AR TARGET SHEET

The following document was too large to scan as one unit; therefore, it has been broken down into sections.

DOCUMENT#	BNFL-5193-RCRA-01
TITLE	River Protection Project Waste Treatment Plant Dangerous Waste Permit Application (5 volumes)
EDMC#	0053076
SECTION	6 of 11

4. Screening Level Risk Assessment and Constituents of Potential Concern

The SLRA must serve several purposes including: (1) meeting EPA guidance specifications; (2) providing risk information for additional stakeholders, including Native American tribes and other public members; (3) identifying potential financial risk associated with building and operating the River Protection Project – Waste Treatment Plant (RPP-WTP); and (4) providing the information necessary to determine what, if any, additional permit conditions are necessary for the operation of the RPP-WTP to be protective of human health and the environment. For these reasons, the overall approach for the screening level risk assessment (SLRA) will be to identify potential risk associated with a worst-case exposure scenario as well as a plausible exposure scenario.

- The worst-case exposure scenario represents worst-case assumptions regarding the location of receptors, exposure pathways, and activity patterns (e.g., subsistence fishing). The receptor locations used in the worst-case scenario are considered hypothetical since the assumed activities (e.g., resident, subsistence farmer) do not currently occur in these locations nor are they expected to occur in the future.

- The plausible exposure scenario represents more realistic assumptions regarding the location of receptors. It reflects current uses of the surrounding land and habitats and reasonable assumptions about future land uses.

As with the worst-case exposure scenario, the plausible exposure scenario will incorporate conservative assumptions regarding human and ecological exposure patterns as the standard for the deterministic (as opposed to probabilistic) risk modeling.

The preliminary risk assessment (PRA) will be conducted prior to construction of the RPP-WTP. This PRA will rely on assumptions of potential emissions and operating conditions. The final risk assessment (FRA) will be conducted after construction of the RPP-WTP and completion of the environmental performance demonstration. The FRA will utilize real emissions data from the environmental performance demonstrations and focus on characterizing any potentially significant risks identified in the PRA.

The PRA will be performed first and is discussed in more detail in this Work Plan. Requirements for the FRA will be partially dictated by the results of the PRA and environmental performance demonstrations. The FRA will include estimated emissions based on engineering calculations (pretreatment system emissions and abated fugitive emissions) and environmental performance demonstration for the LAW and HLW vitrification systems.

Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (EPA 1998a) recommends the selection of Constituents of Potential Concern (COPCs) to focus on compounds that (1) are likely to be emitted, due to the presence of the compound or its precursors in the waste feed; (2) are potential products of incomplete combustion, (3) are potentially toxic to humans; and/or (4) have a definite propensity for bioaccumulating or bioconcentrating in human and ecological food chains. The COPC selection process described in EPA 1998a includes six steps:

1. Start with a list of all compounds analyzed for in the environmental performance demonstrations and note which compounds were detected according to analytical tests listed in the *Quality Assurance Project Plan for the Environmental Performance Demonstration* (BNFL 1999b).

2. Evaluate the type of waste in Envelopes A through D to determine whether any of the compounds that were not detected should be retained as COPCs because they are present in the waste.

3. Exclude compounds that are not detected, are not components of the waste, and do not have toxicological data.

4. Exclude compounds that are not detected, are not components of the waste, and do not have a high potential to be products of incomplete combustion (PICs).

5. Evaluate the 30 largest tentatively identified compounds (TICs) to determine whether any of these compounds have toxicities similar to the detected compounds. If they do not, consider surrogate toxicity data.

6. Evaluate compounds that may be of concern due to other site-specific factors. Include as COPCs any compounds that are a concern due to site-specific factors and may be emitted by the combustion unit.

This process will utilize data collected during the environmental performance demonstration. Because the PRA will be performed before the environmental performance demonstration results are available, it will be necessary to develop a list of COPCs and a list of ROPCs based on information and assumptions rather than emissions measurements. The following sections describe the strategy for identifying PRA chemicals of potential concern (COPCs) and radionuclides of potential concern (ROPCs). The COPC/ROPC selection process is summarized in Figure 4-1. The term COPC is used to represent chemicals associated with the tank waste and melting process, while the term ROPC refers to radioactive constituents of potential concern.

Vapor phase emissions are those emitted as volatile gases. Particle phase emissions are particulate constituents (generally metals or other inorganics). Particle-bound emissions are gaseous constituents that are bound to other particles.

4.1. Preliminary Chemicals of Potential Concern (COPCs)

The preliminary list of COPCs was compiled using input from *the Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project* (Wiemers et al. 1998), the list of PICs identified in Table A.1 of *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA 1998a) and the criteria pollutants regulated by the National Ambient Air Quality Standards. Tables A-1 through A-5 in Appendix A of this Work Plan list 424 nonradioactive Preliminary COPCs evaluated for the SLRA. Final COPCs carried through the quantitative risk assessment will be all COPCs for which necessary toxicity data, physical/chemical parameters, and analytical methods are available. COPCs not included in the quantitative risk assessment will be qualitatively addressed in the uncertainty assessment. The COPC list will be re-evaluated for the FRA following the environmental performance demonstration. The derivation of Tables A-1 through A-6 is discussed below and summarized in Figure 4-1.

4.1.1. Regulatory Data Quality Objectives

Analytes considered during the *Regulatory Data Quality Objectives* process (Wiemers et al 1998) were selected from a large universe of regulated constituents using technically defensible decision logic. The

decision logic selected compounds that could plausibly be in the waste feed and of concern relative to the risk assessment and permitting activities. A consolidated list of 850 chemical compounds (Wiemers et al. 1998) was used as the input for the regulatory data quality objectives (DQOs) process. This list of compounds included:

- Toxic Air Pollutant lists Class A (WAC 173-460-150, toxic air pollutants: known, probable, and potential human carcinogens and acceptable source impact levels) and Class B (WAC 173-460-160, toxic air pollutants, and acceptable source impact levels).

- Underlying Hazardous Constituents (UHC) list (40 *CFR* 268.48).

- Universal Treatment Standards list (40 *CFR* 268.48).

- *Double-Shell Tank (DST) System Dangerous Waste Permit Application* (DOE-RL 1991) constituents, except for waste code F039. To date, no landfill leachate has been added to the tanks. Therefore, these compounds were not included in the regulatory DQO database used to select the COPCs.

- DST Waste Stream Profile Sheet constituents.

The list of 850 compounds was screened to arrive at a final list consisting of 139 organic and 49 inorganic compounds. The initial list of 125 organic compounds includes polychlorinated biphenyls (PCBs). This class of compounds includes 209 separate congeners. Fourteen of these congeners (the coplanar PCBs) are considered to be "dioxin-like" and are evaluated individually. These 14 coplanar PCBs were added to the regulatory DQO list of 125 resulting in a total of 139 organic compounds. Tables A-1 and A-2 in Appendix A identify these organic and inorganic COPCs, respectively. A brief discussion of the methodology and criteria used in the regulatory DQOs to narrow the initial input list is included below. Additional details regarding this process are provided in Wiemers et al. 1998.

The organics were screened based upon the following:

- Detectability in the single-shell/double-shell waste
- Stability in the DST environment
- Toxicity and carcinogenicity
- Availability of SW-846 (EPA 1986) analytical methods
- Association with the operations at the Hanford Site

The inorganics were established by the following:

- Listing the inorganic compounds and metals in the input of the starting lists
- Consolidating the list of metals and ions
- Comparing the resulting list to the Hanford Site waste inventories
- Considering the applicability of SW-846 (EPA 1986) analytical methods
- Assessing alternative sources of information

Toxicity criteria were not used to screen inorganic chemicals because the starting list of inorganics was so much shorter than the list of organic chemicals and there was not as large an unknown component to the inorganics (i.e., not as many compounds that were not detected).

4.1.2. Environmental Protection Agency Products of Incomplete Combustion

The organics and inorganics retained by the DQO process were compared to the EPA list of recommended and potential PICs contained in Table A.1 from EPA 1998a. The 139 organic compounds listed in Table A-3 in this Work Plan are the "Chemicals Recommended for Identification" and the "Chemicals for Potential Identification" that were originally identified in Tables 1 and 2 of the *Draft Exposure Assessment Guidance for Resource Conservation and Recovery Act Hazardous Waste Combustion Facilities* (EPA 1994a). In addition, compounds identified in combustion unit emissions and stack emissions originally identified in the *Review Draft Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combuster Emissions* (EPA 1993d) were included. All 148 PICs from Table A.1 of EPA 1998a not already included as part of the DQO COPCs were added. These additional 148 COPCs are listed in Table A-3 in Appendix A of this report. This was done to assure a conservative approach.

4.1.3. Site-Specific Products of Incomplete Combustion

A bench-scale test of the melter technology was conducted at The Catholic University of America Vitreous State Laboratory in December 1998 (Matlock and Pegg 1999). A surrogate waste feed was used for this test that likely does not represent the constituents in the actual tanks. This surrogate waste was designed to represent the most difficult-to-destroy chemicals potentially present in the tank waste and, thus, to provide a conservative estimate of potential PICs. This test identified 16 additional potential PICs. These chemicals are listed in Table A-4 of Appendix A.

4.1.4. Chemicals Screened in the DQO Process

EPA Region X (1999) does not agree with the screening of chemicals based on toxicity. Therefore, all chemicals not included in the DQO due to low toxicity, regardless of other factors (e.g., number of detects) are included in the list of preliminary COPCs.

The DQO process identified 146 regulated organic chemicals with positive detects in the liquid or vapor phase of the tank waste (PNNL, 1998 – Table B.5). These chemicals were carried through a toxicity ranking which identified 19 higher toxicity chemicals (PNNL, 1998 – Table B.6) and 127 lower toxicity chemicals. All 19 higher toxicity chemicals were retained for analysis (i.e., included with the 188 chemicals identified by the DQO in Figure 4-1 of this RAWP). Eighty-one of the lower toxicity chemicals were also retained for analysis (PNNL, 1998 – Table B.34). The remaining 46 chemicals were eliminated based on the following: 42 had $\leq$10 detects (PNNL, 1998 – Table B.8), 2 were common laboratory contaminants (PNNL, 1998 – Table B.30), and 2 required unique methods for analysis (PNNL, 1998 – Table B.32).

The 46 low toxicity regulated organic chemicals, with positive detects eliminated from the DQO, were compared to the PICs previously added to the list of preliminary COPCs (sections 4.1.2 and 4.1.3 of this RAWP). Based on this comparison, an additional 26 regulated organic chemicals with positive detects eliminated from the DQO due to low toxicity and having $\leq$10 detects or unique methods for analysis were added to the list of preliminary COPCs. These 26 additional chemicals are listed in Table A-5 under the heading "Detected Chemicals eliminated due to low toxicity".

The DQO process further identified 90 regulated organic chemicals that could plausibly be in the tanks but which were never detected (PNNL, 1998 – Table B.22). These chemicals were carried through a toxicity ranking which identified 25 higher toxicity chemicals (PNNL, 1998 – Table B.24) and 65 lower toxicity chemicals (PNNL, 1998 – Table B.23). All 25 higher toxicity chemicals were retained for

analysis (i.e., included with the 188 chemicals identified by the DQO in Figure 4-1 of this RAWP). The 65 lower toxicity chemicals were eliminated.

The 65 low toxicity regulated organic chemicals with no detects, previously eliminated from the DQO, were compared to the PICs previously added to the list of preliminary COPCs (sections 4.1.2 and 4.1.4 of this RAWP). Based on this comparison, an additional 41 regulated organic chemicals with no detects eliminated from the DQO due to low toxicity were added to the list of preliminary COPCs. These 41 additional chemicals were listed in Table A-5 under the heading "Non-detected chemicals eliminated due to low toxicity".

4.1.5. Criteria Pollutants

National Ambient Air Quality Standards (NAAQS) have been established for six criteria pollutants (sulfur dioxide, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead). These criteria pollutants will be addressed in the Prevention of Significant Deterioration (PSD) permit application for this facility. In addition, five of these criteria pollutants are added to the list of preliminary COPCs. Lead was previously included in the COPCs identified by the regulatory DQO process.

4.2. Preliminary Radionuclides of Potential Concern (ROPCs)

The preliminary radionuclides of potential concern (ROPCs) were established based upon *Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes* (Kupfer et al. 1997). Information used to establish the global inventories originated from key historical records, various chemical flowsheets used in reprocessing of irradiated Hanford Site reactor fuels, and from calculations of radionuclide isotope generation and decay. *Predominant Radionuclides in Hanford Site Waste Tanks* (Boothe 1996) provides the basis to consider 40 radionuclides that are estimated to present over 99% of the inherent radiological risks in each of the following five categories for human receptors:

- Long-term or short-term inhalation hazards
- Long-term groundwater hazards
- Long-term external radiation hazards
- Short-term shielding concerns
- Short-term volatile hazards

An additional six radionuclides (yttrium-90, barium-137m, europium-155, curium-242, curium-243, and plutonium-242) were added to the list of 40 because they are important in the source term. The resulting list of 46 radionuclides shown in Table A-6 in Appendix A of this Work Plan comprises the ROPCs. These 46 radionuclides represent around 99% of the activity associated with the 177 single-shell and double-shell waste tanks at the Hanford Site.

4.3. Selection of Final COPCs/ROPCs for the Quantitative Preliminary Risk Assessment

The preliminary COPCs and ROPCs identified in Tables A-1 through A-6 include an extensive list of chemicals and radionuclides (1) potentially present in the waste to be processed and (2) potentially produced as PICs during the processing of waste. Constituents are deleted from the final list of COPCs/ROPCs to be carried through the quantitative risk assessment because:

- Appropriate human health or ecological toxicity data are not available to quantitatively evaluate potential effects of the constituent;

- Appropriate physical/chemical parameters are not available to quantitatively evaluate potential emissions or fate and transport behavior of the constituent through the environment; or

- Emission estimates are not available .

Constituents not included in the quantitative risk assessment will be discussed qualitatively as part of the uncertainty assessment.

4.3.1. Selection of Organic COPCs for Inclusion in the Quantitative PRA

The 370 organic preliminary COPCs identified as described in section 4.1 and Figure 4-1 are listed in Table 4-1 and have been grouped into the following classes:

Volatile Organics Compounds (VOCs)	Semi-volatile Organics Compounds (SVOCs)
Aromatic Halogenated Hydrocarbons	Dioxin and Furan Compounds
Aromatic Nonhalogenated Hydrocarbons	Polychlorinated Biphenyls (PCBs)
Non-aromatic Nonhalogenated Hydrocarbons	Phthalates
Non-aromatic Halogenated Hydrocarbons	Light Polynuclear Aromatic Hydrocarbons (PAHs) [molecular weight (MW)<200 g/mole]
	Heavy PAHs (MW>200 g/mole)
	Light Substituted Benzene Compounds (MW<200 g/mole)
	Other Light SVOCs (MW<200 g/mole)
	Other Heavy SVOCs (MW>200 g/mole)
	Herbicides and Organochlorinated Pesticides

EPA 1994a has identified several of these categories (dioxins/furans, PAHs, PCBs, phthalates, other chlorinated organics and nitroaromatics) as having the highest potential to cause increased risk to human health via indirect exposures.

Organic Chemicals with Adequate Toxicity Data

Toxicity data appropriate for the evaluation of potential impacts to human health due to chronic or acute exposures are available from the sources listed in section 7.2 of this workplan.

Toxicity data appropriate for evaluation of chronic exposures to organic COPCs are summarized in Appendix C. Of the 370 organic preliminary COPCs, about 200 have appropriate toxicity data available for the evaluation of potential chronic effects (cancer and/or non-cancer). More than another 30 organic COPCs can be evaluated for potential chronic effects using toxicity equivalency factors (see sections 7.2.3, 7.2.4, and 7.2.5).

Toxicity data appropriate for the evaluation of potential effects resulting from acute (i.e., 1 hour) exposure to organic COPCs are provided in Table 4-4. This table identifies over 260 of the organic preliminary COPCs with appropriate toxicity data available for evaluation of potential acute effects.

Sources of toxicity data for evaluation of potential impacts to ecological receptor populations are described in section 8.3, Effects Assessment Calculations, of this workplan. These data are summarized for organic preliminary COPCs in various tables in Appendix C. Different toxicity data are provided for each of the different types of receptor populations to be evaluated (e.g., aquatic invertebrates). Organic constituents having appropriate toxicity data available for at least one ecological receptor of interest are found in Appendix C.

Only estimated emission rates are needed to model COPC concentrations in air and soil. Additional physical/chemical data are required to model COPC transport through and uptake by other environmental media (e.g., plants, beef, fish, and other biota). Quantitative exposure modeling will be performed for all pathways and COPCs with appropriate physical/chemical data. If physical/chemical data are available for some but not all pathways (e.g., plant uptake factors are available but beef uptake factors are not) for a COPC, those pathways with available data will be included in the quantitative risk assessment.

Organic Chemicals with Emission Rate Estimates

Potential emission rates will be estimated as described in the Air Quality Permit Application and especially Appendix B of the three parts of the Application, and Section 3 of this Work Plan. The list of COPCs for which there are emission rates is provided in Appendix E. Estimated emission rates will be available for 269 organic COPCs.

The final list of organic COPCs that will be included in the quantitative PRA is provided in Appendix D. COPCs not carried through the quantitative PRA will be discussed qualitatively in the uncertainty evaluation.

4.3.2. Selection of Final Inorganic COPCs for Inclusion in the Quantitative PRA

Inorganic COPCs are summarized in Table 4-2.

Inorganic Chemicals with Adequate Toxicity Data

Toxicity data appropriate for the evaluation of potential impacts to human health due to chronic or acute exposures are available from the sources listed in section 7.2 of this workplan.

Toxicity data appropriate for evaluation of chronic exposures to inorganic COPCs are summarized in Appendix C. Of the 54 (the 49 and the 5 criteria pollutants) inorganic preliminary COPCs, about 20 have appropriate toxicity data available for the evaluation of potential chronic effects (cancer and non-cancer). Two other chemicals without toxicity values can be evaluated for media-specific health based effects; see sections 7.2.7 and 7.2.9.

Toxicity data appropriate for the evaluation of potential effects resulting from acute (i.e., 1 hour) exposure to inorganic COPCs are provided in Table 4-4. This table identifies about 50 of the inorganic preliminary COPCs with appropriate toxicity data available for evaluation of potential acute effects.

Sources of toxicity data for evaluation of potential impacts to ecological receptor populations are described in section 8.3 of this workplan. These data are summarized for inorganic preliminary COPCs in various tables in Appendix C. Different toxicity data are provided for each of the different types of receptor populations to be evaluated (e.g., aquatic invertebrates). Inorganic constituents having appropriate toxicity data available for at least one ecological receptor of interest are found in Appendix C.

Inorganic Chemicals with Adequate Physical/Chemical Data

As previously described for organic COPCs, only estimated emission rates are needed to model COPC concentrations in air and soil. Additional physical/chemical data are required to model COPC transport through and uptake by other environmental media (e.g., plants, beef, fish, and other biota). Quantitative exposure modeling will be performed for all pathways and COPCs with appropriate physical/chemical data. If physical/chemical data are available for some but not all pathways (e.g., plant uptake factors are

available but beef uptake factors are not) for a COPC, those pathways with available data will be included in the quantitative risk assessment.

Inorganic Chemicals Emission Rate Estimates

Estimated emission rates will be available for 53 of 54 inorganic COPCs. They will be developed in the Air Quality Permit Application and especially Appendix B of the three parts of the Application.

The final list of inorganic COPCs that will be included in the quantitative PRA is provided in Appendix D. COPCs not carried through the quantitative PRA will be discussed qualitatively in the uncertainty evaluation. In addition to the inorganic COPCs, ROPCs having potential health effects not associated with radioactivity will be evaluated as inorganic COPCs.

4.3.3. Selection of Final ROPCs for Inclusion in the Quantitative PRA

Preliminary ROPCs are summarized in Table 4-3.

Radionuclides with adequate Toxicity Data

Toxicity data appropriate for the evaluation of potential impacts to human health due to chronic or acute exposures are available from the sources listed in section 7.2 of this workplan.

Toxicity data appropriate for evaluation of chronic exposures to ROPCs are summarized in Table 4-3. Of the 46 preliminary ROPCs, 46 have appropriate toxicity data available for the evaluation of potential chronic effects. Toxicity data appropriate for the evaluation of potential effects resulting from acute (i.e., 1 hour) exposure to ROPCs are provided in Table 4-4.

Sources of toxicity data for evaluation of potential impacts to ecological receptor populations are described in section 8.3 of this workplan. These data are summarized for preliminary ROPCs in Appendix C. ROPCs having appropriate toxicity data available for ecological receptors are found in Appendix C.

Radionuclides Chemicals with Adequate Physical/Chemical Data

As previously described for COPCs, only estimated emission rates are needed to model ROPC concentrations in air and soil. Additional physical/chemical data are required to model ROPC transport through and uptake by other environmental media (e.g., plants, beef, fish, and other biota). Quantitative exposure modeling will be performed for all pathways and ROPCs with appropriate physical/chemical data. If physical/chemical data are available for some but not all pathways (e.g., plant uptake factors are available but beef uptake factors are not) for an ROPC, those pathways with available data will be included in the quantitative risk assessment.

Radionuclides with Emission Rate Estimates

Estimated emission rates will be available for 18 of 46 preliminary ROPCs. They will be developed in the Air Quality Permit Application and especially Appendix B of the three parts of the Application.

The final list of ROPCs that will be included in the quantitative PRA is provided in Appendix D. ROPCs not carried through the quantitative PRA will be discussed qualitatively in the uncertainty evaluation.

4.4. Summary for Identification of COPCs and ROPCs

Figure 4-1 provides a summary of the process used to identify preliminary COPCs and ROPCs for the PRA. The inorganic and organic preliminary COPCs and preliminary ROPCs are listed in Appendix A and summarized in Tables A-1 through A-6. They are also listed in Tables 4-1 (organics), 4-2 (inorganics), and 4-3 (radionuclides). Additional human health data are found in Appendix B and ecological data are found in Appendix C.

The list of 470 COPCs/ROPCs selected for the PRA includes many more compounds than are expected in actual facility emissions. The list is long because assumptions are used to compensate for the high level of uncertainty regarding the exact make-up of the waste and the lack of environmental performance demonstration data (i.e., it was assumed that all chemicals potentially present in the waste will be emitted along with all chemicals identified as PICs from any type of combustion unit. The list of preliminary organic COPCs includes numerous chemicals that have never been detected in the tank waste.

Appendix Tables D-1 through D-6 summarize the current availability of data to quantitatively evaluate the preliminary COPCs/ROPCs. These tables also provide a list of the COPCs/ROPCs that will be quantitatively evaluated in the PRA. Preliminary COPCs/ROPCs not included in the PRA will be addressed qualitatively in the uncertainty assessment.

