

**Appendix 4E**

Details of Risk Assessment for  
Groundwater

R06100 - Cheoy Lee Shipyard Land Contamination Assessment  
Calculations of Risk-Based Assessment Criteria for Groundwater Contamination

Table 1 - Source Concentrations & Oral Slope Factor/Oral Reference Dose for Risk Assessment

Parameter	Source Concentration	Sample I.D.	Noncarcinogenic Oral		Carcinogenic Oral Slope Factor <sup>c</sup> (CSFo) 1/[mg/kg-day]
	[mg/L]		Reference Dose <sup>b</sup> (RfDo) [mg/kg-day]	Minimum Noncarcinogenic Oral Reference Dose <sup>b</sup> (RfDo) [mg/kg-day]	
Antimony	4.40E-02	GW-T22(3-4)	4.00E-04	Not applicable	Not applicable
Arsenic	3.80E-02	GW-T19(5-6)	3.00E-04	Not applicable	1.50E+00
Barium	7.47E-01	GW-T26(1-2)	7.00E-02	Not applicable	Not applicable
Bis(2-ethylhexyl)phthalate (DEHP)	2.70E-02	MW-OB11	2.00E-02	Not applicable	1.40E-02
Cadmium	1.78E-02	GW-T26(1-2)	5.00E-04	Not applicable	Not applicable
Chloroform	7.00E-04	AW-1C	1.00E-02	Not applicable	6.10E-03
Chromium (VI) <sup>a</sup>	6.70E-02	MW-B24	3.00E-03	Not applicable	7.30E-03
Cobalt	1.66E-01	GW-T26(1-2)	6.00E-02	Not applicable	Not applicable
Copper	1.19E+00	GW-T22(3-4)	3.70E-02	Not applicable	Not applicable
Lead	2.25E+00	GW-T26(1-2)	3.60E-03	Not applicable	Not applicable
Molybdenum	5.00E-02	GW-T22(3-4)	5.00E-03	Not applicable	Not applicable
Naphthalene	2.50E-02	MW-B34	2.00E-02	Not applicable	Not applicable
Nickel	7.20E+00	MW-B24	2.00E-02	Not applicable	Not applicable
TPHs	4.59E-01	MW-P8	3.00E-02 to 5.00E+00	3.00E-02	Not applicable
Zinc	1.20E+00	GW-T22(3-4)	3.00E-01 <sup>d</sup>	Not applicable	Not applicable
Dioxins	2.78E-07	AW-11	Not applicable	Not applicable	1.50E+05

<sup>a</sup> Chromium is assumed to be Cr (VI) for conservative assessment.

<sup>b</sup> Source for TPHs : TPH Criteria Working Group, 1999. Total Petroleum Hydrocarbons Criteria Working Group Series Volume 5

– Human Health Risk-Based Evaluation of Petroleum Release Sites: Implementing the Working Group Approach. Massachusetts, U.S.A., Amherst Scientific Publishers.

Source for Antimony (Sb), Arsenic (As), Ba, DEHP, Cd, Chloroform, Cr(VI), Cu, Pb, Mo, Naphthalene, Ni and Zn : USEPA Region IX Risk-based Concentration Table (revised on 1 Nov 2000), USEPA Region IX.

Source for Lead : World Health Organisation.

<sup>c</sup> Source for Arsenic (As), DEHP, Chloroform and Dioxins : USEPA Region IX Risk-based Concentration Table (revised on 1 Nov 2000), USEPA Region IX.

Source for Cr(VI) : USEPA Region III Risk-based Concentration Table, USEPA Region III, March 7, 1995.

**Assumptions:**

**Exposure Pathway:**

The applicable and dominant complete pathway is considered to be direct groundwater ingestion.

**Receptor:**

The most sensitive receptors are considered to be the construction workers.

