Site Spec	d	91	Depth to detected benzene (cm)
	Diffusivity Parameters		
ASTM 96	H	0.22	Henry's Constant for Benzene
ASTM 96	D^{air}	9.30E-02	Air Diffusion Coefficient (cm^2/s)
ASTM 96	D^{wat}	1.10E-05	Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.41E-06	Effective Diffusion Coefficient soil (cm^2/s)
	Prediction of Flux From Benzene Concentration In Soil Vapor		
Lab Data	$C_{v,measured}$	40	Measured Benzene Concentration in Vapor (ppbv)
Unit Conv	$C_{v,measured}$	0.13	Measured Benzene Concentration in Vapor (ug/L)
Calculated	F_{max}	1.19E-11	Maximum Diffusive Vapor Flux Predicted by Benzene Concentration in Soil Vapor (ug/cm^2-sec)
	Outdoor Air Concentration		
ASTM 96	Uair	225	Air velocity (cm/sec)
ASTM 96	W	1500	Width of plume parallel to velocity (cm)
ASTM 96	δair	200	Ambient air mixing height (cm)
Calculated	$C_{v,outdoor}$	3.98E-13	Outdoor Air Concentration (ug/cm^3)
	Dose		
ASTM 96	IR_{air}-outdoor	20	Daily Outdoor Air Inhalation Rate (m^3/day)
ASTM 96	EF	350	Exposure Frequency (days/year)
ASTM 96	ED	30	Exposure Duration (years)
Calculated	Dose	8.35E-05	Dose (mg)
	Risk		
CAL EPA	SF_i	0.1	California Cancer Slope Factor for Benzene (kg-day/mg)
ASTM 96	BW	70	Adult Body Weight (kg)
ASTM 96	AT_c	70	Averaging Time for Carcinogens (years)
Calculated	$Risk_{sv}$	4.67E-12	Outdoor Air Risk Predicted by Soil Vapor Data

Formulas

$$D_s^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

$$F_{max} = D_s^{eff}\frac{C_{v,measured}}{d}$$

$$C_{v,outdoor} = \frac{F_{max} \times W}{U_{air} \times \delta_{air}}$$

$$Dose = C_{v,outdoor} \times IR_{air-indoor} \times EF \times ED$$

$$Risk_{sv} = \frac{Dose \times SF_i}{BW \times AT}$$

Notes:

ASTM 96 = American Society for Testing and Materials, March 5, 1996, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

Site Spec: Depth to detected benzene in the soil vapor sample from boring location SV-8.

Lab Data: Porosity determied by laboratory analysis of soil from boring SV-1 at 6 feet below ground surface (bgs). Benzene concentration in Soil Vapor determined by laboratory analysis of pore space vapor from soil boring SV-8 at 3 feet bgs.

Calculations: Air content and water content calculated from dry density and natural density in soil from boring SV-1 at 6 feet bgs (Calculation attached). Effective diffusivity, diffusive vapor flux, outdoor air concentration, dose and risk calculations from ASTM 96 guidance. Formulas presented above.

VAPOR PATHWAY ANALYSIS CASE STUDY - CHEVRON CASTRO VALLEY (CONTINUED)

Residential Receptors - Comparison of Representative Concentrations to Tier 2 Site-Specific Target Levels - Former Chevron Service Station, 9-5607, 5269 Crow Canyon Road, Castro Valley, California

Source Medium	Exposure Pathway	Potentially Complete Pathway?	Benzene		Benzene	
			Representative Concentration	SSTL	Representative Risk	Acceptable Risk
Ground Water and Soil	Volatilization to Outdoor Air	Y	n/a	n/a	4.67×10^{-12}	10^{-5}
	Vapor Intrusion to Buildings	Y	n/a	n/a	3.75×10^{-9}	10^{-5}
Ground Water (mg/l)	Ingestion	Y	< 0.0005	0.0085	n/a	n/a
	Transport to Crow Creek	Y	< 0.0005	0.001	n/a	n/a

VAPOR PATHWAY ANALYSIS CASE STUDY - CHEVRON CASTRO VALLEY (CONTINUED)