Figure 4-1. Selection of Constituents of Potential Concern

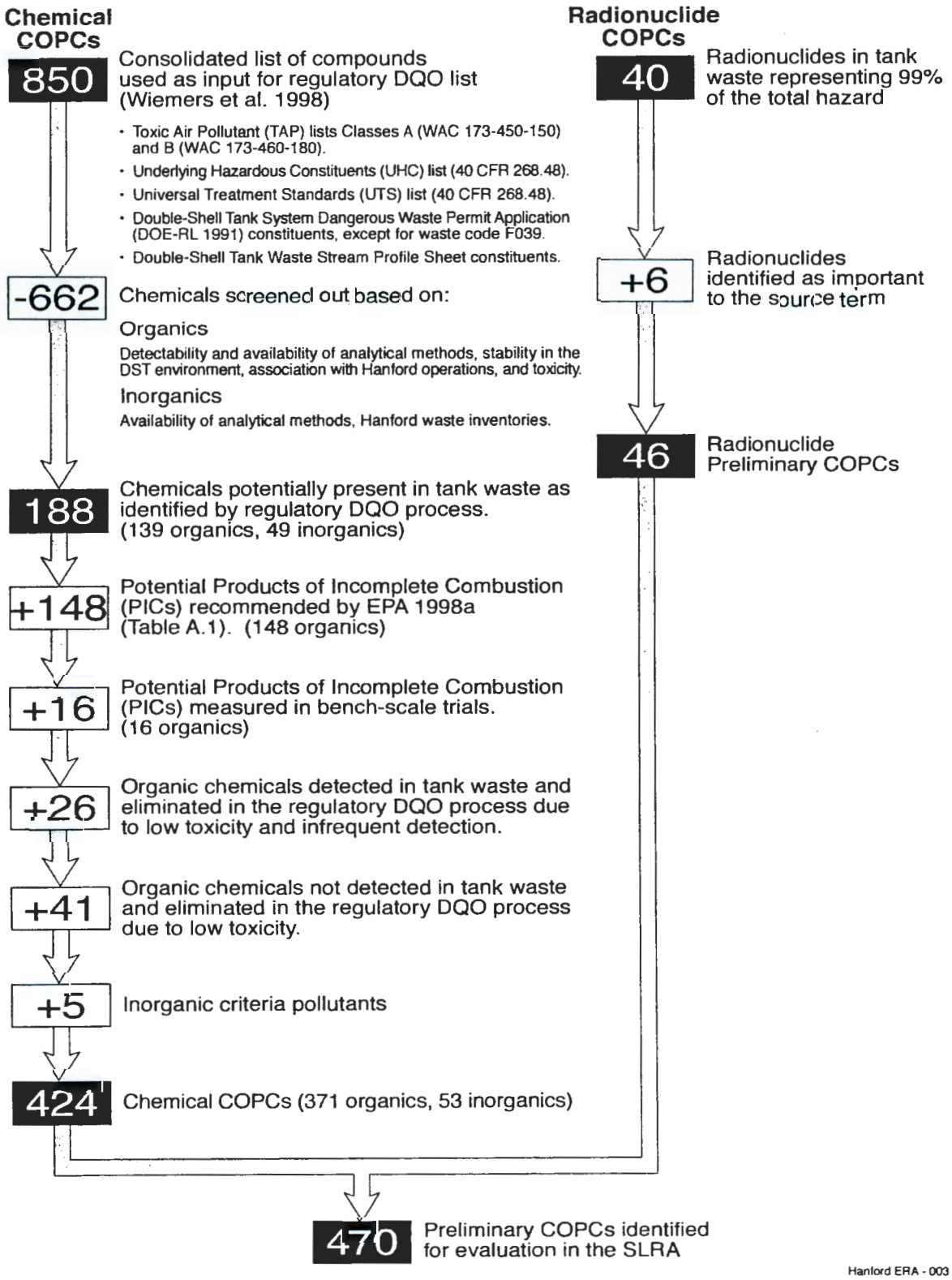


Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity: Oral RfD [b] mg/(kg-d)	Dermal RfD [c] mg/(kg-d)	Inhalation RfC [b] mg/m³	Inhalation RfD [d] mg/(kg-d)	Carcinogenic Slope Factor (kg-day/mg): Oral [b]	Dermal [c]	Inhalation [e]	EPA Class [b]
Aromatic Halogenated Hydrocarbons										
4-Chloro-3-methylphenol	59-50-7	-	-		-	-	-		-	-
2,3,4,6-Tetrachlorophenol	58-90-2	0.50	3.00E-02	1.5E-02	-	-	-	-	-	-
Aromatic Nonhalogenated Hydrocarbons										
2-Nitrotoluene	88-72-2	0.80	1.00E-02[f]	8.0E-03	-	-	-	-	-	-
4-Nitrobiphenyl	92-93-3	-	-	-	-	-	-	-	-	-
Benzaldehyde	100-52-7	0.80	1.00E-01	8.0E-02	-	-	-	-	-	-
Benzene	71-43-2	0.97	-	-	-	-	2.90E-02	2.99E-02	2.90E-02	A
Benzyl alcohol	100-51-6	0.66	3.00E-01[f]	1.98E-01	-	-	-	-	-	-
Ethyl benzene	100-41-4	0.97	1.00E-01	9.70E-02	1.00E+00	2.86E-01	-	-	-	D
m-Xylene	108-38-3	0.80	2.00E+00[f]	1.60E+00	-	-	-	-	-	-
o-Xylene	95-47-6	0.80	2.00E+00[f]	1.60E+00	-	-	-	-	-	-
p-Xylene	106-42-3	0.80	-	-	-	-	-	-	-	-
Styrene	100-42-5	0.80	2.00E-01	1.60E-01	1.00E+00	2.86E-01	-	-	-	-
Toluene	108-88-3	0.80	2.00E-01	1.60E-01	4.00E-01	1.14E-01	-	-	-	D
Non-aromatic Nonhalogenated Hydrocarbons										
1,2-Epoxybutane	106-88-7	0.50	-	-	2.00E-02	5.71E-03	-	-	-	-
1,3-Butadiene	106-99-0	0.80	-	-	-	-	-	-	1.80E+00	B2
1,4-Dioxane	123-91-1	0.80	-	-	-	-	1.10E-02	1.38E-02	-	B2
1-Methylpropyl alcohol	78-92-2	-	-	-	-	-	-	-	-	-
1-Nitropropane	108-03-2	-	-	-	-	-	-	-	-	-
2,2,4-Trimethylpentane	540-84-1	-	-	-	-	-	-	-	-	-
2-Butanone	78-93-3	0.80	6.00E-01	4.80E-01	1.00E+00	2.86E-01	-	-	-	D
2-Butenaldehyde (2-Butenal)	4170-30-3	-	-	-	-	-	-	-	-	-
2-Ethoxyethanol	110-80-5	0.50	4.00E-01[f]	2.00E-01	2.00E-01	5.71E-02	-	-	-	-
2-Heptanone	110-43-0	-	-	-	-	-	-	-	-	-
2-Hexanone	591-78-6	0.66	-	-	-	-	-	-	-	-
2-Methoxyethanol	109-86-4	0.50	1.00E-03[f]	5.0E-04	2.00E-02	5.71E-03	-	-	-	-
2-Methyl-2-propanol	75-65-0	-	-	-	-	-	-	-	-	-
2-Methyl-2-propenenitrile	126-98-7	0.80	1.00E-04	8.00E-05	7.00E-04[f]	2.00E-04	-	-	-	-
2-Methylaziridine	75-55-8	-	-	-	-	-	-	-	-	-
2-Methylpropyl alcohol	78-83-1	0.80	3.00E-01	2.40E-01	-	-	-	-	-	-
2-Pentanone	107-87-9	-	-	-	-	-	-	-	-	-
2-Propanone (Acetone)	67-64-1	0.83	1.00E-01	8.30E-02	-	-	-	-	-	D

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity				Carcinogenic Slope Factor			EPA Class [b]
			Oral RfD [b] mg/(kg-d)	Dermal RfD [c] mg/(kg-d)	Inhalation RfC [b] mg/m^3	Inhalation RfD [d] mg/(kg-d)	Oral [b] (kg-day/mg)	Dermal [c] (kg-day/mg)	Inhalation [e] (kg-day/mg)	
2-Propene-1-ol	107-18-6	0.50	5.00E-03	2.50E-03	-	-	-	-	-	-
2-Propyl alcohol	67-63-0	1.00	-	-	-	-	-	-	-	-
3-Heptanone	106-35-4	-	-	-	-	-	-	-	-	-
3-Methyl-1-butanol	123-51-3	-	-	-	-	-	-	-	-	-
3-Methyl-2-butanone	563-80-4	-	-	-	-	-	-	-	-	-
3-Pentanone	96-22-0	-	-	-	-	-	-	-	-	-
4-Heptanone	123-19-3	-	-	-	-	-	-	-	-	-
4-Methyl-2-pentanone	108-10-1	0.80	8.00E-02[f]	6.40E-02	8.00E-02[f]	2.29E-02	-	-	-	-
4-Methyl-3-penten-2-one	141-79-7	-	-	-	-	-	-	-	-	-
5-Methyl-2-hexanone	110-12-3	-	-	-	-	-	-	-	-	-
Acetaldehyde	75-07-0	0.80	-	-	9.00E-03	2.57E-03	-	-	7.70E-03[g]	B2
Acetamide	60-35-5	-	-	-	-	-	-	-	-	-
Acetic acid	64-19-7	-	-	-	-	-	-	-	-	-
Acetic acid ethyl ester	141-78-6	0.80	9.00E-01	7.20E-01	-	-	-	-	-	-
Acetic acid *n*-butyl ester	123-86-4	-	-	-	-	-	-	-	-	-
Acetonitrile	75-05-8	0.80	6.00E-03	4.80E-03	5.00E-02[f]	1.43E-02	-	-	-	-
Acrolein	107-02-8	0.80	2.00E-02[f]	1.60E-02	2.00E-05	5.71E-06	-	-	-	C
Acrylonitrile	107-13-1	0.80	1.00E-03[f]	8.00E-04	2.00E-03	5.71E-04	5.40E-01	6.75E-01	2.40E-01	B1
Bis(isopropyl)ether	108-20-3	-	-	-	-	-	-	-	-	-
Butane	106-97-8	-	-	-	-	-	-	-	-	-
Carbon disulfide	75-15-0	0.63	1.00E-01	6.30E-02	7.00E-01	2.00E-01	-	-	-	-
Cyanogen	460-19-5	0.80	4.00E-02	3.20E-02	-	-	-	-	-	-
Cyclohexane	110-82-7	-	-	-	-	-	-	-	-	-
Cyclohexanone	108-94-1	0.80	5.00E+00	4.00E+00	-	-	-	-	-	-
Cyclohexene	110-83-8	-	-	-	-	-	-	-	-	-
Cyclopentane	287-92-3	-	-	-	-	-	-	-	-	-
Ethyl alcohol	64-17-5	-	-	-	-	-	-	-	-	-
Ethyl ether	60-29-7	0.80	2.00E-01	1.60E-01	-	-	-	-	-	-
Ethyl methacrylate	97-63-2	0.80	9.00E-02[f]	7.20E-02	-	-	-	-	-	-
Formaldehyde	50-00-0	0.80	2.00E-01	1.60E-01	-	-	-	-	4.50E-02	B1
Formamide	75-12-7	-	-	-	-	-	-	-	-	-
Formic acid	64-18-6	0.50	2.00E+00[f]	1.0E+00	-	-	-	-	-	-
Formic acid, methyl ester	107-31-3	-	-	-	-	-	-	-	-	-
Glycidylaldehyde	765-34-4	0.50	4.00E-04	2.00E-04	1.00E-03[f]	2.86E-04	-	-	-	B2
Methyl acetate	79-20-9	0.50	1.00E+00[f]	5.00E-01	-	-	-	-	-	-

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity				Carcinogenic Slope Factor			EPA Class [b]
			Oral RfD [b] mg/(kg-d)	Dermal RfD [c] mg/(kg-d)	Inhalation RfC [b] mg/m³	Inhalation RfD [d] mg/(kg-d)	Oral [b] (kg-day/mg)	Dermal [c] (kg-day/mg)	Inhalation [c] (kg-day/mg)	
Methyl alcohol	67-56-1	0.80	5.00E-01	4.00E-01	-	-	-	-	-	-
Methyl isocyanate	624-83-9	-	-	-	-	-	-	-	-	-
Methyl methacrylate	80-62-6	0.80	1.40E+00[f]	1.12E+00	7.00E-01	2.00E-01	-	-	-	E
Methyl tert-butyl ether	1634-04-4	0.80	-	-	3.00E+00	8.57E-01	-	-	-	-
Methylacetylene	74-99-7	-	-	-	-	-	-	-	-	-
Methylcyclohexane	108-87-2	0.80	-	-	3.00E+00[f]	8.57E-01	-	-	-	-
N,N-Dimethylacetamide	127-19-5	-	-	-	-	-	-	-	-	-
n-Butyl alcohol	71-36-3	0.50	1.00E-01	5.00E-02	-	-	-	-	-	D
n-Heptane	142-82-5	0.80	-	-	-	-	-	-	-	D
n-Hexane	110-54-3	0.80	6.00E-02[f]	4.80E-02	2.00E-01	5.71E-02	-	-	-	-
Nitromethane	75-52-5	-	-	-	-	-	-	-	-	-
n-Nonane	111-84-2	-	-	-	-	-	-	-	-	-
n-Octane	111-65-9	-	-	-	-	-	-	-	-	-
n-Pentane	109-66-0	-	-	-	-	-	-	-	-	-
n-Propionaldehyde	123-38-6	-	-	-	-	-	-	-	-	-
n-Propyl alcohol	71-23-8	-	-	-	-	-	-	-	-	-
n-Valeraldehyde	110-62-3	-	-	-	-	-	-	-	-	-
Oxirane	75-21-8	0.80	-	-	-	-	1.02E+00[f]	1.28E+00	3.50E-01[f]	B1[f]
p-Cymene	99-87-6	-	-	-	-	-	-	-	-	-
Phosgene	75-44-5	-	-	-	-	-	-	-	-	-
Propargyl alcohol	107-19-7	0.80	2.00E-03	1.60E-03	-	-	-	-	-	-
Propionic acid	79-09-4	-	-	-	-	-	-	-	-	-
Propionitrile	107-12-0	-	-	-	-	-	-	-	-	-
Propylene gylcol monomethyl ether	107-98-2	0.50	7.00E-01[f]	3.50E-01	2.00E+00	5.71E-01	-	-	-	-
p-tert-Butyltoluene	98-51-1	-	-	-	-	-	-	-	-	-
Triethylamine	121-44-8	0.80	-	-	7.00E-03	2.00E-03	-	-	-	-
Trimethylamine	75-50-3	-	-	-	-	-	-	-	-	-
Vinyl acetate	108-05-4	0.65	1.00E+00[f]	6.50E-01	2.00E-01	5.71E-02	-	-	-	-
Non-aromatic Halogenated Hydrocarbons										
1,1,1,2-Tetrachloro-2,2-difluoroethane	76-11-9	-	-	-	-	-	-	-	-	-
1,1,1,2-Tetrachloroethane	630-20-6	0.80	3.00E-02	2.40E-01	-	-	2.60E-02	3.25E-02	2.60E-02	C
1,1,1-Trichloroethane	71-55-6	0.90	2.00E-01[h]	1.80E-01	1.00E+00[h]	2.86E-01	-	-	-	D
1,1,2,2-Tetrachloro-1,2-difluoroethane	76-12-0	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	79-34-5	0.70	-	-	-	-	2.00E-01	2.86E-01	2.00E-01	C
1,1,2,2-Tetrachloroethene	127-18-4	1.00	1.00E-02	1.00E-02	6.00E-01[h]	1.71E-01	5.20E-02[h]	5.20E-02	2.00E-03[h]	-

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity				Carcinogenic Slope Factor			EPA Class [b]
			Oral RfD [b] mg/(kg-d)	Dermal RfD [c] mg/(kg-d)	Inhalation RfC [b] mg/m³	Inhalation RfD [d] mg/(kg-d)	Oral [b] (kg-day/mg)	Dermal [c] (kg-day/mg)	Inhalation [e] (kg-day/mg)	
1,1,2-Trichloroethane	79-00-5	0.81	4.00E-03	3.24E-03	-	-	5.70E-02	7.04E-02	5.70E-02	C
1,1,2-Trichloroethylene	79-01-6	0.15	6.00E-03[h]	9.00E-04	-	-	1.10E-02[h]	7.33E-02	6.00E-03[h]	-
1,1-Dichloroethane	75-34-3	1.00	1.00E-01[f]	1.00E-01	5.00E-01[f]	1.43E-01	-	-	-	C
1,1-Dichloroethene	75-35-4	1.00	9.00E-03	9.00E-03	-	-	6.00E-01	6.00E-01	1.20E+00	C
1,2,2-Trichloro-1,1,2-trifluoroethane	76-13-1	0.80	3.00E+01	2.40E+00	3.00E+01[f]	8.57E+00	-	-	-	-
1,2,3-Trichloropropane	96-18-4	0.80	6.00E-03	4.80E-03	-	-	7.00E+00[f]	8.75E+00	-	B2[f]
1,2-Dibromo-3-chloropropane	96-12-8	0.80	-	-	2.00E-04	5.71E-05	1.40E+00[f]	1.75E+00	2.40E-03	B2[f]
1,2-Dichloro-1,1,2,2-tetrafluoroethane	76-14-2	-	-	-	-	-	-	-	-	-
1,2-Dichloroethane	107-06-2	1.00	-	-	-	-	9.10E-02	9.10E-02	-	B2
1,2-Dichloroethylene	540-59-0	0.80	9.00E-03[f]	7.20E-03	-	-	-	-	-	-
1,2-Dichloropropane	78-87-5	0.74	-	-	4.00E-03	1.14E-03	6.80E-02[f]	9.19E-02	-	B2[f]
1,3-Dichloropropene	542-75-6	0.55	3.00E-04	1.65E-04	2.00E-02	5.71E-03	1.80E-01[f]	3.27E-01	1.30E-01	B2
1,4-Dichloro-2-butene	764-41-0	0.80	-	-	-	-	-	-	9.30E+00	B2[f]
1-Chloroethene	75-01-4	1.00	-	-	-	-	1.90E+00[f]	1.90E+00	3.00E-01	A[f]
2,2-Dichloropropionic acid	75-99-0	0.50	3.00E-02	1.50E-02	-	-	-	-	-	-
2-Chloropropane	75-29-6	0.80	-	-	1.00E-01[f]	2.86E-02	-	-	-	-
3-Chloropropene (allyl chloride)	107-05-1	0.80	-	-	1.00E-03	2.86E-04	-	-	-	C
Bromochloromethane	74-97-5	0.80	-	-	-	-	-	-	-	D
Bromodichloromethane	75-27-4	0.98	2.00E-02	1.96E-02	-	-	6.20E-02	6.33E-02	-	B2
Bromoethene	593-60-2	0.80	-	-	3.00E-03	8.57E-04	-	-	-	B2[f]
Bromoform	75-25-2	0.60	2.00E-02	1.20E-02	-	-	7.90E-03	1.32E-02	3.90E-03	B2
Bromomethane	74-83-9	0.80	1.40E-03	1.12E-03	5.00E-03	1.43E-03	-	-	-	D
Carbon tetrachloride	56-23-5	0.65	7.00E-04	4.55E-04	-	-	1.30E-01	2.00E-01	5.30E-02	B2
Chlorodibromomethane	124-48-1	0.60	2.00E-02	1.20E-02	-	-	8.40E-02	1.40E-01	-	C
Chlorodifluoromethane	75-45-6	0.80	-	-	5.00E+01	1.43E+01	-	-	-	-
Chloroethane	75-00-3	0.80	-	-	1.00E+01	2.86E+00	-	-	-	-
Chloroform	67-66-3	0.20	1.00E-02	2.00E-03	-	-	6.10E-03	3.05E-02	8.10E-02	B2
Chloromethane	74-87-3	0.80	-	-	-	-	1.30E-02[f]	1.63E-02	6.30E-03	C[f]
Chloropentafluoroethane	76-15-3	-	-	-	-	-	-	-	-	-
cis-1,2-Dichloroethene	156-59-2	1.00	1.00E-02[f]	1.00E-02	-	-	-	-	-	D
cis-1,3-Dichloropropene	10061-01-5	-	-	-	-	-	-	-	-	-
Cyanogen bromide	506-68-3	0.80	9.00E-02	7.2E-02	-	-	-	-	-	-
Cyanogen chloride	506-77-4	0.80	5.00E-02	4.00E-02	-	-	-	-	-	-
Dichlorodifluoromethane	75-71-8	0.23	2.00E-01[f]	4.60E-02	2.00E-01[f]	5.71E-02	-	-	-	-

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity: Oral RfD [b] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Dermal RfD [c] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Inhalation RfC [b] mg/m³	Chronic Noncarcinogenic Toxicity: Inhalation RfD [d] mg/(kg-d)	Carcinogenic Slope Factor: Oral [b] (kg-day/mg)	Carcinogenic Slope Factor: Dermal [c] (kg-day/mg)	Carcinogenic Slope Factor: Inhalation [e] (kg-day/mg)	EPA Class [b]
Dichlorofluoromethane	75-43-4	-	-	-	-	-	-	-	-	-
Dichloromethane	75-09-2	0.95	6.00E-02	5.70E-02	3.00E+00[f]	8.57E-01	7.50E-03	7.89E-03	1.65E-03[g]	B2
Difluorodibromomethane	75-61-6	-	-	-	-	-	-	-	-	-
Hexafluoroacetone	684-16-2	-	-	-	-	-	-	-	-	-
Iodomethane	74-88-4	-	-	-	-	-	-	-	-	-
Methylene bromide	74-95-3	0.80	1.00E-02[f]	8.00E-03	-	-	-	-	-	-
Pentachloroethane	76-01-7	-	-	-	-	-	-	-	-	-
trans-1,2-Dichloroethene	156-60-5	1.00	2.00E-02	2.00E-02	-	-	-	-	-	-
trans-1,3-Dichloropropene	10061-02-6	-	-	-	-	-	-	-	-	-
Trichloroacetic acid	76-03-9	0.50	-	-	-	-	-	-	-	C
Trichlorofluoroethane	27154-33-2	-	-	-	-	-	-	-	-	-
Trichlorofluoromethane	75-69-4	0.23	3.00E-01	6.90E-02	7.00E-01[f]	2.00E-01	-	-	-	-
Trifluorobromomethane	75-63-8	-	-	-	-	-	-	-	-	-
Dioxin and Furan Compounds										
1,2,3,4,6,7,8-Heptachlorodibenzo(*p*)dioxin[i]	35822-46-9	-	-	-	-	-	-	-	-	-
1,2,3,4,6,7,8-Heptachlorodibenzofuran[i]	67562-39-4	-	-	-	-	-	-	-	-	-
1,2,3,4,7,8,9-Heptachlorodibenzofuran[i]	55673-89-7	-	-	-	-	-	-	-	-	-
1,2,3,4,7,8-Hexachlorodibenzo(*p*)dioxin[i]	39227-28-6	-	-	-	-	-	-	-	-	-
1,2,3,4,7,8-Hexachlorodibenzofuran[i]	70648-26-9	-	-	-	-	-	-	-	-	-
1,2,3,6,7,8-Hexachlorodibenzo(*p*)dioxin[i]	57653-85-7	-	-	-	-	-	-	-	-	-
1,2,3,6,7,8-Hexachlorodibenzofuran[i]	57117-44-9	-	-	-	-	-	-	-	-	-
1,2,3,7,8,9-Hexachlorodibenzo(*p*)dioxin[i]	19408-74-3	0.50	-	-	-	-	-	-	-	-
1,2,3,7,8,9-Hexachlorodibenzofuran[i]	72918-21-9	-	-	-	-	-	-	-	-	-
1,2,3,7,8-Pentachlorodibenzo(*p*)dioxin[i]	40321-76-4	-	-	-	-	-	-	-	-	-
1,2,3,7,8-Pentachlorodibenzofuran[i]	57117-41-6	0.50	-	-	-	-	-	-	-	-
2,3,4,6,7,8-Hexachlorodibenzofuran[i]	60851-34-5	-	-	-	-	-	-	-	-	-
2,3,4,7,8-Pentachlorodibenzofuran[i]	57117-31-4	0.50	-	-	-	-	-	-	-	-
2,3,7,8-Tetrachlorodibenzo(*p*)dioxin	1746-01-6	0.50	-	-	-	-	1.50E+05[f]	3.00E+05	1.50E+05	B2[f]
2,3,7,8-Tetrachlorodibenzofuran[i]	51207-31-9	0.50	-	-	-	-	-	-	-	-
Dibenzofuran	132-64-9	-	-	-	-	-	-	-	-	-
Octachlorodibenzo(*p*)dioxin[i]	3268-87-9	0.50	-	-	-	-	-	-	-	-
Octachlorodibenzofuran[i]	39001-02-0	0.50	-	-	-	-	-	-	-	-
PCBs [j]: Coplanar										
2,2',3,3',4,4',5- Heptachlorobiphenyl	35065-30-6	-	-	-	-	-	-	-	-	-

