FAXED 5/19/00

CAMBRIA

To:	Eva Chu
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Fax:	(510) 337-9335
Phone:	
From:	Pete McKereghan
Phone:	(510) 420-3325
Pages:	8
Date:	May 19, 2000
Re:	Chevron 9-1723 [redacted]

Fax

Hard Copy to Follow? **Yes** ☐ **No** ☒

Eva –

As requested in our meeting last December, I am sending RBCA spreadsheet tables (Attachment E) from Cambria's report, *Tier 2 RBCA Analysis and Closure Request*, dated July 7, 1998.

These tables support the results presented in Table 2 of the report. Please direct future questions regarding this report to Scott MacLeod.

Thank you,
Pete

cf max 319 mg/m³ benzene soil gas = 319×10^3 µg/m³
= 3.19×10^5 µg/m³
w/ Oak RBCA soil gas ft

Oak RBSL = 3.6×10^6 µg/m³ for commercial scenario

cf avg 2.3 mg/m³ = 2.3×10^3 µg/m³
Oak RBSL = 2.2×10^5 for residential scenario

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TABLE E-1

TIER 2 RBCA - ESTIMATION OF INDOOR AIR CONCENTRATION OF BENZENE VOLATILIZATION FROM GROUND WATER VIA FOUNDATION CRACKS

ONSITE PARKING STRUCTURE - COMMERCIAL SCENARIO

POINT OF EXPOSURE AT SOURCES	C_{gw}	H (2)	D^{air}	D^{water}	D_{cap}^{eff} (3)	D_s^{eff} (4)	D_{ws}^{eff} (5)	D_{crack}^{eff} (6)	VF_{wesp} (1)	C_{Indoor} (7)
Mean concentration from well MW-8	mg/L	cm^3/cm^3	cm^2/s	cm^2/s	cm^2/s	cm^2/s	cm^2/s	cm^2/s	$(mg/m^3)/(mg/L)$	mg/m^3
Benzene	4.6E-02	2.20E-01	9.30E-02	1.10E-05	2.48E-05	8.3E-03	1.3E-04	8.3E-03	2.4E-03	1.11E-04
Toluene	4.0E-03	2.60E-01	8.50E-02	9.40E-06	2.06E-05	7.5E-03	1.1E-04	7.5E-03	2.4E-03	9.56E-06
Ethylbenzene	7.0E-03	3.20E-01	7.60E-02	8.50E-06	1.71E-05	6.7E-03	9.2E-05	6.7E-03	2.5E-03	1.73E-05
Xylenes	1.1E-02	2.90E-01	7.20E-02	8.50E-06	1.71E-05	6.4E-03	9.2E-05	6.4E-03	2.2E-03	2.45E-05

Notes:

(1) VF_{wesp} = Volatilization factor from ground water to enclosed space vapor $(mg/m^3)/(mg/L)$

$$VF_{wesp} = \{H \times [(D_{ws}^{eff} / L_{GW}) / (ER \times L_B)] \times 1E{+}03\ (L/m^3)\} / \{1 + [(D_{ws}^{eff} / L_{GW}) / (ER \times L_B)] \times [(D_{ws}^{eff} / L_{GW}) / (D_{crack}^{eff} / L_{crack})\ \eta)]\}$$

(2) H = Henry's law constant (cm^3/cm^3) = Chemical-specific

(3) D_{ws}^{eff} = Effective diffusion between GW & soil surface (cm^2/s) =

$$D_{ws}^{eff} = (h_{cap} + h_v) / [(h_{cap} / D_{cap}^{eff}) + (h_v / D_s^{eff})]$$

h_{cap} = Thickness of capillary fringe (cm) = 28 0.9 feet

h_v = Thickness of vadose zone (cm) = 124

(4) D_{cap}^{eff} = Effective diffusion through capillary fringe (cm^2/s) = Chemical-specific

$$D_{cap}^{eff} = D^{air} \times (\theta_{acap}^{3.33} / \theta_T^{2}) + [D^{water} \times (1/H) \times (\theta_{wcap}^{3.33} / \theta_T^{2})$$