BENZENE IN THE GROUND WATER TO INDOOR AIR PATHWAY

METHOD	~ CALCULATED EXCESS CANCER RISK
TIER 1 Model Using ground water data (8.2 ppm at ASTM default parameters)	~10^{-3}
TIER 1 Model Using site-specific soil parameters and depth to ground water	~10^{-5}
TIER 2 Model with Site-Specific Parameters Mass balance with biodegradation	~10^{-8}
TIER 1 Model Using site-specific soil vapor data and soil physical parameters	~10^{-9}

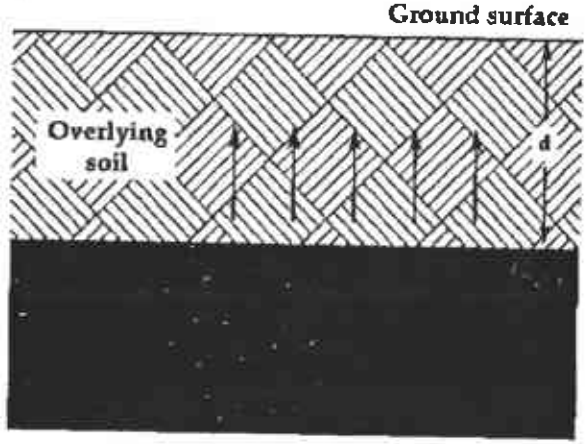
Tier 2 Evaluation - Application of Vapor Data VS Application of Ground Water Data.

 # 1 Low D_s^{eff} may hinder vapor transport from Ground Water Source.

 # 2 Biodegradation may destroy vapors transporting from Ground Water Source.

VAPOR PATHWAY ANALYSIS CASE STUDY - CHEVRON CASTRO VALLEY (CONTINUED)

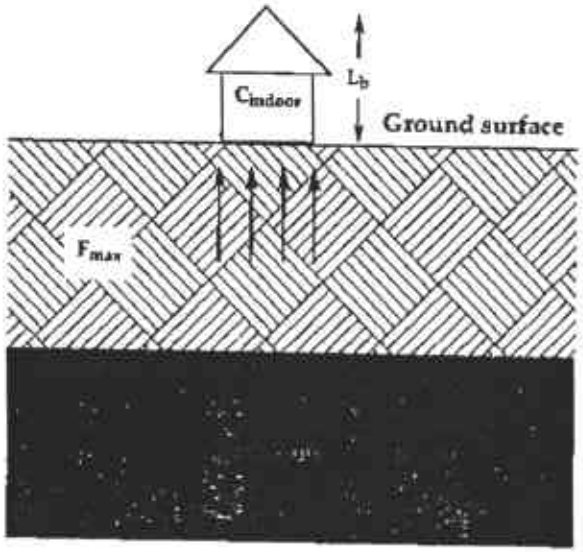
$$F_{max} = D_s^{eff} \frac{C_{v,eq}}{d}$$



$$C_{indoor} = \frac{F_{max}}{ER_{air-indoor} \times L_b}$$

air exchange rate

building volume to floor area ratio



VAPOR PATHWAY ANALYSIS CASE STUDY - CHEVRON CASTRO VALLEY (CONTINUED)

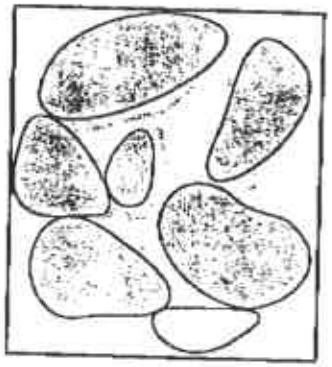
$$Dose = C_{indoor} \times IR_{air-indoor} \times EF \times ED$$

inhalation rate; frequency; duration (# years)

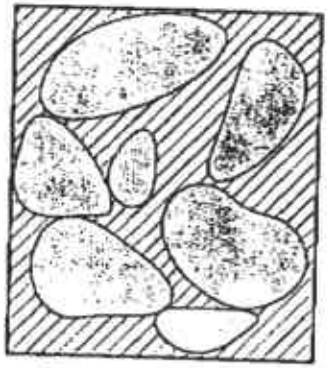
$$Risk = \frac{Dose \times SF_i}{BW \times AT}$$

cancer slope factor; carcinogen averaging time; body weight

VAPOR PATHWAY ANALYSIS CASE STUDY - CHEVRON CASTRO VALLEY (CONTINUED)

