Tetra Tech EM Inc.

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October 20, 1999

Steve Edde
Alameda Point
950 W. Mall Square, Room 245
Alameda, CA 94501

Subject: **Updated Alameda Point/Alameda Annex Benzene Soil Gas Investigation Summary and Summary of Crawl Space Benzene Air Sampling at Parcel 179**

Dear Mr. Edde:

Enclosed is the updated Alameda Point/Alameda Annex Benzene Soil Gas Investigation Summary for your records. Included with the updated soil gas summary is the Summary of Crawl Space Benzene Air Sampling at Parcel 179.

TtEMI is submitting the enclosed updated soil gas summary because we noted an error in the ventilation rate factor used in Scenario #2 (no slab). The updated soil gas summary includes the revised modeling done for Scenario #2 (no slab); Scenario #1 did not change. The revised modeling approach (Scenario #2) was used to evaluate cancer risks associated with vapor intrusion when a crawlspace is present in the overlying structure. This revised approach uses a mass-balance, two compartment model in conjunction with data available from the Johnson and Ettinger model to estimate cancer risks for this latter case.

The original version of the soil gas summary write-up should be discarded and replaced with the version enclosed. The figures that accompanied the original version should be kept for evaluation with this updated version.

Copies of the updated soil gas summary were distributed at the Alameda Point BCT meeting, held October 19, 1999, to Patricia McFadden, Mary Rose Cassa, Brad Job, Phillip Ramsey, Adam Klein, and Peter Russell. These individuals were also e-mailed the Parcel 179 crawl space summary on October 20, 1999.

If you have any questions, please call me at (916) 853-4505.

Sincerely,

Daniel L. Shafer
Installation Coordinator

cc: Dick Hegarty, Alameda Annex
Dina Tasini, ARRA
Jim Pollisini, DTSC-HERD
Mark Reisig, TtEMI

Summary of Crawl Space Benzene Air Sampling at Parcel 179 (George P. Miller Elementary School) Alameda Point

As requested at the October 19, 1999, Base Realignment and Closure (BRAC) Cleanup Team (BCT) monthly tracking meeting, following is a summary of the crawl space benzene air sampling conducted at Parcel 179 (George P. Miller Elementary School) by IT Corporation under the environmental baseline survey (EBS) program for Alameda Point. The air sampling performed at Parcel 179 was conducted to determine if benzene was accumulating in the crawl space beneath the school building. This summary is an addendum to the *Alameda Point/Alameda Annex Benzene Soil Gas Investigation Summary* (Soil Gas Summary), dated October 1, 1999, and as updated and distributed at the October 19, 1999, BCT monthly tracking meeting. Figures 1 and 5b in the Soil Gas Summary apply to this crawl space air sampling summary.

On November 12, 1994, ten (10) air samples were collected in Summa canisters and analyzed in a fixed-base laboratory for benzene (TO-14 analysis). Eight samples were collected from three different areas in the crawl spaces beneath the school building; two samples were collected outside the school building to monitor outdoor ambient air conditions during the crawl space sampling. Air sample locations are presented on Figure 5b.

Of the 10 samples collected, five were collected with one-hour regulators (i.e., the sample canister was filled during a one-hour period); the other five were collected with eight-hour regulators. Three air samples (179-0011, 179-0012, and 179-0014) were located within the 20 ug/L to 100 ug/L contour beneath the school building. The remaining seven air samples (179-0013 and 179-0015 through 179-0020) were located within 1 ug/L to 20 ug/L contour. Benzene was not detected above the method detection limit of 6 ug/m^3 in any of the air samples collected.

As stated in the Soil Gas Summary, benzene was not detected in the soil gas samples collected from Parcel 179. Additionally, benzene was not detected in the air samples collected within the crawl spaces beneath the school building or in outdoor air outside the school building. These findings indicate that benzene has not volatilized from the groundwater beneath Parcel 179 into soil gas or ambient air, and a human health risk of exposure to benzene does not exist at Parcel 179, nor within the school building.

REFERENCE

IT Corporation, 1998. Environmental Baseline Survey, Draft Final Data Evaluation Summaries, Volume IX - Zone 16. Alameda Point. December.

ALAMEDA POINT/ALAMEDA ANNEX BENZENE SOIL GAS INVESTIGATION SUMMARY

INTRODUCTION

The Navy has conducted several soil gas investigations between 1989 and 1995 at Alameda Point and Alameda Annex. During remedial investigations and quarterly groundwater monitoring activities conducted in recent years at the Alameda Annex and in the Alameda Point housing zone, a benzene plume was identified in the shallow groundwater beneath the western half of Alameda Annex IR Site 2 (screening lot and scrapyard). Based on groundwater sampling data collected in February and March 1999, the plume has been mapped extending northwest beneath Alameda Point Parcels 179 and 180 (Miller School and Day Care Center), northeast portion of Parcel 178 (Marina Village housing), and southeastern portion of Parcel 181 (Coast Guard housing) (see Figure 1). The Navy has assessed soil gas samples collected on these parcels and in the housing units over the past ten years and has evaluated the associated human health risk to residents in the housing units based on predicted indoor air concentrations of benzene and has concluded that benzene is not volatilizing to a large extent from groundwater into soil gas in the area and the predicted concentrations of benzene in indoor air do not pose an unacceptable risk to residents living in the housing units. The Navy understands the concern of benzene migration into the housing units and has provided the following summary of soil gas studies that have been conducted in the housing area over the past ten years.

SUMMARY OF INVESTIGATIONS

The objective of the previous studies conducted was to determine if potential human health risks/concerns existed due to the presence of benzene in the shallow groundwater beneath the housing area. The studies were conducted to evaluate whether volatilization of benzene in the groundwater contributed significantly to soil gas in the vadose zone. The following summary presents the soil gas data that were collected during the previous investigations and evaluates that data with respect to the predicted human health risk of exposure in indoor air after (1) migrating upward through a concrete building slab foundation, and (2) migrating upward through a concrete perimeter building foundation.