D^{air} = Diffusion coefficient in air (cm^2/s) = Chemical-specific

θ_{acap} = Volumetric air content in capillary fringe soil (cm^3/cm^3) = 0.042

θ_T = Total soil porosity (cm^3/cm^3) = 0.42

D^{water} = Diffusion coefficient in water (cm^2/s) = Chemical-specific

θ_{wcap} = Volumetric water content in capillary fringe soil (cm^3/cm^3) = 0.378

(5) D_s^{eff} = Effective diffusion in soil - vapor concentration (cm^2/s) = Chemical-specific

$$D_s^{eff} = D^{air} \times (\theta_{as}^{3.33} / \theta_T^{2}) + [D^{water} \times (1/H) \times (\theta_{ws}^{3.33} / \theta_T^{2})$$

θ_{as} = Volumetric air content in vadose zone soil (cm^3/cm^3) = 0.287

θ_{ws} = Volumetric water content in vadose zone soil (cm^3/cm^3) = 0.133

L_{GW} = Depth to ground water = $h_{cap} + h_v$ (cm) 152 5 ft

ER = Enclosed space air exchange rate (1/s) = 0.00023 commercial

L_B = Height of room at foundation level, about 9 feet (cm) 300 commercial

(6) D_{crack}^{eff} = Effective diffusion coefficient through cracks (cm^2/s) = D_s^{eff}

$$D_{crack}^{eff} = D^{air} \times (\theta_{acrack}^{3.33} / \theta_T^{2}) + [D^{water} \times (1/H) \times (\theta_{wcrack}^{3.33} / \theta_T^{2})$$

θ_{acrack} = Volumetric air content in vadose zone soil (cm^3/cm^3) = 0.287

θ_{wcrack} = Volumetric water content in vadose zone soil (cm^3/cm^3) = 0.133

L_{crack} = Thickness of foundation/wall (cm) = 15

η = Area fraction of cracks in foundation/wall (cm^2/cm^2) = 0.01

(7) C_{Indoor} = $C_{gw} \times VF_{wesp}$

TABLE E-2
TIER 2 RBCA - POTENTIAL HEALTH RISKS VIA INHALATION OF INDOOR BENZENE VOLATILIZED FROM GROUND WATER INTO ON-SITE COMMERCIAL BUILDING

VOC Inhalation Equation: CDI (mg/kg-day) = C_a x IR x FC x EF x ED) / (BW x AT)

	RME		RME
CDI = Chronic Daily Intake (mg/kg-day)		BW_c = Body Weight (Carcinogenic Effects) (kg) =	70
C_a = Chemical Concentration in Air (mg/m^3)		BW_{nc} = Body Weight (Noncarcinogenic Effects) (kg) =	70
IR = Inhalation Rate (m^3/day) =	20	AT_c = Averaging Time (Carcinogenic Effects) (days) =	25,550
FC = Fraction from Contaminated Soil	1	AT_{nc} = Averaging Time (Noncarcinogenic Effects) (days) =	9,125
EF = Exposure Frequency (days/year) =	250	TR = Target Excess Cancer Risk =	1E-05
ED = Exposure Duration (years) =	25	THI = Target Hazard Index =	1

Chemical	Concentration (mg/m^3)	Carcinogenic CDI (mg/kg-day)	Noncarcinogenic CDI (mg/kg-day)	Cal-EPA Slope Factor (mg/kg-day)$^{-1}$	Reference Dose mg/kg-day	Excess Cancer Risk	Hazard Quotient	RME - % Risk Contribution		1.00E-05 RBSL mg/L	HI = 1 RBSL mg/L
								Cancer	Hazard		
Benzene	1.1E-04	7.7E-06	2.2E-05	1.0E-01	1.7E-03	8E-07	1.3E-02	100%	100%	5.94E-01	3.61E+00
Toluene	9.6E-06	6.7E-07	1.9E-06		1.1E-01		1.7E-05		0%		2.35E+02
Ethylbenzene	1.7E-05	1.2E-06	3.4E-06		2.9E-01		1.2E-05		0%		6.00E+02
Xylenes	2.4E-05	1.7E-06	4.8E-06		2.0E-01		2.4E-05		0%		4.59E+02
TOTAL						8E-07	1.3E-02	100%	100%		