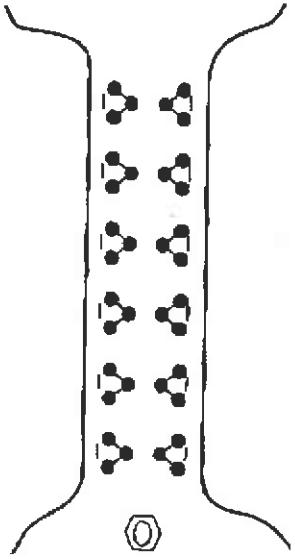


SAND



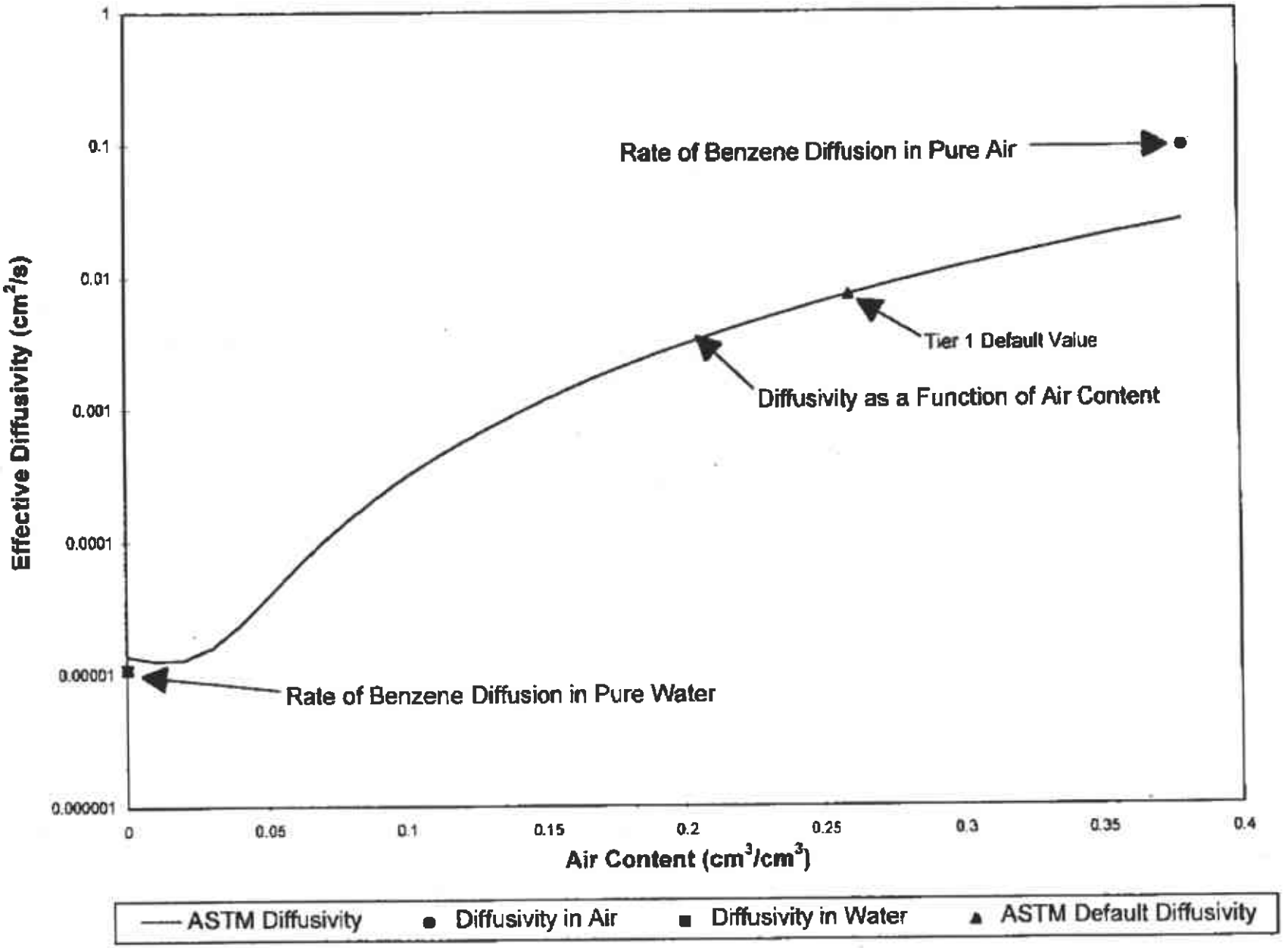
SANDY CLAY