As a point of comparison, a 1.0E-06 residential cancer risk value for benzene in air equates to a concentration of 0.23 ug/m^3. The 1998 area-wide air monitoring program for the Oakland area conducted by the Bay Area Air Quality Management District (BAAQMD) measured levels of benzene in ambient air ranging from 0.32 ug/m^3 to 2.875 ug/m^3, with a mean concentration of 1.342 ug/m^3, which exceed the 1.0E-06 residential cancer risk threshold. The modeled indoor air concentrations calculated from the benzene concentrations detected in soil gas beneath the Alameda Point housing area and Alameda Annex IR Site 2 range from 0.0371 ug/m^3 to 0.0000218 ug/m^3.

In this summary, the Navy has applied the Johnson and Ettinger "Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings" for predicting the concentration of benzene in indoor air from the concentrations detected in soil gas and the associated residential human health risk. Two scenarios were used: (1) assuming upward migration of soil gas vapors through a concrete building foundation slab and (2) assuming upward migration through a concrete perimeter foundation (i.e., no slab).

Parcels 178/179/180 and Alameda Annex Warehouse Area, (Shallow Soil Gas Investigation - PRC 1989)

In October 1989, in consideration of the Navy's warehouse area as a proposed military housing site, a shallow soil gas investigation was conducted to determine the extent of benzene contamination in this area (see Figure 2). Forty-one soil gas samples were collected around the perimeter of the proposed housing site and analyzed for benzene. Of the 41 samples collected, benzene was detected in ~~five of the~~ samples (SG-2, SG-23, SG-34, SG-41 and SG-43) at concentrations ranging from 40 ug/m^3 to 300 ug/m^3. A summary of the results is presented in Appendix A.

All five soil gas samples with benzene detected were located approximately 100 feet to 1,300 feet west, south, and southwest of the 1 ug/L contour. Benzene was not detected in the remaining 36 samples including (1) one sample (SG-29 at Alameda Annex IR Site 2) within the 100 to 700 ug/L contour, (2) three samples (SG-7, SG-8, and SG-27) within the 20 ug/L to 100 ug/L contour, (3) 18 samples within the 1 ug/L to 20 ug/L contour, and (4) 14 samples located outside the 1 ug/L contour.

The modeled indoor air concentration of benzene for this area ranged from 0.000655 ug/m^3 to 0.0000873 ug/m^3. Using the Johnson and Ettinger model and applying the more conservative Department of Toxic Substances Control (DTSC) unit risk factor (URF), the estimated human health risk associated with the predicted concentrations range from 8.3E-08 to 1.1E-08 assuming migration of vapors through a concrete building slab, and 1.9E-08 to 2.5E-09 assuming migration of vapors considering a concrete perimeter foundation. Details for both scenarios are presented in Appendix B.

Parcel 178 - Marina Village Housing, (Risk Assessment Report - PRC 1990)

Additional field investigation data were collected in July and August 1990. A total of 36 soil gas samples were collected and analyzed for benzene (see Figure 3). Of the 36 soil gas samples collected, benzene was detected in 14 samples at concentrations ranging from 10 ug/m^3 to 400 ug/m^3. A summary of the results is presented in Appendix A.

Eleven of the soil gas samples with benzene detected were located approximately 50 feet to 900 feet west, south, and southwest of the 1 ug/L contour. Samples SG-14A, SG-14B, and SG-15B were located within the 1 ug/L to 20 ug/L contour. Benzene was not detected in the remaining 22 samples including (1) six samples (SG-10B, SG-12A, SG-12B, SG-12AA, SG-12AB, and SG-15A) located within the 1 ug/L to 20 ug/L contour and (2) 16 samples located approximately 50 feet to 1,000 feet west and southwest of the 1 ug/L contour.

The modeled indoor air concentration of benzene for this area ranged from 0.000873 ug/m^3 to 0.0000218 ug/m^3. Using the Johnson and Ettinger model and applying the more conservative DTSC URF, the estimated human health risk associated with the predicted concentrations range from 1.1E-07 to 2.8E-09 assuming migration of vapors through a concrete building slab, and 2.5E-08 to 6.3E-10 assuming migration of vapors considering a concrete perimeter foundation. Details for both scenarios are presented in Appendix B.

Sampling Results Technical Memorandum, Screening Lot and Scrapyard Area - 1993

In 1992, as part of the remedial investigation for the Alameda Annex, a soil gas survey was conducted at the screening lot and scrapyard (IR Site 2). A total of 214 soil gas samples were collected between 2 feet and 6 feet below ground surface and analyzed for benzene (see Figure 4). Of the 214 soil gas samples collected, benzene was detected in 13 samples at concentrations ranging from 50 ug/m^3 to 17,000 ug/m^3. Sample SG-T2 contained the concentration of 17,000 ug/m^3. Considering the trend of benzene concentrations detected throughout the housing and IR Site 2 areas (i.e., 10 to 400 ug/m^3) and sample SG-T2 located in an area where benzene was not detected in the groundwater, it appears the soil gas concentration of 17,000 ug/m^3 in SG-T2 is an anomaly. A summary of the results is presented in Appendix A.

Nine of the samples with benzene detected were located approximately 100 feet to 700 feet west, east, and northeast of the 1 ug/L contour. Samples SG-E3 and SG-G3 were located within the 1 ug/L to 20 ug/L contour. Sample SG-H1 was located within the 20 ug/L to 100 ug/L contour. Sample SG-M3 was located within the 100 ug/L to 700 ug/L contour.

Benzene was not detected in the remaining 201 samples including (1) 2 samples (SG-L1 and SG-M1) located within the >700 ug/L contour; (2) 13 samples located within the 100 ug/L to 700 ug/L contour; (3) 22 samples located within the 20 ug/L to 100 ug/L contour; (4) 25 samples located within the 1 ug/L to 20 ug/L contour; and (5) 139 samples located north, south, and east of the 1 ug/L contour.

The modeled indoor air concentration of benzene for this area ranged from 0.0371 ug/m^3 (sample SG-T2) to 0.000109 ug/m^3. Using the Johnson and Ettinger model and applying the more conservative DTSC URF, the estimated human health risk associated with the predicted concentrations range from 4.7E-06 (sample SG-T2) to 1.4E-08 assuming migration of vapors through a concrete building slab, and 1.1E-06 (sample SG-T2) to 3.2E-09 assuming migration of vapors considering a concrete perimeter foundation. Excluding sample SG-T2, the higher end of the range would be 8.3E-08 (with slab) and 1.9E-08 (without slab). Details for both scenarios are presented in Appendix B.

