March 11, 1997
Richmond, CA

Chevron
Research and Technology

RE: Groundwater Evaluation
Chevron Station 9-0504
15900 Hesperian Boulevard
San Lorenzo, California

P. Briggs,
San Ramon, CA:

In response to the request by Alameda County of January 21, 1997, Chevron Research and Technology Company (CRTC) re-evaluated the groundwater transport at the above referenced service station. The intent of the evaluation was to determine the maximum concentration of benzene within well C10 if benzene breakthrough occurs, and to quantify the potential health risk of benzene inhalation for offsite residential receptors. For this evaluation, CRTC, once again, utilized the software program PRINCE by Waterloo Hydrogeologic Software. Additionally, the potential health risk associated with the benzene inhalation from groundwater was evaluated with the methods of ASTM E1739-95; *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.*

CONCLUSIONS

1) Maximum Benzene Concentration in Well C10. PRINCE modeling predicts that the maximum benzene concentration in well C10 will be approximately 11 parts per billion (ppb).

2) Health Risk to Offsite Receptors. The potential health risk associated with the inhalation of benzene in indoor air by residential receptors due to volatilization from groundwater is 2.9×10^{-7}.

BENZENE CONCENTRATION IN MONITORING WELL C10

To evaluate the potential for benzene occurrence in monitoring well C10, the PRINCE software program was used to predict the transport of the chemical from the upgradient source area near monitoring well C8 (see Figure 1 for well locations). The original PRINCE modeling done by CRTC in October 1996, was employed again; however, minor changes were made to two input parameters pursuant to the request by Alameda County. The changes are as follows:

1) Ninety-Five Percent Upper Confidence Level (95UCL). The 95UCL was used to characterize the benzene source at monitoring well C8. For determining the 95UCL, all available monitoring data were used. The 95UCL calculation produced a value of 100 ppb for the benzene observed in C8 (Appendix 1). Recalling, an arithmetic mean of the data was originally used, which yielded a value of 81 ppb benzene.

2) Porosity. An effective porosity of 0.07 was selected to characterize the clayey silt of the site. This value was taken from Everett et al. (1984). The value of 0.07 represents the specific yield for a sandy clay, which CRTC believes adequately represents the conditions at the site. CRTC used the specific yield measurement to represent the effective porosity in that specific yield is that portion of

the void space that is subject to groundwater flow. It should be noted that using a total porosity value for clayey silt will produce a porosity value that is approximately five times higher. Hence, a higher porosity value will produce a lower groundwater seepage velocity, which, in turn, will predict lower benzene concentrations for well C10. Recalling, CRTC originally used a porosity of 0.15 for the groundwater modeling.

Except for the two parameters mentioned above, all other parameters have remained the same from the original modeling of October, 1996. The results of the latest modeling indicate that the maximum benzene concentration in well C10 should be approximately 11 ppb. Appendix 2 shows all the input parameters used in PRINCE and the output from the model in chart format.

GROUNDWATER VAPOR INTRUSION

As noted by Alameda County, the predicted concentration of benzene for monitoring well C10 exceeds the Tier 1 Risk-Based Screening Levels within ASTM E1739-95, as corrected for the CAL-EPA cancer slope factor for benzene, for groundwater vapor intrusion into residential buildings. To address this concern, CRTC evaluated this exposure pathway with site-specific data to quantify the potential health risk. By using the approach within ASTM E1739-95, CRTC technically performed a Tier 2 evaluation for this pathway.

The following steps were used to quantify the potential health risk:

1) Source Concentrations. The benzene concentrations in monitoring well C10 were determined with the PRINCE software program. For the Tier 2 evaluation by ASTM E1739-95, a benzene concentration of 11 ppb was assumed to exist under the residential buildings along the north side of Hesperian Boulevard.

2) Volatilization Factor. To calculate the benzene concentration in indoor air for residential buildings, the Volatilization Factor VF_{wesp} was calculated pursuant to ASTM E1739-95 (Appendix 3).

3) Risk Characterization. To quantify the potential risk for residential receptors, the exposure rate and the lifetime average daily dose were calculated (Appendix 4). Please note that the CAL-EPA cancer slope factor was used to quantify the health risk due to benzene exposure.