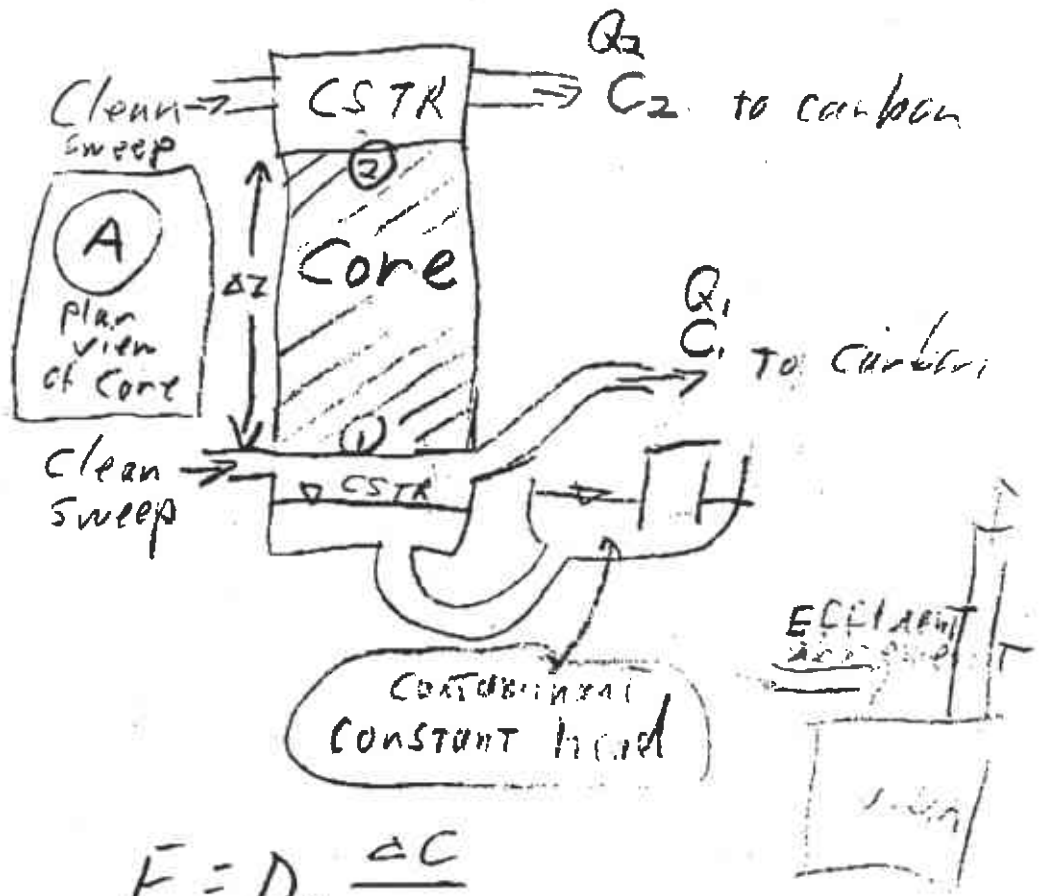
$$D_s^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$