Notes: Blank means no data available or not determined.
Excess cancer risk = Carcinogenic CDI x Slope factor.
Hazard quotient = Noncarcinogenic CDI / Reference dose.

TABLE E-3
TIER 2 RBCA - AMBIENT AIR CONCENTRATIONS OF BENZENE FROM SOIL GAS - ONSITE COMMERCIAL SCENARIO

CHEMICAL	C_{soil} mg/kg	$C_{soilgas}$ mg/m³	H (3) cm³/cm³	k_{oc} cm³/g	k_s cm³/g	D^{air} cm²/s	D^{water} cm²/s	D_s^{eff} (4) cm²/s	AA/SG Factor (1) Unitless	C_{indoor} (2) mg/m³
Benzene	NA	2.3E+00	2.20E-01	3.80E+01	5E-02	9.30E-02	1.10E-05	8.3E-03	3.0E-06	7.0E-06
Toluene	NA	2.1E-01	2.60E-01	1.35E+02	2E-01	8.50E-02	9.40E-06	7.5E-03	2.8E-06	5.9E-07
Ethylbenzene	NA	9.6E-01	3.20E-01	1.29E+03	2E+00	7.60E-02	8.50E-06	6.7E-03	2.5E-06	2.4E-06
Xylenes	NA	2.0E+00	2.90E-01	2.40E+02	3E-01	7.20E-02	8.50E-06	6.4E-03	2.3E-06	4.7E-06

Notes:

VF_{samb} = ASTM Volatilization factor from subsurface soil to ambient air (mg/m³)/(mg/kg), using soil concentration (mg/kg) to estimate ambient air concentration (mg/m³).

$VF_{samb} = \{(H \times \rho_s) / (\theta_{ws} + [k_s \times \rho_s] + [H \times \theta_{as}])\} \times 1E+03\ (cm^3\text{-}kg/m^3\text{-}g) \times 1 / [1 + ([U_{air} \times \delta_{air} \times L_s] / [D_s^{eff} \times W])]$

The VF_{samb} has 2 factors:

a) The factor "$\{(H \times \rho_s) / (\theta_{ws} + [k_s \times \rho_s] + [H \times \theta_{as}])\}$ $(g/cm^3) \times 10^3$ $(cm^3\text{-}kg/m^3\text{-}g)$" (in unit of kg/m^3) multiplied by C_{soil} (mg/kg) will give soil gas concentration (mg/m^3) at source;

b) The rest of the VF_{samb} equation is the attenuation factor between ambient air concentration and soil gas concentration (AA/SG Factor) (unitless), equivalent to for ASTM default scenario.

(1) AA/SG Factor = $1 / \{1 + ([U_{air} \times \delta_{air} \times L_s] / [D_s^{eff} \times W])\}$

The product of Factor (a) and soil concentration can be replaced with the actually measured soil gas concentration at source.