The potential health risk for offsite receptors due to the vapor intrusion from groundwater into residential buildings is 2.9×10^{-7}. This risk is significantly less than the acceptable risk range of 1×10^{-4} and 1×10^{-6} as established by the United States Environmental Protection Agency. Hence, the risk associated with this pathway is deemed acceptable and no corrective action is warranted. The input parameters and references used for this Tier 2 evaluation are in Appendices 5 and 6, respectively.

DISCUSSION

This Tier 2 evaluation for vapor intrusion of groundwater into offsite residential buildings used the site-specific data available at the service station. By using site-specific data, the inhalation risk for offsite residential buildings dropped by an order of magnitude as compared to the risk associated with the Risk-Based Screening Levels (RBSLs). The RBSLs use very conservative assumptions to account for all possible site conditions. Accordingly, the RBSLs for vapor intrusion of groundwater assume that extremely porous sand exists at all sites. However, this is not the case for Chevron's San Lorenzo station. The lithology observed in the subsurface is clayey silt. Hence, when integrating this site-specific lithology

into the RBCA evaluation, the risk is decreased. This reduction is attributable to a decrease in the effective porosity of a clayey silt as compared to a sand.

If you have any questions, or require additional information, please contact me at (510) 242-1284.

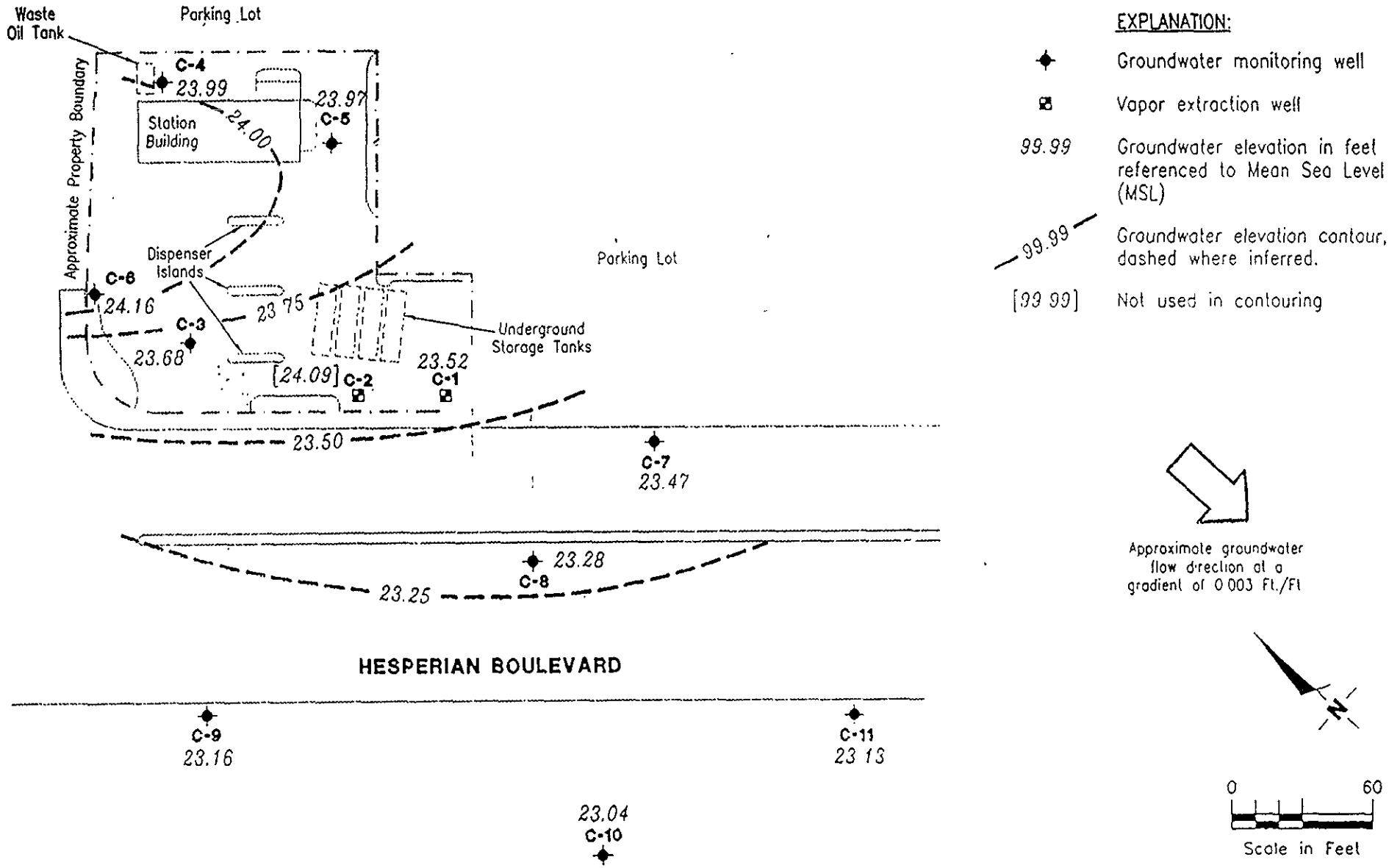
Very truly yours,

Dan Gallagher

Dan Gallagher
Hydrogeologist

Attachments

cc: J. Randall, CPDS
J. Stambolis, CRTC
T. Buscheck, CRTC
R. Magaw, CRTC



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POTENTIOMETRIC MAP
Chevron Service Station No. 9-0504
15900 Hesperian Boulevard
San Lorenzo, California

FIGURE
1

JOB NUMBER	REVIEWED BY	DATE	REVISED DATE
5259		June 21, 1996	

APPENDIX 1

CHEVRON STATION 9-0504, SAN LORENZO, CALIFORNIA
DETERMINATION OF THE NINETY-FIVE PERCENT UPPER CONFIDENCE LEVEL FOR THE BENZENE CONCENTRATIONS IN WELL C8

How did they get this t statistic? I used t = 1.708 & got 95UCL = 98

95%UCL = X + (1.96 * (STDEV/(SQRT n))

95%UCL: ninety-five percent upper confidence level	100.1 ppb
X: arithmetic mean	84.0 ppb
STDEV: standard deviation	41.1
n: number of samples	25.0

GROUNDWATER MONITORING DATA FROM WELL C8

DATE	BENZENE (ppb)
6/21/96	69.0
3/8/96	93.0
12/11/95	100.0
9/22/95	94.0
6/30/95	75.0
3/30/95	86.0
12/14/94	140.0
11/9/94	82.0
9/29/94	120.0
6/8/94	52.0
3/31/94	8.6
10/27/93	49.0

DATE	BENZENE (ppb)
7/28/93	60.0
5/3/93	75.0
1/20/93	81.0
10/29/92	29.0
7/17/92	34.0
4/20/92	110.0
1/27/92	100.0
9/26/91	66.0
6/28/91	180.0
3/6/91	45.0
12/20/90	120.0
9/7/90	170.0
12/8/89	62.0

NOTE:
1) All available monitoring data was used to calculate the 95%UCL.
2) Microsoft Excel was used to calculate the 95%UCL.