The IR Site 2 soil gas survey information from the Sampling Results Technical Memorandum was summarized in the remedial investigation (RI) report for the Alameda Annex. The RI report was finalized in January 1996.

Environmental Baseline Survey, Draft Final Data Evaluation Summaries, Zone 16 Housing - 1998

As part of the environmental baseline survey (EBS) conducted at Alameda Point, 27 soil gas samples were collected among Parcels 178, 179, 180 (day care center), and 181 in 1994-1995 to document the existing environmental conditions in Zone 16 (see Figures 5a through 5d). Benzene was not detected in any of the samples collected. A summary of the results is presented in Appendix A.

Sample 181-0017M was located within the 100 ug/L to 700 ug/L contour on Parcel 181, approximately 140 feet southeast of well MW-47 which showed a concentration of benzene in the groundwater of 251 ug/L during the 1999 groundwater sampling. Four samples (179-0004, 179-0005, 181-0016M, and 181-0018M) were located within the 20 ug/L to 100 ug/L contour on Parcels 179 and 181. Ten samples were located within the 1 ug/l to 20 ug/L contour on Parcels 179, 180, and 181. Twelve samples were located approximately 35 feet to 700 feet west, southwest, northwest, and east of the 1 ug/L contour on Parcels 178, 180, and 181.

Since benzene was not detected at Parcels 178, 179, 180, and 181, a human health risk assessment was not performed.

Conclusions

Numerous soil gas samples have been collected over the past several years within the Alameda Point housing area and Alameda Annex IR Site 2 and analyzed for benzene. On average, the frequency of detection for the 318 samples collected was low (10 percent).

Of the 32 samples in which benzene was detected in the Alameda Point housing area and Alameda Annex IR Site 2, 25 samples were located outside the 1 ug/L contour; 5 samples were located within the

1 ug/L to 20 ug/L contour; 1 sample was located within the 20 ug/L to 100 ug/L contour; and 1 sample was located within the 100 ug/L to 700 ug/L contour.

Of the 286 samples in which benzene was not detected in the Alameda Point housing area and Alameda Annex IR Site 2, 181 samples were located outside the 1 ug/L contour; 59 samples were located within the 1 ug/L to 20 ug/L contour; 29 samples were located within the 20 ug/L to 100 ug/L contour; 15 samples were located within the 100 ug/L to 700 ug/L contour; and 2 samples were located within the 700 ug/L contour.

Between the frequency of detection and the distribution of benzene detects/non-detects with respect to the benzene plume contours in the groundwater, benzene is not volatilizing to a large extent from groundwater into soil gas in the area.

The predicted benzene concentrations in indoor air, as modeled using the Johnson and Ettinger "Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings," do not pose an unacceptable cancer risk to residents living in the housing units at Alameda Point, even considering a conservative estimate assuming no concrete slab foundation. The benzene concentrations predicted in indoor air are lower than concentrations measured during the 1998 Oakland area sampling conducted by the BAAQMD.

Based on the evaluation of the distribution of benzene in soil gas samples that have been collected across Alameda Point Parcels 178, 179, 180, and 181 and Alameda Annex IR Site 2, and the fact that the predicted concentrations in indoor air do not pose an unacceptable risk to residents, the Navy has adequately addressed concerns regarding volatilization of benzene from groundwater into the housing areas and recommends no additional sampling regarding this issue.

REFERENCES

IT Corporation, 1998. Environmental Baseline Survey, Draft Final Data Evaluation Summaries, Volume IX - Zone 16. Alameda Point. December.

PRC Environmental Management, Inc. (PRC), 1989. Shallow Soil Gas Investigation, Military Housing Site. Naval Supply Center Oakland, Alameda Annex. November 27.

PRC, 1990. Risk Assessment Report, Military Housing Site. Naval Supply Center Oakland, Alameda Annex. October 2.

PRC, 1993. Sampling Results Technical Memorandum, Screening Lot and Scrapyard Area. Naval Supply Center Oakland, Alameda Annex and Facility. February.

PRC, 1996. Final Remedial Investigation Report. Fleet and Industrial Supply Center Oakland, Alameda Facility/Alameda Annex. January.

APPENDIX A

APPENDIX A
Soil Gas Sampling Results

Parcels 178/179/180 and Alameda Annex Warehouse Area, (Shallow Soil Gas Investigation - PRC 1989)

Benzene was detected in five out of 41 samples as indicated in the table below. The method detection limit was 40 ug/m^3.

Sample Location	Benzene Concentration (ug/m^3)
SG-2	40
SG-23	40
SG-34	80
SG-41	90
SG-43	300

Parcel 178 - Marina Village Housing, (Risk Assessment Report - PRC 1990)

Benzene was detected in 14 out of 36 samples as indicated in the table below. The method detection limit was typically 60 ug/m^3, but was increased if there was interference in the matrix.

Sample Location	Benzene Concentration (ug/m^3)	Sample Location	Benzene Concentration (ug/m^3)
SG-1A	<60	SG-10A	60
SG-1B	100	SG-10B	<60
SG-2A	100	SG-10AA	100
SG-2B	<60	SG-10AB	<60
SG-3AA	300	SG-11A	60
SG-3AB	<60	SG-11B	<60
SG-4A	<60	SG-12A	<60
SG-4B	<60	SG-12B	<60
SG-5A	<60	SG-12AA	<100
SG-5B	<60	SG-12AB	<100
SG-6A	400	SG-13A	<600
SG-6B	100	SG-13B	<600
SG-7A	<60	SG-14A	60
SG-7B	<60	SG-14B	200
SG-8A	<60	SG-15A	<60
SG-8B	10	SG-15B	100
SG-9A	<200	SG-16A	60
SG-9B	<300	SG-16B	100

Sampling Results Technical Memorandum, Screening Lot and Scrapyard Area - 1993

Benzene was detected in 13 out of 214 samples as indicated in the table below. The method detection limit ranged from 0.09 ug/m^3 to 0.19 ug/m^3 depending on matrix interference. The table below summarizes the soil gas analytical results for benzene (positive detects only); non-detects are not reported.