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity: Oral RfD [b] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Dermal RfD [c] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Inhalation RfC [b] mg/m³	Chronic Noncarcinogenic Toxicity: Inhalation RfD [d] mg/(kg-d)	Carcinogenic Slope Factor: Oral [b] (kg-day/mg)	Carcinogenic Slope Factor: Dermal [c] (kg-day/mg)	Carcinogenic Slope Factor: Inhalation [e] (kg-day/mg)	EPA Class [b]
2,2',3,4,4',5,5'- Heptachlorobiphenyl	35065-29-3	-	-	-	-	-	-	-	-	-
2,3,3',4,4',5'- Hexachlorobiphenyl	69782-90-7	-	-	-	-	-	-	-	-	-
2,3,3',4,4',5- Hexachlorobiphenyl	38380-08-4	-	-	-	-	-	-	-	-	-
2,3,3',4,4',5,5'- Heptachlorobiphenyl	no cas #	-	-	-	-	-	-	-	-	-
2,3,3',4,4'-Pentachlorobiphenyl	32598-14-4	-	-	-	-	-	-	-	-	-
2,3,4,4',5- Pentachlorobiphenyl	74472-37-0	-	-	-	-	-	-	-	-	-
2',3,4,4',5- Pentachlorobiphenyl	no cas #	-	-	-	-	-	-	-	-	-
2,3',4,4',5- Pentachlorobiphenyl	31508-00-6	-	-	-	-	-	-	-	-	-
2,3',4,4',5,5'- Hexachlorobiphenyl	no cas #	-	-	-	-	-	-	-	-	-
3,3',4,4',5- Pentachlorobiphenyl	no cas #	-	-	-	-	-	-	-	-	-
3,3',4,4',5,5'- Hexachlorobiphenyl	32774-16-6	-	-	-	-	-	-	-	-	-
3,3',4,4'-Tetrachlorobiphenyl	32598-13-3	-	-	-	-	-	-	-	-	-
3,4,4',5-Tetrachlorobiphenyl	70362-50-4	-	-	-	-	-	-	-	-	-
PCBs [j]: Non-coplanar										
Polychlorinated biphenyls	1336-36-3	0.90	2.00E-05	1.80E-05	-	-	2.00E+00 [k,l]	2.22E+00	2.00E+00 [k,l]	B2
Phthalates										
Bis(2-ethylhexyl)phthalate (DEHP)	117-81-7	0.19	2.00E-02	3.80E-03	-	-	1.40E-02		-	B2
Butylbenzyl phthalate	85-68-7	0.61	2.00E-01	1.22E-01	-	-	-	-	-	C
Dibutyl phthalate	84-74-2	1.00	1.00E-01	1.00E-01	-	-	-	-	-	D
Diethyl phthalate	84-66-2	0.90	8.00E-01	7.20E-01	-	-	-	-	-	D
Dimethylphthalate	131-11-3	0.90	-	-	-	-	-	-	-	D
n-Dioctyl phthalate	117-84-0	0.90	2.00E-02 [f]	1.80E-02	-	-	-	-	-	-
Light Polycyclic Aromatic Hydrocarbons (molecular weight <200 g/mole)										
2-Chloronapthalene	91-58-7	0.50	8.00E-02	4.00E-02	-	-	-	-	-	-
2-Methyl naphthalene	91-57-6	0.80	-	-	-	-	-	-	-	-
5-Nitroacenaphthene	602-87-9	-	-	-	-	-	-	-	-	-
Acenaphthene	83-32-9	0.31	6.00E-02	1.86E-02	-	-	-	-	-	-
Acenaphthylene	208-96-8	0.31	-	-	-	-	-	-	-	-
Anthracene	120-12-7	0.76	3.00E-01	2.28E-01	-	-	-	-	-	D
Fluorene	86-73-7	0.50	4.00E-02	2.00E-02	-	-	-	-	-	D
Indene	95-13-6	-	-	-	-	-	-	-	-	-
Naphthalene	91-20-3	0.80	2.00E-02	1.60E-02	3.00E-03	8.57E-04	-	-	-	C
Phenanthrene	85-01-8	0.73	-	-	-	-	-	-	-	D
Pyrene	129-00-0	0.31	3.00E-02	9.30E-03	-	-	-	-	-	D

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity: Oral RfD [b] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Dermal RfD [c] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Inhalation RfC [b] mg/m³	Chronic Noncarcinogenic Toxicity: Inhalation RfD [d] mg/(kg-d)	Carcinogenic Slope Factor: Oral [b] (kg-day/mg)	Carcinogenic Slope Factor: Dermal [c] (kg-day/mg)	Carcinogenic Slope Factor: Inhalation [e] (kg-day/mg)	EPA Class [b]
Heavy Polycyclic Aromatic Hydrocarbons (molecular weight >200 g/mole)										
3-Methylcholanthrene	56-49-5	-	-	-	-	-	-	-	-	-
5-Methylchrysene	3697-24-3	-	-	-	-	-	-	-	-	-
Benzo(*a*)anthracene[m]	56-55-3	0.31	-	-	-	-	-	-	-	-
Benzo(*a*)pyrene	50-32-8	0.31	-	-	-	-	7.30E+00	2.35E+01	3.10E+00[n]	B2
Benzo(*b*)fluoranthene[m]	205-99-2	0.31	-	-	-	-	-	-	-	-
Benzo(*e*)pyrene	192-97-2	-	-	-	-	-	-	-	-	-
Benzo(*g,h,i*)perylene	191-24-2	0.31	-	-	-	-	-	-	-	D
Benzo(*j*)fluoranthene	205-82-3	-	-	-	-	-	-	-	-	-
Benzo(*k*)fluoranthene[m]	207-08-9	0.31	-	-	-	-	-	-	-	-
Benzo[a,i]pyrene	191-30-0	-	-	-	-	-	-	-	-	-
Chrysene[m]	218-01-9	0.31	-	-	-	-	-	-	-	-
Dibenz(*a,h*)anthracene[m]	53-70-3	0.31	-	-	-	-	-	-	-	-
Dibenz[a,h]acridine	226-36-8	-	-	-	-	-	-	-	-	-
Dibenz[a,j]acridine	224-42-0	-	-	-	-	-	-	-	-	-
Dibenzo(*a,e*)fluoranthene	5385-75-1	-	-	-	-	-	-	-	-	-
Dibenzo(*a,h*)fluoranthene	no cas #	-	-	-	-	-	-	-	-	-
Dibenzo[a,e]pyrene	192-65-4	-	-	-	-	-	-	-	-	-
Dibenzo[a,h]pyrene	189-64-0	-	-	-	-	-	-	-	-	-
Dibenzo[a,i]pyrene	189-55-9	-	-	-	-	-	-	-	-	-
Fluoranthene	206-44-0	0.31	4.00E-02	1.24E-02	-	-	-	-	-	D
Hexachloronaphthalene	1335-87-1	-	-	-	-	-	-	-	-	-
Indeno(1,2,3-*cd*)pyrene[m]	193-39-5	0.31	-	-	-	-	-	-	-	-
Octachloronaphthalene	2234-13-1	-	-	-	-	-	-	-	-	-
Pentachloronaphthalene	1321-64-8	-	-	-	-	-	-	-	-	-
Tetrachloronaphthalene	1335-88-2	-	-	-	-	-	-	-	-	-
Trichloronaphthalene	1321-65-9	-	-	-	-	-	-	-	-	-
Light Substituted Benzene Compounds (MW <200 g/mole)										
1,2,3-Trichlorobenzene	87-61-6	-	-	-	-	-	-	-	-	-
1,2,4-Trichlorobenzene	120-82-1	0.97	1.00E-02	9.70E-03	2.00E-01[f]	5.71E-02	-	-	-	D
1,2,4-Trimethyl benzene	95-63-6	-	-	-	-	-	-	-	-	-
1,2-Dichlorobenzene	95-50-1	0.80	9.00E-02	7.20E-02	2.00E-01[f]	5.71E-02	-	-	-	D
1,3,5-Trimethyl benzene	108-67-8	-	-	-	-	-	-	-	-	-
1,3-Dichlorobenzene	541-73-1	0.80	-	-	-	-	-	-	-	D
1,3-Dinitrobenzene	99-65-0	0.65	1.00E-04	6.50E-05	-	-	-	-	-	D

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity				Carcinogenic Slope Factor			EPA Class [b]
			Oral RfD [b] mg/(kg-d)	Dermal RfD [c] mg/(kg-d)	Inhalation RfC [b] mg/m³	Inhalation RfD [d] mg/(kg-d)	Oral [b] (kg-day/mg)	Dermal [c] (kg-day/mg)	Inhalation [e] (kg-day/mg)	
1,4-Dichlorobenzene	106-46-7	0.90	-	-	8.00E-01	2.29E-01	2.40E-02[f]	2.67E-02	-	C[f]
1,4-Dinitrobenzene	100-25-4	0.50	4.00E-04[f]	2.00E-04	-	-	-	-	-	-
2,4,5-Trichlorophenol	95-95-4	0.50	1.00E-01	5.00E-02	-	-	-	-	-	-
2,4,6-Trichlorophenol	88-06-2	0.50	-	-	-	-	1.10E-02	2.20E-02	1.00E-02	B2
2,4-Dichlorophenol	120-83-2	0.82	3.00E-03	2.46E-03	-	-	-	-	-	-
2,4-Dimethylphenol	105-67-9	0.50	2.00E-02	1.00E-02	-	-	-	-	-	-
2,4-Dinitrophenol	51-28-5	1.00	2.00E-03	2.00E-03	-	-	-	-	-	-
2,4-Dinitrotoluene	121-14-2	0.85	2.00E-03	1.70E-03	-	-	6.80E-01[e]	8.00E-01	-	B2
2,6-Dinitrotoluene	606-20-2	0.85	1.00E-03[f]	8.50E-04	-	-	6.80E-01[e]	8.00E-01	-	B2
2-Chlorophenol	95-57-8	0.50	5.00E-03	2.50E-03	-	-	-	-	-	-
2-Chlorotoluene	95-49-8	0.80	2.00E-02	1.60E-02	-	-	-	-	-	-
2-Nitrophenol	88-75-5	-	-	-	-	-	-	-	-	-
4,6-Dinitro-*o*-cresol	534-52-1	1.00	-	-	-	-	-	-	-	-
4-Chlorotoluene	106-43-4	-	-	-	-	-	-	-	-	-
4-Nitrophenol	100-02-7	1.00	-	-	-	-	-	-	-	-
alpha-Methylstyrene	98-83-9	0.80	7.00E-02[f]	5.60E-02	-	-	-	-	-	-
Aniline	62-53-3	0.50	-	-	1.00E-03	2.86E-04	5.70E-03	1.14E-01	-	B2
Benzotrichloride	98-07-7	0.50	-	-	-	-	1.30E+01	2.60E+01	-	B2
Benzyl chloride	100-44-7	0.80	-	-	-	-	1.70E-01	2.13E-01	-	B2
Bromobenzene	108-86-1	-	-	-	-	-	-	-	-	-
Chlorobenzene	108-90-7	0.31	2.00E-02	6.20E-03	2.00E-02[f]	5.71E-03	-	-	-	D
Cumene	98-82-8	0.80	1.00E-01	8.00E-02	4.00E-01	1.14E-01	-	-	-	D
m-Cresol	108-39-4	0.50	5.00E-02	2.50E-02	-	-	-	-	-	C
n-Butyl benzene	104-51-8	-	-	-	-	-	-	-	-	-
Nitrobenzene	98-95-3	0.97	5.00E-04	4.85E-04	2.00E-03[f]	5.71E-04	-	-	-	D
n-Propyl benzene	103-65-1	-	-	-	-	-	-	-	-	-
o-Cresol	95-48-7	0.50	5.00E-02	2.50E-02	-	-	-	-	-	C
o-Dinitrobenzene	528-29-0	0.93	4.00E-04[f]	3.72E-04	-	-	-	-	-	D
o-Nitroaniline	88-74-4	0.50	-	-	2.00E-04[f]	5.71E-05	-	-	-	-
o-Toluidine	95-53-4	0.50	-	-	-	-	2.40E-01[f]	4.80E-01	-	B2[f]
p-Chloroaniline	106-47-8	0.50	4.00E-03	2.00E-03	-	-	-	-	-	-
p-Cresol	106-44-5	0.65	5.00E-03[f]	3.25E-03	-	-	-	-	-	C
Phenol	108-95-2	0.90	6.00E-01	5.40E-01	-	-	-	-	-	D
p-Nitrochlorobenzene	100-00-5	-	-	-	-	-	-	-	-	-

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity				Carcinogenic Slope Factor			EPA Class [b]
			Oral RfD [b] mg/(kg-d)	Dermal RfD [c] mg/(kg-d)	Inhalation RfC [b] mg/m^3	Inhalation RfD [d] mg/(kg-d)	Oral [b] (kg-day/mg)	Dermal [c] (kg-day/mg)	Inhalation [e] (kg-day/mg)	
p-Toluidine	106-49-0	0.50	-	-	-	-	1.90E-01[f]	3.80E-01	-	C[f]
sec-Butyl benzene	135-98-8	-	-	-	-	-	-	-	-	-
tert-Butyl benzene	98-06-6	-	-	-	-	-	-	-	-	-
Toluene-2,6-diamine	823-40-5	0.50	2.00E-01[f]	1.00E-01	-	-	-	-	-	-
Trimethyl benzene	25551-13-7	0.97	-	-	-	-	-	-	-	-
Other Light Semivolatile Compounds (molecular weight <200 g/mole)										
1,1`-Biphenyl	92-52-4	0.50	5.00E-02	2.50E-02	-	-	-	-	-	D
1,1-Dimethylhydrazine	57-14-7	0.50	-	-	-	-	-	-	-	-
1,2-Dimethylhydrazine	540-73-8	0.50	-	-	-	-	-	-	-	B2[f]
1,2-Diphenylhydrazine	122-66-7	0.50	-	-	-	-	8.00E-01	1.60E+00	8.00E-01	B2
1,3-Propane sultone	1120-71-4	-	-	-	-	-	-	-	-	-
2,4-Toluene diisocyante	584-84-9	-	-	-	-	-	-	-	-	-
2-Chloroacetophenone	532-27-4	0.50	-	-	3.00E-05	8.57E-06	-	-	-	-
2-Propenoic acid	79-10-7	0.50	5.00E-01	2.50E-01	1.00E-03	2.86E-04	-	-	-	-
4,4-Methylenedianiline	101-77-9	0.50	-	-	-	-	-	-	-	-
Acetophenone	98-86-2	0.80	1.00E-01	8.00E-02	-	-	-	-	-	D
Benzoic acid	65-85-0	1.00	4.00E+00	4.00E+00	-	-	-	-	-	D
bis(2-Chloroethoxy)methane	111-91-1	0.50	-	-	-	-	-	-	-	D
bis(2-Chloroethyl) ether	111-44-4	0.50	-	-	-	-	1.10E+00	2.20E+00	1.10E+00	B2
Chlorocyclopentadiene	41851-50-7	0.50	-	-	-	-	-	-	-	D
Cyclohexanol	108-93-0	-	-	-	-	-	-	-	-	-
Dichloroisopropyl ether	108-60-1	0.50	-	-	-	-	7.00E-02[f]	1.40E-01	3.50E-02	C[f]
Dichloromethyl ether	542-88-1	0.80	-	-	-	-	2.20E+02	2.75E+02	2.20E+02	A
Dichloropentadiene	no cas #	-	-	-	-	-	-	-	-	-
Dimethyl sulfate	77-78-1	0.50	-	-	-	-	-	-	-	B2
Dimethylaniline	121-69-7	0.50	2.00E-03	1.00E-03	-	-	-	-	-	-
Di-*n*-propylnitrosamine	621-64-7	0.25	-	-	-	-	7.00E+00	2.80E+01	-	B2
Diphenyl ether	101-84-8	-	-	-	-	-	-	-	-	-
Epichlorohydrin	106-89-8	0.80	2.00E-03[f]	1.60E-03	1.00E-03	2.86E-04	9.90E-03	1.24E-02	4.20E-03	B2
Ethyl carbamate (urethane)	51-79-6	-	-	-	-	-	-	-	-	-
Ethyl methanesulfonate	62-50-0	-	-	-	-	-	-	-	-	-
Ethylene dibromide	106-93-4	0.80	-	-	2.00E-04[f]	5.71E-05	8.50E+01	1.06E+02	7.60E-01	B2
Ethylene glycol	107-21-1	0.50	2.00E+00	1.00E+00	-	-	-	-	-	-
Ethylene glycol monobutyl ether	111-76-2	0.50	5.00E-01	2.50E-01	1.30E+01	3.71E+00	5.00E-01	-	-	-

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity: Oral RfD [b] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Dermal RfD [c] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Inhalation RfC [b] mg/m³	Chronic Noncarcinogenic Toxicity: Inhalation RfD [d] mg/(kg-d)	Carcinogenic Slope Factor: Oral [b] (kg-day/mg)	Carcinogenic Slope Factor: Dermal [c] (kg-day/mg)	Carcinogenic Slope Factor: Inhalation [e] (kg-day/mg)	EPA Class [b]
Ethylene glycol monoethyl ether acetate	111-15-9	0.50	3.00E-01[f]	1.50E-01	-	-	-	-	-	-
Ethylene thiourea	96-45-7	0.50	8.00E-05	4.00E-05	-	-	1.10E-01[f]	2.20E-01	-	B2[f]
Furfural	98-01-1	0.50	3.00E-03	1.50E-03	5.00E-02[f]	1.43E-02	-	-	-	-
Maleic hydrazide	123-33-1	0.50	5.00E-01	2.50E-01	-	-	-	-	-	-
Malononitrile	109-77-3	0.80	2.00E-05[f]	1.60E-05	-	-	-	-	-	-
Methyl styrene (mixed isomers)	25013-15-4	0.80	6.00E-03[f]	4.80E-03	4.00E-02[f]	1.14E-02	-	-	-	-
Methylhydrazine	60-34-4	0.50	-	-	-	-	-	-	-	-
N,N-Diphenylamine	122-39-4	0.50	2.50E-02	1.25E-02	-	-	-	-	-	-
Nitric acid, propyl ester	627-13-4	-	-	-	-	-	-	-	-	-
N-Nitrosodi-*n*-butylamine	924-16-3	0.50	-	-	-	-	5.40E+00	1.08E+01	5.40E+00	B2
N-Nitrosomorpholine	59-89-2	-	-	-	-	-	-	-	-	-
N-Nitroso-N,N-dimethylamine	62-75-9	0.50	-	-	-	-	5.10E+01	1.02E+02	5.10E+01	B2
o-Anisidine	90-04-0	-	-	-	-	-	-	-	-	-
Oxalic acid	144-62-7	-	-	-	-	-	-	-	-	-
Phthalic anhydride	85-44-9	0.50	2.00E+00	1.00E+00	1.20E-01[f]	3.43E-02	-	-	-	-
p-Phthalic acid	100-21-0	0.50	1.00E+00[f]	5.00E-01	-	-	-	-	-	-
Pyridine	110-86-1	0.50	1.00E-03	5.00E-04	-	-	-	-	-	-
Quinoline	91-22-5	0.50	-	-	-	-	1.20E+01[f]	2.40E+01	-	C[f]
Quinone	106-51-4	-	-	-	-	-	-	-	-	-
Safrole	94-59-7	-	-	-	-	-	-	-	-	-
Tetrahydrofuran	109-99-9	-	-	-	-	-	-	-	-	-
Other Heavy Semivolatile Compounds (molecular weight >200 g/mole)										
1,2,4,5-Tetrachlorobenzene	95-94-3	0.80	3.00E-04	2.40E-04	-	-	-	-	-	-
1,3,5-Trinitrobenzene	99-35-4	0.65	3.00E-02	1.95E-02	-	-	-	-	-	-
2,6-Bis(tert-butyl)-4-methylphenol	128-37-0	-	-	-	-	-	-	-	-	-
2-Cyclohexyl-4,6-dinitrophenol	131-89-5	0.50	2.00E-03	1.00E-03	-	-	-	-	-	-
2-*sec*-Butyl-4,6-dinitrophenol	88-85-7	0.50	1.00E-03	5.00E-04	-	-	-	-	-	D
3,3'-Dimethoxybenzidine	119-90-4	0.50	-	-	-	-	1.40E-02[f]	2.80E-02	-	B2[f]
3,3-Dichlorobenzidine	91-94-1	0.50	-	-	-	-	4.50E-01	9.00E-01	-	B2
4-Bromophenylphenyl ether	101-55-3	0.50	-	-	-	-	-	-	-	D
Ammonium perfluorooctanoate	3825-26-1	-	-	-	-	-	-	-	-	-
Azobenzene	103-33-3	0.50	-	-	-	-	1.10E-01	2.22E-01	1.10E-01	B2
Bis(3-tert-butyl-4-hydroxy-6-methyl-phenyl)sulfide	96-69-5	-	-	-	-	-	-	-	-	-
Captan	133-06-2	0.50	1.30E-01	6.50E-02	-	-	3.50E-03[f]	7.00E-03	-	B2[f]

