Appendix R. Dose and Dose Ratio Estimations

R-1. Dose Estimation

Three scenarios were selected for exposure dose analysis: residential, occupational, and recreational. Assumptions regarding exposures for these scenarios are based on EPA guidelines and are listed in Table R-1.

Dose analysis was carried out using concentration data or estimated concentrations (e.g., for air). Concentrations in air were estimated from air dispersion modeling (Appendices I and S). The Risk Assessment Information System (RAIS) was first used to screen all offsite contaminant concentrations (Appendix H; offsite monitored surface water, groundwater, and soil concentrations). Only contaminant concentrations that resulted in dose levels above EPA-suggested standards (e.g., as determined based on cancer risk exceeding 10^{-6} and Hazard Indices exceeding unity for systemic diseases) were considered for further analysis. Contaminant concentrations (from monitoring data for offsite groundwater, surface water, and soil) that exceeded health-based standards or guidelines are provided in Appendix N, with the corresponding detection levels provided in Appendix H and Table R-2. Air inhalation doses are given in Appendix T. Exposure doses and dose ratios were estimated for recreational, occupational, and residential exposure scenarios. The estimated potential air exposure (inhalation) doses were divided by the Average Lifetime Acceptable Daily Dose (ALADD) to derive dose ratios, which were used to compare conservative exposure scenarios for chemical and location screening purposes. ALADDs were calculated as follows:

Carcinogens: ALADD = 1×10^{-6} cancer risk / EPA's cancer potency factor
Systemic contaminants: ALADD = EPA's reference dose

Specific health-based standards or guidelines for the ALADD calculations are listed in Table R-3, and the ALADD values are given in Table R-4. Dose ratios exceeding unity are presented in Table R-5.

R-2. Estimations of Doses from Exposure to Contaminated Offsite Soil and Groundwater

Exposure pathways for the various scenarios were as follows:

- Residential: (1) soil ingestion, (2) ingestion of edible crops, (3) groundwater ingestion,[R-1] (4) groundwater dermal contact while showering, (5) groundwater inhalation during household use,[R-2] and (6) surface water dermal contact.

- Recreational: (1) soil ingestion, (2) groundwater ingestion, and (3) surface water dermal contact.

- Occupational: (1) soil ingestion and (2) groundwater ingestion.

[R-1] Groundwater ingestion, inhalation, or contact would only apply to residents or workers using water that taps into a private well which uses groundwater as a source. This condition applies to residential scenarios 3, 4, and 5, residential scenario 2, and occupational scenario 2.
[R-2] "Household use" refers to cleaning, mopping, etc., with private well water (see footnote 1).

Table R-1. Deviation from the General Equation Where Applicable

Medium	Pathway	Scenario					
		Recreational		Occupational		Residential	
		Dose Eqn	Exposure Assumptions	Dose Eqn	Exposure Assumptions	Dose Eqn	Exposure Assumptions
SW	Dermal contact	(C × CF × PC × SA × ET × EF × ED) / (AT × BW)	C = SW conc. (mg/L) CF = 1 m/100 cm × 1000 L/m^3 PC = chem. spec. permeab. factor (cm/h) SA = 1.94 m^2 ET = 1 h/d; EF = 45 d/yr	NA		(C × CF × PC × SA × ET × EF × ED) / (AT × BW)	C = SW conc. (mg/L) CF = 1 m/100 cm × 1000 L/m^3 PC = chem. spec. permeab. factor (cm/h); EF = 45 d/yr SA = 1.94 m^2; ET = 1 h/d
Soil	Ingestion	(C × FI × EF × ET × CF × ED × IR) / (AT × BW)	C = soil conc. (mg/kg) FI = fraction ingested (1) EF = 75 d/yr; ET = 1 hr/d; CF = 1 d/24 hr IR = 0.0001 kg/d	(C × FI × EF × ED × IR) / (AT × BW)	C = soil conc. (mg/kg) FI = fraction ingested (1) EF = 225 d/yr IR = 0.0001 kg/d	(C × FI × EF × ED × IR) / (AT × BW)	C = soil conc. (mg/kg) FI = fraction ingested (1) EF = 350 d/yr; IR = 0.0001 kg/d
	Vegetable ingestion	NA		NA		(C × BUF × FI × IR × EF × ED) / (AT × BW)	C = soil conc. (mg/kg)* BUF = chem. spec. soil to plant biouptake factor FI = fraction ingested (0.4) IR= 0.2 kg/d; EF = 350 d/yr
GW	Ingestion	(C × IR × EF × ET × ED) / (AT × BW)	C = conc. in GW (mg/L) IR = 0.05 L/d EF = 45 d/yr; ET = 1 hr/d	(C × IR × EF × ED) / (AT × BW)	C = conc. in GW (mg/L) IR = 0.8 L/d EF = 225 d/yr	(C × IR × EF × ED) / (AT × BW)	C = conc. in GW (mg/L) IR = 2 L/d; EF = 350 d/yr
	Indoor inhalation	NA		NA		(C × IR × K × EF × ED) / (AT × BW)	C = conc. in GW (mg/L) K = 0.0005 × 1000 L/m^3 EF = 350 d/yr; IR = 20 m^3/d
	Dermal contact during showering	NA		NA		(C × CF × PC × ET × SA × ED × EF) / (AT × BW)	C = conc. in GW (mg/L) CF = 1 m/100 cm × 1000 L/m^3 PC = chem. spec permeab. factor ET = 0.24 h/d SA = 1.94 m^2; EF = 350 d/yr