(2) $C_{Ambient}$ = $C_{soilgas}$ x AA/SG Factor

(3)	H =	Henry's law constant (cm^3/cm^3) =	Chemical-specific
	ρ_s =	Soil bulk density (g/cm^3) =	2
	θ_{as} =	Volumetric air content in vadose zone soil (cm^3/cm^3) =	0.287
	θ_{ws} =	Volumetric water content in vadose zone soil (cm^3/cm^3) =	0.133
	k_s =	Soil-water sorption coefficient (cm^3/g) = $k_{oc} \times f_{oc}$ =	Chemical-specific
	k_{oc} =	Carbon-water sorption coefficient (cm^3/g) =	Chemical-specific
	f_{oc} =	Fraction of organic carbon in soil (g/g) =	0.0014
(4)	D_s^{eff} =	Effective diffusion in soil - vapor concentration (cm^2/s) =	Chemical-specific
		$D_s^{eff} = D^{air} \times (\theta_{as}^{3.33} / \theta_T^2) + [D^{water} \times (1/H) \times (\theta_{ws}^{3.33} / \theta_T^2)$	
	D^{air} =	Diffusion coefficient in air (cm^2/s) =	Chemical-specific
	D^{water} =	Diffusion coefficient in water (cm^2/s) =	Chemical-specific
	θ_T =	Total soil porosity (cm^3/cm^3) =	0.42
	U_{air} =	Wind speed in the mixing zone (cm/s) =	225
	δ_{air} =	Ambient air mixing zone height (cm) =	200
	L_s =	Depth to subsurface soil sources (cm)	91 Soil gas sample collected at 3 feet bgs
	W =	Width of source area perpendicular to wind direction (cm)	1500

TABLE E-4
POTENTIAL HEALTH RISKS VIA INHALATION OF AMBIENT BENZENE FROM SOIL GAS
ONSITE COMMERCIAL SCENARIO

VOC Inhalation Equation: CDI (mg/kg-day) = C_a x IR x FC x EF x ED) / (BW x AT)

	RME		RME
CDI = Chronic Daily Intake (mg/kg-day)		BW_c = Body Weight (Carcinogenic Effects) (kg) =	70
C_a = Chemical Concentration in Air (mg/m^3)		BW_{nc} = Body Weight (Noncarcinogenic Effects) (kg) =	70
IR = Inhalation Rate (m^3/day) =	2E+01	AT_c = Averaging Time (Carcinogenic Effects) (days) =	25,550
FC = Fraction from Contaminated Source =	1	AT_{nc} = Averaging Time (Noncarcinogenic Effects) (days) =	9,125
EF = Exposure Frequency (days/year) =	250	TR = Target Excess Cancer Risk =	1E-05
ED = Exposure Duration (years) =	25	THI = Target Hazard Index =	1

Chemical	Concentration (mg/m^3)	Carcinogenic CDI (mg/kg-day)	Noncarcinogenic CDI (mg/kg-day)	Cal-EPA Slope Factor (mg/kg-day)$^{-1}$	Reference Dose mg/kg-day	Excess Cancer Risk	Hazard Quotient	RME - % Risk Contribution		1.00E-05 RBSL* mg/m^3	HI = 1 RBSL* mg/m^3
								Cancer	Hazard		
Benzene	7.0E-06	4.9E-07	1.4E-06	1.0E-01	1.7E-03	5E-08	8.0E-04	100%	99%	4.73E+02	1.25E+03
Toluene	5.9E-07	4.1E-08	1.2E-07		1.1E-01		1.1E-06		0%		9.48E+05
Ethylbenzene	2.4E-06	1.7E-07	4.6E-07		2.9E-01		1.6E-06		0%		6.28E+05
Xylenes	4.7E-06	3.3E-07	9.2E-07		2.0E-01		4.6E-06		1%		2.18E+05
TOTAL						5E-08	8.1E-04	100%	100%		

Notes:
Commercial exposure parameters are the USEPA standard default values.
* RBSL for soil gas

TABLE E-5

TIER 2 RBCA - INDOOR AIR CONCENTRATIONS OF BENZENE MIGRATED INTO COMMERCIAL BUILDINGS VIA FOUNDATION CRACKS ESTIMATED FROM MEASURED SOIL GAS LEVELS