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity				Carcinogenic Slope Factor			EPA Class [b]
			Oral RfD [b] mg/(kg-d)	Dermal RfD [c] mg/(kg-d)	Inhalation RfC [b] mg/m³	Inhalation RfD [d] mg/(kg-d)	Oral [b] (kg-day/mg)	Dermal [c] (kg-day/mg)	Inhalation [e] (kg-day/mg)	
Chlorobenzilate	510-15-6	0.50	2.00E-02	1.00E-02	-	-	2.70E-01[f]	5.40E-01	2.70E-01[f]	B2
Dibutylphosphate	107-66-4	-	-	-	-	-	-	-	-	-
Dimethyl aminoazobenzene	60-11-7	-	-	-	-	-	-	-	-	-
Hexachlorobenzene	118-74-1	0.50	8.00E-04	4.00E-04	-	-	1.60E+00	3.20E+00	1.60E+00	B2
Hexachlorobutadiene	87-68-3	0.50	2.00E-04[f]	1.00E-04	-	-	7.80E-02	1.56E-01	7.80E-02	C
Hexachlorocyclopentadiene	77-47-4	0.50	7.00E-03	3.50E-03	7.00E-05[f]	2.00E-05	-	-	-	D
Hexachloroethane	67-72-1	0.50	1.00E-03	5.00E-04	-	-	1.40E-02	2.80E-02	1.40E-02	C
Hexachlorophene	70-30-4	0.50	3.00E-04	1.50E-04	-	-	-	-	-	-
Hexamethylene-1,5-diisocyanate	822-06-0	0.50	-	-	1.00E-05	2.86E-06	-	-	-	-
Mirex	2385-85-5	0.50	2.00E-04	1.00E-04	-	-	-	-	-	B2[f]
Nitrofen	1836-75-5	-	-	-	-	-	-	-	-	-
Pentachlorobenzene	608-93-5	0.80	8.00E-04	6.40E-04	-	-	-	-	-	D
Pentachloronitrobenzene	82-68-8	0.80	3.00E-03	2.40E-03	-	-	2.60E-01[f]	3.25E-01	-	C[f]
Pentachlorophenol	87-86-5	1.00	3.00E-02	3.00E-02	-	-	1.20E-01		-	B2
Picric acid	88-89-1	-	-	-	-	-	-	-	-	-
Pronamide	23950-58-5	0.50	7.50E-02	3.75E-02	-	-	-	-	-	-
Strychnine	57-24-9	0.50	3.00E-04	1.50E-04	-	-	-	-	-	-
Terphenyls	26140-60-3	-	-	-	-	-	-	-	-	-
Tributyl phosphate	126-73-8	-	-	-	-	-	-	-	-	-
Trifluralin	1582-09-8	0.50	7.50E-03	3.75E-03	-	-	7.70E-03	1.54E-02	-	C
Triphenylamine	603-34-9	-	-	-	-	-	-	-	-	-
Herbicides and Organochlorinated Pesticides										
2,4,5-T	93-76-5	0.50	1.00E-02	5.00E-03	-	-	-	-	-	-
2,4-D and esters	94-75-7	0.80	1.00E-02	8.00E-03	-	-	-	-	-	-
4,4-DDD	72-54-8	0.70	-	-	-	-	2.40E-01	3.43E-01	-	B2
4,4-DDE	72-55-9	0.70	-	-	-	-	3.40E-01	4.86E-01	-	B2
4,4-DDT	50-29-3	0.70	5.00E-04	3.50E-04	-	-	3.40E-01	4.86E-01	3.40E-01	B2
Aldrin	309-00-2	0.50	3.00E-05	1.50E-05	-	-	1.70E+01	3.4E+01	1.70E+01	B2
alpha-BHC	319-84-6	0.97	-	-	-	-	6.30E+00	6.49E+00	6.30E+00	B2
beta-BHC	319-85-7	0.91	-	-	-	-	1.80E+00	1.98E+00	1.80E+00	C
Chlordane	57-74-9	0.50	5.00E-04	2.50E-04	7.00E-04	2.00E-04	3.50E-01	7.00E-01	1.30E+00	B2
Delta-BHC	319-86-8	0.50	-	-	-	-	-	-	-	D
Dieldrin	60-57-1	0.50	5.00E-05	2.50E-05	-	-	1.60E+01	3.2E+01	1.60E+01	B2
Endothall	145-73-3	0.50	2.00E-02	1.00E-02	-	-	-	-	-	-
Endrin	72-20-8	0.02	3.00E-04	6.00E-06	-	-	-	-	-	D

Table 4-1. Human Health Chemical Toxicity Values for Organic Constituents of Potential Concern

Organic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity: Oral RfD [b] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Dermal RfD [c] mg/(kg-d)	Chronic Noncarcinogenic Toxicity: Inhalation RfC [b] mg/m³	Chronic Noncarcinogenic Toxicity: Inhalation RfD [d] mg/(kg-d)	Carcinogenic Slope Factor: Oral [b] (kg-day/mg)	Carcinogenic Slope Factor: Dermal [c] (kg-day/mg)	Carcinogenic Slope Factor: Inhalation [e] (kg-day/mg)	EPA Class [b]
gamma-BHC (Lindane)	58-89-9	0.97	3.00E-04	2.91E-04	-	-	1.30E+00[f]	1.34E+00	-	B2[f]
Heptachlor	76-44-8	0.72	5.00E-04	3.60E-04	-	-	4.50E+00	6.25E+00	4.50E+00	B2
Isodrin	465-73-6	-	-	-	-	-	-	-	-	-
Methoxychlor	72-43-5	0.50	5.00E-03	2.50E-03	-	-	-	-	-	D
Silvex (2,4,5-TP)	93-72-1	0.50	8.00E-03	4.00E-03	-	-	-	-	-	D
Toxaphene	8001-35-2	0.50	-	-	-	-	1.10E+00	2.20E+00	1.10E+00	B2

- = not available
RfC = reference concentration
RfD = reference dose

[a] Gastrointestinal absorption factors are from the Risk Assessment Information System (RAIS) maintained by the Oak Ridge National Laboratory (ORNL); see the web site http://risk.lsd.ornl.gov/tox/tox_values.html. These values are used in the calculation of dermal toxicity values from oral toxicity values.

[b] Oral RfDs, inhalation RfCs, oral slope factors, and EPA classifications are from IRIS (EPA 1998c), unless otherwise noted.

[c] Dermal toxicity values are calculated from oral toxicity values as follows: Dermal RfD = (Oral RfD) x (G.I. Absorption Factor); Dermal Slope Factor = (Oral Slope Factor)/(G. I. Absorption Factor).

[d] Inhalation RfDs are calculated from inhalation RfCs; see section 7.2.1 (Noncarcinogenic Health Effects).

[e] Inhalation slope factors are from HEAST (EPA 1997a), unless otherwise noted.

[f] Toxicity value obtained from HEAST (EPA 1997a).

[g] The inhalation slope factor was calculated from the inhalation unit risk, which is provided by IRIS (EPA 1998c). See section 7.2.2.

[h] Provisional value obtained from Superfund Health Risk Technical Support Center, which can be contacted at (513) 569-7300.

[i] Toxicity Equivalency Factor (TEF) approach is used to evaluate these dioxins/furans, with exposure concentrations converted to equivalent concentrations of 2,3,7,8-TCDD by multiplying the concentration by the appropriate TEF. See section 7.2.3.

[j] Coplanar PCBs are evaluated with the TEF approach, using 2,3,7,8-TCDD as the basis; see section 7.2.5. Non-coplanar PCBs are evaluated with the toxicity of PCBs (including RfDs for Aroclor-1254).

[k] Toxicity value obtained from IRIS (EPA 1998c).

[l] The cancer potency of PCB mixtures is determined using a three tiered approach that depends on the information provided. Criteria for use of the High Risk and Persistence Tier include: food chain exposure; sediment or soil ingestion; dust or aerosol inhalation; dermal exposure if an absorption factor has been applied; any early-life exposure; and the presence of dioxin-like, tumor-promoting, or persistent congeners. The value presented, 2.00E+00 $(mg/kg\text{-}day)^{-1}$, is the upper bound slope factor for the High Risk and Persistence Tier. The central-estimate slope factor for the tier is 1.00E+00 $(mg/kg\text{-}day)^{-1}$.

[m] TEF approach is used to evaluate these carcinogenic PAHs, with exposure concentrations converted to equivalent concentrations of benzo(*a*)pyrene by multiplying the concentration by the appropriate TEF. See section 7.2.4.

[n] Provisional inhalation toxicity value developed by NCEA.

[o] Cancer Slope factor is from IRIS (EPA 1998c), but is for "Dinitrotoluene mixture, 2,4/2,6-." The value presented is based on a study using technical grade DNT.

Table 4-2. Human Health Toxicity Values for Inorganic Constituents of Potential Concern

Inorganic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity				Carcinogenic Slope Factor			EPA Class [b]
			Oral RfD [b] mg/(kg-d)	Dermal RfD [c] mg/(kg-d)	Inhalation RfC [b] mg/m^3	Inhalation RfD [d] mg/(kg-d)	Oral [b] (kg-day/mg)	Dermal [c] (kg-day/mg)	Inhalation [e] (kg-day/mg)	
Metals										
Aluminum	7429-90-5	0.10	-	-	-	-	-	-	-	-
Antimony	7440-36-0	0.02	4.00E-04	8.00E-06	-	-	-	-	-	-
Arsenic	7440-38-2	0.41	3.00E-04	1.23E-04	-	-	1.50E+00	3.66E+00	-	A
Barium	7440-39-3	0.07	7.00E-02	4.90E-03	5.00E-04 [f]	1.43E-04	-	-	-	D
Beryllium	7440-41-7	0.01	2.00E-03	2.00E-05	2.00E-02	5.71E-03	-	-	8.40E+00	B1
Bismuth	7440-69-9	-	-	-	-	-	-	-	-	-
Boron	7440-42-8	0.90	9.00E-02	8.10E-02	2.00E-02 [f]	5.71E-03	-	-	-	-
Cadmium	7440-43-9	0.01	1.00E-03	1.00E-05	-	-	-	-	-	B1
Calcium	7440-70-2	-	-	-	-	-	-	-	-	-
Chromium (particulates) [g]	7440-47-3	0.02	3.00E-03	6.00E-05	1.00E-04	2.86E-05	-	-	4.10E+01	A
Chromium (chromic acid mist) [g]	7440-47-3	0.02	3.00E-03	6.00E-05	8.00E-06	2.29E-06	-	-	4.10E+01	A
Cobalt	7440-48-4	0.80	-	-	-	-	-	-	-	-
Copper	7440-50-8	0.30	-	-	-	-	-	-	-	D
Iron	7439-89-6	0.15	-	-	-	-	-	-	-	-
Lead	7439-92-1	0.15	-	-	-	-	-	-	-	B2
Lithium	7439-93-2	0.80	-	-	-	-	-	-	-	-
Magnesium	7439-95-4	0.20	-	-	-	-	-	-	-	-
Manganese	7439-96-5	0.04	4.60E-02 [h]	1.84E-03	5.00E-05	1.43E-05	-	-	-	D
Mercury	7439-97-6	0.07	-	-	-	-	-	-	-	C
Molybdenum	7439-98-7	0.38	5.00E-03	1.90E-03	-	-	-	-	-	-
Nickel [i]	7440-02-0	0.27	2.00E-02 [i]	5.40E-03	-	-	-	-	8.40E-01 [i]	A [i]
Potassium	7440-09-7	-	-	-	-	-	-	-	-	-
Rhodium	7440-16-6	-	-	-	-	-	-	-	-	-
Selenium	7782-49-2	0.44	5.00E-03	2.20E-03	-	-	-	-	-	D
Silicon	7440-21-3	-	-	-	-	-	-	-	-	-
Silver	7440-22-4	0.18	5.00E-03	9.00E-04	-	-	-	-	-	D
Sodium	7440-23-5	1.00	-	-	-	-	-	-	-	-
Strontium	7440-24-6	0.20	6.00E-01	1.20E-01	-	-	-	-	-	-
Tantalum	7440-25-7	-	-	-	-	-	-	-	-	-
Thallium	7440-28-0	0.15	-	-	-	-	-	-	-	-
Tin	7440-31-5	0.10	6.00E-01 [f]	6.00E-02	-	-	-	-	-	-
Tungsten	7440-33-7	-	-	-	-	-	-	-	-	-
Uranium	7440-61-1	0.85	3.00E-03	2.55E-03	-	-	-	-	-	-
Vanadium	7440-62-2	0.01	7.00E-03 [f]	7.00E-05	-	-	-	-	-	-
Yttrium	7440-65-5	-	-	-	-	-	-	-	-	-
Zinc	7440-66-6	0.20	3.00E-01	6.00E-02	-	-	-	-	-	D
Zirconium	7440-67-7	0.80	-	-	-	-	-	-	-	-
Non-metals and Anions										
Ammonia/ Ammonium	7664-41-7	0.20	-	-	1.00E-01	2.86E-02	-	-	-	-
Bromide	24959-67-9	-	-	-	-	-	-	-	-	-
Chloride	16887-00-6	1.00	-	-	-	-	-	-	-	-
Cyanide	57-12-5	0.17	2.00E-02	3.40E-03	-	-	-	-	-	D
Fluoride [j]	16984-48-8	0.97	6.00E-02	5.82E-02	-	-	-	-	-	-

Table 4-2. Human Health Toxicity Values for Inorganic Constituents of Potential Concern

Inorganic COPC	CAS Number	G.I. Absorption Factor [a] (unitless)	Chronic Noncarcinogenic Toxicity				Carcinogenic Slope Factor			EPA Class [b]
			Oral RfD [b] mg/(kg-d)	Dermal RfD [c] mg/(kg-d)	Inhalation RfC [b] mg/m^3	Inhalation RfD [d] mg/(kg-d)	Oral [b] (kg-day/mg)	Dermal [c] (kg-day/mg)	Inhalation [e] (kg-day/mg)	
Hydroxide	14280-30-9	-	-	-	-	-	-	-	-	-
Iodine	7553-56-2	-	-	-	-	-	-	-	-	-
Nitrate	14797-55-8	0.50	1.60E+00	8.00E-01	-	-	-	-	-	-
Nitrite	14797-65-0	0.50	1.00E-01	5.00E-02	-	-	-	-	-	-
Phosphate	14265-44-2	-	-	-	-	-	-	-	-	-
Phosphorus	7723-14-0	0.20	-	-	-	-	-	-	-	-
Sulfate	14808-79-8	0.20	-	-	-	-	-	-	-	-
Total Sulfur	63705-05-5	-	-	-	-	-	-	-	-	-
Criteria Pollutants										
Carbon dioxide	124-38-9	-	-	-	-	-	-	-	-	-
Nitrogen dioxide	10102-44-0	0.20	-	-	-	-	-	-	-	-
Ozone	10028-15-6	-	-	-	-	-	-	-	-	-
Particulate matter	no cas #	-	-	-	-	-	-	-	-	-
Sulfur dioxide	7446-09-5	-	-	-	-	-	-	-	-	-

CAS = Chemical Abstract Service
- = not available
NOAEL = no observed adverse effect level
RfC = reference concentration
RfD = reference dose
TRV = toxicity reference value

[a] Gastrointestinal absorption factors are from the Risk Assessment Information System (RAIS) maintained by the Oak Ridge National Laboratory (ORNL); see the web site http://risk.lsd.ornl.gov/tox-values.html. These values are used in the calculation of dermal toxicity from oral toxicity values.

[a] Oral RfDs, inhalation RfCs, oral slope factors, and EPA classifications are from IRIS (EPA 1998c), unless otherwise noted.

[c] Dermal toxicity values are calculated from oral toxicity values as follows: Dermal RfD = (Oral RfD) × (G.I. Absorption Factor); Dermal Slope Factor = (Oral Slope Factor)/(G.I. Absorption Factor).

[d] Inhalation RfDs are calculated from inhalation RfCs; see section 7.2.1 (Noncarcinogenic Health Effects).

[e] Inhalation slope factors are from HEAST (EPA 1997a), unless otherwise noted.

[f] Toxicity value obtained from HEAST (EPA 1997a).

[g] Toxicity for Chromium VI (chromic acid mist) is used to evaluate chromium in water; otherwise, the toxicity for Chromium VI (particulates) is used to evaluate chromium.

[h] The chronic oral RfD for the total oral intake of manganese is 1.40E-01. However, when assessing exposure to manganese from drinking water or soil, IRIS (EPA 1998c) recommends using a modifying factor of 3, thereby lowering the RfD to 4.60E-02.

[i] Nickel will be evaluated as a potential carcinogen via the inhalation pathway using a slope factor calculated from the inhalation unit risk factor for nickel refinery dust. The oral RfD for nickel soluble salts will be used to evaluate noncarcinogenic effects for nickel. See section 7.2.8.

[j] Toxicity for Fluorine (Soluble Fluoride) is used to evaluate Fluoride.

Table 4-3. Human Health Toxicity Values for Radionuclides of Potential Concern

Radionuclide	CAS Number	Ingestion [a] (risk/pCi)	Inhalation [a] (risk/pCi)	External Radiation to Soil [a] (risk/year per pCi/g soil)	External Radiation for Air Submersion [b] (m^3/Bq-sec)	Isotopes used to calculate Slope Factor for External Radiation for Air Submersion [c]
Actinium-227+D [d]	14952-40-0	6.26E-10	7.87E-08	9.30E-07	1.34E-15	Ac-227, Th-227 (98.62%), Fr-223 (1.38%), Ra-223, Rn-219, Po-215, Pb-211, Bi-211, Tl-207 (99.727%), Po-211 (0.273%), Pb-207
Americium-241	14596-10-2	3.28E-10	3.85E-08	4.59E-09	5.00E-17	Am-241
Americium-243+D [d]	14993-75-0	3.31E-10	3.82E-08	2.66E-07	6.83E-16	Am-243, Np-239
Antimony-125+D [d]	14234-35-6	3.54E-12	5.85E-12	1.34E-06	1.52E-15	Sb-125, Te-125
Barium-137m [e]	13981-97-0	2.43E-15	1.57E-15	2.21E-06	2.16E-15	
Cadmium-113	no cas #	NA	NA	NA	3.29E-19	
Carbon-14	14762-75-5	1.03E-12	6.99E-15	0.00E+00	3.66E-20	
Cesium-134	13967-70-9	4.73E-11	2.89E-11	5.88E-06	5.68E-15	
Cesium-137+D [d]	10045-97-3	3.16E-11	1.91E-11	2.09E-06	1.37E-18	Cs-137
Cobalt-60	10198-40-0	1.89E-11	6.88E-11	9.76E-06	9.63E-15	
Curium-242	15510-73-3	3.83E-11	3.16E-09	2.34E-11	2.59E-19	Cm-242
Curium-243+D [d]	15757-87-6	2.51E-10	2.89E-08	1.71E-07	4.16E-16	Cm-243
Curium-244	13981-15-2	2.11E-10	2.43E-08	2.07E-11	2.15E-19	Cm-244
Europium-152	14683-23-9	5.73E-12	7.91E-11	4.08E-06	4.25E-15	Eu-152, Gd-152
Europium-154	15585-10-1	9.37E-12	9.15E-11	4.65E-06	4.63E-15	
Europium-155	14391-16-3	1.65E-12	9.60E-12	6.08E-08	1.64E-16	
Iodine-129	15046-84-1	1.84E-10	1.22E-10	2.69E-09	1.85E-17	
Neptunium-237+D [d]	13994-20-2	3.00E-10	3.45E-08	4.62E-07	7.43E-16	Np-237, Pa-233
Nickel-59	14336-70-0	1.85E-13	4.01E-13	0.00E+00	0.00E+00	
Nickel-63	13981-37-8	5.50E-13	1.01E-12	0.00E+00	0.00E+00	
Niobium-93m [e]	7440-03-1	6.64E-13	4.33E-12	3.64E-11	1.92E-19	
Plutonium-238	13981-16-3	2.95E-10	2.74E-08	1.94E-11	2.28E-19	Pu-238
Plutonium-239	15117-48-3	3.16E-10	2.78E-08	1.26E-11	2.56E-19	Pu-239
Plutonium-240	14119-33-6	3.15E-10	2.78E-08	1.87E-11	2.24E-19	Pu-240
Plutonium-241+D [d]	14119-32-5	5.20E-12	2.81E-10	0.00E+00	4.89E-21	Pu-241
Plutonium-242	13982-10-0	3.00E-10	2.64E-08	1.55E-11	1.91E-19	Pu-242
Protactinium-231	14331-85-2	1.49E-10	2.42E-08	2.71E-08	1.24E-16	Pa-231
Radium-226+D [d]	13982-63-3	2.96E-10	2.75E-09	6.74E-06	6.74E-15	Ra-226, Rn-222, Po-218, Pb-214, Bi-214, Po-214 (99.979%), Pb-210, Bi-210, Po-210, Pb-206
Radium-228+D [d]	15262-20-1	2.48E-10	9.94E-10	3.28E-06	9.77E-15	Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Po-212 (64.07%), Tl-208 (35.93%), Pb-208

Table 4-3. Human Health Toxicity Values for Radionuclides of Potential Concern

Radionuclide	CAS Number	Ingestion [a] (risk/pCi)	Inhalation [a] (risk/pCi)	External Radiation to Soil [a] (risk/year per pCi/g soil)	External Radiation for Air Submersion [b] (m^3/Bq-sec)	Isotopes used to calculate Slope Factor for External Radiation for Air Submersion [c]
Ruthenium-106+D [d]	13967-48-1	3.45E-11	1.15E-10	7.57E-07	7.85E-16	Ru-106, Rh-106, Pd-106
Samarium-151	15715-94-3	4.60E-13	4.63E-12	2.92E-13	1.52E-21	
Selenium-79	no cas #	NA	NA	NA	5.39E-20	
Strontium-90+D [d]	10098-97-2	5.59E-11	6.93E-11	1.40E-18	1.40E-18	Sr-90
Technetium-99	14133-76-7	1.40E-12	2.89E-12	6.19E-13	3.72E-19	
Thorium-229+D [d]	15594-54-4	3.56E-10	8.26E-08	7.68E-07	1.08E-15	Th-229, Ra-225, Ac-225, Fr-221, At-217, Bi-213, Po-213 (97.84%), Tl-209 (2.16%), Pb-209
Thorium-232	7440-29-1	3.28E-11	1.93E-08	1.97E-11	5.35E-19	Th-232
Tin-126	15832-50-5	2.12E-11	4.26E-11	3.32E-08	1.04E-14	Sn-126, Sb-126
Tritium	10028-17-8	7.15E-14	9.59E-14	0.00E+00	0.00E+00	
Uranium-232	14158-29-3	8.12E-11	5.29E-08	3.42E-11	8.67E-19	U-232
Uranium-233	13968-55-3	4.48E-11	1.41E-08	3.52E-11	1.09E-18	U-233
Uranium-234	13966-29-5	4.44E-11	1.40E-08	2.14E-11	1.56E-18	U-234, Th-230
Uranium-235+D [d]	15117-96-1	4.70E-11	1.30E-08	2.65E-07	5.43E-16	U-235, Th-231
Uranium-236	13982-70-2	4.21E-11	1.32E-08	1.72E-11	2.67E-19	U-236
Uranium-238+D [d]	7440-61-1	6.20E-11	1.24E-08	6.57E-08	7.04E-15	U-238, Th-234, Pa-234
Yttrium-90	10098-91-6	1.50E-11	9.90E-12	0.00E+00	1.66E-14	Y-90, Zr-90, Nb-90
Zirconium-93	15751-77-6	5.21E-13	5.26E-12	0.00E+00	0.00E+00	Zr-93

NA = slope factor is not available

[a] Cancer slope factors are from HEAST (EPA 1995d).