Notes: Eqn = equations; **SW** = surface water; **S** = soil; **GW** = groundwater; **C** = contaminant concentration; **CF** = unit conversion factors; **PF** = permeability factor (chemical-specific; see Table R-4); **SA** = skin surface area (EPA, 1992); **ET** = exposure time (EPA, 1992); **EF** = exposure frequency (EPA, 1991a–c); **ED** = exposure duration (30 yr) (EPA, 1991a–d); **AT** = averaging time (365 d/yr × ED for non-carcinogens, 365 d/yr × 70 yr for carcinogens) (EPA, 1989b–d, 1991a–d); **BW** = body weight (70 kg) (EPA, 1991a–c); **FI** = fraction ingested (Exposure Factors Handbook, EPA, 1995); **IR** = intake rate (EPA, 1995b); **BUF** = plant biouptake factors, which is the ratio of contaminant concentration in a plant to the contaminant concentration in soil; represents the amount fraction of contaminant in soil uptake by the plant [(mg/kg) / (mg/kg) = unitless]; **K** = volatilization factor (0.0005 × 1000 L/m^3) (EPA, 1991a–c); **NA** = not applicable. * Ingestion of vegetables from groundwater contamination calculated directly from RAIS. *All chemical-specific factors were taken from the EPA Web site: http://rais.ornl.gov/homepage/rap_tool.shtml.*

Table R-2. Offsite Monitored Concentrations and Detection Locations Used to Estimate Doses and Dose Ratios

Contaminant	Medium	Detection Location		
		South	**East**	**North**
Lead	S (mg/kg)	383		280
	GW (mg/L)		0.05–2.239	
Beryllium	S (mg/kg)	500–1000		
	SW (mg/L)			0.005–0.008
	GW (mg/L)		0.007–0.123	
Arsenic	S (mg/kg)	1–14		8.2–24
	GW (mg/L)		0.0727–3.217	
Manganese	GW (mg/L)		0.39–35	
Chloromethane	GW (mg/L)			0.019
TCE	GW (mg/L)			0.01–0.9
Vinyl chloride	GW (mg/L)			0.064
Benzene	GW (mg/L)			0.0038
	SW (mg/L)			0.0056
Carbon tetrachloride	GW (mg/L)			0.0045
1,1-DCE	GW (mg/L)			0.019
Cis-1,2-DCE	GW (mg/L)			0.027–0.63
DEHP	SW (mg/L)			0.066–0.17
PCB	SW (mg/L)			0.092–0.12
Perchlorate	GW (mg/L)			0.004–0.15
	V (mg/kg)		32–57	

Notes: SW = surface water; GW = groundwater; S = soil; V = vegetation.