ASTM Effective Diffusivity as a Function of Air Content

Benzene as the Representative Chemical of Concern





$$F = D_e \frac{\Delta C}{\Delta Z}$$

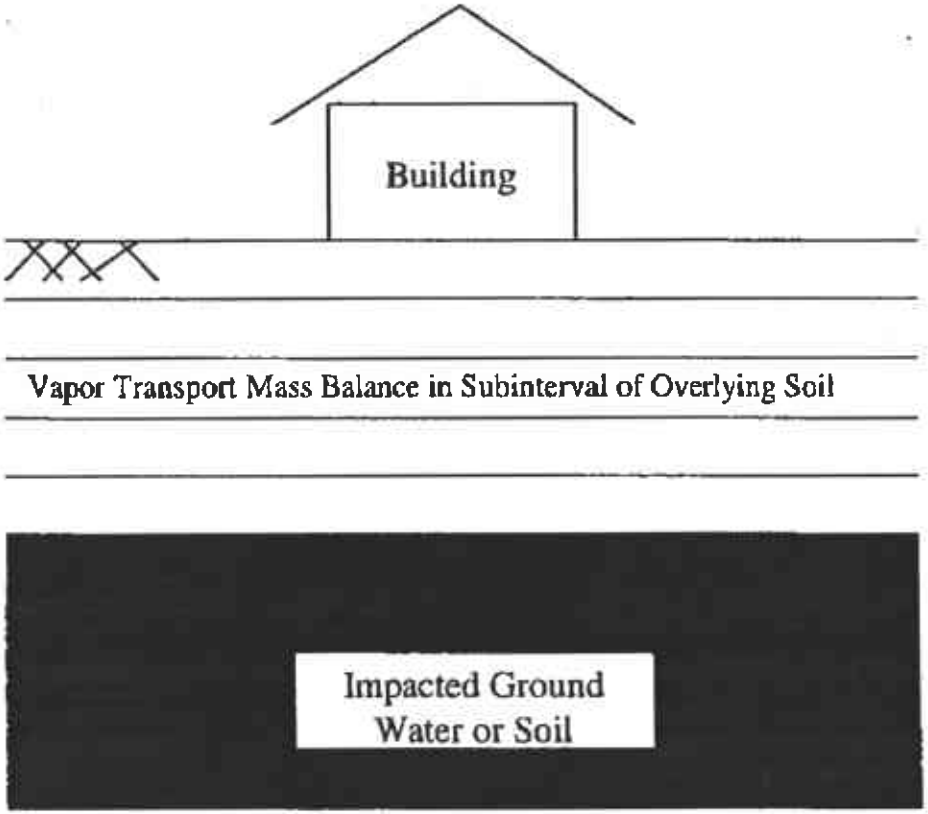
$$D_e = F \frac{\Delta Z}{\Delta C}$$

$$F = \frac{C_2 Q_2}{A}$$

$$\Delta C = C_1 - C_2$$

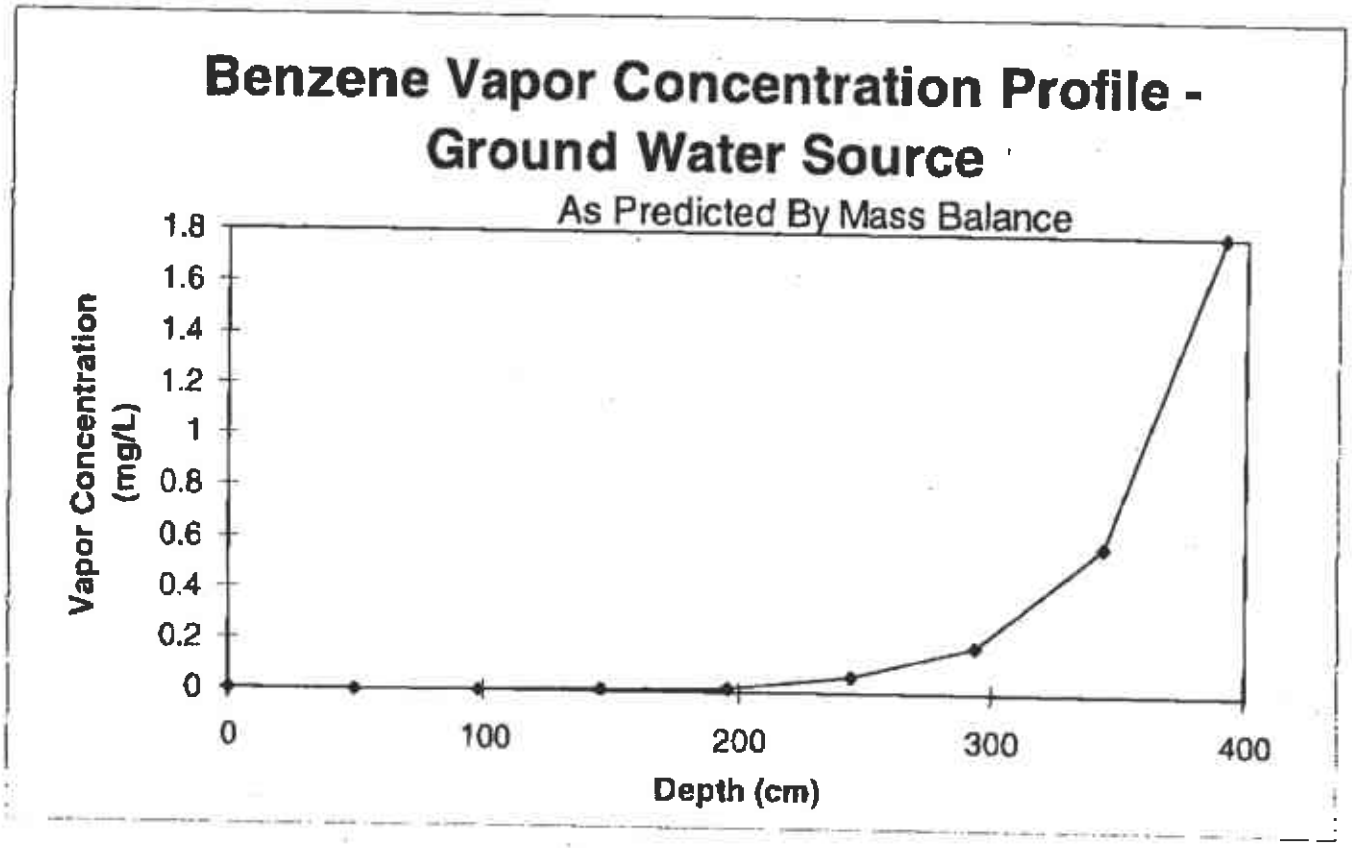
$$D_e = \frac{C_2 Q_2 \Delta Z}{A(C_1 - C_2)}$$

VAPOR PATHWAY ANALYSIS CASE STUDY - CHEVRON CASTRO VALLEY (CONTINUED)



$$V\frac{dC}{dt} = A(Flux_{in}) - A(Flux_{out}) - (bioattenuation)$$

VAPOR PATHWAY ANALYSIS CASE STUDY - CHEVRON CASTRO VALLEY (CONTINUED)



VAPOR PATHWAY ANALYSIS CASE STUDY - CHEVRON CASTRO VALLEY (CONTINUED)

Modification of ASTM 95 Vapor Pathway Model - Vadose Zone Bioattenuation by Finite Difference

Indoor Air Risk Predicted by Ground Water Data

Former Chevron Service Station 9-5607, 5269 Crow Canyon Road, Castro Valley, California

Standard ASTM Calculations

Soil Specific Parameters

Lab Data	ρ_s	2.21 Bulk Density(g/cm^3) or (kg/L)
Calculated	θ_{as}	0.01 Air Content (v/v)
Calculated	θ_{ws}	0.27 Water Content (v/v)
Lab Data	θ	0.28 Porosity (v/v)
Site Spec	d	391 Depth to Ground Water Source (cm) [C-9, 12.84 ft, 4/3/89]

Diffusivity Parameters

ASTM 96	H	0.22 Henry's Constant for Benzene
ASTM 96	D^{air}	9.30E-02 Air Diffusion Coefficient (cm^2/s)
ASTM 96	D^{wat}	1.10E-05 Water Diffusion Coefficient (cm^2/s)
Calculated	D^{eff}_s	8.40635E-06 Effective Diffusion Coefficient soil (cm^2/s)

Calculation of Vapor Concentration Within Impacted Soil

Lab Data	$C_{s,measured}$	8.2 Benzene Concentration in Ground Water (mg/L)
Calculated	$C_{v,eq}$	1.80 Equilibrium Vapor Concentration in Soil Plume (mg/L)