APPENDIX 2

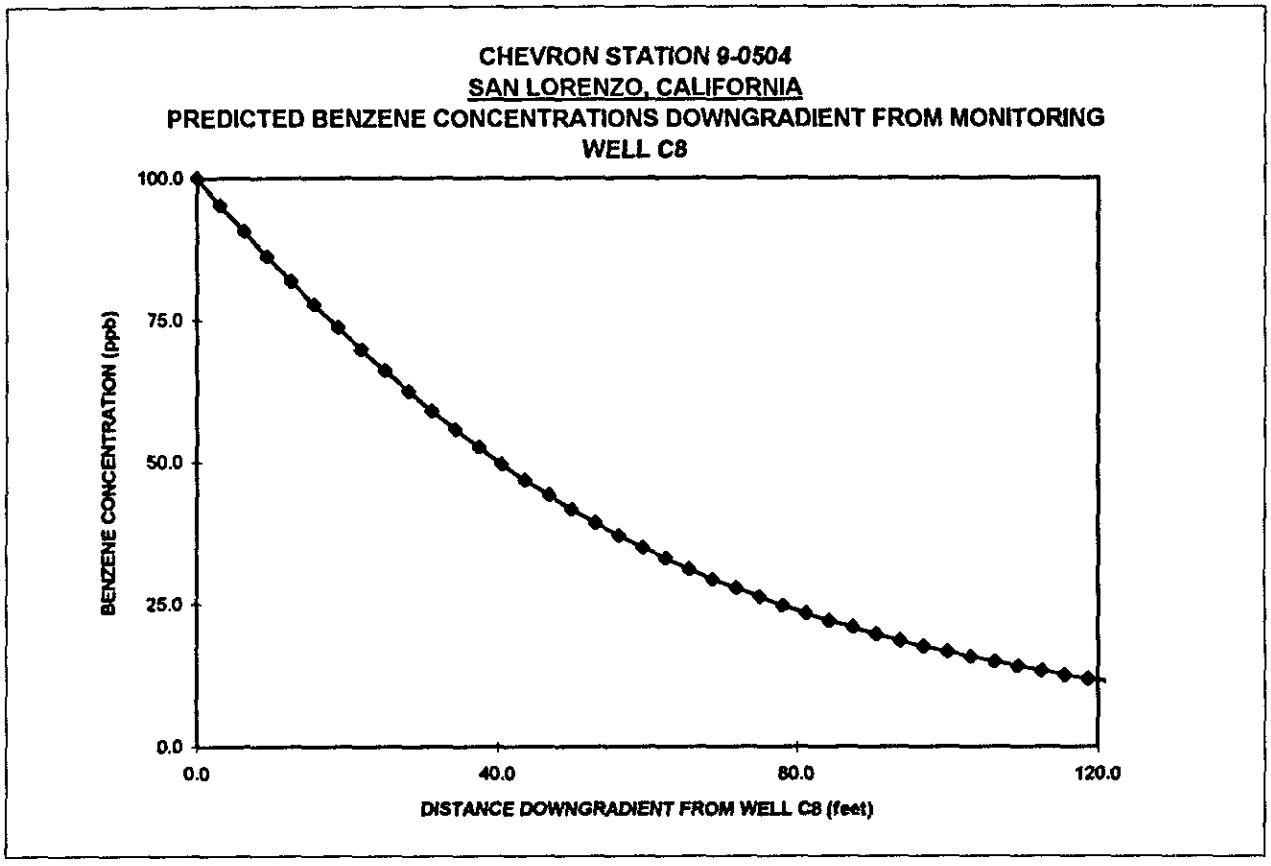
CHEVRON STATION 9-0504, SAN LORENZO, CALIFORNIA
DETERMINATION OF THE BENZENE CONCENTRATIONS DOWNGRADIENT FROM WELL C8

The downgradient benzene profile from well C8 is shown below. The evaluation was made using the software program PRINCE. The model simulates the concentration distribution downgradient from a strip source. The strip source for this case is assumed to exist at monitoring well C8 and to have a benzene concentration of 100 ppb (95%UCL). The results from the modeling show that the benzene concentration at monitoring well C10, which is 120 feet downgradient from well C8, should have a maximum concentration of 11 ppb. However, historical data suggests that benzene concentrations in well C10 should be much lower. Detectable concentrations of benzene in well C10 have occurred only twice in the last twenty-five monitoring events and both those events had concentrations of less than 5 ppb.