[b] External exposure slope factors for air submersion (for morbidity) are from Table 2.3 in EPA Federal Guidance Report No. 13 (EPA 1999b).

[c] Isotopes used to calculate the external exposure slope factors for air submersion are listed for parent isotopes only. All daughters in the decay chain are included in the calculation of the slope factor, until another isotope on the ROPC list is encountered. For example, Neptunium-237 decays into Protactinium-233, which decays into Uranium-233, which decays into other isotopes. Since Uranium-233 is on the ROPC list, its slope factor is not used to calculate the slope factor for Neptunium-237. The external exposure slope factor for air submersion for Neptunium-237 is obtained by adding the values in Table 2.3 (from EPA 1999b) for Neptunium-237 and Protactinium-233.

[d] +D slope factors from HEAST include contributions from short-lived daughter products.

[e] m designates isotopes in a metastable state.

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)
ORGANICS	-	-	-	-	-	-	-	-	-	-	-	-	-
Aromatic Halogenated Hydrocarbons													
2,3,4,6-Tetrachlorophenol	58-90-2	-	-	-	-	-	-	-	-	-	-	-	-
4-Chloro-3-methylphenol	59-50-7	-	-	-	-	-	-	-	-	2.00E+01	mg/m³	5.83E+00	2.00E+01
Aromatic Nonhalogenated Hydrocarbons													
2-Nitrotoluene	88-72-2	-	-	-	-	-	-	-	-	-	-	-	-
4-Nitrobiphenyl	92-93-3	-	-	-	-	-	-	-	-	7.50E-01	mg/m³	8.14E+00	7.50E-01
Benzaldehyde	100-52-7	-	-	-	-	-	-	-	-	1.50E+01	mg/m³	4.34E+00	1.50E+01
Benzene	71-43-2	-	-	-	-	5.00E+01	ppm	1.30E+00	mg/m³	1.60E+02	mg/m³	3.19E+00	1.60E+02
Benzyl alcohol	100-51-6	-	-	-	-	-	-	-	-	5.53E+01	mg/m³	4.42E+00	5.53E+01
Ethyl benzene	100-41-4	-	-	-	-	-	-	-	-	5.42E+02	mg/m³	4.34E+00	5.42E+02
m-Xylene	108-38-3	-	-	-	-	-	-	2.20E+01	mg/m³	6.51E+02	mg/m³	4.34E+00	2.20E+01
o-Xylene	95-47-6	-	-	-	-	-	-	2.20E+01	mg/m³	6.51E+02	mg/m³	4.34E+00	2.20E+01
p-Xylene	106-42-3	-	-	-	-	-	-	2.20E+01	mg/m³	6.51E+02	mg/m³	4.34E+00	2.20E+01
Styrene	100-42-5	-	-	-	-	5.00E+01	ppm	2.10E+01	mg/m³	2.13E+02	mg/m³	4.26E+00	2.13E+02
Toluene	108-88-3	-	-	-	-	5.00E+01	ppm	3.70E+01	mg/m³	1.88E+02	mg/m³	3.77E+00	1.88E+02
Non-aromatic Nonhalogenated Hydrocarbons													
1,2-Epoxybutane	106-88-7	-	-	-	-	-	-	-	-	2.95E+02	mg/m³	2.95E+00	2.95E+02
1,3-Butadiene	106-99-0	-	-	-	-	1.00E+01	ppm			2.21E+01	mg/m³	2.21E+00	2.21E+01
1,4-Dioxane	123-91-1	-	-	-	-	-	-	3.00E+00	mg/m³	2.70E+02	mg/m³	3.60E+00	3.00E+00
1-Methylpropyl alcohol	78-92-2	-	-	-	-	-	-	-	-	4.55E+02	mg/m³	3.03E+00	4.55E+02
1-Nitropropane	108-03-2	-	-	-	-	-	-	-	-	2.73E+02	mg/m³	3.64E+00	2.73E+02
2,2,4-Trimethylpentane	540-84-1	-	-	-	-	-	-	-	-	3.50E+02	mg/m³	4.67E+00	3.50E+02
2-Butanone	78-93-3	-	-	-	-	-	-	1.30E+01	mg/m³	8.84E+02	mg/m³	2.95E+00	1.30E+01
2-Butenaldehyde (2-Butenal)	4170-30-3	-	-	1.90E-01	ppm	2.00E+00	ppm	-	-	5.73E+00	mg/m³	2.86E+00	5.44E-01
2-Ethoxyethanol	110-80-5	-	-	-	-	-	-	3.70E-01	mg/m³	5.53E+01	mg/m³	3.68E+00	3.70E-01
2-Heptanone	110-43-0	-	-	-	-	-	-	-	-	7.00E+02	mg/m³	4.67E+00	7.00E+02
2-Hexanone	591-78-6	-	-	-	-	-	-	-	-	4.09E+01	mg/m³	4.09E+00	4.09E+01
2-Methoxyethanol	109-86-4	-	-	-	-	-	-	9.30E-02	mg/m³	4.67E+01	mg/m³	3.11E+00	9.30E-02
2-Methyl-2-propanol	75-65-0	-	-	-	-	-	-	-	-	4.55E+02	mg/m³	3.03E+00	4.55E+02
2-Methyl-2-propenenitrile	126-98-7	-	-	-	-	-	-	-	-	2.74E+00	mg/m³	2.74E+00	2.74E+00
2-Methylaziridine	75-55-8	-	-	-	-	-	-	-	-	1.40E+01	mg/m³	2.33E+00	1.40E+01
2-Methylpropyl alcohol	78-83-1	-	-	-	-	-	-	-	-	4.55E+02	mg/m³	3.03E+00	4.55E+02
2-Pentanone	107-87-9	-	-	-	-	-	-	-	-	8.80E+02	mg/m³	3.52E+00	8.80E+02
2-Propanone (Acetone)	67-64-1	-	-	-	-	-	-	-	-	2.37E+03	mg/m³	2.37E+00	2.37E+03
2-Propene-1-ol	107-18-6	-	-	1.80E+00	ppm	-	-	-	-	9.50E+00	mg/m³	2.37E+00	4.27E+00
2-Propyl alcohol	67-63-0	-	-	-	-	-	-	3.20E+00	mg/m³	9.83E+02	mg/m³	2.46E+00	3.20E+00
3-Heptanone	106-35-4	-	-	-	-	-	-	-	-	-	-	-	-
3-Methyl-1-butanol	123-51-3	-	-	-	-	-	-	-	-	4.50E+02	mg/m³	3.60E+00	4.50E+02
3-Methyl-2-butanone	563-80-4	-	-	-	-	-	-	-	-	-	-	-	-

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)
3-Pentanone	96-22-0	-	-	-	-	-	-	-	-	-	-	-	-
4-Heptanone	123-19-3	-	-	-	-	-	-	-	-	-	-	-	-
4-Methyl-2-pentanone	108-10-1	-	-	-	-	-	-	-	-	3.07E+02	mg/m³	4.09E+00	3.07E+02
4-Methyl-3-penten-2-one	141-79-7	-	-	-	-	-	-	-	-	1.00E+02	mg/m³	4.01E+00	1.00E+02
5-Methyl-2-hexanone	110-12-3	-	-	-	-	-	-	-	-	2.80E+03	mg/m³	4.67E+00	2.80E+03
Acetaldehyde	75-07-0	-	-	-	-	1.00E+01	ppm	-	-	1.80E+01	mg/m³	1.80E+00	1.80E+01
Acetamide	60-35-5	-	-	-	-	-	-	-	-	7.50E+01	mg/m³	2.41E+00	7.50E+01
Acetic acid	64-19-7	-	-	-	-	-	-	-	-	3.68E+01	mg/m³	2.45E+00	3.68E+01
Acetic acid ethyl ester	141-78-6	-	-	-	-	-	-	-	-	4.32E+03	mg/m³	3.60E+00	4.32E+03
Acetic acid n-butyl ester	123-86-4	-	-	-	-	-	-	-	-	-	-	-	-
Acetonitrile	75-05-8	-	-	-	-	-	-	-	-	1.01E+02	mg/m³	1.68E+00	1.01E+02
Acrolein	107-02-8	-	-	3.00E-02	ppm	1.00E-01	ppm	1.90E-04	mg/m³	2.29E-01	mg/m³	2.29E+00	6.87E-02
Acrylonitrile	107-13-1	-	-	-	-	1.00E+01	ppm	-	-	2.17E+01	mg/m³	2.17E+00	2.17E+01
Bis(isopropyl)ether	108-20-3	-	-	-	-	-	-	-	-	-	-	-	-
Butane	106-97-8	-	-	-	-	-	-	-	-	5.70E+03	mg/m³	2.38E+00	5.70E+03
Carbon disulfide	75-15-0	-	-	-	-	1.00E+00	ppm	6.20E+00	mg/m³	3.73E+01	mg/m³	3.11E+00	3.11E+00
Cyanogen	460-19-5	-	-	-	-	-	-	-	-	6.38E+01	mg/m³	2.13E+00	6.38E+01
Cyclohexane	110-82-7	-	-	-	-	-	-	-	-	3.10E+03	mg/m³	3.44E+00	3.10E+03
Cyclohexanone	108-94-1	-	-	-	-	-	-	-	-	3.01E+02	mg/m³	4.01E+00	3.01E+02
Cyclohexene	110-83-8	-	-	-	-	-	-	-	-	1.01E+03	mg/m³	3.36E+00	1.01E+03
Cyclopentane	287-92-3	-	-	-	-	-	-	-	-	-	-	-	-
Ethyl alcohol	64-17-5	-	-	-	-	-	-	-	-	5.65E+03	mg/m³	1.88E+00	5.65E+03
Ethyl ether	60-29-7	-	-	-	-	-	-	-	-	1.52E+03	mg/m³	3.03E+00	1.52E+03
Ethyl methacrylate	97-63-2	-	-	-	-	-	-	-	-	-	-	-	-
Formaldehyde	50-00-0	-	-	-	-	1.00E+00	ppm	9.40E-02	mg/m³	1.23E+00	mg/m³	1.23E+00	1.23E+00
Formamide	75-12-7	-	-	-	-	-	-	-	-	2.76E+01	mg/m³	1.84E+00	2.76E+01
Formic acid	64-18-6	-	-	-	-	-	-	-	-	1.88E+01	mg/m³	1.88E+00	1.88E+01
Formic acid, methyl ester	107-31-3	-	-	-	-	-	-	-	-	-	-	-	-
Glycidylaldehyde	765-34-4	-	-	-	-	-	-	-	-	2.21E-01	mg/m³	2.95E+00	2.21E-01
Methyl acetate	79-20-9	-	-	-	-	-	-	-	-	-	-	-	-
Methyl alcohol	67-56-1	-	-	-	-	2.00E+02	ppm	2.80E+01	mg/m³	2.62E+02	mg/m³	1.31E+00	2.62E+02
Methyl isocyanate	624-83-9	-	-	-	-	2.50E-02	ppm	-	-	5.83E-02	mg/m³	2.33E+00	5.83E-02
Methyl methacrylate	80-62-6	-	-	-	-	-	-	-	-	1.23E+03	mg/m³	4.09E+00	1.23E+03
Methyl tert-butyl ether	1634-04-4	-	-	-	-	-	-	-	-	4.32E+02	mg/m³	3.60E+00	4.32E+02
Methylacetylene	74-99-7	-	-	-	-	-	-	-	-	2.78E+03	mg/m³	1.64E+00	2.78E+03
Methylcyclohexane	108-87-2	-	-	-	-	-	-	-	-	4.82E+03	mg/m³	4.01E+00	4.82E+03
N,N-Dimethylacetamide	127-19-5	-	-	-	-	-	-	-	-	-	-	-	-
n-Butyl alcohol	71-36-3	-	-	-	-	-	-	-	-	1.52E+02	mg/m³	3.03E+00	1.52E+02
n-Heptane	142-82-5	-	-	-	-	-	-	-	-	1.80E+03	mg/m³	4.10E+00	1.80E+03
n-Hexane	110-54-3	-	-	-	-	-	-	-	-	5.28E+02	mg/m³	3.52E+00	5.28E+02
Nitromethane	75-52-5	-	-	-	-	-	-	-	-	1.50E+02	mg/m³	2.50E+00	1.50E+02

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)
n-Nonane	111-84-2	-	-	-	-	-	-	-	-	1.05E+03	mg/m³	5.24E+00	1.05E+03
n-Octane	111-65-9	-	-	-	-	-	-	-	-	-	-	-	-
n-Pentane	109-66-0	-	-	-	-	-	-	-	-	1.80E+03	mg/m³	2.95E+00	1.80E+03
n-Propionaldehyde	123-38-6	-	-	-	-	-	-	-	-	7.50E+01	mg/m³	2.37E+00	7.50E+01
n-Propyl alcohol	71-23-8	-	-	-	-	-	-	-	-	6.14E+02	mg/m³	2.46E+00	6.14E+02
n-Valeraldehyde	110-62-3	-	-	-	-	-	-	-	-	-	-	-	-
Oxirane	75-21-8	-	-	-	-	-	-	-	-	1.35E+01	mg/m³	1.80E+00	1.35E+01
p-Cymene	99-87-6	-	-	-	-	-	-	-	-	-	-	-	-
Phosgene	75-44-5	-	-	-	-	-	-	4.00E-03	mg/m³	4.04E-01	mg/m³	4.04E+00	4.00E-03
Propargyl alcohol	107-19-7	-	-	-	-	-	-	-	-	6.87E+00	mg/m³	2.29E+00	6.87E+00
Propionic acid	79-09-4	-	-	-	-	-	-	-	-	3.03E+01	mg/m³	3.03E+00	3.03E+01
Propionitrile	107-12-0	-	-	-	-	-	-	-	-	3.38E+01	mg/m³	2.25E+00	3.38E+01
Propylene gylcol monomethyl ether	107-98-2	-	-	-	-	-	-	-	-	5.52E+02	mg/m³	3.68E+00	5.52E+02
p-tert-Butyltoluene	98-51-1	-	-	-	-	-	-	-	-	-	-	-	-
Triethylamine	121-44-8	-	-	-	-	-	-	2.80E+00	mg/m³	1.24E+01	mg/m³	4.14E+00	2.80E+00
Trimethylamine	75-50-3	-	-	-	-	1.00E-01	ppm	-	-	3.63E+01	mg/m³	2.42E+00	2.42E-01
Vinyl acetate	108-05-4	-	-	-	-	5.00E+00	ppm	-	-	1.76E+01	mg/m³	3.52E+00	1.76E+01
Non-aromatic Halogenated Hydrocarbons													
1,1,1,2-Tetrachloro-2,2-difluoroethane	76-11-9	-	-	-	-	-	-	-	-	-	-	-	-
1,1,1,2-Tetrachloroethane	630-20-6	-	-	-	-	-	-	-	-	5.14E+01	mg/m³	6.86E+00	5.14E+01
1,1,1-Trichloroethane	71-55-6	-	-	-	-	3.50E+02	ppm	6.80E+01	mg/m³	1.91E+03	mg/m³	5.45E+00	1.91E+03
1,1,2,2-Tetrachloro-1,2-difluoroethane	76-12-0	-	-	-	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	79-34-5	-	-	-	-	-	-	-	-	2.06E+01	mg/m³	6.86E+00	2.06E+01
1,1,2,2-Tetrachloroethene	127-18-4	-	-	-	-	1.00E+02	ppm	2.00E+01	mg/m³	6.78E+02	mg/m³	6.78E+00	6.78E+02
1,1,2-Trichloroethane	79-00-5	-	-	-	-	-	-	-	-	1.64E+02	mg/m³	5.45E+00	1.64E+02
1,1,2-Trichloroethylene	79-01-6	-	-	-	-	1.00E+02	ppm	-	-	5.37E+02	mg/m³	5.37E+00	5.37E+02
1,1-Dichloroethane	75-34-3	-	-	-	-	-	-	-	-	1.21E+03	mg/m³	4.04E+00	1.21E+03
1,1-Dichloroethene	75-35-4	-	-	-	-	-	-	-	-	7.92E+01	mg/m³	3.96E+00	7.92E+01
1,2,2-Trichloro-1,1,2-trifluoroethane	76-13-1	-	-	-	-	-	-	-	-	9.57E+03	mg/m³	7.66E+00	9.57E+03
1,2,3-Trichloropropane	96-18-4	-	-	-	-	-	-	-	-	1.81E+02	mg/m³	6.03E+00	1.81E+02
1,2-Dibromo-3-chloropropane	96-12-8	-	-	-	-	-	-	-	-	7.24E-01	mg/m³	9.66E+00	7.24E-01
1,2-Dichloro-1,1,2,2-tetrafluoroethane	76-14-2	-	-	-	-	-	-	-	-	2.10E+04	mg/m³	6.99E+00	2.10E+04
1,2-Dichloroethane	107-06-2	-	-	-	-	-	-	-	-	8.09E+00	mg/m³	4.04E+00	8.09E+00
1,2-Dichloroethylene	540-59-0	-	-	1.30E+01	ppm[h]	-	-	-	-	2.38E+03	mg/m³	3.96E+00	5.15E+01
1,2-Dichloropropane	78-87-5	-	-	-	-	-	-	-	-	5.08E+02	mg/m³	4.62E+00	5.08E+02
1,3-Dichloropropene	542-75-6	-	-	-	-	-	-	-	-	1.36E+01	mg/m³	4.54E+00	1.36E+01
1,4-Dichloro-2-butene	764-41-0	-	-	-	-	-	-	-	-	7.66E-02	mg/m³	5.11E+00	7.66E-02
1-Chloroethene	75-01-4	-	-	-	-	-	-	1.80E+02	mg/m³	1.28E+01	mg/m³	2.55E+00	1.80E+02
2,2-Dichloropropionic acid	75-99-0	-	-	-	-	-	-	-	-	-	-	-	-
2-Chloropropane	75-29-6	-	-	-	-	-	-	-	-	-	-	-	-
3-Chloropropene (Allyl chloride)	107-05-1	-	-	-	-	3.00E+00	ppm	-	-	9.38E+00	mg/m³	3.13E+00	9.38E+00

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m^3)
Bromochloromethane	74-97-5	-	-	-	-	-	-	-	-	1.06E+03	mg/m^3	5.29E+00	1.06E+03
Bromodichloromethane	75-27-4	-	-	-	-	-	-	-	-	4.00E+00	mg/m^3	6.70E+00	4.00E+00
Bromoethene	593-60-2	-	-	-	-	-	-	-	-	6.56E+01	mg/m^3	4.37E+00	6.56E+01
Bromoform	75-25-2	-	-	-	-	-	-	-	-	1.55E+01	mg/m^3	1.03E+01	1.55E+01
Bromomethane	74-83-9	-	-	-	-	-	-	3.90E+00	mg/m^3	5.82E+01	mg/m^3	3.88E+00	3.90E+00
Carbon tetrachloride	56-23-5	-	-	1.20E+01	ppm	2.00E+01	ppm	1.90E+00	mg/m^3	1.26E+02	mg/m^3	6.29E+00	7.54E+01
Chlorodibromomethane	124-48-1	-	-	-	-	-	-	-	-	6.00E+00	mg/m^3	8.51E+00	6.00E+00
Chlorodifluoromethane	75-45-6	-	-	-	-	-	-	-	-	4.42E+03	mg/m^3	3.53E+00	4.42E+03
Chloroethane	75-00-3	-	-	-	-	-	-	-	-	7.91E+03	mg/m^3	2.64E+00	7.91E+03
Chloroform	67-66-3	-	-	-	-	-	-	1.50E-01	mg/m^3	9.76E+00	mg/m^3	4.88E+00	1.50E-01
Chloromethane	74-87-3	-	-	-	-	-	-	-	-	2.06E+02	mg/m^3	2.06E+00	2.06E+02
Chloropentafluoroethane	76-15-3	-	-	-	-	-	-	-	-	-	-	-	-
cis-1,2-Dichloroethene	156-59-2	-	-	-	-	-	-	-	-	7.92E+02	mg/m^3	3.96E+00	7.92E+02
cis-1,3-Dichloropropene	10061-01-5	-	-	-	-	-	-	-	-	1.13E+01	mg/m^3	4.54E+00	1.13E+01
Cyanogen bromide	506-68-3	-	-	-	-	-	-	-	-	-	-	-	-
Cyanogen chloride	506-77-4	-	-	-	-	-	-	-	-	1.51E-01	mg/m^3	2.51E+00	1.51E-01
Dichlorodifluoromethane	75-71-8	-	-	-	-	-	-	-	-	1.48E+04	mg/m^3	4.94E+00	1.48E+04
Dichlorofluoromethane	75-43-4	-	-	-	-	-	-	-	-	1.26E+02	mg/m^3	4.21E+00	1.26E+02
Dichloromethane	75-09-2					2.00E+02	ppm			6.94E+02	mg/m^3	3.47E+00	6.94E+02
Difluorodibromomethane	75-61-6	-	-	-	-	-	-	-	-	-	-	-	-
Hexafluoroacetone	684-16-2	-	-	-	-	-	-	-	-	2.04E+00	mg/m3	6.79E+00	2.04E+00
Iodomethane	74-88-4	-	-	-	-	2.50E+01	ppm	-	-	1.45E+02	mg/m^3	5.80E+00	1.45E+02
Methylene bromide	74-95-3	-	-	-	-	-	-	-	-	2.50E+02	mg/m^3	7.11E+00	2.50E+02
Pentachloroethane	76-01-7	-	-	-	-	-	-	-	-	3.00E+01	mg/m^3	8.27E+00	3.00E+01
trans-1,2-Dichloroethylene	156-60-5	-	-	-	-	-	-	-	-	4.95E+01	mg/m^3	3.96E+00	4.95E+01
trans-1,3-Dichloropropene	10061-02-6	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroacetic acid	76-03-9	-	-	-	-	-	-	-	-	6.68E+00	mg/m^3	6.68E+00	6.68E+00
Trichlorofluoroethane	27154-33-2	-	-	-	-	-	-	-	-	-	-	-	-
Trichlorofluoromethane	75-69-4	-	-	-	-	-	-	-	-	2.81E+03	mg/m^3	5.61E+00	2.81E+03
Trifluorobromomethane	75-63-8	-	-	-	-	-	-	-	-	1.83E+04	mg/m^3	6.09E+00	1.83E+04
Dioxin and Furan Compounds													
1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin	35822-46-9	-	-	-	-	-	-	-	-	-	-	-	-
1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562-39-4	-	-	-	-	-	-	-	-	-	-	-	-
1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673-89-7	-	-	-	-	-	-	-	-	-	-	-	-
1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin	39227-28-6	-	-	-	-	-	-	-	-	-	-	-	-
1,2,3,4,7,8-Hexachlorodibenzofuran	70648-26-9	-	-	-	-	-	-	-	-	7.50E-03	mg/m^3	1.53E+01	7.50E-03
1,2,3,6,7,8-Hexachlorodibenzo(p)dioxin	57653-85-7	-	-	-	-	-	-	-	-	1.50E-02	mg/m^3	1.60E+01	1.50E-02
1,2,3,6,7,8-Hexachlorodibenzofuran	57117-44-9	-	-	-	-	-	-	-	-	2.50E-03	mg/m^3	1.55E+01	2.50E-03
1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin	19408-74-3	-	-	-	-	-	-	-	-	-	-	-	-
1,2,3,7,8,9-Hexachlorodibenzofuran	72918-21-9	-	-	-	-	-	-	-	-	-	-	-	-
1,2,3,7,8-Pentachlorodibenzo(p)dioxin	40321-76-4	-	-	-	-	-	-	-	-	2.50E-03	mg/m^3	1.46E+01	2.50E-03