Table R-3. Chronic Systemic Reference Doses, Chronic Cancer Potency Factors, and Biouptake Factors for Dose Ratio Evaluations

Chemical	Target Organ	Systemic Reference Doses (RfD)			Cancer Potency Factors (PF)			Biouptake Factors	
		Oral RfD mg/kg-d	**Inhalation RfD** mg/kg-d	**Dermal RfD** mg/kg-d	**Oral PF** Risk per mg/kg-d	**Inhalation PF** Risk per mg/kg-d	**Dermal PF** Risk per mg/kg-d	**k** cm/h	**Soil to Plant (Wet) Uptake**
Arsenic	Skin	3.0E04	—	1.23E-04	1.5	15.1	3.66	1.93E-03	0.01
Benzene	Blood	4.0E-03	8.57E-03	3.8E-03	0.055	0.0273	0.0567	2.07E-02	0.47
Beryllium	Lung	2.0E-03	5.71E-06	2.0E-05	4.3	8.4	430	6.60E-04	0.0025
1,3-Butadiene	CNS	—	5.71E-04	—	—	0.105	—	2.31E-02	0.53
Cadmium	Lung	5.0E-04	—	5.0E-06	—	6.3	—	3.50E-04	0.14
Carbon tetrachloride	Liver	7.0E-04	—	4.5E-04	0.13	0.0525	0.2	2.24E-02	0.18
Chloromethane	Liver	—	2.57E-02	—	0.013	0.0063	0.0163	4.15E-03	2.3
Chromium VI particulates	Lung	3.0E-03	2.86E-05	6.0E-05	—	42	—	1.00E-03	0.0001
1,1-DCA	Liver	1.0E-01	1.43E-01	1.0E-01	—	—	—	8.86E-03	0.7
1,2-DCA	Liver	—	—	—	0.091	0.091	0.091	5.34E-03	1.0
1,1-DCE	Liver	5.0E-02	5.71E-02	5.0E-02	0.6	0.175	0.6	1.59E-02	0.7
1,2-DCE (mixed)	Liver	9.0E-03	—	7.2E-03	—	—	—	1.49E-02	4.1
Cis-1,2-DCE	Liver	1.0E-02	—	1.0E-02	—	—	—	1.49E-02	0.61
Trans-1,2-DCE	Liver	2.0E-02	—	2.0E-02	—	—	—	1.49E-02	4.1
UDMH	Liver	—	—	—	3	17.2	6.0	1.17E-04	3.5
DEHP	Liver	2.0E-02	—	3.8E-03	0.014	—	0.0737	1.97E+00	0.011
Hydrazine	Liver	—	—	—	3	17.2	6.0	4.12E-05	130
Lead	CNS	—	—	—	—	—	—	3.42E-04	0.0007
Manganese	Thyroid	4.6E-02	1.43E-05	1.84E-03	—	—	—	1.28E-03	0.069
Mercury	CNS	—	8.57E-05	—	—	—	—	3.14E-04	0.3
MMH	Liver	—	—	—	3	17.2	6.0	1.79E-04	31
Nickel	All	2.0E-02	—	5.4E-03	—	—	—	3.29E-04	0.05
NDMA	Liver	8.0E-06	—	4.0E-06	51	49	102	2.65E-04	16
Perchlorate	Thyroid	7.0E-04	—	—	—	—	—	8.00E-05	—
PCB	All	—	—	—	2	2	2.22	9.22E-01	0.0025
Toluene	CNS	2.0E-01	1.14E-01	1.6E-01	—	—	—	4.53E-02	0.21
TCE	Liver	3.0E-04	1.14E-02	4.5E-05	0.4	0.4	2.67	1.57E-02	0.31
Vinyl chloride	Liver	3.0E-03	2.86E-02	3.0E-03	1.4	0.0308	1.4	1.13E-02	1.2
Zinc	Enzyme	3.0E-01	—	6.0E-02	—	—	—	3.42E-04	0.26

Notes: All health standards and chemical-specific factors were taken from the EPA Web site: http://risk.lsd.ornl.gov/homepage/rap_tool.shtml. **k** = permeability factor.

Table R-4. Acceptable Lifetime Average Daily Doses (mg/kg-d) as Determined from Reference Doses and Cancer Potency Factors (for 1×10^{-6} risk or one cancer per one million people)

