

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 Reference Dose ^b (RfDo)	Minimum Noncarcinogenic Oral Reference Dose ^b (RfDo)	Carcinogenic Oral Slope Factor ^c (CSFo)
	[mg/L]		[mg/kg-day]	[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) ^a	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	Not applicable	Not applicable
Dioxins	2.76E-07	AW-11	Not applicable	Not applicable	1.50E+05

^a Chromium is assumed to be Cr (VI) for conservative assessment.

^b 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), Co, 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.

^c 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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Calculations of Risk-Based Assessment Criteria for Groundwater Contamination

Table 2 - Calculations for Direct Groundwater Ingestion

Calculations	Antimony		Arsenic		Barium		DEHP		Chloroform		Cadmium		Chloroform		Cr (VI)		Cobalt		Copper		Lead	
	(NA)	(CA)	(NA)	(CA)	(NA)	(CA)	(NA)	(CA)	(NA)	(CA)	(NA)	(CA)	(NA)	(CA)	(NA)	(CA)	(NA)	(CA)	(NA)	(CA)	(NA)	(CA)
1. Groundwater conc. [mg/L] =	4.40E-02	3.80E-02	3.80E-02	3.80E-02	7.47E-01	7.47E-01	2.70E-02	2.70E-02	7.00E-04	7.00E-04	1.78E-02	1.78E-02	7.00E-04	7.00E-04	6.70E-02	6.70E-02	1.66E-01	1.66E-01	1.19E+00	1.19E+00	2.25E+00	2.25E+00
2. Natural attenuation factor =	1	1	1	1	1	1	1	1	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	3.80E-02	7.47E-01	7.47E-01	2.70E-02	2.70E-02	7.00E-04	7.00E-04	1.78E-02	1.78E-02	7.00E-04	7.00E-04	6.70E-02	6.70E-02	1.66E-01	1.66E-01	1.19E+00	1.19E+00	2.25E+00	2.25E+00
4. Exposure multiplier [L/kg/day] = (IR x EF x ED) / (BW x AT) =	1.41E-04	1.41E-04	1.41E-04	2.01E-06	1.41E-04	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	2.01E-06	1.41E-04	1.41E-04	1.41E-04	1.41E-04	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	1.05E-04	1.05E-04	3.80E-06	5.43E-08	9.86E-08	1.41E-09	2.51E-06	2.51E-06	9.86E-08	1.41E-09	9.44E-06	1.35E-07	2.34E-05	2.34E-05	1.67E-04	1.67E-04	3.18E-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	1.05E-04	1.05E-04	3.80E-06	5.43E-08	9.86E-08	1.41E-09	2.51E-06	2.51E-06	9.86E-08	1.41E-09	9.44E-06	1.35E-07	2.34E-05	2.34E-05	1.67E-04	1.67E-04	3.18E-04	3.18E-04
7. Maximum Toxicant Intake Rate [mg/kg/day] =	6.20E-06	5.35E-06	7.65E-08	1.05E-04	1.05E-04	1.05E-04	3.80E-06	5.43E-08	9.86E-08	1.41E-09	2.51E-06	2.51E-06	9.86E-08	1.41E-09	9.44E-06	1.35E-07	2.34E-05	2.34E-05	1.67E-04	1.67E-04	3.18E-04	3.18E-04
8. Noncarcinogenic Oral Reference Dose [mg/kg-day] =	4.00E-04	3.00E-04	7.00E-02	7.00E-02	7.00E-02	2.00E-02	2.00E-02	2.00E-02	1.00E-02	1.00E-02	5.00E-04	5.00E-04	1.00E-02	1.00E-02	3.00E-03	3.00E-03	6.00E-02	6.00E-02	3.70E-02	3.70E-02	3.60E-03	3.60E-03
9. Individual Chemical of Concern Hazard Index = (7) / (8) =	1.55E-02	1.78E-02	1.09E-03	1.09E-03	1.09E-03	1.90E-04	1.90E-04	1.90E-04	9.86E-06	9.86E-06	5.02E-03	5.02E-03	9.86E-06	9.86E-06	3.15E-03	3.15E-03	3.90E-04	3.90E-04	4.52E-03	4.52E-03	8.82E-02	8.82E-02
10. Maximum Carcinogenic Intake Rate [mg/kg/day] =			7.65E-08	7.65E-08	7.65E-08	5.43E-08	5.43E-08	5.43E-08	1.41E-09	1.41E-09			1.41E-09	1.41E-09	1.35E-07	1.35E-07						
11. Carcinogenic Oral Slope Factor (1/[mg/kg-day]) =			1.50E+00	1.50E+00	1.40E-02	1.40E-02	1.40E-02	1.40E-02	6.10E-03	6.10E-03			6.10E-03	6.10E-03	7.30E-03	7.30E-03						
12. Individual Chemical of Concern (COC) Risk = (10) x (11) =			1.15E-07	1.15E-07	7.61E-10	7.61E-10	7.61E-10	7.61E-10	8.59E-12	8.59E-12			8.59E-12	8.59E-12	9.84E-10	9.84E-10						
Total pathway hazard index = (after adding contributions from all chemical of concern)	1.91E-01 (< 1 (USEPA recommended hazard index))																					
Total pathway carcinogenic risk = (contributed by Arsenic, DEHP, Chloroform, Chromium (VI) and Dioxins)	2.00E-07 (< 1.00E-06 (USEPA lifetime cancer risk level))																					
RBSL [mg/L] = Min. of (Groundwater Conc. / Hazard Quotient) &L (Groundwater Conc. x Cancer Risk / Risk of Contaminant)																						
= Minimum of	2.84E+00	2.13E+00	N/A	N/A	4.97E+02	4.97E+02	1.42E+02	N/A	7.10E+01	N/A	3.55E+00	3.55E+00	8.14E+01	8.14E+01	2.13E+01	N/A	4.26E+02	4.26E+02	2.63E+02	2.63E+02	2.56E+01	2.56E+01
	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>	>>
Groundwater conc. [mg/L] =	4.40E-02	3.80E-02	3.80E-02	3.80E-02	7.47E-01	7.47E-01	2.70E-02	2.70E-02	7.00E-04	7.00E-04	1.78E-02	1.78E-02	7.00E-04	7.00E-04	6.70E-02	6.70E-02	1.66E-01	1.66E-01	1.19E+00	1.19E+00	2.25E+00	2.25E+00
Risk	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

Keys : NA = Noncancer, 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 [(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	1.76E-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
Total pathway hazard index = (after adding contributions from all chemical of concern)						
Total pathway carcinogenic risk = (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