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)
1,2,3,7,8-Pentachlorodibenzofuran	57117-41-6	-	-	-	-	-	-	-	-	-	-	-	-
2,3,4,6,7,8-Hexachlorodibenzofuran	60851-34-5	-	-	-	-	-	-	-	-	1.50E-03	mg/m³	1.53E+01	1.50E-03
2,3,4,7,8-Pentachlorodibenzofuran	57117-31-4	-	-	-	-	-	-	-	-	7.50E-05	mg/m³	1.39E+01	7.50E-05
2,3,7,8-Tetrachlorodibenzo(p)dioxin	1746-01-6	-	-	-	-	-	-	-	-	3.50E-03	mg/m³	1.32E+01	3.50E-03
2,3,7,8-Tetrachlorodibenzofuran	51207-31-9	-	-	-	-	-	-	-	-	2.00E-03	mg/m³	1.25E+01	2.00E-03
Dibenzofuran	132-64-9	-	-	-	-	-	-	-	-	-	-	-	-
Octachlorodibenzo(p)dioxin	3268-87-9	-	-	-	-	-	-	-	-	-	-	-	-
Octachlorodibenzofuran	39001-02-0	-	-	-	-	-	-	-	-	-	-	-	-
PCBs													
2,2',3,3',4,4',5- Heptachlorobiphenyl	35065-30-6	-	-	-	-	-	-	-	-	-	-	-	-
2,2',3,4,4',5,5'- Heptachlorobiphenyl	35065-29-3	-	-	-	-	-	-	-	-	-	-	-	-
2,3,3',4,4',5'- Hexachlorobiphenyl	69782-90-7	-	-	-	-	-	-	-	-	-	-	-	-
2,3,3',4,4',5- Hexachlorobiphenyl	38380-08-4	-	-	-	-	-	-	-	-	-	-	-	-
2,3,3',4,4',5,5'- Heptachlorobiphenyl	no cas #	-	-	-	-	-	-	-	-	-	-	-	-
2,3,3',4,4'-Pentachlorobiphenyl	32598-14-4	-	-	-	-	-	-	-	-	-	-	-	-
2,3,4,4',5- Pentachlorobiphenyl	74472-37-0	-	-	-	-	-	-	-	-	-	-	-	-
2',3,4,4',5- Pentachlorobiphenyl	no cas #	-	-	-	-	-	-	-	-	-	-	-	-
2,3',4,4',5- Pentachlorobiphenyl	31508-00-6	-	-	-	-	-	-	-	-	-	-	-	-
2,3',4,4',5,5'- Hexachlorobiphenyl	no cas #	-	-	-	-	-	-	-	-	-	-	-	-
3,3',4,4',5- Pentachlorobiphenyl	no cas #	-	-	-	-	-	-	-	-	-	-	-	-
3,3',4,4',5,5'- Hexachlorobiphenyl	32774-16-6	-	-	-	-	-	-	-	-	-	-	-	-
3,3',4,4'-Tetrachlorobiphenyl	32598-13-3	-	-	-	-	-	-	-	-	-	-	-	-
3,4,4',5-Tetrachlorobiphenyl	70362-50-4	-	-	-	-	-	-	-	-	-	-	-	-
Polychlorinated biphenyls (PCBs)	1336-36-3	4.00E-02	mg/m3	-	-	-	-	-	-	3.00E+00	mg/m³	-	4.00E-02
Phthalates													
Bis(2-ethylhexyl)phthalate (DEHP)	117-81-7	-	-	-	-	-	-	-	-	1.00E+01	mg/m³	1.60E+01	1.00E+01
Butylbenzyl phthalate	85-68-7	-	-	-	-	-	-	-	-	5.00E+02	mg/m³	1.28E+01	5.00E+02
Dibutyl phthalate	84-74-2	-	-	-	-	-	-	-	-	1.50E+01	mg/m³	1.14E+01	1.50E+01
Diethyl phthalate	84-66-2	-	-	-	-	-	-	-	-	1.50E+01	mg/m³	9.08E+00	1.50E+01
Dimethylphthalate	131-11-3	-	-	-	-	-	-	-	-	1.50E+01	mg/m³	7.94E+00	1.50E+01
n-Dioctyl phthalate	117-84-0	-	-	-	-	-	-	-	-	1.50E+02	mg/m³	1.60E+01	1.50E+02
Light Polycyclic Aromatic Hydrocarbons													
2-Chloronapthalene	91-58-7	-	-	-	-	-	-	-	-	6.00E-01	mg/m³	6.65E+00	6.00E-01
2-Methyl naphthalene	91-57-6	-	-	-	-	-	-	-	-	2.00E+01	mg/m³	5.81E+00	2.00E+01
5-Nitroacenaphthene	602-87-9	-	-	-	-	-	-	-	-	-	-	-	-
Acenaphthene	83-32-9	-	-	-	-	-	-	-	-	1.25E+00	mg/m³	6.30E+00	1.25E+00
Acenaphthylene	208-96-8	-	-	-	-	-	-	-	-	2.00E-01	mg/m³	6.22E+00	2.00E-01
Anthracene	120-12-7	-	-	-	-	-	-	-	-	6.00E+00	mg/m³	7.28E+00	6.00E+00
Fluorene	86-73-7	-	-	-	-	-	-	-	-	7.50E+01	mg/m³	6.79E+00	7.50E+01
Indene	95-13-6	-	-	-	-	-	-	-	-	1.42E+02	mg/m³	4.75E+00	1.42E+02
Naphthalene	91-20-3	-	-	-	-	-	-	-	-	7.86E+01	mg/m³	5.24E+00	7.86E+01

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)
Phenanthrene	85-01-8	-	-	-	-	-	-	-	-	2.00E+00	mg/m³	7.28E+00	2.00E+00
Pyrene	129-00-0	-	-	-	-	-	-	-	-	1.50E+01	mg/m³	8.27E+00	1.50E+01
Heavy Polycyclic Aromatic Hydrocarbons													
3-Methylcholanthrene	56-49-5	-	-	-	-	-	-	-	-	1.50E+00	mg/m³	1.10E+01	1.50E+00
5-Methylchrysene	3697-24-3	-	-	-	-	-	-	-	-				
Benzo(a)anthracene	56-55-3	-	-	-	-	-	-	-	-	6.00E-01	mg/m³	9.33E+00	6.00E-01
Benzo(a)pyrene	50-32-8	-	-	-	-	-	-	-	-	7.50E+00	mg/m³	1.03E+01	7.50E+00
Benzo(b)fluoranthene	205-99-2	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(e)pyrene	192-97-2	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	191-24-2	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.13E+01	3.00E+01
Benzo(j)fluoranthene	205-82-3	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	207-08-9	-	-	-	-	-	-	-	-	-	-	-	-
Benzo[a,i]pyrene	191-30-0	-	-	-	-	-	-	-	-	-	-	-	-
Chrysene	218-01-9	-	-	-	-	-	-	-	-	2.00E-01	mg/m³	9.33E+00	2.00E-01
Dibenz(a,h)anthracene	53-70-3	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.14E+01	3.00E+01
Dibenz[a,h]acridine	226-36-8	-	-	-	-	-	-	-	-	-	-	-	-
Dibenz[a,j]acridine	224-42-0	-	-	-	-	-	-	-	-	-	-	-	-
Dibenzo(a,e)fluoranthene	5385-75-1	-	-	-	-	-	-	-	-	-	-	-	-
Dibenzo(a,h)fluoranthene	no cas #	-	-	-	-	-	-	-	-	-	-	-	-
Dibenzo[a,e]pyrene	192-65-4	-	-	-	-	-	-	-	-	-	-	-	-
Dibenzo[a,h]pyrene	189-64-0	-	-	-	-	-	-	-	-	-	-	-	-
Dibenzo[a,i]pyrene	189-55-9	-	-	-	-	-	-	-	-	-	-	-	-
Fluoranthene	206-44-0	-	-	-	-	-	-	-	-	3.00E-02	mg/m³	8.27E+00	3.00E-02
Hexachloronaphthalene	1335-87-1	-	-	-	-	-	-	-	-	2.00E-01	mg/m³	1.37E+01	2.00E-01
Indeno(1,2,3-cd)pyrene	193-39-5	-	-	-	-	-	-	-	-	-	-	-	-
Octachloronaphthalene	2234-13-1	-	-	-	-	-	-	-	-	3.00E-01	mg/m³	1.65E+01	3.00E-01
Pentachloronaphthalene	1321-64-8	-	-	-	-	-	-	-	-	-	-	-	-
Tetrachloronaphthalene	1335-88-2	-	-	-	-	-	-	-	-	-	-	-	-
Trichloronaphthalene	1321-65-9	-	-	-	-	-	-	-	-	-	-	-	-
Light Substituted Benzene Compounds													
1,2,3-Trichlorobenzene	87-61-6	-	-	-	-	-	-	-	-	5.00E+01	mg/m³	7.42E+00	5.00E+01
1,2,4-Trichlorobenzene	120-82-1	-	-	-	-	-	-	-	-	3.71E+01	mg/m³	7.42E+00	3.71E+01
1,2,4-Trimethyl benzene	95-63-6	-	-	-	-	-	-	-	-	1.80E+02	mg/m³	4.91E+00	1.80E+02
1,2-Dichlorobenzene	95-50-1	-	-	-	-	-	-	-	-	3.00E+02	mg/m³	6.01E+00	3.00E+02
1,3,5-Trimethyl benzene	108-67-8	-	-	-	-	-	-	-	-	3.68E+02	mg/m³	4.91E+00	3.68E+02
1,3-Dichlorobenzene	541-73-1	-	-	-	-	-	-	-	-	3.60E+01	mg/m³	6.01E+00	3.60E+01
1,3-Dinitrobenzene	99-65-0	-	-	-	-	-	-	-	-	3.00E+00	mg/m³	6.87E+00	3.00E+00
1,4-Dichlorobenzene	106-46-7	-	-	-	-	-	-	-	-	6.61E+02	mg/m³	6.01E+00	6.61E+02
1,4-Dinitrobenzene	100-25-4	-	-	-	-	-	-	-	-	-	-	-	-
2,4,5-Trichlorophenol	95-95-4	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	8.07E+00	3.00E+01
2,4,6-Trichlorophenol	88-06-2	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	8.07E+00	3.00E+01

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)
2,4-Dichlorophenol	120-83-2	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	6.66E+00	3.00E+01
2,4-Dimethylphenol	105-67-9	-	-	-	-	-	-	-	-	-	-	-	-
2,4-Dinitrophenol	51-28-5	-	-	-	-	-	-	-	-	7.50E+00	mg/m³	7.53E+00	7.50E+00
2,4-Dinitrotoluene	121-14-2	-	-	-	-	-	-	-	-	6.00E-01	mg/m³	7.44E+00	6.00E-01
2,6-Dinitrotoluene	606-20-2	-	-	-	-	-	-	-	-	6.00E-01	mg/m³	7.44E+00	6.00E-01
2-Chlorophenol	95-57-8	-	-	-	-	-	-	-	-	5.25E+00	mg/m³	5.25E+00	5.25E+00
2-Chlorotoluene	95-49-8	-	-	-	-	-	-	-	-	3.88E+02	mg/m³	5.17E+00	3.88E+02
2-Nitrophenol	88-75-5	-	-	-	-	-	-	-	-	-	-	-	-
4,6-Dinitro-o-cresol	534-52-1	-	-	-	-	-	-	-	-	5.00E-01	mg/m³	8.10E+00	5.00E-01
4-Chlorotoluene	106-43-4	-	-	-	-	-	-	-	-	3.88E+02	mg/m³	5.17E+00	3.88E+02
4-Nitrophenol	100-02-7	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	5.69E+00	3.00E+01
alpha-Methylstyrene	98-83-9	-	-	-	-	-	-	-	-	-	-	-	-
Aniline	62-53-3	-	-	8.00E+00[h]	ppm	-	-	-	-	2.28E+01	mg/m³	3.81E+00	3.05E+01
Benzotrichloride	98-07-7	-	-	-	-	-	-	-	-	1.00E-01	mg/m³	7.99E+00	1.00E-01
Benzyl chloride	100-44-7	-	-	-	-	1.00E+00	ppm	2.40E-01	mg/m³	5.17E+00	mg/m³	5.17E+00	5.17E+00
Bromobenzene	108-86-1	-	-	-	-	-	-	-	-	4.81E+01	mg/m³	6.42E+00	4.81E+01
Chlorobenzene	108-90-7	-	-	-	-	-	-	-	-	1.38E+02	mg/m³	4.60E+00	1.38E+02
Cumene	98-82-8	-	-	-	-	-	-	-	-	7.37E+02	mg/m³	4.91E+00	7.37E+02
m-Cresol	108-39-4	-	-	-	-	-	-	-	-	-	-	-	-
n-Butyl benzene	104-51-8	-	-	-	-	-	-	-	-	1.10E+02	mg/m³	5.49E+00	1.10E+02
Nitrobenzene	98-95-3	-	-	-	-	-	-	-	-	1.51E+01	mg/m³	5.03E+00	1.51E+01
n-Propyl benzene	103-65-1	-	-	-	-	-	-	-	-	3.68E+02	mg/m³	4.91E+00	3.68E+02
o-Cresol	95-48-7	-	-	-	-	-	-	-	-	-	-	-	-
o-Dinitrobenzene	528-29-0	-	-	-	-	-	-	-	-	-	-	-	-
o-Nitroaniline	88-74-4	-	-	-	-	-	-	-	-	-	-	-	-
o-Toluidine	95-53-4	-	-	-	-	-	-	-	-	2.63E+01	mg/m³	4.38E+00	2.63E+01
p-Chloroaniline	106-47-8	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	5.21E+00	3.00E+01
p-Cresol	106-44-5	-	-	-	-	-	-	-	-	-	-	-	-
Phenol	108-95-2	-	-	-	-	1.00E+01	ppm	5.80E+00	mg/m³	3.85E+01	mg/m³	3.85E+00	3.85E+01
p-Nitrochlorobenzene	100-00-5	-	-	-	-	-	-	-	-	2.00E+00	mg/m³	6.44E+00	2.00E+00
p-Toluidine	106-49-0	-	-	-	-	-	-	-	-	-	-	-	-
sec-Butyl benzene	135-98-8	-	-	-	-	-	-	-	-	2.74E+01	mg/m³	5.49E+00	2.74E+01
tert-Butyl benzene	98-06-6	-	-	-	-	-	-	-	-	1.10E+02	mg/m³	5.49E+00	1.10E+02
Toluene-2,6-diamine	823-40-5	-	-	-	-	-	-	-	-	-	-	-	-
Trimethyl benzene	25551-13-7	-	-	-	-	-	-	-	-	-	-	-	-
Other Light Semivolatile Compounds													
1,1'-Biphenyl	92-52-4	-	-	-	-	-	-	-	-	4.00E+00	mg/m³	6.30E+00	4.00E+00
1,1-Dimethylhydrazine	57-14-7	-	-	-	-	-	-	-	-	1.84E+00	mg/m³	2.46E+00	1.84E+00
1,2-Dimethylhydrazine	540-73-8	-	-	-	-	-	-	-	-	3.69E+00	mg/m³	2.46E+00	3.69E+00
1,2-Diphenylhydrazine	122-66-7	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	7.53E+00	3.00E+01
1,3-Propane sultone	1120-71-4	-	-	-	-	-	-	-	-	2.50E+00	mg/m³	4.99E+00	2.50E+00

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m^3)
2,4-Toluene diisocyante	584-84-9	-	-	2.00E-02	ppm	-	-	-	-	1.42E-01	mg/m^3	7.12E+00	1.42E-01
2-Chloroacetophenone	532-27-4	-	-	-	-	-	-	-	-	-	-	-	-
2-Propenoic acid	79-10-7	-	-	-	-	2.00E+00	ppm	6.00E+00	mg/m^3	5.89E+00	mg/m^3	2.95E+00	5.89E+00
4,4-Methylenedianiline	101-77-9	-	-	-	-	-	-	-	-	8.10E-01	mg/m^3	8.10E+00	8.10E-01
Acetophenone	98-86-2	-	-	-	-	-	-	-	-	3.00E+01	mg/m^3	4.91E+00	3.00E+01
Benzoic acid	65-85-0	-	-	-	-	-	-	-	-	1.25E+01	mg/m^3	4.99E+00	1.25E+01
Bis(2-chloroethoxy)methane	111-91-1	-	-	-	-	-	-	-	-	-	-	-	-
Bis(2-chloroethyl) ether	111-44-4	-	-	-	-	-	-	-	-	5.85E+01	mg/m^3	5.85E+00	5.85E+01
Chlorocyclopentadiene	41851-50-7	-	-	-	-	-	-	-	-	-	-	-	-
Cyclohexanol	108-93-0	-	-	-	-	-	-	-	-	-	-	-	-
Dichloroisopropyl ether	108-60-1	-	-	-	-	-	-	-	-	6.99E+01	mg/m^3	6.99E+00	6.99E+01
Dichloromethyl ether	542-88-1	-	-	-	-	-	-	-	-	1.41E-02	mg/m^3	4.70E+00	1.41E-02
Dichloropentadiene	no cas #	-	-	-	-	-	-	-	-	-	-	-	-
Dimethyl sulfate	77-78-1	-	-	-	-	-	-	-	-	1.55E+00	mg/m^3	5.16E+00	1.55E+00
Dimethylaniline	121-69-7	-	-	-	-	-	-	-	-	-	-	-	-
di-n-Propylnitrosamine	621-64-7	-	-	-	-	-	-	-	-	2.00E-01	mg/m^3	5.32E+00	2.00E-01
Diphenyl ether	101-84-8	-	-	-	-	-	-	-	-	-	-	-	-
Epichlorohydrin	106-89-8	-	-	5.00E+00	ppm	2.00E+00	ppm	1.30E+00	mg/m^3	7.56E+00	mg/m^3	3.78E+00	1.89E+01
Ethyl Carbamate (urethane)	51-79-6	-	-	-	-	-	-	-	-	-	-	-	-
Ethyl methanesulfonate	62-50-0	-	-	-	-	-	-	-	-	-	-	-	-
Ethylene dibromide	106-93-4	-	-	-	-	-	-	-	-	1.54E+02	mg/m^3	7.68E+00	1.54E+02
Ethylene glycol	107-21-1	-	-	-	-	-	-	-	-	5.07E+01	mg/m^3	2.54E+00	5.07E+01
Ethylene glycol monobutyl ether	111-76-2	-	-	-	-	-	-	1.40E+01	mg/m^3	3.62E+02	mg/m^3	4.83E+00	1.40E+01
Ethylene glycol monoethyl ether acetate	111-15-9	-	-	-	-	-	-	1.40E-01	mg/m^3	8.10E+01	mg/m^3	5.40E+00	1.40E-01
Ethylene thiourea	96-45-7	-	-	-	-	-	-	-	-	1.00E+01	mg/m^3	4.18E+00	1.00E+01
Furfural	98-01-1	-	-	-	-	-	-	-	-	7.85E+00	mg/m^3	3.93E+00	7.85E+00
Maleic hydrazide	123-33-1	-	-	-	-	-	-	-	-	-	-	-	-
Malononitrile	109-77-3	-	-	-	-	-	-	-	-	-	-	-	-
Methyl styrene (mixed isomers)	25013-15-4	-	-	-	-	-	-	-	-	-	-	-	-
Methylhydrazine	60-34-4	-	-	-	-	-	-	-	-	3.77E-01	mg/m^3	1.88E+00	3.77E-01
N,N-Diphenylamine	122-39-4	-	-	-	-	-	-	-	-	3.00E+01	mg/m^3	6.92E+00	3.00E+01
Nitric acid, propyl ester	627-13-4	-	-	-	-	-	-	-	-	-	-	-	-
N-Nitrosodi-n-butylamine	924-16-3	-	-	-	-	-	-	-	-	-	-	-	-
N-Nitrosomorpholine	59-89-2	-	-	-	-	-	-	-	-	3.00E+01	mg/m^3	4.75E+00	3.00E+01
N-Nitroso-N,N-dimethylamine	62-75-9	-	-	-	-	-	-	-	-	2.50E+00	mg/m^3	3.03E+00	2.50E+00
o-Anisidine	90-04-0	-	-	-	-	-	-	-	-	1.50E+00	mg/m^3	5.03E+00	1.50E+00
Oxalic acid	144-62-7	-	-	-	-	-	-	-	-	2.00E+00	mg/m^3	3.68E+00	2.00E+00
Phthalic anhydride	85-44-9	-	-	-	-	-	-	-	-	1.80E+01	mg/m^3	6.05E+00	1.80E+01
p-Phthalic acid	100-21-0	-	-	-	-	-	-	-	-	-	-	-	-
Pyridine	110-86-1	-	-	-	-	-	-	-	-	4.85E+01	mg/m^3	3.23E+00	4.85E+01
Quinoline	91-22-5	-	-	-	-	-	-	-	-	3.17E+00	mg/m^3	5.28E+00	3.17E+00