**Input Parameters for Calculations (for Direct Groundwater Ingestion):**

IR = water ingestion rate [L/day] =	0.02
EF = exposure frequency [day/yr] =	180 (assume construction workers expose for 6 months of site formation works)
ED = exposure duration [yr] =	1 (construction workers)
BW = body weight [kg] =	70
AT = Averaging time [day] =	365 (for non-carcinogens: ED x 365 days)
	25550 (for carcinogens: 70 yrs x 365 days)

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Table 2 - Calculations for Direct Groundwater Ingestion

Calculations	Antimony	Arsenic		Barium	DEHP		Cadmium		Chloroform		Cr (VI)		Copper	Lead
		(NA)	(CA)		(NA)	(CA)	(NA)	(CA)	(NA)	(CA)				
1. Groundwater conc. [mg/L] =	4.40E-02	3.80E-02	3.80E-02	7.47E-01	2.70E-02	2.70E-02	1.78E-02	7.00E-04	7.00E-04	6.70E-02	6.70E-02	1.66E-01	1.19E+00	2.25E+00
2. Natural attenuation factor =	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3. Exposure medium [mg/L] = (1) / (2) =	4.40E-02	3.80E-02	3.80E-02	7.47E-01	2.70E-02	2.70E-02	1.78E-02	7.00E-04	7.00E-04	6.70E-02	6.70E-02	1.66E-01	1.19E+00	2.25E+00
4. Exposure multiplier [L/kg/day] = (IR x EF x ED) / (BW x AT) =	1.41E-04	1.41E-04	2.01E-06	1.41E-04	1.41E-04	2.01E-06	1.41E-04	2.01E-06	1.41E-04	2.01E-06	1.41E-04	2.01E-06	1.41E-04	1.41E-04
5. Average Daily Intake Rate [mg/kg/day] = (3) x (4) =	6.20E-06	5.35E-06	7.65E-08	1.05E-04	3.80E-06	5.43E-08	2.51E-06	9.86E-08	1.41E-09	9.44E-06	1.35E-07	2.34E-05	1.67E-04	3.18E-04
6. Maximum Pathway Intake [mg/kg/day] = (groundwater ingestion as dominant pathway)	6.20E-06	5.35E-06	7.65E-08	1.05E-04	3.80E-06	5.43E-08	2.51E-06	9.86E-08	1.41E-09	9.44E-06	1.35E-07	2.34E-05	1.67E-04	3.18E-04
7. Maximum Toxicant Intake Rate [mg/kg/day] =	6.20E-06	5.35E-06	7.65E-08	1.05E-04	3.80E-06	5.43E-08	2.51E-06	9.86E-08	1.41E-09	9.44E-06	1.35E-07	2.34E-05	1.67E-04	3.18E-04
8. Noncarcinogenic Oral Reference Dose [mg/kg-day] =	4.00E-04	3.00E-04	7.00E-02	7.00E-02	2.00E-02	2.00E-02	5.00E-04	1.00E-02	3.00E-03	6.00E-02	3.00E-02	3.70E-02	3.70E-02	3.60E-03
9. Individual Chemical of Concern Hazard Index = (7) / (8) =	1.55E-02	1.78E-02	1.50E-03	1.90E-04	1.90E-04	1.90E-04	5.02E-03	9.86E-06	3.15E-03	3.90E-04	4.52E-03	8.82E-02	8.82E-02	8.82E-02
10. Maximum Carcinogenic Intake Rate [mg/kg/day] =			7.65E-08		5.43E-08			1.41E-09			1.35E-07			
11. Carcinogenic Oral Slope Factor (1/[mg/kg-day]) =			1.50E+00		1.40E-02			6.10E-03			7.30E-03			
12. Individual Chemical of Concern (COC) Risk = (10) x (11) =			1.15E-07		7.61E-10			8.59E-12			9.84E-10			
<b>Total pathway hazard index =</b> (after adding contributions from all chemical of concern)	<b>1.91E-01 (&lt; 1 (USEPA recommended hazard index))</b>													
<b>Total pathway carcinogenic risk =</b> (contributed by Arsenic, DEHP, Chloroform, Chromium (VI) and Dioxins)	<b>2.00E-07 (&lt; 1.00E-06 (USEPA lifetime cancer risk level))</b>													
RBSL [mg/L] = Min. of (Groundwater Conc. / Hazard Quotient) or (Groundwater Conc. x Cancer Risk / Risk of Contaminant)	2.84E+00	2.13E+00	N/A	4.97E+02	1.42E+02	N/A	3.55E+00	7.10E+01	N/A	2.13E+01	N/A	4.26E+02	2.63E+02	2.56E+01
= Minimum of	>>	and	>>	and	and	and	>>	and	>>	and	>>	>>	>>	>>
Groundwater conc. [mg/L] =	4.40E-02	3.80E-02	3.80E-02	7.47E-01	2.70E-02	2.70E-02	1.78E-02	7.00E-04	7.00E-04	6.70E-02	6.70E-02	1.66E-01	1.19E+00	2.25E+00
Risk	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

