August 24, 1999

ENVIRONMENTAL PROTECTION

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Alameda County
Health Care Services Agency
Environmental Health Services
1131 Harbor Bay Parkway
Suite 250
Alameda, CA 94502-6577
Attn: Ms. Eva Chu

SUBJECT: SUBMITTAL OF RISK ASSESSMENT REPORT, WEYERHAEUSER PAPER COMPANY, 1801 HIBBARD ST., ALAMEDA 94501 STID 1202

Dear Ms. Chu,

West & Associates is pleased to submit the enclosed "Closure Risk Assessment" for the Weyerhaeuser Paper Company property in Alameda. As detailed in the risk assessment, we have concluded that the low concentrations of contaminants proposed to be left onsite do not pose an unacceptable risk to future residential development.

We appreciate your cooperation in reviewing our risk assessment this week so that Larry Seto can continue to process the site closure upon his return from vacation August 30. Should you have any questions regarding the risk assessment please contact me at (707) 451-1360.

Yours truly,

Warren D. Hansen
for

Brian W. West PE
President
West & Associates Environmental Engineers, Inc.

BWW/eb

cc: Mr. James E. McCourt PE, Weyerhaeuser Office of the Environment
Mr. Warren Hansen PE, Onsite Enterprises 425/883-2391

to dwongboard@hotmail.com

RISK-BASED CORRECTIVE ACTION (RBCA)
EVALUATION OF POST-REMEDIATION CLEANUP LEVELS

WEYERHAEUSER PAPER COMPANY – ALAMEDA BOX PLANT

August 1999

EXECUTIVE SUMMARY

A review of health risks associated with residual contaminants at the Alameda Box Plant site was undertaken using site-Specific data in accordance with general methodologies set forth under the RBCA ASTM Standard ES-38. The site has been proposed to the Alameda County Health Agency for closure and the agency has requested this evaluation as part of its final review.

Low-level contamination remaining in a small area of the site include gasoline residues (benzene, ethylbenzene and xylenes) in soil and groundwater and trace amounts of chlorinated solvents (1,1-dichloroethane, trichloroethene and tetrachloroethene) in groundwater. Potential exposure pathways at the site included subsurface sources (groundwater and subsurface soil) to indoor and ambient air (residential scenario); and limited direct contact with soil (worker scenario). Both adult and child exposure assumptions were evaluated for the residential scenario.

The results of the analysis indicate that residual contaminant concentrations do not pose a human health risk in excess of either the target excess individual lifetime cancer risk or the non-carcinogenic target hazard index. The limiting exposure pathway is represented by carcinogenic compounds present in groundwater and potentially migrating to indoor air. However, taken together, all carcinogenic compounds detected in groundwater only comprised approximately 12 and 90 percent of the allowable carcinogenic risk to adults and children, respectively. Analysis of the worker exposure scenario also indicated that existing subsurface soil concentrations are well below those that would result in unacceptable risk levels. Based on the methods, assumptions and limitations set forth in this evaluation, the post-remediation contaminant levels at the site are sufficiently protective and additional corrective actions are not needed at this time.

RISK-BASED CORRECTIVE ACTION (RBCA)
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SCOPE AND APPROACH

This human-health risk-based evaluation of residual contaminants at the Alameda Box Plant site is based on general "streamlined" procedures set forth in the ASTM Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (ASTM 1994). Figure 1 shows the overall approach used in the risk evaluation process. Contaminated media remaining in groundwater and subsurface soil have been identified by site testing (monitoring wells and boreholes). Detected contaminants include benzene, ethylbenzene and xylenes in groundwater and subsurface soil, and three chlorinated volatile compounds in groundwater. The concentrations of these contaminants are based on the most recent (post-remediation) sampling events. Results indicate residual contamination to be present in only a limited area of the site. It is therefore appropriate to evaluate both the maximum concentrations (worst case) and average concentrations representing overall site conditions.

Once contaminants are identified, toxicity data available through the Integrated Risk Information System (IRIS – EPA, 1994), Health Effects Summary Assessment Tables (HEAST) and other sources are compiled for use in calculating risk-based screening levels at the point(s) of exposure. Physical constants are also identified as needed to evaluate cross-media transport. Exposure pathways and scenarios are evaluated as part of defining the "conceptual site model". For some pathways, such as direct contact with soil, exposure parameters (i.e., Table X2.4 in the ASTM Standard) may be used in conjunction with simple exposure models to calculate "risk-based screening levels" (RBSLs). Where cross-media transport is involved, a transport model such as those listed in Table X2.1 of the Standard may be used to calculate transfer coefficients. An RBSL indicates the maximum allowable concentration (i.e., cleanup level) that may exist in that media without exceeding the target risk levels for that contaminant. For example, where groundwater may be imparting vapors to air, an RBSL for air is first calculated using simple exposure models. A transport model is then used to estimate the corresponding groundwater concentration that will not exceed that RBSL (i.e., the corresponding RBSL for groundwater).

At sites where multiple carcinogenic and non-carcinogenic contaminants are present, there must be an evaluation of how each contaminant and associated pathways contribute to a total site hazard index (for non-carcinogens) and target excess individual lifetime cancer risk (for carcinogens). The final stage of the assessment therefore includes a summation of the individual risks from all contaminants and pathways to be sure additive effects are taken into account. For this assessment, The target site hazard index is 1.0 and the allowable excess individual lifetime cancer risk is 1×10^{-5}.