Contaminant	Dermal ALADD	Oral ALADD	Inhalation ALADD
Arsenic	2.73×10^{-7}	6.67×10^{-7}	6.6×10^{-8}
Benzene	1.76×10^{-5}	1.8×10^{-5}	3.66×10^{-5}
Beryllium	2.0×10^{-9}	2.33×10^{-7}	1.19×10^{-7}
Carbon tetrachloride	5.0×10^{-6}	7.6×10^{-6}	1.9×10^{-5}
Chloromethane	6.14×10^{-5}	7.69×10^{-5}	1.59×10^{-4}
Cis 1,2-DCE	1.0×10^{-2}	1.0×10^{-2}	—
1,1-DCE	1.667×10^{-6}	1.67×10^{-6}	5.7×10^{-6}
DEHP	1.36×10^{-5}	7.14×10^{-5}	—
Lead	—	—	—
Manganese	1.84×10^{-3}	4.6×10^{-2}	1.43×10^{-5}
PCB	4.5×10^{-7}	5.0×10^{-7}	5.0×10^{-7}
Perchlorate	—	7.0×10^{-4}	—
TCE	3.75×10^{-7}	2.5×10^{-6}	2.5×10^{-6}
Vinyl chloride	7.14×10^{-7}	7.14×10^{-7}	3.25×10^{-5}

Note: ALADDs were calculated from reference doses for manganese, perchlorate, and cis-1,2-DCE.

Table R-5. Estimations of Dose and Dose Ratios for Monitored Offsite Groundwater, Surface Water, and Soil Concentration

Chemical	**Location**	**Medium**	**Pathway**	**Scenario**					
				Recreational		**Occupational**		**Residential**	
				Dose (mg/kg-d)	Dose Ratio	Dose (mg/kg-d)	Dose Ratio	Dose (mg/kg-d)	Dose Ratio
Lead	South	S	Ingestion	See LeadSpread[1] results for residential concerns (Table R-7)					
	East	GW	Ingestion						
	North	S	Ingestion						
Arsenic	South	S	Ingestion	5.0×10^{-9} to 7.0×10^{-8}	<1	3.8×10^{-7} to 5.3×10^{-6}	1 to 8	5.9×10^{-7} to 8.2×10^{-6}	1 to 12
			Veg. ing.	—	—	—	—	4.7×10^{-6} to 6.6×10^{-5}	7 to 99
	North	S	Ingestion	4.1×10^{-8} to 1.2×10^{-7}	<1	1.0×10^{-6} to 3.0×10^{-6}	2 to 5	4.8×10^{-6} to 1.4×10^{-5}	7 to 21
			Veg. ing.	—	—	—	—	3.9×10^{-45} to 1.1×10^{-4}	58 to 170
Chloromethane	North	GW	Ingestion	7.2×10^{-7}	<1	5.7×10^{-5}	1	2.2×10^{-4}	3
			Inhalation	—	—	—	—	1.1×10^{-3}	7
			Dermal	—	—	—	—	2.2×10^{-6}	<1
			Veg. ing.	—	—	—	—	8.4×10^{-4}	11
TCE	Northeast	GW	Ingestion	3.8×10^{-7} to 3.4×10^{-5}	0 to 14	3.0×10^{-5} to 2.7×10^{-3}	12 to 1,100	1.2×10^{-4} to 1.1×10^{-2}	48 to 4,200
			Inhalation	—	—	—	—	5.9×10^{-4} to 5.3×10^{-2}	230 to 21,000
			Dermal	—	—	—	—	4.5×10^{-6} to 4.0×10^{-4}	12 to 1,000
			Veg. ing.	—	—	—	—	1×10^{-4} to 1×10^{-2}	44 to 4,000
Vinyl chloride	Northeast	GW	Ingestion	2.4×10^{-6}	3	2.0×10^{-4}	270	7.5×10^{-4}	1,100
			Inhalation	—	—	—	—	3.8×10^{-3}	120
			Dermal	—	—	—	—	2.1×10^{-5}	29
			Veg. ing.	—	—	—	—	1.7×10^{-3}	2,400
Perchlorate*	North	GW	Ingestion	3.5×10^{-7} to 1.3×10^{-5}	<1	2.8×10^{-5} to 1.1×10^{-3}	<1 to 20 to 1	1.1×10^{-4} to 4.1×10^{-3}	<10 to 62
	East	V	Ingestion	—	—	—	—	9.3×10^{-3} to 1.7×10^{-2}	13 to 24

[1] LeadSpread 7 was used to evaluate blood lead levels from potential environmental exposure to lead. LeadSpread is a software tool, developed by the California Department of Toxic Substances Control, to estimate blood lead concentrations resulting from lead exposure via dietary intake, drinking water, soil and dust ingestion, inhalation, and dermal contact. The above five pathways are added to obtain estimate of median blood lead concentration resulting from the multi-pathway exposure. Ninetieth, ninety-fifth, ninety-eighth, and ninety-ninth percentile concentrations are estimated from the median by assuming a log-normal distribution with a geometric standard deviation of 1.6. LeadSpread can be downloaded from http://www.dtsc.ca.gov/AssessingRisk/leadspread.cfmhttp://www.dtsc.ca.gov/AssessingRisk/leadspread.cfm.