Sample Location	Benzene Concentration (ug/m^3)
SG-C1-5'	50
SG-H1-5'	200
SG-E3-5'	50
SG-G3-5'	50
SG-O6-5'	300
SG-M3-3'	100
SG-Y1-2'	200
SG-X8-3.5'	60
SG-V5-2'	100
SG-W6-2.5'	50
SG-V6-2.5'	60
SG-V7-2'	60
SG-T2-4'	17,000

Environmental Baseline Survey, Draft Final Data Evaluation Summaries, Zone 16 Housing - 1998

Benzene was not detected in the 27 samples collected.

APPENDIX B

Converting Soilgas Benzene Concentrations to Benzene Concentrations in a Building and then Converting to Cancer Risk Values

Scenario 1 - Concrete Slab (Revised)

Sample Area	Sample Location	Soil Gas Benzene Concentration (µg/L)	Soil Gas Benzene Concentration (µg/m³)	Soil Gas Benzene Dilution Concentration[A] (µg/m³)	Dilution Concentration Cancer Risk Value[B]		
					Tetra Tech Value[C]	DTSC Value[D]	USEPA Value[E]
Military Housing Site 1989	SG-2	0.04	40	1.4E-04	6.3E-09	1.1E-08	3.0E-09
	SG-23	0.04	40	1.4E-04	6.3E-09	1.1E-08	3.0E-09
	SG-34	0.08	80	2.9E-04	1.3E-08	2.2E-08	6.0E-09
	SG-41	0.09	90	3.2E-04	1.4E-08	2.5E-08	6.8E-09
	SG-43	0.3	300	1.1E-03	4.7E-08	8.3E-08	2.3E-08
Military Housing Site 1990b	SG-1A	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-1B	0.1	100	3.6E-04	1.6E-08	2.8E-08	7.5E-09
	SG-2A	0.1	100	3.6E-04	1.6E-08	2.8E-08	7.5E-09
	SG-2B	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-3AA	0.3	300	1.1E-03	4.7E-08	8.3E-08	2.3E-08
	SG-3AB	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-4A	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-4B	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-5A	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-5B	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-6A	0.4	400	1.4E-03	6.3E-08	1.1E-07	3.0E-08
	SG-6B	0.1	100	3.6E-04	1.6E-08	2.8E-08	7.5E-09
	SG-7A	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-7B	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-8A	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-8B	0.01	10	3.6E-05	1.6E-09	2.8E-09	7.5E-10
	SG-9A	< 0.2	< 200	< 7.2E-04	< 3.1E-08	< 5.5E-08	< 1.5E-08
	SG-9B	< 0.3	< 300	< 1.1E-03	< 4.7E-08	< 8.3E-08	< 2.3E-08
	SG-10A	0.06	60	2.2E-04	9.4E-09	1.7E-08	4.5E-09
	SG-10B	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-10AA	0.1	100	3.6E-04	1.6E-08	2.8E-08	7.5E-09
	SG-10AB	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-11A	0.06	60	2.2E-04	9.4E-09	1.7E-08	4.5E-09
	SG-11B	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-12A	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-12B	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-12AA	< 0.1	< 100	< 3.6E-04	< 1.6E-08	< 2.8E-08	< 7.5E-09
	SG-12AB	< 0.1	< 100	< 3.6E-04	< 1.6E-08	< 2.8E-08	< 7.5E-09
	SG-13A	< 0.6	< 600	< 2.2E-03	< 9.4E-08	< 1.7E-07	< 4.5E-08
	SG-13B	< 0.6	< 600	< 2.2E-03	< 9.4E-08	< 1.7E-07	< 4.5E-08
	SG-14A	0.06	60	2.2E-04	9.4E-09	1.7E-08	4.5E-09
	SG-14B	0.2	200	7.2E-04	3.1E-08	5.5E-08	1.5E-08
	SG-15A	< 0.06	< 60	< 2.2E-04	< 9.4E-09	< 1.7E-08	< 4.5E-09
	SG-15B	0.1	100	3.6E-04	1.6E-08	2.8E-08	7.5E-09
	SG-16A	0.06	60	2.2E-04	9.4E-09	1.7E-08	4.5E-09
	SG-16B	0.1	100	3.6E-04	1.6E-08	2.8E-08	7.5E-09

[illegible]

Scenario 1 - Concrete Slab (Revised)

Sample Area	Sample Location	Soil Gas Benzene Concentration (µg/L)	Soil Gas Benzene Concentration (µg/m^3)	Soil Gas Benzene Dilution Concentration^A (µg/m^3)	Dilution Concentration Cancer Risk Value^B		
					Tetra Tech Value^C	DTSC Value^D	USEPA Value^E
Screening Lot & Scrapyard Area 1993 - Area 1	SG-C1-5'	0.05	50	1.8E-04	7.8E-09	1.4E-08	3.8E-09
	SG-H1-5'	0.2	200	7.2E-04	3.1E-08	5.5E-08	1.5E-08
	SG-E3-5'	0.05	50	1.8E-04	7.8E-09	1.4E-08	3.8E-09
	SG-G3-5'	0.05	50	1.8E-04	7.8E-09	1.4E-08	3.8E-09
Screening Lot & Scrapyard Area 1993 - Area 2	SG-O6-5'	0.3	300	1.1E-03	4.7E-08	8.3E-08	2.3E-08
	SG-M3-3'	0.1	100	3.6E-04	1.6E-08	2.8E-08	7.5E-09
	SG-Y1-2'	0.2	200	7.2E-04	3.1E-08	5.5E-08	1.5E-08
Screening Lot & Scrapyard Area 1993 - Area 3	SG-X8-3.5'	0.06	60	2.2E-04	9.4E-09	1.7E-08	4.5E-09
	SG-V5-2'	0.1	100	3.6E-04	1.6E-08	2.8E-08	7.5E-09
	SG-W6-2.5'	0.05	50	1.8E-04	7.8E-09	1.4E-08	3.8E-09
	SG-V6-2.5'	0.05	50	1.8E-04	7.8E-09	1.4E-08	3.8E-09
	SG-V7-2'	0.06	60	2.2E-04	9.4E-09	1.7E-08	4.5E-09
	SG-T2-4'	17	17,000	6.1E-02	2.7E-06	4.7E-06	1.3E-06