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)
Quinone	106-51-4	-	-	-	-	-	-	-	-	1.33E+00	mg/m³	4.42E+00	1.33E+00
Safrole	94-59-7	-	-	-	-	-	-	-	-	-	-	-	-
Tetrahydrofuran	109-99-9	-	-	-	-	-	-	-	-	7.37E+02	mg/m³	2.95E+00	7.37E+02
Other Heavy Semivolatile Compounds													
1,2,4,5-Tetrachlorobenzene	95-94-3	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	8.82E+00	3.00E+01
1,3,5-Trinitrobenzene	99-35-4	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	8.71E+00	3.00E+01
2,6-Bis(tert-butyl)-4-methylphenol	128-37-0	-	-	-	-	-	-	-	-	-	-	-	-
2-Cyclohexyl-4,6-dinitrophenol	131-89-5	-	-	-	-	-	-	-	-	-	-	-	-
2-sec-Butyl-4,6-dinitrophenol	88-85-7	-	-	-	-	-	-	-	-	4.50E+00	mg/m³	9.82E+00	4.50E+00
3,3-Dichlorobenzidine	91-94-1	-	-	-	-	-	-	-	-	6.21E+00	mg/m³	1.03E+01	6.21E+00
3,3'-Dimethoxybenzidine	119-90-4	-	-	-	-	-	-	-	-	5.00E+00	mg/m³	9.99E+00	5.00E+00
4-Bromophenylphenyl ether	101-55-3	-	-	-	-	-	-	-	-	-	-	-	-
Ammonium perfluorooctanoate	3825-26-1	-	-	-	-	-	-	-	-	-	-	-	-
Azobenzene	103-33-3	-	-	-	-	-	-	-	-	-	-	-	-
Bis(3-tert-butyl-4-hydroxy-6-methyl-phenyl)sulfide	96-69-5	-	-	-	-	-	-	-	-	-	-	-	-
Captan	133-06-2	-	-	-	-	-	-	-	-	1.50E+01	mg/m³	1.23E+01	1.50E+01
Chlorobenzilate	510-15-6	-	-	-	-	-	-	-	-	2.50E-01	mg/m³	1.33E+01	2.50E-01
Dibutylphosphate	107-66-4	-	-	-	-	-	-	-	-	1.72E+01	mg/m³	8.59E+00	1.72E+01
Dimethyl aminoazobenzene	60-11-7	-	-	-	-	-	-	-	-	7.50E+01	mg/m³	9.21E+00	7.50E+01
Hexachlorobenzene	118-74-1	-	-	-	-	-	-	-	-	7.50E-02	mg/m³	1.16E+01	7.50E-02
Hexachlorobutadiene	87-68-3	-	-	-	-	3.00E+00	ppm	-	-	3.20E+01	mg/m³	1.07E+01	3.20E+01
Hexachlorocyclopentadiene	77-47-4	-	-	-	-	-	-	-	-	2.23E-01	mg/m³	1.11E+01	2.23E-01
Hexachloroethane	67-72-1	-	-	-	-	-	-	-	-	2.90E+01	mg/m³	9.68E+00	2.90E+01
Hexachlorophene	70-30-4	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.66E+01	3.00E+01
Hexamethylene-1,5-diisocyanate	822-06-0	-	-	-	-	-	-	-	-	1.03E-01	mg/m³	6.88E+00	1.03E-01
Mirex	2385-85-5	-	-	-	-	-	-	-	-	7.50E-02	mg/m³	2.23E+01	7.50E-02
Nitrofen	1836-75-5	-	-	-	-	-	-	-	-	-	-	-	-
Pentachlorobenzene	608-93-5	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.02E+01	3.00E+01
Pentachloronitrobenzene	82-68-8	-	-	-	-	-	-	-	-	1.50E+00	mg/m³	1.21E+01	1.50E+00
Pentachlorophenol	87-86-5	-	-	-	-	-	-	-	-	1.50E+00	mg/m³	1.09E+01	1.50E+00
Picric acid	88-89-1	-	-	-	-	-	-	-	-	3.00E-01	mg/m³	9.36E+00	3.00E-01
Pronamide	23950-58-5	-	-	-	-	-	-	-	-	-	-	-	-
Strychnine	57-24-9	-	-	-	-	-	-	-	-	3.00E-01	mg/m³	1.37E+01	3.00E-01
Terphenyls	26140-60-3	-	-	-	-	-	-	-	-	1.25E+00	mg/m³	9.41E+00	1.25E+00
Tributyl phosphate	126-73-8	-	-	-	-	-	-	-	-	6.53E+00	mg/m³	1.09E+01	6.53E+00
Trifluralin	1582-09-8	-	-	-	-	-	-	-	-	7.50E-02	mg/m³	1.37E+01	7.50E-02
Triphenylamine	603-34-9	-	-	-	-	-	-	-	-	-	-	-	-
Herbicides and Organochlorinated Pesticides													
2,4,5-T	93-76-5	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.04E+01	3.00E+01
2,4-D and esters	94-75-7	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	9.03E+00	3.00E+01
4,4-DDD	72-54-8	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.31E+01	3.00E+01

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)
4,4-DDE	72-55-9	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.30E+01	3.00E+01
4,4-DDT	50-29-3	-	-	-	-	-	-	-	-	3.00E+00	mg/m³	1.45E+01	3.00E+00
Aldrin	309-00-2	-	-	-	-	-	-	-	-	7.50E-01	mg/m³	1.49E+01	7.50E-01
alpha-BHC	319-84-6	-	-	-	-	-	-	-	-	7.50E+00	mg/m³	1.19E+01	7.50E+00
beta-BHC	319-85-7	-	-	-	-	-	-	-	-	2.00E+00	mg/m³	1.19E+01	2.00E+00
Chlordane	57-74-9	-	-	-	-	-	-	-	-	1.50E+00	mg/m³	1.67E+01	1.50E+00
Delta-BHC	319-86-8	-	-	-	-	-	-	-	-	-	-	-	-
Dieldrin	60-57-1	-	-	-	-	-	-	-	-	7.50E-01	mg/m³	1.56E+01	7.50E-01
Endothall	145-73-3	-	-	-	-	-	-	-	-	-	-	-	-
Endrin	72-20-8	-	-	-	-	-	-	-	-	3.00E-01	mg/m³	1.56E+01	3.00E-01
gamma-BHC (Lindane)	58-89-9	-	-	-	-	-	-	-	-	1.50E+00	mg/m³	1.19E+01	1.50E+00
Heptachlor	76-44-8	-	-	-	-	-	-	-	-	1.50E-01	mg/m³	1.53E+01	1.50E-01
Isodrin	465-73-6	-	-	-	-	-	-	-	-	-	-	-	-
Methoxychlor	72-43-5	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.41E+01	3.00E+01
Silvex (2,4,5-TP)	93-72-1	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.10E+01	3.00E+01
Toxaphene	8001-35-2	-	-	-	-	-	-	-	-	1.00E+00	mg/m³	1.69E+01	1.00E+00
INORGANICS													
Metals													
Aluminum	7429-90-5	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.10E+00	3.00E+01
Antimony	7440-36-0	-	-	-	-	-	-	-	-	1.50E+00	mg/m³	4.98E+00	1.50E+00
Arsenic	7440-38-2	-	-	-	-	-	-	1.90E-04	mg/m³	3.00E-02	mg/m³	3.06E+00	1.90E-04
Barium	7440-39-3	-	-	-	-	-	-	-	-	1.50E+00	mg/m³	5.61E+00	1.50E+00
Beryllium	7440-41-7	-	-	-	-	-	-	-	-	5.00E-03	mg/m³	3.68E-01	5.00E-03
Bismuth	7440-69-9	-	-	-	-	-	-	-	-	5.00E+00	mg/m³	8.54E+00	5.00E+00
Boron	7440-42-8	-	-	-	-	-	-	-	-	7.50E+00	mg/m³	4.42E-01	7.50E+00
Cadmium	7440-43-9	-	-	-	-	-	-	-	-	3.00E-02	mg/m³	4.59E+00	3.00E-02
Calcium	7440-70-2	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.64E+00	3.00E+01
Chromium (and VI)	18540-29-9	-	-	-	-	-	-	-	-	1.50E+00	mg/m³	2.13E+00	1.50E+00
Cobalt	7440-48-4	-	-	-	-	-	-	-	-	6.00E-02	mg/m³	2.41E+00	6.00E-02
Copper	7440-50-8	-	-	-	-	-	-	1.00E-01	mg/m³	3.00E+00	mg/m³	2.60E+00	1.00E-01
Iron	7439-89-6	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	2.28E+00	3.00E+01
Lead	7439-92-1	-	-	-	-	-	-	-	-	1.50E-01	mg/m³	8.47E+00	1.50E-01
Lithium	7439-93-2	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	2.84E-01	3.00E+01
Magnesium	7439-95-4	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	9.94E-01	3.00E+01
Manganese	7439-96-5	-	-	-	-	-	-	-	-	3.00E+00	mg/m³	2.25E+00	3.00E+00
Mercury	7439-97-6	-	-	-	-	-	-	1.80E-03	mg/m³	1.00E-01	mg/m³	8.20E+00	1.80E-03
Molybdenum	7439-98-7	-	-	-	-	-	-	-	-	1.50E+01	mg/m³	3.92E+00	1.50E+01
Nickel	7440-02-0	-	-	-	-	-	-	6.00E-03	mg/m³	3.00E+00	mg/m³	2.40E+00	6.00E-03
Potassium	7440-09-7	-	-	-	-	-	-	-	-	2.00E+00	mg/m³	1.60E+00	2.00E+00
Rhodium	7440-16-6	-	-	-	-	-	-	-	-	3.00E+00	mg/m³	4.21E+00	3.00E+00

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)
Selenium	7782-49-2	-	-	-	-	-	-	-	-	6.00E-01	mg/m³	3.23E+00	6.00E-01
Silicon	7440-21-3	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	1.15E+00	3.00E+01
Silver	7440-22-4	-	-	-	-	-	-	-	-	3.00E-01	mg/m³	4.41E+00	3.00E-01
Sodium	7440-23-5	-	-	-	-	-	-	-	-	1.50E+02	mg/m³	9.40E-01	1.50E+02
Strontium	7440-24-6	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	3.58E+00	3.00E+01
Tantalum	7440-25-7	-	-	-	-	-	-	-	-	-	-	-	-
Thallium	7440-28-0	-	-	-	-	-	-	-	-	3.00E-01	mg/m³	8.35E+00	3.00E-01
Tin	7440-31-5	-	-	-	-	-	-	-	-	6.00E+00	mg/m³	4.85E+00	6.00E+00
Tungsten	7440-33-7	-	-	-	-	-	-	-	-	1.00E+01	mg/m³	7.51E+00	1.00E+01
Uranium	7440-61-1	-	-	-	-	-	-	-	-	6.00E-01	mg/m³	9.73E+00	6.00E-01
Vanadium	7440-62-2	-	-	-	-	-	-	-	-	7.50E-02	mg/m³	2.08E+00	7.50E-02
Yttrium	7440-65-5	-	-	-	-	-	-	-	-	3.00E+00	mg/m³	3.63E+00	3.00E+00
Zinc	7440-66-6	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	2.67E+00	3.00E+01
Zirconium	7440-67-7	-	-	-	-	-	-	-	-	1.00E+01	mg/m³	3.73E+00	1.00E+01
Non-metals and Anions													
Ammonia/Ammonium	7664-41-7	-		2.50E+01	ppm	2.50E+01	ppm	3.20E+00	mg/m³	1.74E+01	mg/m³	6.96E-01	1.74E+01
Bromide	24959-67-9	-	-	-	-	-	-	-	-	-	-	-	-
Chloride	16887-00-6	-	-	-	-	-	-	-	-	-	-	-	-
Cyanide	57-12-5	-	-	-	-	-	-	-	-	5.00E+00	mg/m³	1.06E+00	5.00E+00
Fluoride	16984-48-8	-	-	-	-	-	-	-	-	7.50E+00	mg/m³	7.76E-01	7.50E+00
Hydroxide	14280-30-9	-	-	-	-	-	-	-	-	-	-	-	-
Iodine	7553-56-2	-	-	-	-	1.00E-01	ppm	-	-	1.04E+00	mg/m³	1.04E+01	1.04E+00
Nitrate	14797-55-8	-	-	-	-	-	-	-	-	3.00E+01	mg/m³	-	3.00E+01
Nitrite	14797-65-0	-	-	-	-	-	-	-	-	-	-	-	-
Phosphate	14265-44-2	-	-	-	-	-	-	-	-	-	-	-	-
Phosphorus	7723-14-0	-	-	-	-	-	-	-	-	3.00E-01	mg/m³	5.06E+00	3.00E-01
Sulfate	14808-79-8	-	-	-	-	-	-	1.20E-01	mg/m³	-	-	-	1.20E-01
Total Sulfur	63705-05-5	-	-	-	-	-	-	-	-	7.50E-01	mg/m³	1.31E+00	7.50E-01
Criteria Pollutants													
Carbon dioxide	124-38-9	-	-	-	-	-	-	-	-	5.40E+04	mg/m³	1.80E+00	5.40E+04
Nitrogen dioxide	10102-44-0	-	-	5.00E-01	ppm	-	-	4.70E-01	mg/m³	3.76E+00	mg/m³	1.88E+00	9.40E-01
Ozone	10028-15-6	-	-	-	-	-	-	1.80E-01	mg/m³	1.96E-01	mg/m³	1.96E+00	1.80E-01
Particulate matter	no cas #	-	-	-	-	-	-	-	-	-	-	-	-
Sulfur dioxide	7446-09-5	-	-	-	-	3.00E-01	ppm	6.60E-01	mg/m³	7.85E-01	mg/m³	2.62E+00	7.85E-01

[a] Provisional acute 1-hour inhalation value, obtained from National Center for Environmental Assessment (NCEA).
[b] Acute exposure guideline level (AEGL-1) values (1-hour averaging time), obtained from EPA Region X, unless otherwise noted.
[c] Emergency Response Planning Guidelines (ERPG-1) values, obtained from http://www.scapa.bnl.gov/scapawl.htm.
[d] Acute reference exposure level (AREL) values, obtained from California EPA (see http://oehha.ca.gov/scientific/relnums.htm).
[e] Temporary Emergency Response Limit (TEEL-1) values, obtained from http://tis.eh.doe.gov/web/chem_safety/teel.html.
[f] Conversion Factor, for converting from ppm to mg/m³, from http://tis.eh.doe.gov/web/chem_safety/teel.html.
[g] Acute Inhalation Exposure Criteria (AIEC) in mg/m³, used to quantify hazard quotients for short term inhalation exposures to COPCs.

Table 4-4. Acute Inhalation Exposure Criteria for COPCs

COPC	CAS Number	NCEA Provis. Value[a]		AEGL-1[b]		ERPG-1[c]		AREL[d]		TEEL-1[e]		Conv. Factor[f]	AIEC[g] (mg/m³)

The following hierarchy was used in selecting the AIEC:

1. Values from NCEA (as provided by EPA Region X)
2. AEGL-1
3. ERPG-1
4. AREL
5. TEEL-1
6. SCAPA-approach.

[h] Acute exposure guideline level (AEGL-1) values (1-hour averaging time), obtained from EPA Federal Register, October 30, 1997 (Volume 62, Number 210).

5. Quantification of Emissions

Following the identification of constituents of potential concern (COPCs) (section 4), emission rates must be estimated for each chemical and radionuclide source. These emission rates will be used along with air dispersion modeling to estimate exposure point concentrations for both human and ecological receptor populations. Emission rates will be estimated for the preliminary risk assessment PRA (section 5.2) and final risk assessment FRA (section 5.3) as described below and in section 3. The primary difference between the PRA and the FRA is the estimation of emission rates. In the PRA, estimation of emission rates relies upon modeling and engineering designs, while the FRA utilizes environmental performance demonstration results to estimate emission rates. Both assessments rely on modeling to estimate exposure point concentrations resulting from these emissions.

5.1. Emission Sources

The SLRA will evaluate potential emissions from three operating conditions as specified by EPA 1998a guidance and defined below:

Stack Emissions – Chemicals and radionuclides released from the waste treatment plant stacks as a result of normal (also known as routine) operations.

Process Upset Emissions – Chemicals and radionuclides released from the waste treatment plant stacks as a result of nonroutine operations (such as a process malfunction). Upset emissions are assumed to be at a greater rate than normal stack emissions because the upset condition is assumed to result in decreased destruction or removal efficiency (DRE) or increased PIC formation. However, upset emissions are for a shorter duration. For the PRA, the conservative assumption that all upset conditions result in increased emission rates for short durations will be used, as described in section 5.2.2.

Fugitive Emissions – Fugitive emissions include chemicals and radionuclides released from the waste treatment plant from all non-stack sources (such as chemical storage areas). EPA guidance includes leaks from the combustion chamber due to "puffs" as a source of fugitive emissions. A "puff" results when a slug of high British Thermal Unit (BTU) waste is burned causing a rapid increase in the formation of combustion gases that exceeds the volume of the combustion chamber. Waste processed by the waste treatment plant will be of uniformly low BTU content.

Potential accidental releases (such as failure of tanks or transportation accidents) will not be included in the SLRA. Accident scenarios are addressed in the hazards analysis and other nuclear and process safety documents.

5.2. Emission Assumptions for the Preliminary Risk Assessment

The PRA will be conducted prior to construction of the waste treatment plant; therefore, no site-specific emission data will be available for the plant. A combination of data from other facilities, process and design information, model data, laboratory studies, and default assumptions will be used to estimate emission rates for COPCs and ROPCs for the PRA. These data, when available, will be published in the Work Plan. Otherwise, they will be published in the PRA report.

5.2.1. Stack Emissions

The following sections describe the waste feed, assumptions associated with the waste feed, and the approaches used for estimating stack emissions for different categories of COPCs and ROPCs. For the PRA different approaches will be used to estimate stack emissions for different categories of COPCs/ROPCs (i.e., COPCs present in waste feed) as described below. Actual emission rate calculations will be developed in the Air Quality Permit Application and especially Appendix B of the three parts of the Application and summarized in section 3 of this Work Plan. Estimated emission rates will be tabulated in Appendix E.

5.2.1.1. COPCs/ROPCs in Waste Feed

The RPP-WTP plant includes four treatment plants: pretreatment, LAW pretreatment, LAW vitrification, and HLW vitrification plants. Offgas from the treatment plants may be combined before exiting the plant stack. The following four waste types will be treated in the RPP-WTP:

- Envelope A. This LAW feed envelope will contain cesium and technetium at concentrations high enough to warrant their removal during pretreatment, to ensure the ILAW glass meets applicable requirements.

- Envelope B. This LAW feed envelope will contain higher concentrations of cesium than Envelope A. Both cesium and technetium will be removed to comply with the specifications for ILAW. This envelope will contain higher concentrations of chlorine, chromium, fluorine and phosphates, and sulfates, than those found in Envelope A, which may limit the rate of waste incorporation into the glass.

- Envelope C. This LAW feed envelope will contain organically complexed strontium and transuranic (TRU) compounds, that will require removal in a processing step unique to this waste envelope. As with Envelopes A and B, cesium and technetium will also require removal in the pretreatment process to ensure that the ILAW specifications can be met.

- Envelope D. HLW feed envelope will be in the form of a slurry containing 10 to 200 grams of solids per liter of slurry. The liquid fraction of the slurry will be comprised on envelope A, B, or C waste, and the solid fraction will be Envelope D waste. Envelope D waste will be delivered via pipeline into a receipt vessel or vessels located in the pretreatment plant.

Waste in Envelopes A, B, and C will be treated by the LAW treatment train. As part of this treatment, solids, cesium, strontium/TRU (Envelope C only), and technetium will be removed from the waste during pretreatment (that is, prior to entering the melter). The amount of waste from each envelope will depend on the sodium content of the waste. Waste Envelope D, which includes the solids, strontium, transuranics, cesium, and technetium removed from Envelopes A, B, and C, will be treated by the HLW treatment train.

Waste feed may vary over the operating lifetime of the waste treatment plant. Initial plans call for the plant to process Envelope B (LAW) waste through the pretreatment system only (that is, without vitrification) and Envelope D (HLW) through the entire process for the first two years. During the next nine years of operation both LAW (Envelopes A, B, and C) and HLW (Envelope D) will be processed through the waste treatment plant.

As a conservative approach, the following assumptions will be used in estimating waste feed rates for the PRA.

- The waste treatment plant will operate at full capacity starting at year 1 (that is, the first two years of reduced throughput will not be accounted for).

- The waste treatment plant will operate at full capacity for the entire 40-year design life of the facility. This assumed operating period is longer than the operating period covered by the current permit application.

- Waste feed volume for years 1 and 2 will be equal to those expected for each year 3 through 40. This is a conservative assumption because the waste feed for years 1 and 2 will actually be less than for each year 3 through 11 and there is no reason to believe that the waste feed volume for the following years 12 through 40 will be any greater.

- Acceptance of waste feed by the waste treatment plant will be based on the feed parameters for which the pretreatment and vitrification processes are designed. The constituent concentrations defined in the waste envelopes represent the maximum anticipated constituent concentrations in the waste feed.

- The concentration of each inorganic COPC and ROPC in the LAW waste used to estimate emission rates for the PRA will be the maximum envelope concentration limits or the maximum concentration reported in the most recent characterization data, whichever is larger. For organics, the COPC concentrations will represent the estimated total mass of total organic carbon (TOC) assumed to be present in the feed less the mass known to be accounted for by chelating agents and simple organic acids.

- The concentration of each COPC and ROPC in the HLW waste used to estimate emission rates for the PRA will be the maximum feed composition limit for this waste. The maximum feed composition limit is conservatively estimated based on:

  - Envelope D concentration limits
  - A maximum solids content of 200 g/L
  - A minimum sodium concentration of 3M
  - An assumption that all of the solids in the waste are present in their oxide form

Measured constituent concentrations reported in the Tank Waste Information Network System (TWINS) Tank Characterization Database (PNL 1998) do not exceed the envelope concentration limits for any constituents.

Emission rate estimates for organic and inorganic COPCs and ROPCs in the waste feed will be estimated as described below.

Organic Chemicals in Waste Feed

Organic chemicals are not the primary component of the waste material to be processed by the waste treatment plant; however, a variety of organic chemicals will be present in the waste material. Table 4-1 identifies the organic COPCs potentially present in the waste feed. The COPCs that are not products of incomplete combustion (PICs) (that is, that are potentially present in the waste feed) will be modeled through the process and treatment train. The COPCs will be used to represent the TOC mass in the waste

feed, less the mass known to be chelating agents or simple organic acids. The TOC mass in the waste feed will be estimated in the following manner.

To maintain a conservative bias in the risk assessment, it is assumed that the waste feed will contain 9% organic carbon. This is more than twice the organic concentration allowable under the BNFL Inc. contract. Samples were collected and analyzed for organic chemicals from two tanks in August 1999 (Klinger et al., 1999). One sample and a duplicate were analyzed from each tank. These two tanks are estimated, by BNFL, to have some of the highest concentrations of organic chemicals in Hanford tank waste. The results of this analysis showed that tank AN107 had higher concentration of organic chemicals. Historical analyses of Hanford tank wastes have revealed that 78% to 99% of TOC can be accounted for by chelating agents and simple organic acids (Campbell et al. 1995). Assuming the most conservative contribution of organic constituents are hazardous constituents, other than chelating agents (22%), the most conservative TOC in the waste feed (9%), and a conservative density of the waste, the estimated worst-case concentration of organic constituents in the waste feed is 29,700 mg/L. This value was compared to the total mass of speciated organic chemicals identified by the analysis of the two samples from Tank AN107 (1 sample and 1 duplicate) by summing the maximum detected concentration of each detected chemical and the maximum detection limit for each non-detected chemical. Based on these results, the total mass of identified organic chemicals is 23.9 mg/L.