There are significant uncertainties associated with risk assessment methodologies, and these need to be recognized in considering the results of all assessments of this nature. Where Tier-1 methodologies are used, certain site parameters may be different than assumed literature or standard values. Many physical and chemical processes known to occur in nature are not necessarily represented in exposure and transport models, including synergistic effects of certain chemicals and complex biochemical contaminant transformations. The presence of special populations, site development procedures or other future site conditions not addressed in this evaluation may result in higher overall site risks. Ecological risks were not included as part of this assessment, and it is assumed that no ecological resources are present at the site that would be impaired. The ASTM Standard includes procedures for upgrading risk assessments when additional site information is available and/or site conditions undergo significant change.

Limited information is available regarding site parameters such as those listed in Table X2.5 of the ASTM Standard. Although a residential land use scenario is assumed, there are no residential structures currently located on the property. The default (Tier-1) values given for these parameters in the ASTM Standard were therefore employed in this assessment. Exceptions include the known depths to groundwater and subsurface contaminant sources. For these reasons, this assessment can only be viewed as a "screening" of risks estimated to represent given future site conditions.

SUMMARY OF SITE CONDITIONS AND CONTAMINANTS

Contaminants at the Alameda Site appear to be limited to a relatively small area of the property. Results of borehole tests (West & Associates 1999b) show contamination to be limited to deeper soils, at depths exceeding approximately 7 ft. BGS. Groundwater, located at approximately 12 ft. BGS, contain limited concentrations of contaminants as summarized in Table 1. Soil data used in this assessment include the borehole samples obtained July 16, 1999 (West & Associates 199b). Groundwater data include the most recent round of samples obtained on August 13, 1998 (Excelchem 1999). Maximum and average concentrations of contaminants in soil and groundwater are included in Table 1. Maximum concentrations are maximum levels detected in any well or borehole. Averaged concentrations include detected concentrations, as well as one-half of the reported detection limits for sampling locations where no detectable concentrations were present.

EXPOSURE PATHWAYS AND SCENARIOS

The "conceptual site model" used in this assessment is shown in Figure 2. The final site use scenario is residential and assumes residential structures will be constructed with both adult and child inhabitants. Although low levels of groundwater contaminants remain at the site, it has reportedly been demonstrated that contamination is not migrating off-site (West & Associates, 1999b). Due to the high salinity, the shallow groundwater under the site is unsuitable as a drinking water source.

Based on available site information, the following exposure pathways and scenarios are included in this evaluation:

- Residential Scenario: Adult and Child:
  - Groundwater-to-indoor air
  - Subsurface Soil-to-indoor air
  - Groundwater-to-ambient air
  - Subsurface soil-to-ambient air
- Worker Scenario: Utility trench construction/maintenance
  - Direct contact: subsurface soil

Flux factors for the subsurface sources-to-ambient air pathways are usually compared to those for the indoor air pathway for the same site conditions and assumptions. The indoor air pathway is commonly the "limiting" pathway and dominates the risk associated with vapors. This "screening" is included in this evaluation in order to properly focus the assessment and avoid needless detailed analysis of minor pathway contributions.

RISK-BASED SCREENING LEVELS AT POINTS OF EXPOSURE

Risk-Based Screening Levels (RBSLs) for each contaminant are calculated for purposes of the risk evaluation. These concentrations correspond to the incremental carcinogenic target risk (1 x 10-5) or non-carcinogenic target hazard quotient (1.0). They are compared to the measured or estimated concentrations at the site to derive an overall site risk. For the Alameda site, air (inhalation) and soil (direct contact) are media for which health-based screening levels must be derived. Contaminant toxicity data used in deriving RBSLs include carcinogenic slope factors (SF) and non-carcinogenic reference doses (RfDs) (Table 2). Where toxicity data were available in the EPA" Integrated Risk Information System (IRIS), these were used as first priority. In some circumstances, certain toxicity indices have been withdrawn from IRIS pending ongoing review. Where this is the case, indices published in the ASTM Standard were employed or former values as reported in IRIS or HEAST were used.

The derivation of carcinogenic and non-carcinogenic RBSLs for air for the adult and child residential exposure scenario is shown in Table 3. The RBSLs are in units of mg/m3 to be compatible with the vapor flux term for the indoor air pathway. All exposure parameter values are the defaults set forth in the ASTM Standard.

The derivation of carcinogenic and non-carcinogenic RBSLs for soil (direct contact – worker scenario) is shown in Table 4. Only Benzene (carcinogen) and ethylbenzene and xylenes (non-carcinogens) were detected in soil. The exposure parameters are the default industrial values set forth in the ASTM Standard with the exposure frequency (days/yr) modified to 30 (default =250) to represent a more realistic worker scenario. The resulting soil RBSLs are in units of mg/kg to be directly comparable with soil concentrations presented in Table 1.