100 – 200 + 2.7×10^{-8}

200 ~ 300 + 2.8×10^{-8}

s:\group\air\alameda\finalvapormodel2\Scenario 1-Concrete

CONVERTING OFFGAS BENZENE CONCENTRATIONS TO BENZENE CONCENTRATIONS IN A BUILDING AND THEN CONVERTING TO CANCER RISK VALUES

Converting Offgas Benzene Concentrations to Benzene Concentrations in a Building and then Converting to Cancer Risk Values

Scenario 1 - Concrete Slab (Revised)

Notes:

[A] A dilution factor is applied to the soil gas concentrations to account for:
1) the flow rate into the building through the concrete (maximum convective transport rate, Uv,max)
[it is assumed that convective transport is much larger than diffusion and, thus, diffusion is not considered]
2) the flow rate into the building through the windows vents and other openings (the volumetric exchange rate, ERv)

Dilution Factor = 3.59E-06 unitless, ratio
Dilution Factor => Uv,max / ERv

where, Uv,max => Volumetric Maximum Convective Transport Rate, cm^3/sec
ER_v => Volumetric Exchange Rate in Enclosed Building, cm^3/sec

Calculations

ER_v = 56,375 cm^3/sec, Volumetric Exchange Rate in Enclosed Building (based on Johnson-Etinger Model)
ER_v => ER * V cm^3/sec, Volumetric Exchange Rate in Enclosed Building

Parameters, ER = 0.000125 /sec, Enclosed-space air exchange rate, 1/sec (default value from Johnson-Ettinger Model) (converted from 0.45/hour)
V= 451,000,000 cm^3, Volume of space (default value from Johnson-Ettinger model)

$U_{v,max}$ = 0.20 cm/sec, Volumetric Maximum Convective Transport Rate

$$U_{v,max} \Rightarrow \frac{1 * k_v \nabla P}{\mu v * R_v}$$ cm/sec, Volumetric Maximum Convective Transport Rate

Parameters, k_v = 1.0E-06 cm^2, permeability to vapor flow
∇P = 40 $g/cm^2\text{-}sec^2$, vapor phase pressure gradient
Value used (40) is in $g/cm\text{-}sec^2$
μv = 1.80E-04 g/cm-sec, vapor viscosity
Value used (.00018) is in g/cm-sec
R_v = 1.10 unitless, porous media "retardation" factor (no immiscible hydrocarbon present outside of source area)
$R_v \Rightarrow [\theta_w/H + k_s\rho_s/H + \theta v]$

where, θ_w = 0.12 cm^3 of water / cm^3 of soil, volumetric content of soil pore water
H = 0.22 g/cm^3 of vapor / g/cm^3 of water, Henry's Law Constant
ρ_s = 1.7 g/cm^3, soil bulk density (default value[a])
θv = 0.26 cm^3 of vapor / cm^3 of soil, volumetric content of soil vapor
k_s = 0.038 cm^3 of water / gram of soil
$k_s \Rightarrow f_{oc} * k_{oc}$ cm^3 of water / gram of soil

Equations obtained from Table X3.1, Example Screening Level Transport Models (Risk-Based Corrective Action Applied at Petroleum Release)

CONVERTING OFFGAS BENZENE CONCENTRATIONS TO BENZENE CONCENTRATION IN A BUILDING AND THEN CONVERTING TO CANCER RISK VALUES

Converting Offgas Benzene Concentrations to Benzene Concentrations in a Building and then Converting to Cancer Risk Values

Scenario 1 - Concrete Slab (Revised)

Notes:

where, f_{oc}= 0.001 gram of carbon / gram of soil, fraction of organic carbon in soil (default value)

k_{oc}= 38.02 cm^3 of water / gram of carbon, carbon water sorption coefficient (chemical-specific)

default value => Table X2.6, Example Screening Level Transport Models (Risk-Based Corrective Action Applied at Petroleum Release)

Dilution Factor = Uv,max / ERv

where, Uv,max => Volumetric Maximum Convective Transport Rate, cm^3/sec

ER_v => Volumetric Exchange Rate in Enclosed Building, cm^3/sec

The diluted soil gas values can be compared to the following:

1E-06 Residential Cancer Risk Value for Benzene =	0.23 (μg/m³) =>	0.07 ppb
Minumum ambient benzene concentration in Oakland =	0.319 (μg/m³) =>	0.1 ppb
Maximum ambient benzene concentration in Oakland =	2.875 (μg/m³) =>	0.9 ppb
Average ambient benzene concentration in Oakland =	1.342 (μg/m³) =>	0.42 ppb

Thus, the ambient concentration generally exceeds the Cancer Risk Value.

Converting parts per billion (ppb) to micrograms per cubic meter (μg/m³) =>

(μg/m³) = ppb*MW/(0.02445*1000)

where, ppb => Parts per billion

MW => Molecular weight (78.1 grans/gram-mole)

0.02445 => T*R/P

Temperature (Kelvin) *Gas Constant (millibar*cubic meter/gram-mole*Kelvin) / Pressure (millibar)

298.16 * 0.0831 / 1013.2

1000 => 1000 parts per billion / parts per million

Notes:

[B] Converting dilution concentration to target cancer risk

The dilution concentration value is converted to a target cancer risk value by using
the equation for inhalation exposure to carcinogenic contaminant in air.
[U.S. Environmental Protection Agency (USEPA) Region 9 Preliminary Remediation Goals (PRGs) 1998]

calculations:

$$C(\mu g/m^3) = \frac{TR * AT_c * 1000\ \mu g/mg}{Ef_r * InhF_{adj} * CSF_i}$$

where:

$C(\mu g/m^3)$ => Concentration in micrograms per cubic meters
TR => Target cancer risk
AT_c => Averaging time - carcinogen (default value - 25,550 days)
1000 μg/mg => 1000 microgram per milligram
Efr => Exposure frequency - residential (default value - 350 days per year)
$InhF_{adj}$ => Inhalation factor - [default value 11 (m^3*yr)/(kg*d)] - 11 cubic meters * years / kilograms *days
CSF_i => Cancer slope factor inhaled for benzene - [default value 0.029 kg*d/mg] - 0.029 kilograms * days / miligrams

This equation can also be solved for TR (Target cancer risk)

$$TR = \frac{C(\mu g/m3) * Ef_r * InhF_{adj} * CSF_i}{AT_c * 1000\ \mu g/mg}$$

[C] Tetra Tech values were obtained from calculations outlined in Notes [A] and [B].