WA - Calculation of Vapor Concentration Profile

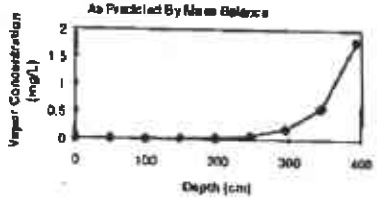
Howard	Thalf	16 Contaminant Vadose Zone Half Life (days)
Calculated	R	5.01409E-07 First order Rate Constant (sec^{-1})
Accuracy	n	8 Number of Subintervals
Calculated	Δz	49 Subinterval Height (cm)
Calculated	X	0.291790033 Matrix Coefficient (unitless)
Calculated	$C_{s,soX}$	0.52638922 (mg/L)

Matrix of linear equations solved using HP 48G calculator matrix solver program.
Results displayed below.

Subinterval	Depth (cm)	Vapor Conc (mg/L)
Surface	0	0
8	49	0.000684084
7	98	0.002000286
6	147	0.006266211
5	196	0.019459342
4	245	0.06037537
3	294	0.187305622
2	343	0.581082242
1	391	1.8

Vapor Concentration Profile

As Predicted By Mass Balance



Standard ASTM Calculations Continued

Vapor Flux From Shallowest Subinterval to Surface

Calculated	F	1.00E-10 Diffusive Vapor Flux (ug/cm^2-sec)

Indoor Air Concentration

ASTM 96	Lb	200 Enclosed Space Volume/Infiltration Area Ratio (cm)
ASTM 96	ER_{air}-indoor	0.00014 Enclosed Space Air Exchange Rate (sec^{-1})
Calculated	C_{indoor}	3.585E-09 Enclosed Space Air Concentration (ug/cm^3)

Dose

ASTM 96	IR_{air}-indoor	15 Daily Indoor Inhalation Rate (m^3/day)
ASTM 96	EF	350 Exposure Frequency (days/year)
ASTM 96	ED	30 Exposure Duration (years)
Calculated	Dose	0.56 Dose (mg)

SSTL

CAL EPA	SF_i	0.1 California Cancer Slope Factor for Benzene (kg-day/mg)
ASTM 96	BW	70 Adult Body Weight (kg)
ASTM 96	AT_c	70 Averaging Time for Carcinogens (years)
Calculated	$Risk_a$	3.16E-06 Risk - Ground Water to Indoor Air
	$Risk_{acc}$	1.00E-05 Acceptable Risk - Ground Water to Indoor Air
	SSTL	2,597 SSTL Benzene in Ground Water (mg/L)

sensitive receptors
children
pregnant women

ASTM Formulas

$$D^{eff}_s = D^{air}\frac{\theta^{3.33}_{as}}{\theta^2_T} + D^{wat}\frac{1}{H}\frac{\theta^{3.33}_{ws}}{\theta^2_T}$$

$$C_{v,eq} = H \times C_{s,measured}$$

$$F = D^{eff}_s\frac{C_{v,sub-1}}{\Delta z}$$

$$C_{indoor} = \frac{F}{ER_{air-indoor} \times L_b}$$

$$Dose = C_{indoor} \times IR_{air-indoor} \times EF \times ED$$

$$Risk = \frac{Dose \times SF_i}{BW \times AT}$$

WA Formulas

$$\Delta z = \frac{d}{n}$$

$$R = \frac{-Ln(0.5)}{t_{half}}$$

$$X = \frac{B^2}{\left[2D^{eff}_s + \theta_{as} + \Delta z^2 + R\right]}$$

$$SSTL = C_{s,measured}\frac{RISK_{acc}}{RISK_a}$$

Notes:

ASTM 96 = American Society for Testing and Materials, March 5, 1996, Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, E 1739-95.

Site Spec: Depth to ground water. Shallowest depth to ground water around C-9.

Lab Data: Benzene concentration in ground water from well C-9 on January 16, 1996.

Accuracy: Number of subintervals depends on the accuracy desired.

Calculations: Effective diffusion, diffusive vapor flux, equilibrium vapor concentration just above water table, diffusive vapor flux, enclosed space air concentration, dose and risk calculations from ASTM 96 guidance. Vapor concentration profile calculated by subinterval mass calculation. SSTL calculated by interpolation. Formulas presented above.