CROSS-MEDIA CONTAMINANT TRANSPORT

Applicable pathways at the Alameda site include cross-media transport from subsurface sources (groundwater and soil) to indoor and ambient air. The following models are used to derive vapor flux (VF) terms which, when divided into the RBSLs for the appropriate chemical and point of exposure (air) yield an equivalent allowable source concentration. This section describes the assumptions and models used for deriving the vapor flux terms to indoor and ambient air. A summary of the calculated effective diffusion coefficients and volatilization factors derived using the various models is included in Table 5. Table 6 provides the assumed parameter values for the models, and Table 7 is a summary of the chemical-specific physical constants needed to calculate diffusion coefficients and volatilization factors. Description of each model is provided below:

Groundwater-to-Enclosed Space (VFwesp): The Johnson & Ettinger model used for estimating subsurface source-to-indoor air volatilization factors makes uses the Farmer Model for subsurface source-to-soil gas flux, with an additional flux term for soil gas moving into a structure through cracks in the foundation. An additional term has been added to accommodate contaminant degradation with time for finite source contaminants:

$$VFwesp = \frac{H * \left[\frac{D_{ws}^{eff} / L_{GW}}{ER * L_B}\right]}{1 + \left[\frac{D_{ws}^{eff} / L_{GW}}{ER * L_B}\right] + \left[\frac{D_{ws}^{eff} / L_{GW}}{\left(D_{crack}^{eff} * L_{crack}\right) * \eta}\right]} * 10^3 * \left[1/\lambda - e^{-\lambda T}/\lambda\right]/T$$

The units for VFwesp are:

$$\left[\frac{(mg / m^3 - air)}{mg / L - H_2O}\right]$$

Effective Diffusion Coefficients are calculated as follows:

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

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

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

$$D_{ws}^{eff} = (h_{cap} + h_v) * \left[\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}}\right]^{-1}$$

Subsurface Soil-to-Enclosed Space (VFsesp): This model is similar to the one provided above, with additional and modified terms to represent subsurface soil as the contaminant source:

$$VFsesp = \frac{\frac{H * P_b}{(\theta_{ws} + k_s * P_b + H\theta_{as})} * \left[\frac{D_s^{eff} / L_S}{ER * L_B}\right]}{1 + \left[\frac{D_s^{eff} / L_S}{ER * L_B}\right] + \left[\frac{D_s^{eff} / L_S}{\left(D_{crack}^{eff} * L_{crack}\right) * \eta}\right]} * 10^3 * \left[1/\lambda - e^{-\lambda T}/\lambda\right]/T$$

The units for VFsesp are:

$$\left[\frac{(mg / m^3 - air}{mg / kg - soil}\right]$$

Effective Diffusion coefficients for this model are defined above.

Groundwater-to-Ambient Air (VFwamb): This is the Farmer Model with an additional term to accommodate contaminant degradation with time for finite source contaminants:

$$VFwamb = \frac{H}{1+\left[\frac{U_{air} * \delta_{air} * L_{GW}}{W * D_{ws}^{eff}}\right]} * 10^3 * \left[1/\lambda - e^{-\lambda T}/\lambda\right]/T$$

The units for VFwamb are:

$$\left[\frac{(mg/m^3 - air)}{mg/L - H_2O}\right]$$

The diffusion coefficients in this model are the same as those defined above for the indoor air pathway models.

Subsurface Soil-to-Ambient Air (VFsamb): This is the Farmer Model with additional and modified terms to represent subsurface soil as the contaminant source:

$$VFsamb = \frac{H * P_s}{(\theta_{ws} + k_s * P_b + H\theta_{as}) * \left[1 + \frac{U_{air} * \delta_{air} * L_S}{W * D_s^{eff}}\right]} * 10^3 * \left[1/\lambda - e^{-\lambda T}/\lambda\right]/T$$

The units for VFsamb are:

$$\left[\frac{(mg/m^3 - air}{mg/kg - soil}\right]$$

The diffusion coefficients in this model are the same as those defined above.

As can be seen in Table 5, the calculated volatilization factors for the ambient air pathway are almost 2 orders of magnitude smaller than the corresponding factors for the indoor air pathway. When divided into the RBSLs for air, these result in allowable source concentrations that are correspondingly larger. For this reason, the remainder of this assessment focuses on the indoor air pathway as the "limiting" exposure pathway for vapors.

POST-REMEDIATION RISK LEVELS

Residential Exposure Scenario – Adult

A summary of the risk represented by residual contaminants to adults in the residential scenario is presented in Table 8. For each contaminant, the RBSL for the source (groundwater or soil) is calculated by dividing the RBSL for air for adults (Table 3) by the appropriate volatilization factor

(Table 5). This RBSLw or RBSLs represents the concentration at which the particular contaminant imparts a hazard quotient of 1.0 (or incremental carcinogenic risk of 1 x 10-5). The maximum and average source concentrations (first two columns in Table 8) are each divided by the RBSL to calculate a percent of the total site risk. The sum of these percentages is then calculated (for both groundwater and subsurface soil sources). If they are less than 100 percent than the overall target hazard index (1.0) and carcinogenic risk (1 x 10-5) has not been exceeded. If the sum exceeds 100 percent, then additional corrective actions would need to be considered. As shown in Table 8, the total percentages do not exceed 100 percent. The total percentage of the allowable carcinogenic risk is approximately 12 percent, using maximum contaminant concentrations and 2.6 percent using average concentrations. The non-carcinogenic risk is negligible.

Residential Exposure Scenario – Child

A corresponding calculation of risk represented by residual contaminants to children in the residential scenario is presented in Table 9. The same methodology as described above for the adult exposure is used, with appropriate RBSLs as derived in Table 3 and the volatilization factors in Table 5. Results show that the total risk does not exceed the established target levels. [redacted] The non-carcinogenic risk is negligible.

Worker Exposure Scenario

As shown below, comparison of the residual benzene, ethylbenzene and xylene concentrations in subsurface soil to the RBSLs calculated in Table 4 indicate that these contaminant concentrations are orders of magnitude below those resulting in a direct contact hazard to workers.