Notes:

[D] DTSC values obtained from Johnson - Ettinger Model (DTSC version).
The original reference for this model is:

Users's Guide for the Johnson and Ettinger (1991) Model for Subsurface Bapor Intrusion into Buildings
Prepared by Environmental Quality Mangement, Inc. - Durham, North Carolina
Contract No. 68-D30035 Work Assignment No. III-106
U.S. Environmental Protection Agency
Office of Emergency and Remedial Response
Toxics Integration Branch (5202G)
Washingtron, D.C. 20450
September 1997

The DTSC has its own version of this model. This version is similar to the USEPA version.
The major difference is the unit risk factor (URF) that is used.
In the DTSC version, URF = 2.96E-05 ($1/\mu g/m^3$).

[E] USEPA values obtained from Johnson - Ettinger Model (USEPA version).
The reference for this model is:

Users's Guide for the Johnson and Ettinger (1991) Model for Subsurface Bapor Intrusion into Buildings
Prepared by Environmental Quality Mangement, Inc. - Durham, North Carolina
Contract No. 68-D30035 Work Assignment No. III-106
U.S. Environmental Protection Agency
Office of Emergency and Remedial Response
Toxics Integration Branch (5202G)
Washingtron, D.C. 20450
September 1997

The original USEPA version of this model is similar to the DTSC version.
The major difference is the unit risk factor (URF) that is used.
In the original USEPA version, URF = 8.3E-06 ($1/\mu g/m^3$).

...nverting Soilgas Benzene Concentrations to Benzene Concentrations in a Building and then Converting to Cancer Risk ...

Scenario 2 - No Concrete Slab (revised)

Sample Area	Sample Location	Soil Gas Benzene Concentration (µg/L)	Soil Gas Benzene Concentration (µg/m³)	Cg[A] (g/cm³)	J[B] (g/cm²/s)	J[C] (g/m²/s)	C[D] (µg/m³)	C[E] (µg/m³)	Dilution Concentration Cancer Risk Value[F] DTSC	USEPA
Military Housing Site 1989	SG-2	0.04	40	4.00E-11	2.12E-14	2.12E-10	2.82E+00	8.73E-05	2.5E-09	7.2E-10
	SG-23	0.04	40	4.00E-11	2.12E-14	2.12E-10	2.82E+00	8.73E-05	2.5E-09	7.2E-10
	SG-34	0.08	80	8.00E-11	4.24E-14	4.24E-10	5.65E+00	1.75E-04	5.1E-09	1.4E-09
	SG-41	0.09	90	9.00E-11	4.77E-14	4.77E-10	6.36E+00	1.96E-04	5.7E-09	1.6E-09
	SG-43	0.3	300	3.00E-10	1.59E-13	1.59E-09	2.12E+01	6.55E-04	1.9E-08	5.4E-09
Military Housing Site 1990b	SG-1A	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-1B	0.1	100	1.00E-10	5.30E-14	5.30E-10	7.06E+00	2.18E-04	6.3E-09	1.8E-09
	SG-2A	0.1	100	1.00E-10	5.30E-14	5.30E-10	7.06E+00	2.18E-04	6.3E-09	1.8E-09
	SG-2B	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-3AA	0.3	300	3.00E-10	1.59E-13	1.59E-09	2.12E+01	6.55E-04	1.9E-08	5.4E-09
	SG-3AB	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-4A	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-4B	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-5A	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-5B	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-6A	0.4	400	4.00E-10	2.12E-13	2.12E-09	2.82E+01	8.73E-04	2.5E-08	7.2E-09
	SG-6B	0.1	100	1.00E-10	5.30E-14	5.30E-10	7.06E+00	2.18E-04	6.3E-09	1.8E-09
	SG-7A	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-7B	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-8A	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-8B	0.01	10	1.00E-11	5.30E-15	5.30E-11	7.06E-01	2.18E-05	6.3E-10	1.8E-10
	SG-9A	< 0.2	< 200	1.00E-10	5.30E-14	5.30E-10	7.06E+00	2.18E-04	< 6.3E-09	< 1.8E-09
	SG-9B	< 0.3	< 300	1.50E-10	7.95E-14	7.95E-10	1.06E+01	3.27E-04	< 9.5E-09	< 2.7E-09
	SG-10A	0.06	60	6.00E-11	3.18E-14	3.18E-10	4.24E+00	1.31E-04	3.8E-09	1.1E-09
	SG-10B	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-10AA	0.1	100	1.00E-10	5.30E-14	5.30E-10	7.06E+00	2.18E-04	6.3E-09	1.8E-09
	SG-10AB	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-11A	0.06	60	6.00E-11	3.18E-14	3.18E-10	4.24E+00	1.31E-04	3.8E-09	1.1E-09
	SG-11B	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-12A	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-12B	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-12AA	< 0.1	< 100	5.00E-11	2.65E-14	2.65E-10	3.53E+00	1.09E-04	< 3.2E-09	< 9.1E-10
	SG-12AB	< 0.1	< 100	5.00E-11	2.65E-14	2.65E-10	3.53E+00	1.09E-04	< 3.2E-09	< 9.1E-10
	SG-13A	< 0.6	< 600	3.00E-10	1.59E-13	1.59E-09	2.12E+01	6.55E-04	< 1.9E-08	< 5.4E-09
	SG-13B	< 0.6	< 600	3.00E-10	1.59E-13	1.59E-09	2.12E+01	6.55E-04	< 1.9E-08	< 5.4E-09
	SG-14A	0.06	60	6.00E-11	3.18E-14	3.18E-10	4.24E+00	1.31E-04	3.8E-09	1.1E-09
	SG-14B	0.2	200	2.00E-10	1.06E-13	1.06E-09	1.41E+01	4.36E-04	1.3E-08	3.6E-09
	SG-15A	< 0.06	< 60	3.00E-11	1.59E-14	1.59E-10	2.12E+00	6.55E-05	< 1.9E-09	< 5.4E-10
	SG-15B	0.1	100	1.00E-10	5.30E-14	5.30E-10	7.06E+00	2.18E-04	6.3E-09	1.8E-09
	SG-16A	0.06	60	6.00E-11	3.18E-14	3.18E-10	4.24E+00	1.31E-04	3.8E-09	1.1E-09
	SG-16B	0.1	100	1.00E-10	5.30E-14	5.30E-10	7.06E+00	2.18E-04	6.3E-09	1.8E-09