Input parameters for the PRINCE model are as follows:

hydraulic conductivity	39.0 feet per day (Weiss Associates, 1992)
porosity	0.07 unitless (Everett et al., 1984)
groundwater gradient	0.004 unitless (Gettler-Ryan, 1996)
biodegradation rate	0.0034 per day (Buscheck et al., 1993) = .34%
longitudinal dispersivity	12 feet: 10% of flow field (Pickens and Grisak, 1981)
transverse dispersivity	4 feet: 33% of longitudinal dispersivity (ASTM, 1995)
bulk density	1.7 grams per milliliter (ASTM, 1995)
fraction organic carbon	0.005 unitless (estimate: half of value from ASTM, 1995)
carbon partitioning coefficient	83 milliliters per gram (USEPA, 1986)
strip source width	50 feet (estimate)

going to go ahead & assume this biodecay rate (probably pretty conservative)



APPENDIX 3

CALCULATION OF THE GROUNDWATER VOLATILIZATION FACTOR TO ENCLOSED SPACE

The vapor model used to calculate the benzene concentration in indoor air due to groundwater volatilization was taken from ASTM E1739-95, *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.* The equation determines the indoor vapor concentration for a chemical due to impacted groundwater beneath a building. The building can be either a residential or commercial structure, depending on the selection of the input parameters. In this case, the building was assumed to be residential based on the current land use adjacent to monitoring well C10.

The formula is as follows:

$$VF_{wesp} = \frac{H\left[\frac{D_{WS}^{eff}/L_{GW}}{ER\,L_B}\right]}{1+\left[\frac{D_{WS}^{eff}/L_{GW}}{ER\,L_B}\right]+\left[\frac{D_{WS}^{eff}/L_{GW}}{(D_{crack}^{eff}/L_{crack})n}\right]} \times 10^3$$

The cross-media transfer coefficients from ASTM E1739-95 are given below; where D_s^{eff} is the effective diffusivity in vadose zone soil, D_{crack}^{eff} is the effective diffusivity through foundation cracks, D_{ws}^{eff} is the effective diffusivity above the water table, and D_{cap}^{eff} is the effective diffusivity in the capillary zone:

$$D_{ws}^{eff} = \left(h_{cap} + h_v\right)\left[\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}}\right]^{-1.0}$$

$$D_{crack}^{eff} = D^{air}\frac{\theta_{acrack}^{3.33}}{\theta_T^2} + \left[\frac{D_{wat}}{H}\right]\left[\frac{\theta_{wcrack}^{3.33}}{\theta_T^2}\right]$$

$$D_{cap}^{eff} = D^{air}\frac{\theta_{acap}^{3.33}}{\theta_T^2} + \left[\frac{D_{wat}}{H}\right]\left[\frac{\theta_{wcap}^{3.33}}{\theta_T^2}\right]$$

$$D_s^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + \left[\frac{D_{wat}}{H}\right]\left[\frac{\theta_{ws}^{3.33}}{\theta_T^2}\right]$$

Solving these equations for the site-specific parameters of service station 9-0504 yields a volatilization factor (VF_{wesp}) of 0.003 mg/m^3 per mg/liter. The input parameters are summarized in Appendix 5. Where appropriate, residential input parameters were used.

checks out ✓ ok refer to attached notes

APPENDIX 4

CALCULATION OF RISK

The potential risk associated with the inhalation of vapors due to the volatilization of chemicals from groundwater can be calculated from the formulas in ASTM E1739-95, *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.* The calculations performed here will evaluate the potential health risk of benzene in residential indoor air due to groundwater volatilization. The determination of risk consists of four steps: 1) the calculation of indoor air concentrations, 2) the calculation of inhalation exposure rates, 3) the calculation of a lifetime average daily dose and, 4) the calculation of the cancer risk.

Calculation of Indoor Air Concentrations

The concentration of benzene in indoor air for a residential building adjacent to monitoring well C10 is 0.000033 mg/m^3, as determined by the following equation:

$$Ca = VF_{wesp} \times SC$$

where:

Ca	=	concentration in air (mg/m^3)
VF_{wesp}	=	volatilization factor (0.003 mg/m^3 / mg/liter; Appendix Three)
SC	=	source concentration (0.011 mg/liter, Appendix Two)

Calculation of Inhalation Exposure Rates

The exposure rate of residential occupants of buildings adjacent to monitoring well C10 is 0.088 m^3/kg-d, as determined by the following equation:

$$ER = \frac{CR \times EF \times ED}{BW \times AT}$$

where:

ER	=	exposure rate (m^3/kg-d)
CR	=	contact rate (15 m^3/day; ASTM, 1995)
EF	=	exposure frequency (350 days/year; ASTM, 1995)
ED	=	exposure duration (30 years; ASTM, 1995)
BW	=	body weight (70 kg; ASTM, 1995)
AT	=	averaging time (25550 days; ASTM, 1995)

Calculation of a Lifetime Average Daily Dose

The lifetime average daily dose for occupants of residential buildings adjacent to monitoring well C10 is 0.0000029 mg/kg-d, as determined by the following equation:

$$LADD = Ca \times ER$$

where:

LADD	=	lifetime average daily dose (mg/kg-d)
Ca	=	concentration in air (0.000033 mg/m^3; from above equation)
ER	=	exposure rate (0.088 m^3/kg-d; from above equation)

Calculation of Cancer Risk

The cancer risk due to benzene exposure for occupants of residential buildings adjacent to monitoring well C10 is 0.00000029 (2.9×10^{-7}), as determined by the following equation:

$$RISK = LADD \times CSF$$

where:

RISK	=	cancer risk (unitless)
LADD	=	lifetime average daily dose (0.0000029 mg/kg-d; from above equation)
CSF	=	cancer slope factor for benzene (0.1 kg-d/mg; CAL-EPA, 1994)

APPENDIX 5

SUMMARY OF CHEMICAL AND PHYSICAL PROPERTIES

Table of parameters used to determine the volatilization factor VF_{wesp}.

PARAMETER	VALUE	REFERENCE
H: henry's law constant (unitless) Benzene	0.22	ASTM, 1995
h_v: thickness vadose zone (cm)	185 ≅ 6.5'	estimate
h_{cap}: thickness capillary zone (cm)	30 ≅ 1'	estimate
ER: enclosed air exchange rate (L/s)	0.00014	ASTM, 1995 (residential)
L_b: enclosed space volume/infiltration area ratio (cm)	200	ASTM, 1995 (residential)
L_{crack}: foundation or wall thickness (cm)	15	ASTM, 1995
n: areal fraction of cracks in wall/foundation (unitless)	0.01	ASTM, 1995
D_{air}: diffusion coefficient in air (cm^2/s) Benzene	0.093	ASTM, 1995
D_{water}: diffusion coefficient in water (cm^2/s) Benzene	0.000011	ASTM, 1995
θ_t: soil porosity (unitless)	0.07	Everett et al., 1984
θ_{as}: air content in vadose zone soils (unitless)	0.05	estimate
θ_{ws}: water content in vadose zone soils (unitless)	0.02	estimate
θ_{acrack}: air content in foundation/wall cracks (unitless)	0.05	estimate
θ_{wcrack}: water content in foundation/wall cracks (unitless)	0.02	estimate
θ_{acap}: air content in capillary fringe (unitless)	0.02	estimate
θ_{wcap}: water content in capillary fringe (unitless)	0.05	estimate

Low = 8' = 240 cm ?

Note:

1) Sum of θ_{as} and θ_{ws} must equal total porosity.
2) Sum of θ_{acap} and θ_{wcap} must equal total porosity.
3) Residential parameters were used for ER and L_b.

Table of parameters used to characterize the cancer risk.

PARAMETER	VALUE	REFERENCE
CR: contact rate (m^3/day)	15	ASTM, 1995 (residential)
EF: exposure frequency (days/year)	350	ASTM, 1995 (residential)
ED: exposure duration (years)	30	ASTM, 1995 (residential)
BW: body weight (kg)	70	ASTM, 1995 (residential)
AT: averaging time (days)	25550	ASTM, 1995 (residential)
CSF: cancer slope factor for benzene (kg-d/mg)	0.1	CAL-EPA, 1994

APPENDIX 6

REFERENCES

American Society for Testing and Materials. 1995. Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites. ASTM E1739-95, Philadelphia, PA.

Buscheck, T. E., K. T. O'Reilly, and S. N. Nelson. 1993. Evaluation of Intrinsic Bioremediation at Field Sites. Proceedings, Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration, p. 367-381. National Ground Water Association/API, Houston, TX.

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