Soil Contaminant	Maximum Site Concentration (mg/kg)	RBSL-soil (Table 4) (mg/kg)
Benzene	0.005	1.0 (carcinogenic)
Ethylbenzene	0.071	101 (non-carc)
Xylenes	0.009	2028 (non-carc)

SUMMARY

The results of the analysis indicate that residual contaminant concentrations do not pose a human health risk in excess of either the target excess individual lifetime cancer risk or the non-carcinogenic target hazard index. The limiting exposure pathway is represented by carcinogenic compounds present in groundwater and potentially migrating to indoor air. However, taken together, all carcinogenic compounds detected in groundwater only comprised approximately 12 and 90 percent of the allowable carcinogenic risk to adults and children, respectively. Analysis of the worker exposure scenario also indicated that existing subsurface soil concentrations are well below those that would result in unacceptable risk levels. Based on the methods, assumptions and limitations set forth in this evaluation, the post-remediation contaminant levels at the site are sufficiently protective and additional corrective actions are not needed at this time.

REFERENCES

ASTM 1994. Emergency Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (ES 38 – 94). American Society for Testing and Materials. Philadelphia, PA. July 1994.

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Johnson, P.C., and R.A. Ettinger. 1991. Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings. Environmental Science and Technology. Vol. 25. P. 1445-1452.

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U.S. Environmental Protection Agency. 1989. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual, Part A. EPA/540/1-89/002. NTIS No. PB90-155581. Washington, DC.

West & Associates 1999a. Letter to L. Seto, Alameda County Health Agency from B.W. West. May 17, 1999.

West & Associates 1999b. Letter to L. Seto, Alameda County Health Agency from B. Mahoney. July 21, 1999