Converting Soilgas Benzene Concentrations to Benzene Concentrations in a Building and then Converting to

Scenario 2 - No Concrete Slab (revised)

Sample Area	Sample Location	Soil Gas Benzene Concentration (µg/L)	Soil Gas Benzene Concentration (µg/m^3)	Cg^A (g/cm^3)	J^B (g/cm^2/s)	J^C (g/m^2/s)	C^D (µg/m^3)	C^E (µg/m^3)	Dilution Concentration Cancer Risk Value^F	
									DTSC	USEPA
Screening Lot & Scrapyard Area 1993 - Area 1	SG-C1-5'	0.05	50	5.00E-11	2.65E-14	2.65E-10	3.53E+00	1.09E-04	3.2E-09	9.1E-10
	SG-H1-5'	0.2	200	2.00E-10	1.06E-13	1.06E-09	1.41E+01	4.36E-04	1.3E-08	3.6E-09
	SG-E3-5'	0.05	50	5.00E-11	2.65E-14	2.65E-10	3.53E+00	1.09E-04	3.2E-09	9.1E-10
	SG-G3-5'	0.05	50	5.00E-11	2.65E-14	2.65E-10	3.53E+00	1.09E-04	3.2E-09	9.1E-10
Screening Lot & Scrapyard Area 1993 - Area 2	SG-O6-5'	0.3	300	3.00E-10	1.59E-13	1.59E-09	2.12E+01	6.55E-04	1.9E-08	5.4E-09
	SG-M3-3'	0.1	100	1.00E-10	5.30E-14	5.30E-10	7.06E+00	2.18E-04	6.3E-09	1.8E-09
	SG-Y1-2'	0.2	200	2.00E-10	1.06E-13	1.06E-09	1.41E+01	4.36E-04	1.3E-08	3.6E-09
Screening Lot & Scrapyard Area 1993 - Area 3	SG-X8-3.5'	0.06	60	6.00E-11	3.18E-14	3.18E-10	4.24E+00	1.31E-04	3.8E-09	1.1E-09
	SG-V5-2'	0.1	100	1.00E-10	5.30E-14	5.30E-10	7.06E+00	2.18E-04	6.3E-09	1.8E-09
	SG-W6-2.5'	0.05	50	5.00E-11	2.65E-14	2.65E-10	3.53E+00	1.09E-04	3.2E-09	9.1E-10
	SG-V6-2.5'	0.05	50	5.00E-11	2.65E-14	2.65E-10	3.53E+00	1.09E-04	3.2E-09	9.1E-10
	SG-V7-2'	0.06	60	6.00E-11	3.18E-14	3.18E-10	4.24E+00	1.31E-04	3.8E-09	1.1E-09
	SG-T2-4'	17	17,000	1.70E-08	9.00E-12	9.00E-08	1.20E+03	3.71E-02	1.1E-06	3.1E-07

Notes:

^{A} Soil gas concentration in units of g/cm^3

^{B} Benzene flux into crawlspace in units of g/cm^2/s

^{C} Benzene flux into crawlspace in units of g/m^2/s

^{D} Steady-state benzene concentration in crawlspace air

^{E} Steady-state benzene concentration in living space air

^{F} Cancer risk associated with inhalation of living space air

ESTIMATING BENZENE CANCER RISKS DUE TO VAPOR INTRUSION AT ALAMEDA POINT AND ALAMEDA ANNEX

Introduction

Volatile chemical contaminants in soil pose a potential health risk due to possible intrusion of vapors from the soil into an overlying building. Human exposure to the contaminant occurs when the airborne contaminant is inhaled. To assess the health risks associated with this vapor intrusion exposure pathway, the Johnson-Ettinger (JE) vapor intrusion model (Johnson and Ettinger, 1991; EQM, 1997) is typically used. A spreadsheet version of this model is available from both the U.S. Environmental Protection Agency (EPA) and the California Department of Toxic Substances Control (DTSC) as this model is recommended by both agencies for assessing the vapor intrusion exposure pathway. The EPA and DTSC spreadsheet models also allow calculation of cancer risks due to this pathway. The JE model was used to calculate the cancer risks associated with benzene soil gas measurements collected at Alameda Point and Alameda Annex.

The JE model does not consider the presence of a crawlspace below the living space in a residence. Therefore, a second modeling approach was used to evaluate cancer risks associated with vapor intrusion when a crawlspace is present in the overlying structure. This second approach uses a mass-balance, two-compartment model in conjunction with data available from the JE model to estimate cancer risks for this latter case.

The Johnson-Ettinger Model

The JE model is a complex transport model that calculates the concentration of airborne contaminant in a hypothetical building overlying contaminated soil or groundwater. The air concentration of contaminant in the building is calculated based on the underlying soil, soil gas or groundwater concentration. Contaminant is assumed to move from the contaminant source by diffusion until it approaches the building. Near the building, soil gas is drawn into the building as the result of convection driven by a negative pressure differential between the living space and the soil surface. The JE model assumes that a cement slab floor is present in the overlying building and that vapors penetrate into the building by convection via seams or cracks at the floor-wall joint. The spreadsheet version of the JE model calculates the concentration of contaminant in the overlying building and, based on that concentration, also calculates the associated cancer risk due to inhalation exposure. The JE model is quite complex and complete documentation of the numerous model assumptions and parameters is provided in EQM (1997).