Chemical	Location	Medium	Pathway	Scenario					
				Recreational		Occupational		Residential	
				Dose (mg/kg-d)	Dose Ratio	Dose (mg/kg-d)	Dose Ratio	Dose (mg/kg-d)	Dose Ratio
Benzene	North	GW	Ingestion	1.4×10^{-7}	<1	1.1×10^{-5}	1	4.5×10^{-5}	3
			Inhalation	—	—	—	—	2.2×10^{-4}	6
			Dermal	—	—	—	—	2.2×10^{-6}	<1
			Veg. ing.	—	—	—	—	5.5×10^{-5}	3
Carbon tetrachloride	North	GW	Ingestion	1.7×10^{-7}	<1	1.4×10^{-5}	2	5.3×10^{-5}	7
			Inhalation	—	—	—	—	2.6×10^{-4}	14
			Dermal	—	—	—	—	2.9×10^{-6}	1
			Veg. ing.	—	—	—	—	4.1×10^{-5}	5
1,1-DCE	North	GW	Ingestion	7.2×10^{-7}	<1	5.7×10^{-5}	23	2.2×10^{-4}	89
			Inhalation	—	—	—	—	1.1×10^{-3}	200
			Dermal	—	—	—	—	8.6×10^{-6}	5
			Veg. ing.	—	—	—	—	3.4×10^{-4}	20
Cis-1,2-DCE	Northeast	GW	Ingestion	2.38×10^{-6} to 5.5×10^{-5}	<1	1.9×10^{-4} to 4.4×10^{-3}	<1	8.0×10^{-4} to 1.7×10^{-2}	0 to 2
			Dermal	—	—	—	—	1.4×10^{-5} to 3.2×10^{-4}	<1
			Veg. ing.	—	—	—	—	1.0×10^{-3} to 2.4×10^{-2}	0 to 2

Notes: SW = surface water; GW = groundwater; S = soil; V = vegetation (plant material); Veg. ing. = ingestion of vegetation. Hazard indices were calculated for contaminants for which cancer potency factors were not available. These include manganese, cis-1,2-DCE, and perchlorate. In these cases the reference dose, a systemic toxicity health-based standard, was used to compare the doses. Dose ratios above unity represent potential exposure scenarios of concern.
* There is no evidence of perchlorate detection in edible plants. The indicated value is only provided to demonstrate a hypothetical case, since the Dayton canal flows into Orcutt Ranch (see also footnote b in Table 6-5 of Chapter 6).

Table R-6. Inhalation Dose Ratio (DR) Ranges[a] for Lifetime Residents (Since 1953) Based on Max Receptor Air Concentrations (Appendix T)[b]

Receptor Location	Hydrazines and UDMH: Rocket Engine Testing (RET) and Thermal Treatment Facility (TTF)	TCE: Stripping Towers (ST) and Rocket Engine Testing (RET)
West Hills	2-14	47-314
Bell Canyon	3–35	40-241
Dayton Canyon	2-11	36-265
Simi Valley	0–4	30-229
Santa Susana Knolls	<0	10-75
Canoga Park	0–7	10-72
Chatsworth	0-1	8-72
Woodland Hills	0–8	7-74
Hidden Hills	0–3	30-86
Black Canyon	1-5	8-304
Sage Ranch (SR)	0-2	2-87
Brandeis Bardin Institute (BBI)[c]	1-3	17-503

Notes: ***a.*** Dose ratio = LADD/ALADD. ***b.*** Dose ratios are based on single to multiple source emissions.; DR calculations are presented in Appendix T).
c. DRs for BBI were multiplied by 0.25 to reflect summer only residency. DRs for SR were multiplied by 2/7 to reflect weekend use only.