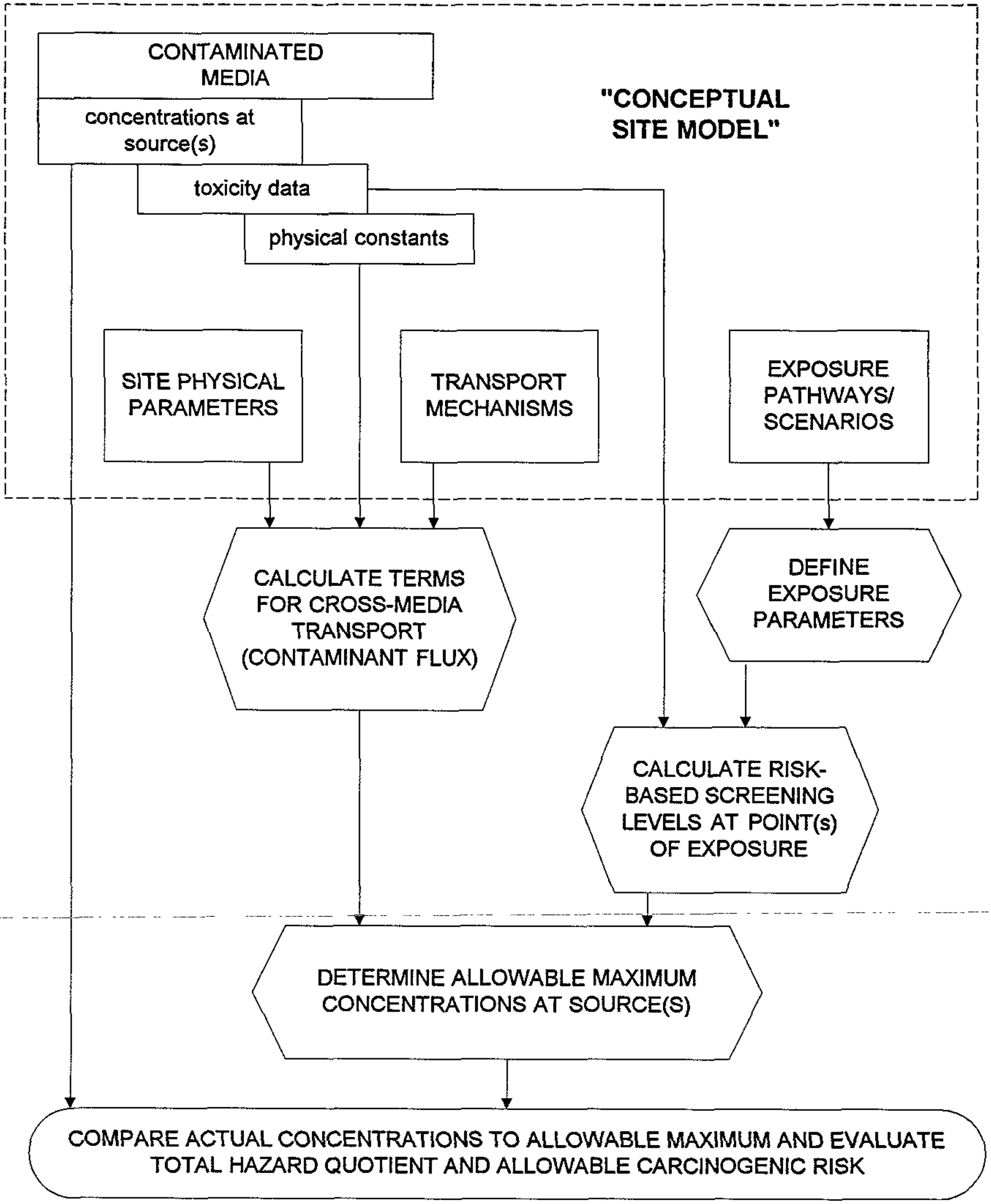

FIGURE 1 - RISK EVALUATION PROCESS - ALAMEDA BOX PLANT

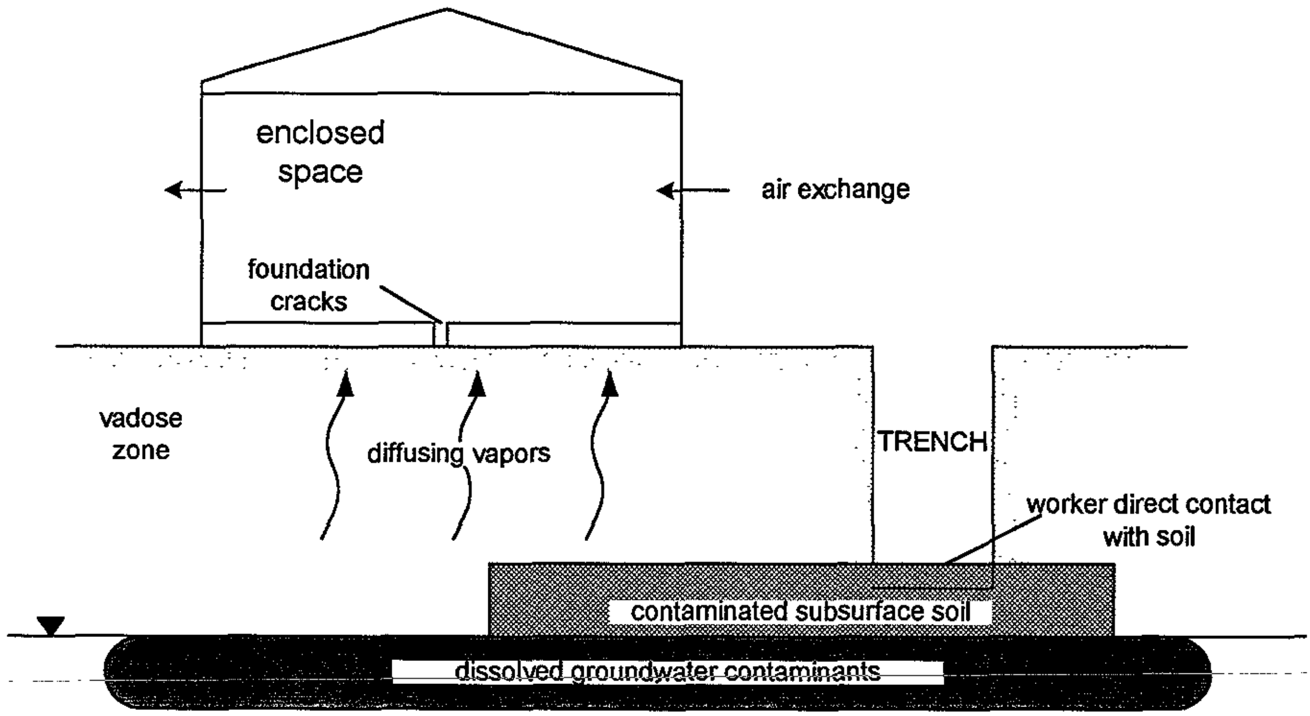

FIGURE 2 - CONCEPTUAL SITE MODEL - ALAMEDA BOX PLANT SITE
(adapted from ASTM ES 38-94)

TABLE 1 - SITE DATA USED IN EVALUATION: GROUNDWATER AND SUBSURFACE SOIL

GROUNDWATER - DATA SET - WEYERHAUSER BOX PLANT - REPORT DATED AUGUST 19, 1998*

Contaminant	MW-3B (ug/L)	MW-4B (ug/L)	MW-5 (ug/L)	MW-6 (ug/L)	MW-10 (ug/L)	MW-11 (ug/L)	MAXIMUM (ug/L)	AVG (ug/L)
Benzene	**99**	0.25	0.25	0.25	0.25	0.25	99.0	16.71
Ethylbenzene	**51.9**	0.25	0.25	0.25	0.25	0.25	51.9	8.86
M&P xylene	**13.9**	0.25	0.25	0.25	0.25	0.25	13.9	2.53
1,1-Dichloroethane	**37.4**	0.25	**7.6**	**4.1**	0.25	0.25	37.4	8.31
Trichloroethene	**5**	**0.7**	0.25	0.25	0.25	0.25	5.0	1.12
Tetrachloroethene	**5**	**1.3**	0.25	0.25	0.25	0.25	5.0	1.22

SUBSURFACE SOIL - DATA SET - WEYERHAUSER BOX PLANT - REPORTED JULY 19, 1999*

Contaminant	B-9 (mg/kg)	B-10 (mg/kg)					MAXIMUM (mg/kg)	AVG (mg/kg)
Benzene	**0.005**	0.0025					0.005	0.004
Ethylbenzene	**0.071**	**0.049**					0.071	0.060
M&P xylene	**0.009**	0.0025					0.009	0.006

* **B8** = Detected Concentration (above detection limit). Otherwise value = 0.5 x detection limit.
MW = monitoring well. B = soil boring