Cement Floor Barrier Exposure Scenario

The standard application of the JE model assumes that contaminant vapors enter the building only through cracks at the intersection of the walls and floors. A cement floor otherwise prevents entry of vapors into the building. To estimate benzene cancer risks where it is assumed that a cement floor presents a barrier to vapor intrusion from the ground, the JE model was used. Two versions of the model were used, the EPA version and the DTSC version. The only difference between the two versions is that each agency uses a different unit risk factor (URF) to convert the calculated air concentration to its corresponding cancer risk. The DTSC URF is higher (2.9E-05 per $\mu g/m^3$) than the EPA URF (8.3E-06 per $\mu g/m^3$). Thus, the DTSC version of the JE model results in a higher calculated cancer risk for the same air concentration. Other than this difference, the models were run using the same default assumptions.

The soil gas measurements and resulting cancer risk estimates calculated using the JE model are listed in the table. The table shows that the maximum cancer risks for virtually all soil gas samples were less than 1E-06, the level of cancer risk considered acceptable by federal and state regulatory agencies. Note that this approach to assess the health risks associated with vapor intrusion is the most widely used and accepted by regulatory agencies.

Crawlspace Exposure Scenario

A second modeling approach was used to estimate the cancer risks that might be associated with a situation where there is a crawlspace underneath the building. For this second approach, a two-compartment mass-balance model was used to estimate the steady-state concentration of benzene in an overlying building.

In this approach, a hypothetical building of the same dimensions as that used by the JE model was assumed to have a crawlspace two feet high (0.6 meters [m]) directly beneath the building. Contaminant emitted as soil gas from the soil surface is assumed to directly enter the crawlspace. Contaminant leaves the crawlspace by ventilation of the crawlspace and by convective flow into the overlying living space. The rate of this convective flow was assumed to be identical to that assumed by the JE model. This assumption is conservative since, in the presence of a crawlspace, a negative pressure differential exerted across the floor would tend to draw air into the crawlspace from outside the building rather than from the soil.

Airborne contaminant leaves the living space of the building through ventilation after complete mixing with the living space air. This simple model can be expressed mathematically as follows:

$$V1\frac{dC1}{dt} = JA - Q1C1 - Q2C1 \quad (1)$$

$$V2\frac{dC2}{dt} = Q2C1 - Q3C2 \quad (2)$$

where:

C1	=	concentration of benzene in living space air (g/m^3)
C2	=	concentration of benzene in crawlspace air (g/m^3)
J	=	emission flux of benzene from the ground surface ($g/m^2/s$)
A	=	area of floor of building (m^2)
Q1	=	ventilation rate of the crawlspace (m^3/s)
Q2	=	convective flow from crawlspace into living space (m^3/s)
Q3	=	ventilation rate of living space (m^3/s)
t	=	time (s)
V1	=	volume of crawlspace (m^3)
V2	=	volume of living space (m^3)

If it is assumed conservatively that the emission flux does not change over time and that the ventilation rate is constant, then the air concentration of benzene in the crawlspace and living space will reach a steady-state or constant value. Under these conditions the differentials in the above equation equal zero and Equations 1 and 2 can be rearranged to solve for C1 and C2 as follows:

$$C1 = \frac{JA}{Q1 + Q2} \quad (3)$$

$$C2 = \frac{Q2C1}{Q3} \quad (4)$$

The ventilation rate for the living space, Q3, was calculated to be 0.056 m^3/s by multiplying the building volume of 451 m^3 by an air exchange rate of 0.45 per hour (/hr) (EQM, 1997). The ventilation rate for the crawlspace was calculated in an analogous manner, assuming the same air exchange rate of 0.45/hr and a total crawlspace volume of 55.45 m^3. The crawlspace volume was calculated based on a total floor area of 92.42 m^2, the same floor area as is used in the JE model. The convective flow from the crawlspace into the living space was assumed to be identical to that specified in the JE model, 1.73E-06 m^3/s.

The emission flux, *J*, was calculated using Farmer's model (EPA, 1992). Farmer's model allows conversion of a soil gas measurement to a corresponding emission flux as shown below:

$$J = \frac{D_a P_a^{10/3} C_g}{P_t^2 L} \tag{5}$$

where:

L	=	distance from the contamination source to the ground surface (cm)
D_a	=	diffusivity of benzene in air (cm^2/s)
P_a	=	air-filled soil porosity (unitless)
P_t	=	total soil porosity (unitless)
C_g	=	soil gas concentration (g/cm^3)
J	=	emission flux per unit area ($g/cm^2/s$)

The value for *L*, the distance between the contamination source and the ground surface, was conservatively assumed to be 1 cm. D_a, P_a, and P_t were assumed to be 8.8E-03, 0.13, and 0.43 respectively (EPA, 1996). The soil gas concentration of benzene was obtained from the table.

Given the value of *J* calculated above, the steady-state concentration of benzene in the crawlspace, C1, was then calculated using Equation 3. The calculated steady-state value for C1 was then inserted into Equation 4 to solve for C2, the steady-state concentration of benzene in the living space air. Cancer risks associated with the resulting steady-state benzene concentration in living space air were calculated using both the DTSC and EPA URF values as follows:

$$\text{Cancer risk} = C2 * URF \tag{6}$$

The cancer risks calculated for each benzene soil gas measurement using both the DTSC and EPA URF values are shown in the table. The table shows that when the presence of a crawlspace is considered, the cancer risks due to inhalation exposure to benzene in the living space drop considerably to a range of between 1E-10 and 1E-9. These values are well below the range typically considered acceptable by most state and federal regulatory agencies which is 1E-06 to 1E-04.

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BENZENE SOIL GAS INVESTIGATION SUMMARY DATED 1 OCTOBER 1999

ORIGINAL VERSION IS NOT ON FILE

EXTENSIVE RESEARCH WAS PERFORMED BY NAVFAC SOUTHWEST TO LOCATE THE ORIGINAL VERSION. THIS PAGE HAS BEEN INSERTED AS A PLACEHOLDER AND WILL BE REPLACED SHOULD THE MISSING ITEM BE LOCATED.

QUESTIONS MAY BE DIRECTED TO:

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