R-3. Exposure to Lead

The standard elevated blood lead level (BLL) for adults set by the Centers for Disease Control and Prevention is 25 µg/dL of whole blood. This level recognizes that every adult has accumulated some lead contamination. The recommended BLL for a child is currently 10 µg/dL of blood. For lead, which does not have consensus systemic or cancer standards, the LeadSpread 7 model (developed by the California Department of Toxic Substances Control) can be used to estimate potential blood lead levels and the associated Dose Ratios (DRs) from relevant offsite monitoring data (Table R-7). This model estimates potential blood lead levels resulting from exposure to lead via dietary intake, drinking water, soil and dust ingestion, inhalation, and dermal contact. The contributions via the above pathways are added to estimate the median blood lead concentration resulting from the multi-pathway exposure.

The LeadSpread 7 model calculations indicate that for Bell Canyon and the Chatsworth area, the blood lead in children could exceed the recommended health standard of 10 µg/dL blood (Table R-7). For example, at the reported lead level of 383 mg/kg at a residence in Bell Canyon (see Appendix H, Table H-4), the LeadSpread results indicate, that pica children (children eating dirt) may have up to an estimated 13.7 µg/dL and 19.5 µg/dL lead BLL if they were playing outside every day, eating dirt, or eating food from gardens in areas with these lead levels. It is noted that recent monitoring of groundwater at the Chatsworth Reservoir (DWP, 2004) indicated groundwater lead levels of 59 to 2,239 µg/L (Appendix H, Table H-5). LeadSpread calculations suggest that ingestion of untreated and undiluted groundwater from private wells in the areas between SSFL and the Chatsworth Reservoir could result in BLLs between 13 and 315 µg/dL. The above scenario would be expected to occur if residents obtained their water from private wells and did not treat the groundwater before use or consumption. Unfortunately, the likelihood of occurrence of such exposure scenarios is unknown.

It should be noted that that Francek (1992) measured median soil-lead concentration in roadside soils of 280 mg/kg (range: 100 to 840 mg/kg), compared to 200 mg/kg (range: 100 to 220 mg/kg) in background soils. Elevated soil-lead levels are generally due to a combination of sources, it is often difficult to determine whether elevated soil-lead levels are a function of a point source emitter, lead-based paint, or leaded gasoline emissions (EPA, 1998). In addition, soil composition and background levels may vary substantially from region to region.[R-3] Therefore, it is often difficult to identify the existence of a point source by determining if there is a decrease of lead concentration with distance from a suspected source. Although lead levels in soils offsite to SSFL have been found to exceed the recommended health standard of 10 µg/dl blood for children[R-4], given the limited monitoring of lead in offsite soils, it is not possible to determine the source of this lead contamination. It is plausible that some lead contamination is the result of various contributions included, but not limited to, past usage of leaded gasoline, lead-based paints, lead containing batteries, or potential transport with stormwater drainages from SSFL.[R-5]

[R-3] Lead soil levels at the Sodium Disposal Facility (a site of hazardous waste incineration) were detected up to 864 mg/kg (GRC, 1990); this soil sample was taken in 1987 at a depth of 0.5 to 1 foot. A soil sample at one Bell Canyon residence was determined to contain up to 383 mg/kg of lead (CA EPA, 1999). The Residential Soil Screening Level is 150 mg/kg.

[R-4] Lead levels in Bell Canyon resulted in potential blood lead levels of up to 14 and 20 µg/dL for children and soil-eating children, respectively.

[R-5] Lead levels in stormwater runoff at NPDES Outfall 001 were measured at 40 µg/L (MCL = 12 µg/L) in 1995 analytes (Boeing, 1995).

Table R-7. Results from Evaluation of Offsite Lead Concentrations Surrounding SSFL

Lead Level	**Medium**	**Primary Exposure Route**	**Location**	**Blood Lead Levels** (µg/dL) **and *Dose Ratios*** (95th percentile)			
				Residential Exposure			**Occupational Exposure**
				Adult	Child	[a]Pica Child	
383 mg/kg	Soil	Soil ingestion	Bell Canyon residence	5 *<1*	14 *1*	20 *2*	3 *<1*
59–2239 µg/L	Groundwater	Groundwater ingestion	Chatsworth Reservoir	9–273 *<1-11*	13–315 *1-32*	16–317 *2-32*	8–271 *<1-11*
50 µg/L	Groundwater	Groundwater ingestion	Woolsey Canyon	8 *<1*	12 *1*	14 *1*	6 *<1*

Notes: ***a.*** A pica child is a child (1 to 2 years old) who eats soil.