TABLE 2 - CONTAMINANT TOXICITY DATA

CONTAMINANT: CAS:	Benzene 71-43-2	ref/ note	Ethyl-benzene 100-41-4	ref/ note	M&P xylene 133-02-07	ref/ note	1,1-Dichloro-ethane 75-34-3	ref/ note	Trichloro-ethene 79-01-6	ref/ note	Tetrachloro-ethene 127-18-4	ref/ note
Inhalation Carc Slope Factor (SFi)(mg/kg-day^{-1})	0.029	1	N/A	1	N/A	1	N/A		0.017	2/2	5.10E-02	2
Inhalation Non-Carc Ref. Dose (RfDi)(mg/kg-day)	N/A	1	0.28571	2/2	0.2	2/2	0.1	2/2	N/A		0.01	2/1
Oral Carc Slope Factor (SFo)(mg/kg-day^{-1})	0.029		NA		NA		---		---		---	
Oral Non-Carc Ref. Dose (RfDo)(mg/kg-day)	N/A		0.1	3	2.0	3	---		---		---	

REFERENCES:

1 EPA Integrated Risk Information System (IRIS) (www.epa.gov/iris)
2 From HEAST 1991 and 1995
3 ASTM ES-38

NOTES:

1 Oral RfD. Inhalation RfD not available
2 Inhalation RfD

TABLE 3 - CALCULATION OF RISK-BASED SCREENING LEVELS FOR AIR

CARCINOGENIC RBSLa:

$$\text{RBSLa-c} = \frac{TR \times BW \times Atc \times 365}{IR \times ED \times EF \times SF}$$

NON-CARCINOGENIC RBSLa:

$$\text{RBSLa-nc} = \frac{THQ \times BW \times AT \times 365 \times RfD}{IR \times ED \times EF}$$

Chemical	Inhalation Slope Fctr (Table 2)	Inhalation RfD (Table 2)	ADULT RBSLa-c mg/m3	ADULT RBSLa-nc mg/m3	CHILD RBSLa-c mg/m3	CHILD RBSLa-nc mg/m3
Benzene	0.029	N/A	2.94E-03	---	3.84E-04	---
Ethylbenzene	N/A	0.28571	---	1.04E+00	---	3.18E-01
M&P xylene	N/A	0.2	---	7.30E-01	---	2.22E-01
1,1-Dichloroethane	N/A	0.1	---	3.65E-01	---	1.11E-01
Trichloroethene	0.017	N/A	5.01E-03	---	6.54E-04	---
Tetrachloroethene	5.10E-02	1.00E-02	1.67E-03	3.65E-02	2.18E-04	1.11E-02

EXPOSURE ASSUMPTIONS

CARCINOGENIC - RESIDENTIAL

	Parameter	units	ADULT	CHILD
TR	Carcinogenic Target Risk	(fraction)	0.00001	0.00001
AT	averaging time - carc	years	70	6
BW	body weight	kg	70	16
IR	inhalation rate	m3/day	20	15
ED	exposure duration	years	30	6
EF	exposure frequency	days/yr	350	350

NON-CARCINOGENIC - RESIDENTIAL

	Parameter	units	ADULT	CHILD
THQ	target hazard quotient		1	1
AT	averaging time - non-carc	years	30	6
BW	body weight	kg	70	16
IR	inhalation rate	m3/day	20	15
ED	exposure duration	years	30	6
EF	exposure frequency	days/yr	350	350

TABLE 4 - CALCULATION OF RISK-BASED SCREENING LEVEL FOR SOIL DIRECT CONTACT

WORKER EXPOSURE SCENARIO: EXCAVATED SOIL - CARCINOGENIC RBSLs

CHEMICAL	ORAL SLOPE FACTOR (SFo) (mg/kg-day)	RBSLcarc-soil (mg/kg)
Benzene	0.029	1.0

WORKER EXPOSURE SCENARIO: EXCAVATED SOIL - NON-CARCINOGENIC RBSLs

CHEMICAL	ORAL REF. DOSE (RfDo) (mg/kg-day)	RBSLcarc-soil (mg/kg)
Ethylbenzene	0.1	101
Xylenes	2.0	2028

METHODS:

RBSLcarc -soil-worker (mg/kg) =

$$\frac{TR \times BW \times ATc \times 365}{EF \times ED \times 1000 \times [(SFo \times 10\text{-}6 \times (IRsoil \times RAFo + SA \times M \times RAFd)]}$$

RBSLnon-carc -soil-worker (mg/kg) =

$$\frac{THQ \times BW \times ATn \times 365}{EF \times ED \times 1000 \times [(1/RfDo \times 10\text{-}6 \times (IRsoil \times RAFo + SA \times M \times RAFd)]}$$

ASSUMPTIONS AND SOURCES:

PARAMETER		UNITS	ASSUMED VALUE	SOURCE
Target excess risk(carc)	TRc	--	1.00E-05	assumed
Target hazard quotient (non-carc)	THQ	--	1.0	assumed
worker body wt	BW	kg	70	ASTM ES-38
averaging time (carc)	ATc	years	70	ASTM ES-38
averaging time (non-carc)	ATn	years	25	ASTM ES-38
exposure frequency	EF	days/years	30 250	PJ*
exposure duration	ED	years	25	ASTM ES-38
oral slope factor (carc)	SFo	chem-specific	chem-specific	
oral reference dose (non-carc)	RfDo	chem-specific	chem-specific	
soil ingestion rate	IRsoil	mg/day	50	ASTM ES-38
oral adsorpt factor	RAFo	--	1	ASTM ES-38
skin surface area	SA	cm2/day	3160	ASTM ES-38
adherance factor	M	mg/cm2	0.5	ASTM ES-38
derm adsorpt factor	RAFd		0.5	ASTM ES-38