CHEMICAL	C_{soil} mg/kg	$C_{soilgas}$ mg/m³	H (3) cm³/cm³	k_{oc} cm³/g	k_s cm³/g	D^{air} cm²/s	D^{water} cm²/s	D_s^{eff} (4) cm²/s	D_{crack}^{eff} (5) cm²/s	IA/SG Factor (1) Unitless	C_{Indoor} (2) mg/m³
Benzene	NA	2.3E+00	2.20E-01	3.80E+01	5E-02	9.30E-02	1.10E-05	8.3E-03	8.3E-03	7.5E-05	1.7E-04
Toluene	NA	2.1E-01	2.60E-01	1.35E+02	2E-01	8.50E-02	9.40E-06	7.5E-03	3.6E-05	3.5E-07	7.5E-08
Ethylbenzene	NA	9.6E-01	3.20E-01	1.29E+03	2E+00	7.60E-02	8.50E-06	6.7E-03	2.6E-05	2.6E-07	2.4E-07
Xylenes	NA	2.0E+00	2.90E-01	2.40E+02	3E-01	7.20E-02	8.50E-06	6.4E-03	2.9E-05	2.8E-07	5.6E-07

Notes:

VF_{ssup} = ASTM Volatilization factor from subsurface soil to enclosed space vapor (mg/m³)/(mg/kg), using soil concentration (mg/kg) to estimate indoor air concentration (mg/m³).

$$VF_{ssup} = \{((H \times \rho_s) / \theta_{ws} + (k_s \times \rho_s) + (H \times \theta_{as})) \times 1E+03\ (cm^3\text{-}kg/m^3\text{-}g) \times [(D_s^{eff} / L_s) / (ER \times L_B)]\} / \{1 + [(D_s^{eff} / L_s) / (ER \times L_B)] \times [(D_s^{eff} / L_s) / (D_{crack}^{eff} / L_{crack})\ \eta]\}$$

The VF_{ssup} has 2 factors:

1) The factor "$[(H \times \rho s) / \theta ws + (k_s \times \rho_s) + (H \times \theta_{as})]\ (g/cm^3) \times 10^3\ (cm^3\text{-}kg/m^3\text{-}g)$" (in unit of kg/m³) multiplied by C_{soil} (mg/kg) will give soil gas concentration (mg/m³) at source;

2) The rest of the VF_{ssup} equation is the attenuation factor between indoor air concentration and soil gas concentration (IA/SG Factor) (unitless), equivalent to for ASTM default scenario.

(1) IA/SG Factor = $\{[(D_s^{eff} / L_s) / (ER \times L_B)]\} / \{1 + [(D_s^{eff} / L_s) / (ER \times L_B)] \times [(D_s^{eff} / L_s) / (D_{crack}^{eff} / L_{crack})\ \eta]\}$

The product of Factor (1) and soil concentration can be replaced with the actually measured soil gas concentration at source.

(2) C_{Indoor} = $C_{soilgas}$ x IA/SG Factor

(3) H = Henry's law constant (cm³/cm³) = Chemical-specific

ρ_s = Soil bulk density (g/cm³) = 2

θ_{as} = Volumetric air content in vadose zone soil (cm³/cm³) = 0.287

θ_{ws} = Volumetric water content in vadose zone soil (cm³/cm³) = 0.133

k_s = Soil-water sorption coefficient (cm³/g) = $k_{oc} \times f_{oc}$ = Chemical-specific

k_{oc} = Carbon-water sorption coefficient (cm³/g) = Chemical-specific

f_{oc} = Fraction of organic carbon in soil (g/g) = 0.0014

(4) D_s^{eff} = Effective diffusion in soil - vapor concentration (cm²/s) = Chemical-specific

$$D_s^{eff} = D^{air} \times (\theta_{as}^{3.33} / \theta_T^{2}) + [D^{water} \times (1/H) \times (\theta_{ws}^{3.33} / \theta_T^{2})$$

D^{air} = Diffusion coefficient in air (cm²/s) = Chemical-specific

D^{water} = Diffusion coefficient in water (cm²/s) = Chemical-specific

θ_T = Total soil porosity (cm³/cm³) = 0.42

L_s = Depth to subsurface soil sources (cm) = 91 Soil gas sample collected at 3 feet bgs