Keys : NA = Noncarcinogen, CA = Carcinogen

Table 2 - Calculations for Direct Groundwater Ingestion

Calculations	Molybdenum	Naphthalene	Nickel	TPHs	Zinc	Dioxins
1. Groundwater conc. [mg/L] =	5.00E-02	2.50E-02	7.20E+00	4.59E-01	1.20E+00	2.76E-07
2. Natural attenuation factor =	1	1	1	1	1	1
3. Exposure medium [mg/L] = (1) / (2) =	5.00E-02	2.50E-02	7.20E+00	4.59E-01	1.20E+00	2.76E-07
4. Exposure multiplier [L/kg/day] = (IR x EF x ED) / (BW x AT) =	1.41E-04	1.41E-04	1.41E-04	1.41E-04	1.41E-04	2.01E-06
5. Average Daily Intake Rate [mg/kg/day] = (3) x (4) =	7.05E-06	3.52E-06	1.01E-03	6.47E-05	1.69E-04	5.56E-13
6. Maximum Pathway Intake [mg/kg/day] = (groundwater ingestion as dominant pathway)	7.05E-06	3.52E-06	1.01E-03	6.47E-05	1.69E-04	5.56E-13
7. Maximum Toxicant Intake Rate [mg/kg/day] =	7.05E-06	3.52E-06	1.01E-03	6.47E-05	1.69E-04	
8. Noncarcinogenic Oral Reference Dose [mg/kg-day] =	5.00E-03	2.00E-02	2.00E-02	3.00E-02	3.00E-01	
9. Individual Chemical of Concern Hazard Index = (7) / (8) =	1.41E-03	1.78E-04	5.07E-02	2.16E-03	5.64E-04	
10. Maximum Carcinogenic Intake Rate [mg/kg/day] =						5.56E-13
11. Carcinogenic Oral Slope Factor (1/[mg/kg-day]) =						1.50E+05
12. Individual Chemical of Concern (COC) Risk = (10) x (11) =						8.33E-08
<b>Total pathway hazard index =</b> (after adding contributions from all chemical of concern)						
<b>Total pathway carcinogenic risk =</b> (contributed by Arsenic, DEHP, Chloroform, Chromium (VI) and D						
RBSL [mg/L] =						
Min. of (Groundwater Conc. / Hazard Quotient) or (Groundwater Conc. x Cancer Risk / Risk of Contaminant)						
= Minimum of	3.55E+01	1.42E+02	1.42E+02	2.13E+02	2.13E+03	3.31E-06
Groundwater conc. [mg/L] =	5.00E-02 (in mg/L)	2.50E-02 (in mg/L)	7.20E+00 (in mg/L)	4.59E-01 (in mg/L)	1.20E+00 (in mg/L)	2.76E-07 (in mg/L)
Risk	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

Keys : NA = Noncancer, CA = Carcinogen