*PJ = professional judgment: assumes maximum 1 month/year in site trench

TABLE 5 - SUBSURFACE SOURCE-TO-INDOOR AIR MODEL: DIFFUSION AND VOLATILIZATION FACTORS

	Deff-cap	Deff-s	Deff-ws	Deff-crack	VFwesp	VFsesp	VFwamb	VFsamb	Drf
Benzene	1.12E-05	6.87E-03	5.98E-04	6.87E-03	1.08E-02	6.66E-03	1.59E-05	1.74E-05	1.22E-01
Ethylbenzene	6.17E-06	5.85E-03	3.41E-04	5.85E-03	1.09E-02	3.36E-03	1.41E-05	3.76E-06	3.65E-02
M&P xylene	7.88E-06	5.46E-03	4.26E-04	5.46E-03	9.18E-03	1.17E-03	1.30E-05	2.38E-06	5.71E-02
1,1-Dichloroethane	4.91E-06	5.79E-03	2.74E-04	5.79E-03	1.66E+02	5.38E+02	2.03E-05	2.73E-05	1.00E+00
Trichloroethene	7.02E-06	6.39E-03	3.87E-04	6.39E-03	1.43E-02	5.90E-02	1.87E-05	5.89E-05	1.00E+00
Tetrachloroethene	2.66E-06	5.62E-03	1.52E-04	5.62E-03	1.93E-02	1.04E-04	2.12E-05	1.61E-08	1.00E+00

Deff-cap = Effective diffusion coefficient through capillary fringe
Deff-s = Effective diffusion coefficient in soil based on vapor-phase concentration
Deff-ws = Effective diffusion coefficient between groundwater and soil surface
Deff-crack = Effective diffusion coefficient through foundation cracks
VFwesp = Volatilization factor: groundwater-to-enclosed space vapors
VFsesp = Volatilization factor: subsurface soil-to-enclosed space vapors
VFwamb = Volatilization factor: groundwater-to-ambient air
VFsamb = Volatilization factor: subsurface soil-to-ambient air
Drf = Decay Rate Factor (1/r - e-rT/r)/T

TABLE 6 - SUBSURFACE SOURCE-TO-INDOOR AIR MODEL: ASSUMED PARAMETER VALUES

Parameter		Assumed Value	Units	Source
CONSTANTS				
viscosity of gas	u	1.80E-04	g/cm-s	J&E (constant)
Henry's Law constant	H	1.21	(cm3-H20)/(cm3-air)	chemical-specific
carbon-water sorp coeff	Koc	131826	ml/g	chemical-specific
diffusion coeff in air	Dair	0.072	cm2/s	chemical-specific
diffusion coeff in water	Dwtr	0.0000082	cm2/s	chemical-specific
soil-water sorption coeff	Kd	1318.2567	ml/g	chemical-specific
SITE-RELATED				
fraction of organic carbon	Foc	0.01	(fraction)	PJ
thickness of capillary fringe	h-cap	5	cm	PJ
thickness of vadose zone	h-v	**288**	cm	from data
vol air content in capillary fringe soil	Oacap	0.02	(fraction)	PJ
vol water content in cap fringe soil	Owcap	0.36	(fraction)	PJ
vol air content in vadoze zone soil	Oas	0.26	(fraction)	PJ
vol water content in vadose zone soil	Ows	0.12	(fraction)	PJ
total soil porosity	Ot	0.38	(fraction)	= Oas + Ows
soil bulk density	Pb	1.7	g/cm3	ASTM, 95
soil permeability	k	1.00E-07	cm2	J&E
depth to groundwater	Lgw	**288**	cm	from data
depth to top of subsur contam soil	Ls	**201.6**	cm	from data
Wind speed in mixing zone	Ua	225	cm/s	ASTM, 95
ambient air mixing zone height	da	200	cm	ASTM, 95
width of source area parallel to wind	W	1500	cm	ASTM, 95
STRUCTURAL-RELATED				
area of building	Ab	1.38E+06	cm2	J&E
bldg ventilation rate	Qbld	3.86E+04	cm3/s	calculated
thickness of foundation	Lcrack	19.2	cm	PJ
building underpressure	dP	1.00E+02	g/cm-s2	J&E
floor/wall seam perimeter	Xcrk	3400	cm	J&E
depth of crack below surface	Zcrk	200	cm	J&E
area of cracks/area of bldg	N	0.01	(fraction)	ASTM, 95
volumetric air content in crks	O-acrack	0.26	[cm3-air/cm3-total vo	PJ
volumetric wtr content in crks	O-wcrack	0.12	[cm3-wtr/cm3-total v	PJ
Air exchange rate	ER	1.40E-04	l/s	ASTM, 95
volume to infiltration ratio	LB	200	cm	ASTM, 95

TABLE 7 - PHYSICAL CONSTANTS FOR CONTAMINANTS

CONTAMINANT: Constant	Benzene 71-43-2	ref/ note	Ethyl-benzene 100-41-4	ref/ note	M&P xylene 133-02-07	ref/ note	1,1-Dichloro-ethane 75-34-3	ref/ note	Trichloro-ethene 79-01-6	ref/ note	Tetrachloro-ethene 127-18-4	ref/ note
H (cm3-H20)/(cm3-air)	0.23	2	0.36	2	0.26	2/2	0.64	1/1	0.42	1/1	1.21	1/1
Koc (ml/g)	81.2	2	363	2	537	2/2	58	1	18	1	131826	1
Dair (cm2/s)	0.088	2	0.075	2	0.07	2/2	0.07	1	0.082	1	0.072	1
Dwtr (cm2/s)	9.80E-06	2	7.80E-06	2	7.80E-06	2/2	1.05E-05	1	1.05E-05	1	8.20E-06	1
Contaminant decay rate (r) (1/yrs)	0.3285	3	1.095	3	0.7	3	1.00E-06	5	1.00E-06	5	1.00E-06	5
Contaminant Half Life T1/2)(yrs)	2	3	0.62	3	1	3	0	5	0	5	0	5