ER = Enclosed space air exchange rate (1/s) = 0.00023 industrial

L_B = Height of room at foundation level (cm) = 300

(5) D_{crack}^{eff} = Effective diffusion coefficient through cracks (cm²/s) = D^{eff}

$$D_{crack}^{eff} = D^{air} \times (\theta_{acrack}^{3.33} / \theta_T^{2}) + [D^{water} \times (1/H) \times (\theta_{wcrack}^{3.33} / \theta_T^{2})$$

θ_{acrack} = Volumetric air content in vadose zone soil (cm³/cm³) = 0.287

θ_{wcrack} = Volumetric water content in vadose zone soil (cm³/cm³) = 0.133

L_{crack} = Thickness of foundation/wall (cm) = 15

η = Area fraction of cracks in foundation/wall (cm²/cm²) = 0.01

TABLE E-6

POTENTIAL HEALTH RISKS VIA INHALATION OF BENZENE MIGRATED INTO COMMERCIAL BUILDING VIA FOUNDATION CRACKS ESTIMATED FROM MEASURED SOIL GAS LEVELS

VOC Inhalation Equation: CDI (mg/kg-day) = C_a x IR x FC x EF x ED) / (BW x AT)

	RME		RME
CDI = Chronic Daily Intake (mg/kg-day)		BW_c = Body Weight (Carcinogenic Effects) (kg) =	70
C_a = Chemical Concentration in Air (mg/m^3)		BW_{nc} = Body Weight (Noncarcinogenic Effects) (kg) =	70
IR = Inhalation Rate (m^3/day) =	20	AT_c = Averaging Time (Carcinogenic Effects) (days) =	25,550
FC = Fraction from Contaminated Source =	1	AT_{nc} = Averaging Time (Noncarcinogenic Effects) (days) =	9,125
EF = Exposure Frequency (days/year) =	250	TR = Target Excess Cancer Risk =	1E-05
ED = Exposure Duration (years) =	25	THI = Target Hazard Index =	1

Chemical	Concentration (mg/m^3)	Carcinogenic CDI (mg/kg-day)	Noncarcinogenic CDI (mg/kg-day)	Cal-EPA Slope Factor (mg/kg-day)$^{-1}$	Reference Dose mg/kg-day	Excess Cancer Risk	Hazard Quotient	RME - % Risk Contribution		1.00E-05 RBSL* mg/m^3	HI = 1 RBSL* mg/m^3
								Cancer	Hazard		
Benzene	1.7E-04	1.2E-05	3.4E-05	1.0E-01	1.7E-03	1E-06	2.0E-02	100%	100%	1.90E+01	1.16E+02
Toluene	7.5E-08	5.2E-09	1.5E-08		1.1E-01		1.3E-07		0%		1.62E+06
Ethylbenzene	2.4E-07	1.7E-08	4.8E-08		2.9E-01		1.6E-07		0%		5.80E+06
Xylenes	5.6E-07	3.9E-08	1.1E-07		2.0E-01		5.5E-07		0%		3.62E+06
TOTAL						1E-06	2.0E-02	100%	100%		

Notes: Blank means no data available or not determined.

Excess cancer risk = Carcinogenic CDI x Slope factor.

Hazard quotient = Noncarcinogenic CDI / Reference dose.

* RBSL for soil gas

TABLE E-7
ESTIMATION OF SOIL GAS CONCENTRATION
IN mg/m^3 FROM ppm/v

Chemical	Soil Gas ppm/v	Molecular Weight (MW)	Soil Gas (a) mg/m^3
Benzene	0.72	78.1	2.3
Toluene	0.057	92	0.21
Ethylbenzene	0.22	106.2	0.96
Xylenes	0.46	106.2	2.0

Notes:
(a) Soil gas (mg/m^3) = [Soil gas (ppm/v) x MW x 1,000 L/m^3] / 24,450

$$\frac{100\ ppm/v \times MW \times 1000\ L/m3}{24,450} = \frac{100 \times 78.1 \times 1000}{24,450} = 319.49\ mg/m^3$$