R-4. Exposure to Radionuclides

Offsite radionuclide monitoring data are insufficient to provide a reliable exposure analysis. It is also noted that high tritium levels—in excess of health-based standards—were recently detected in offsite groundwater northwest of Area IV. Despite the lack of monitoring data, an approximate analysis was undertaken by the study team with the results provided in Table R-8 with an indication of the likelihood of such exposures.

There is significant uncertainty in the estimated dose ratios (Table R-8) given that available offsite monitoring data are insufficient, monitoring techniques were deficient and background sample locations were inappropriate. Although dose ratios above unity were encountered, the potential exposure pathways leading to such exposures were highly conservative and in some cases unlikely to occur. For example, dose ratios above unity that were estimated for radiological contaminants detected in surface water NPDES outfalls were the consequence of ingestion of contaminated fish from recreational fishing. Although recreational fishing has been reported further downstream of these outfalls, it is not known to occur at the outfalls. Exposures of potential concern in the Ahmanson Ranch area include exposures to K-40 via crop, milk, or livestock ingestion. While such exposures may have been a concern in the past, this land has been recently designated open space and consequently the above exposure scenarios are unlikely. Exposures of concern at Brandeis-Bardin include intake of plutonium-238 via crop ingestion. However, the area in which this radionuclide was detected was sold to Rocketdyne for use as a buffer land, and hence does exposure via the above scenario is unlikely at present.

Table R-8. Offsite Radiological Contaminants

Chemical	**Phase**	**Concentration** pCi/L (W) or pCi/g (S)	**Year**	**Location / Sample ID**	**Ref**	**Is Exposure Likely?**	**Exposure Scenario/ Pathway**	**Dose Ratio**
Radium (combined 226/228)	W	<500	1993	NPDES Outfall 002	2	Unlikely	Recreational/fish ingestion	30,000
Thorium-228	S	1.8	1998	Bell Canyon	3	Yes	Residential/crop ingestion	0.0021
							Occupational/excavation	0.4
							Residential/incidental soil ingestion/inhalation	0.07
Thorium-232	S	1.5					Residential/crop ingestion	0.017
							Occupational/excavation	0.2
							Residential/incidental soil ingestion/inhalation	0.44
Tritium	S	0.36					Occupational/excavation	0.000024
							Residential/incidental soil ingestion/inhalation	0.000048
Potassium-40	S	8.3–23	2000	Ahmanson Ranch	1	Unlikely	Residential/crop ingestion	84
						Yes	Occupational/excavation	0.13
Thorium-228	S	0.5–0.90				Unlikely as detected 0.5 ft depth.	Recreational/incidental soil ingestion/inhalation	<<1
Thorium-232	S	0.54–0.97				Unlikely as detected 0.5 ft depth.	Recreational/incidental soil ingestion/inhalation	<<1
Cesium-137	S	ND–0.32				Unlikely as detected 0.5 ft depth.	Recreational/incidental soil ingestion/inhalation	<<1
Plutonium-238	S	0.19–0.22	1992	BBI	5	Unknown	Residential/ crop ingestion	1.6
						Yes	Occupational/excavation	0.0004
Radium (total 226/228)	W	3.4 ± 3.8 to 15 ± 25	1992–1993	Outfall 003-006	2	Unlikely	Recreational/ fish ingestion	1400
Strontium-90	W	5.1 ± 5.7 to <500	1992–1995				Recreational/ fish ingestion	1200
Cesium-137	S	0.016–0.27	1997	Canoga Park SSFL Recreation Center	4	Yes	Recreational/ incidental soil ingestion/ inhalation	<<1

Notes: ND = not detected * Background samples from Ogden, 1995. † DHS-based health comparisons. **Phase Designations:** W = water; S = soil; A = air.
Location Designations: MW = monitoring wells at Las Virgenes Creek and East Las Virgenes Creek in Ahmanson Ranch; BBI = Brandeis-Bardin Institute.
Comments: IDM = insensitive detection method.
References: ***1.*** Klinefelder, 2000. ***2*** NPDES Annual Monitoring Reports. ***3.*** Ogden Inc., 1998a. ***4.*** Lawrence Livermore National Laboratory, 1997. ***5.*** McLaren/Hart, 1993, 1995.