REFERENCES/NOTES:

1 MSTRLOOK.XLS (properties - ASTM workbook)
2 National TPH Criteria Work Group: Selection of Representative TPH Fraction based on Fate and Transport Considerations. December 1996
3 ASTM, 1994 (Standard)
4 U.S. EPA Region 10 (Dr. Marcia Bailey)
5 no data - conservative estimate

TABLE 8 - RESULTS: RESIDENTIAL EXPOSURE SCENARIO - ADULT

			CARCINOGENIC			NONCARCINOGENIC		
ADULT - RESIDENTIAL	maximum est. GW conc. (ug/L)	avg est. GW conc. (ug/L)	RBSLw-c =RBSLa-c/VFwesp (ug/L)	Percent Risk: max est. GW conc/ RBSLw-c x 100	Percent Risk: avg est. GW conc/ RBSLw-c x 100	RBSLw-nc =RBSLa-nc/VFwes (ug/L)	Percent Risk: max est. GW conc/ RBSLw-nc x 100	Percent Risk: avg est. GW conc/ RBSLw-nc x 100
GROUNDWATER-TO-INDOOR AIR								
Benzene	99.0	16.71	2.23E+03	4.4	0.7			
Ethylbenzene	51.9	8.86				2.62E+06	1.98E-05	3.38E-06
M&P xylene	13.9	2.53				1.39E+06	1.00E-05	1.82E-06
1,1-Dichloroethane	37.4	8.31				2.20E+04	1.70E-03	3.78E-04
Trichloroethene	5.0	1.12	3.51E+02	1.4	0.3			
Tetrachloroethene	5.0	1.22	8.67E+01	5.8	1.4	1.89E+03	2.65E-03	6.44E-04
SOIL-TO-INDOOR AIR	maximum est. Soil conc. (mg/kg)	avg est. Soil conc. (mg/kg)	RBSLs-c =RBSLa-c/VFsesp (mg/kg)	Percent Risk: max est. soil conc/ RBSLw-c x 100	Percent Risk: avg est. soil conc/ RBSLw-c x 100	RBSLs-nc =RBSLa-nc/VFsesp (mg/kg)	Percent Risk: max est. soil conc/ RBSLs-nc x 100	Percent Risk: avg est. soil conc/ RBSLs-nc x 100
Benzene	0.005	0.004	3.62E+00	0.1	0.1			
Ethylbenzene	0.071	0.060				8.49E+03	8.36E-06	7.07E-06
M&P xylene	0.009	0.006				1.09E+04	8.26E-07	5.28E-07
		TOTAL (GW AND SOIL:)		11.8	2.6	TOTAL:	0.0	0.0
			PERCENT>100?	NO	NO	PERCENT>100?	NO	NO

TABLE 9 - RESULTS: RESIDENTIAL EXPOSURE SCENARIO - CHILD

CHILD - RESIDENTIAL	maximum est. GW conc. (ug/L)	avg est. GW conc. (ug/L)	CARCINOGENIC RBSLw-c =RBSLa-c/VFwesp (ug/L)	Percent Risk: max est. GW conc/ RBSLw-c x 100	Percent Risk: avg est. GW conc/ RBSLw-c x 100	NONCARCINOGENIC RBSLw-nc =RBSLa-nc/VFwes (ug/L)	Percent Risk: max est. GW conc/ RBSLw-nc x 100	Percent Risk: avg est. GW conc/ RBSLw-nc x 100
GROUNDWATER-TO-INDOOR AIR								
Benzene	99.0	16.71	2.89E+02	34.2	5.8			
Ethylbenzene	51.9	8.86				7.98E+05	0.000065	0.000011
M&P xylene	13.9	2.53				4.24E+05	0.000033	0.000006
1,1-Dichloroethane	37.4	8.31				6.71E+03	0.005574	0.001238
Trichloroethene	5.0	1.12	4.59E+01	10.9	2.4			
Tetrachloroethene	5.0	1.22	1.13E+01	44.2	10.8	5.77E+02	0.008666	0.002109
SOIL-TO-INDOOR AIR	maximum est. Soil conc. (mg/kg)	avg est. Soil conc. (mg/kg)	RBSLs-c =RBSLa-c/VFsesp (mg/kg)	Percent Risk: max est. soil conc/ RBSLw-c x 100	Percent Risk: avg est. soil conc/ RBSLw-c x 100	RBSLs-nc =RBSLa-nc/VFsesp (mg/kg)	Percent Risk: max est. soil conc/ RBSLs-nc x 100	Percent Risk: avg est. soil conc/ RBSLs-nc x 100
Benzene	0.005	0.004	4.73E-01	1.1	0.8			
Ethylbenzene	0.071	0.060				2.59E+03	0.000027	0.000023
M&P xylene	0.009	0.006				3.33E+03	0.000003	0.000002
			TOTAL PCNT:	90.4	19.8	TOTAL PCNT:	0.014367	0.003389
			PERCENT>100?	NO	NO	PERCENT>100?	NO	NO