The organic COPCs in the waste feed will be used to represent the total TOC mass in the waste feed by using a scaling factor (that is, all detected and non-detected concentrations of each organic constituent are multiplied by a scaling factor of 29,700/23.9).

Once COPC concentrations in the waste feed are established, emission rates will be estimated as follows:

$$E_i = [F_{LAW} \times C_{LAWi} \times (1\text{-}DRE_i)] + [F_{HLW} \times C_{HLWi} \times (1\text{-}DRE_i)]$$

where

E_i = emission rate for chemical i (g/s)
F = LAW or HLW waste feed rate (L/s)
C_i = chemical i concentration in LAW or HLW feed (g/L)
DRE_i = destruction and removal efficiency for chemical i for the total treatment process (%/100)

The DRE will be estimated based on (1) results from bench-scale experiments of the melter technology conducted by The Catholic University of America, Vitreous State Laboratory beginning in November 1998 (Matlock and Pegg 1999), (2) thermodynamic modeling of chemicals not included in the bench-scale experiments, and (3) process and design specifications for the pretreatment process and post-treatment APCS. The DRE value to be used in the PRA will be selected following completion of preliminary thermodynamic modeling and facility design.

This approach for determining DRE is proposed for the following reason: the miscellaneous treatment unit regulations allow flexibility in selecting performance standards by recognizing that the units are not intended to perform all functions specified in the regulations for which specific regulations are applicable (e.g., incinerators). The primary function of vitrification melters is to incorporate dangerous and radioactive constituents into a stable glass form to the extent technically and economically feasible. Asking these vitrification units to perform other functions, such as destruction of organics to an extremely high percentage DRE, places a burden on the units that may impact the ability of the units to perform their primary functions (that is, make acceptable glass). Therefore, it is proposed that the quantities of hazardous organic constituents in the waste feed be investigated (during technology development testing) and the applicable DRE be established that is adequately protective of human health and the environment as defined by the risk assessment process.

Radionuclides in Waste Feed

Table 4-3 lists the ROPCs known or suspected to be present in the waste feed materials. Emission rates for these radionuclides will be estimated based on an assumed maximum radionuclide feed rate and an estimated system removal efficiency (SRE) for the waste treatment plant process. Emission estimates for normal operations will be calculated as:

$$E_i = [F_{LAW} \times C_{LAWi} \times (1\text{-}SRE_i)] + [F_{HLW} \times C_{HLWi} \times (1\text{-}SRE_i)]$$

where

E_i = emission rate for radionuclide *i* (pCi/s)
F = LAW or HLW waste feed rate (L/s)
C_i = radionuclide *i* concentration in LAW or HLW feed (pCi/L)
SRE_i = system removal efficiency for radionuclide *i* (%/100)

The SRE will be estimated based on (1) results from bench-scale experiments of the melter technology conducted by The Catholic University of America, Vitreous State Laboratory in November 1998 (Matlock and Pegg 1999), (2) thermodynamic modeling because experimental SREs will be based on cold surrogates (that is, no radionuclides are used), and (3) process and design specifications for the pretreatment process and post-treatment APCS. This SRE applies across the entire process (pretreatment, vitrification, and offgas). The SRE value to be used in the PRA will be selected following completion of preliminary thermodynamic modeling and facility design.

Inorganics in Waste Feed

Metals and other inorganics will be introduced into the system both as components of the waste stream and as process inputs to the treatment system (such as glass-forming materials including Al_2O_3, Fe_2O_3, and so on). Table 4-2 lists the inorganic COPCs known or suspected to be present in the waste feed and treatment feed materials. Emission rates for these inorganics will be estimated based on an assumed maximum feed rate and estimated SRE for the waste treatment plant process. Emission estimates for normal operations will be calculated as:

$$E_i = [F_{LAW} \times C_{LAWi} \times (1\text{-}SRE_i)] + [F_{HLW} \times C_{HLWi} \times (1\text{-}SRE_i)]$$

where

E_i = emission rate for metal *i* (g/s)
F = LAW or HLW waste feed rate (L/s)
C_i = metal *i* concentration in LAW or HLW feed (g/L)
SRE_i = system removal efficiency for metal *i* (%/100).

Concentrations of the glass formers will be specified by the process design. The SRE will be estimated based on (1) results from bench-scale experiments of the melter technology conducted by The Catholic University of America, Vitreous State Laboratory beginning in November 1998 (Matlock and Pegg 1999), (2) thermodynamic modeling of metals not included in the bench-scale experiments, and (3) process and design specifications for the pretreatment process and post-treatment APCS. This SRE applies across the entire process (pretreatment, vitrification, and offgas). The SRE value to be used in the PRA will be selected following completion of preliminary thermodynamic modeling and facility design.

In the case of mercury, assumptions must be made regarding the chemical speciation of the emissions as well as the total emission rate. The following conservative EPA 1998a default assumptions regarding mercury speciation will be used for the PRA:

Chemical state	% of total mercury exiting the stack
Vapor phase	80
Elemental Mercury (Hg)	(20)
Divalent Hg^{+2}	(60)
Particulate phase	20
Elemental Hg	(0.2)
Divalent Hg^{+2}	(19.8)

It is assumed that elemental mercury would be the form that leaves the stacks. Once settled in moist areas, mercury could be methylated. The fraction of methylmercury in soil is assumed to be 2% and 15%, respectively, in wetland soil and sediment (EPA Region X, 1999). Methylmercury fractions based on data for mesic soils are expected to overestimate methylmercury fractions in Hanford's xeric soils. Under the most conducive conditions for methylation of mercury in the environment, methylmercury seldom is more than a few percent of the inorganic mercury. For example, two different and independent methods concluded that methylmercury represented less than 0.01% of the total mercury in floodplain soils at East Fork Poplar Creek (EFPC) near Oak Ridge, Tennessee. Therefore, a conservative estimate of methylmercury in Hanford soils for the PRA could be 0.1% of total mercury. Measurements taken from wetland soils at EFPC showed methylmercury did not exceed 2.3% of total mercury. Therefore, 15% of total mercury is a conservative estimate of the fraction of methylmercury in sediment and wetland soil at Hanford for the PRA. Methylmercury was less than 0.1% (filtered) and 0.03% (unfiltered) of the total mercury in surface water. Therefore, it is assumed for the PRA that the fraction of methylmercury in Hanford surface water is 1% of total dissolved mercury. If measurements of methylmercury can be found for Hanford media, then they may be used in lieu of the EPA guidance of 2% for soil, 15% for sediment and wetland soil, and 1% for surface water.

Metals may originate from the following sources in addition to the glass forming chemicals and tank waste to be processed:

- Chromium may be associated with refractory material lining the melter
- Copper, nickel, palladium, and zinc may be used as catalysts in the APCS

These metals will be addressed to the extent possible in a quantitative fashion in the PRA.

5.2.1.2. PCDDs/PCDFs

Combustion Emissions Technical Resource Document (CETRED) (EPA 1994b) provides a technical analysis of emissions of polychlorinated dibenzo-p-dioxin (PCDDs)/polychlorinated dibenzofurans (PCDFs) from four types of hazardous waste combustion facilities: cement kilns, lightweight aggregate kilns, incinerators, and industrial boilers. The results of this analysis indicate that the best controlled hazardous waste combustion facilities can generally achieve a PCDD/PCDF emission level of 0.17 ng TEQ/dry standard cubic meter (DSCM) at 7% O_2. The RPP-WTP differs from these combustion facilities in both technology and waste feed. The anticipated MACT standard is 0.2 ng TEQ/DSCM at 7% O_2.

The RPP-WTP will be required to meet the dioxin/furan MACT standard once promulgated. Therefore, the anticipated MACT standard of 0.2 ng TEQ/DSCM at 7% O_2 will be used as the assumed stack concentration for the PRA and converted to an emission rate based on the designed volumetric flow rate of the melter.

Under the current industry-standard dioxin analytical method (EPA method 1613), dioxins in water can be analyzed at a part-per-quadrillion level, whereas dioxins in solid media (such as waste mixtures, soil, fish tissue) can be analyzed at a part-per-trillion level. These analytical limits are higher than many of the human health risk preliminary remediation goals (PRGs) and equivalent to ecological toxicity reference values (TRVs). For example, using data based on the dioxin, 2,3,7,8 TCDD, the PRGs for agricultural land-use scenarios are one order of magnitude lower than the detection limit using EPA method 1613. Thus, under the best analytical conditions (few interferences) the analyses for dioxins in some matrices would not be below levels that might cause unacceptable risk. It should be noted that the PRGs in the example above are based on movement of the dioxin through the food chain into beef, milk, and vegetables. The PRGs based on more direct exposure pathways (such as dermal contact to or ingestion of dioxin-contaminated soils) are higher (that is, part-per-trillion) and are the same order of magnitude that can be analytically achieved. This situation is because the food chain models use bioaccumulation factors and tend to be conservative in the estimation of concentrations after transfers.

Alternatively, ecological TRVs are at or near the same order of magnitude as the analytical detection limits. The lowest TRVs (4E-6 microgram/L) are for freshwater environments, whereas the analytical detection limit in water is around 10E-6 microgram/L. Adherence to laboratory procedures that reduce interferences and do not increase the detection limits would result in dioxin analytical measurements that are comparable to units in the risk characterization for ecological receptors.

Toxics Best Available Control Technology (TBACT) standards (based on a top down assessment of control options as required for the Clean Air Act permitting) will be addressed in separate documents but not the RAWP.

5.2.1.3. Other Products of Incomplete Combustion

Many organic COPCs are not present in the RPP-WTP waste stream. However, they may be present in stack emissions as PICs. Based on emissions testing during the laboratory studies, it is assumed some PICs may be emitted from the waste treatment plant. Indicator PICs, such as chlorinated benzenes, et al., will be modeled using thermodynamic assumptions and models, and results from the laboratory studies. Maximum Achievable Control Technology (MACT) standards may also be used to develop PIC emissions rates. The EPA is committed to establishing technology-based regulations for hazardous air pollutants (HAPs) under the *Clean Air Act* (CAA Amendments of 1990). The EPA process for establishing MACT standards is based on measured emission levels achieved by the best performing facilities.

5.2.1.4. Unknown Emissions

Unknown emissions are the percentage of organic emissions that cannot be quantitatively analyzed during the environmental performance demonstration. Unknown emissions are nearly impossible to estimate for the PRA. However, use of the COPCs to represent the total organic fraction in the waste will address risk concerns associated with unknown emissions.

This methodology results in scaling up estimated waste feed concentrations of each organic COPC by a factor of 1242, which will result in a conservative estimate of emissions and risk. This will also be discussed in the uncertainty section.

5.2.2. Process Upset Conditions

Process upset conditions include periods of startup, shutdown, process malfunction (that is, the unit is operating outside the permitted operating conditions), or equipment failure. Process upset conditions are generally assumed to result in greater than normal stack emissions during the short period of the upset. However, the EPA 1998a has indicated that upsets are not generally expected to significantly increase stack emissions over the lifetime of a facility.

The potential for increased emissions during upset events will be addressed through the application of an upset factor. This upset factor is based on the amount of time the facility is expected to operate in an upset condition, and the estimated magnitude of stack emissions during upset relative to routine operating conditions. The preferred method for estimating this upset factor is through the use of data from existing facilities that have operating conditions similar to the proposed waste treatment plant. The frequency and duration of upset events may be estimated based on EPA 1998a:

- Data from emissions monitoring systems that measure operating parameters such as stack carbon monoxide or oxygen
- Data on combustion chamber, air pollution control system (APCS), or stack gas temperature
- Ratio of automatic waste feed cut-off frequency and duration to operating time
- Variations in the APCS operating conditions

The potential magnitude of emissions during upset events may be estimated based on stack test data collected during upset conditions.

EPA default upset factors represent worst-case conditions and will be used for the PRA unless sufficient process information is available to estimate conservative, site-specific upset factors. These default upset factors are based on the data described above from operating hazardous waste combustion facilities. These default upset factors are expected to over-predict upset emissions from the waste treatment plant for several reasons including:

- Carbon monoxide is frequently used as an indicator of upset conditions, and automatic waste feed cut-offs are often triggered by increased stack gas concentrations of carbon monoxide. However, routine operations such as adjusting waste feed or air intake rates will cause brief spikes in carbon monoxide concentration.
- Test data used for these defaults are based on hazardous waste combustion facilities designed for the destruction of liquid and/or solid organic waste. The technology and waste feed of the RPP-WTP melter are different and less subject to upset than these facilities.
- The waste treatment plant will include a standby offgas treatment system designed to treat emissions during an upset event.

EPA 1998a default upset factors are 2.8 for organic chemicals and 1.45 for metals calculated as shown below:

Organics. A default facility is assumed to operate under upset conditions 20% of the time and stack emissions are assumed to be 10 times greater than normal during this time.

$$\text{Upset Factor} = (0.80)\,(1) + (0.20)\,(10) = 2.8$$

Metals. A default facility is assumed to operate under upset conditions 5% of the time with stack emissions 10 times greater than normal during this time.

$$\text{Upset Factor} = (0.95)\,(1) + (0.05)\,(10) = 1.45$$

EPA has not determined a default upset factor for radionuclides. For the PRA, radionuclides are assumed to behave similarly to metals with an upset factor of 1.45. The same upset factors will be used for both the plausible and worst-case scenarios in the PRA and the FRA.

Site-specific upset factors may be derived based on the following:

- Data describing upset frequency, duration, and impact on emissions from similar melter facilities
- Process design data describing the potential for, and potential impact of, upset conditions at the waste treatment plant

The potential for increased emissions during upset conditions is addressed in section 3. The most likely condition that would result in a process upset in the LAW and HLW melters is a pressure surge in the melters resulting in a "bypass event". Potential emissions associated with bypass events will be evaluated separately from upsets that are due to deteriorated operations. The melter is designed to avoid bypass events through the use of an alternative route for emissions. This alternative route will prevent bypass events unless power is lost. In the event of a complete power failure, a bypass event could occur for a brief time (1 minute or less) until backup power is initiated. In the event of a power failure, the offgas would be released to the confinement cell and exhausted through the cell ventilation HEPA filter or returned to the melter and, then, exhausted through the vessel vent offgas system when power is restored.

5.2.3. Fugitive Emissions

Fugitive emissions include emissions of COPCs to air from any source except the stack. Because of the stringent controls designed to prevent radiation exposures and especially the negative pressures of the processing facilities, it is not anticipated that fugitive emissions will be emitted from either the pretreatment, LAW treatment, or HLW treatment processes. Insignificant amounts of fugitive emissions are anticipated from the materials storage areas that support processing plants as described below.

5.2.3.1. Waste Treatment Processing Facilities

The waste treatment plant ventilation system is being designed to confine all sources of radiation and radiological contamination and, thus, fugitive releases of COPCs to the environment are not anticipated. Confinement will be achieved through a combination of barriers or barrier systems, coupled with a cascade ventilation system that will be designed to conform to stringent nuclear facility ventilation standards.

The key to eliminating fugitive emissions is that the more contaminated areas are maintained at a greater negative pressure with respect to the less contaminated areas. Because of this pressure gradient, no fugitive emissions should be released from the processing plants (pretreatment, LAW pretreatment, LAW vitrification, and HLW vitrification). The air flow from this containment system is HEPA filtered and routed into the LAW and HLW offgas streams for treatment before emission to the environment.

5.2.3.2. Material Storage Systems

There are two storage facilities not directly associated with the main processing plant that have the potential to be minor sources of fugitive emissions: the glass former storage system and the nitric acid storage system.

The glass former storage bins will provide bulk storage for the alumina, boric acid, iron oxide, and similar materials that will be used as part of a recipe to support glass formation in the melters. These materials have no radiological contamination and do not contain COPCs, but very small levels of particulate emissions may occur from periodic refilling of the bins by outside vendors. The storage systems will have baghouses installed to minimize emissions during filling and normal operations.

The wet chemical storage system will be maintained to provide the nitric acid and other bulk chemicals used in operating the process plant. Emissions from this facility are not expected to be significant.

5.3. Measured Emission Rates for the Final Risk Assessment

The FRA will be conducted following construction of the waste treatment plant and completion of the environmental performance demonstration (see BNFL 1999c). Emission rates for the FRA will be estimated based on the environmental performance demonstration results.

The environmental performance demonstration program will be conducted in support of the *RPP-WTP Dangerous Waste Permit Application* (BNFL 1999a) using the "Universal Approach" to permitting described in EPA 1989a. With this approach, a single set of operating conditions is sought for treating a relatively broad range of waste. To establish the set of operating conditions, the following worst-case environmental performance demonstrations will be performed on the LAW vitrification and offgas treatment systems (LAW treatment system), and the HLW vitrification and offgas treatment systems (HLW treatment system):

- Low-temperature test designed to maximize the potential emissions of organic compounds
- High-temperature test designed to maximize the potential emissions of metals

Given that the waste treatment plant will not operate at the extreme limits of its operating envelope all the time, EPA 1998a provides for an additional test condition consisting of normal or average system operating parameters that may be specified in the testing program. If, as a result of the PRA, it appears that estimating potential risks based on emissions from worst-case DRE and/or SRE conditions are overly conservative, the normal operations test will be incorporated into the environmental performance demonstration. The normal operations test condition would be representative of long-term facility operations with equipment settings equivalent to those used during actual waste treatment. If the normal operations test condition is included in the environmental performance demonstration, these results will be compared to those derived under worst-case conditions and will be used for estimating emission rates in the FRA.

5.3.1. Stack Emissions

To minimize the dose to sampling and analytical personnel and to obtain useful detection limits in the environmental performance demonstration, a surrogate waste (performance demonstration feed) will be used to represent tank waste. The performance demonstration feed is a nonradioactive blend of chemicals (including radioactive surrogates), water, and glass-formers designed to mimic waste to be treated by the waste treatment plant spiked with specific principal organic dangerous constituents (PODCs), metals, and

chlorinated compounds. The performance demonstration feed will be formulated to represent worst-case blends of difficult-to-destroy PODCs, metals, and chlorinated compounds. One performance demonstration feed will be developed that will consist of the worst-case constituent concentration conditions for the LAW Envelopes A, B, and C for testing the LAW melter. A second performance demonstration feed will be developed that consists of the worst-case constituent concentration conditions for the HLW Envelope D for testing the HLW melter. The specific makeup of performance demonstration feed will be identified in the *Environmental Performance Test Plan* (BNFL 1999c) and will include surrogates for primary radionuclides.

Sufficient quantities of PODCs, metals, and chlorinated compounds will be part of the performance demonstration feed to measure the following:

- DRE for each PODC
- SRE for the selected metals and radionuclide surrogates
- Gaseous HCl and Cl_2 emissions
- Particulate matter emissions
- Emission rates for PCDDs/PCDFs
- Emission rates of other organic constituents

Chemicals to be spiked in the performance demonstration feed will be selected based on the compound's heat of combustion, thermal stability-based incinerability ranking, predicted behavior based on thermodynamic calculations, the results of small-scale testing and technology demonstrations, and Hanford waste analytical data as described in the *Environmental Performance Demonstration Plan*.

Different approaches will be used to estimate stack emissions for different categories of COPCs as described below.

5.3.1.1. COPCs Identified in Waste Feed

Chemicals and radionuclides present in the waste feed may be present in stack emissions and will be evaluated in the FRA as described below. Emission rates calculated from the measured removal efficiency across the waste treatment plant will be estimated based on the chemical feed rate and DRE/SRE as described previously for the PRA. Chemical feed rates will be estimated as described previously using any new information that may become available after completion of the PRA (such as new concentration data for tank waste, and waste feed information based on updated process designs). The DRE/SRE to be used for the FRA will be based on the performance demonstration results.

Spiked Chemicals (PODCs, metals, radionuclide surrogates). Stack emissions will be estimated from the DRE/SRE demonstrated for these chemicals. The DRE/SRE will be calculated as:

$$\text{DRE/SRE} = [(Q_{feed} - Q_{emission})/Q_{feed}] \times 100$$

where

Q_{feed} = feed rate of the chemical (g/s)

$Q_{emission}$ = emission rate of the chemical at the stack (g/s). The upper confidence limit on the average stack gas concentration will be used. If the chemical is detected in some but not all three of the runs, the detected concentration(s) will be used along with the detection limit for the chemical that was not detected.

The detection limit being used in a situation where chemicals are not detected is the method detection limit (MDL)-derived reported detection limit (RDL) for non-isotope dilution and is consistent with EPA 1998a. For isotope dilution methods where chemicals are not detected, the method or the method-defined estimated detection limit (EDL) is used and is consistent with EPA 1998a.

COPCs in Tank Waste and Included in Performance Demonstration Feed. If the chemical is detected in some but not all stack gas samples, the detected concentration(s) will be used along with the detection limit for the chemical that was not detected. Since the performance demonstration feed will contain worst-case concentrations of COPCs from all three LAW Envelopes, an adjustment may be made for the amount of each envelope to be included in the actual waste feed.

COPCs in Tank Waste but Not Included in Performance Demonstration Feed. Stack emissions will be estimated from the DRE/SRE demonstrated for PODCs or other COPCs. The DRE/SRE will be estimated as described above. The PODCs are intended to represent the most difficult to destroy chemicals. Therefore, the DRE/SRE estimated from other COPCs included in the performance demonstration feed may be used to estimate emissions of more easily destroyed COPCs.

5.3.1.2. PCDDs/PCDFs

Dioxin and furan congeners are not present in the waste treatment plant feed stream. However, they may be present in stack emissions as PICs. PCDDs/PCDFs identified in stack emissions will be evaluated as the upper confidence limit on the average from the three environmental performance demonstration runs. If a congener is detected in some but not all three of the runs, the detected concentration(s) will be used along with the detection limit for the non-detects. PCDDs/PCDFs not identified in stack emissions will be evaluated at their detection limit.

5.3.1.3. Other COPCs

Chemicals not present in waste may be present in stack emissions as PICs and will be evaluated in the FRA as described below.

COPCs Identified in Stack Emissions. For COPCs not present in the tank waste or performance demonstration feed but identified in stack emissions, the lesser of the 95th percentile or maximum stack gas concentration from the environmental performance demonstration will be used to develop the emission rate estimated used in the risk assessment (EPA 1998a). If the chemical is detected in some, but not all three of the runs, the detected concentration(s) will be used along with one-half the detection limit for the non-detect samples in these calculations.

COPCs That Are Potential PICs or Risk Drivers. COPCs that are not present in the tank waste or environmental performance demonstration feed and are not identified in stack emissions during the environmental performance demonstration, but which may be expected in the stack emissions as PICs (based on thermodynamic modeling) or are risk drivers will be evaluated at one-half their detection limit.

COPCs That Are Not Potential PICs or Risk Drivers. COPCs that are not present in the tank waste or environmental performance demonstration feed, are not identified in stack emissions during the environmental performance demonstration, are not expected in the stack emissions as PICs (based on thermodynamic modeling), and are not risk drivers will be assumed to be not present (that is, emission rate = 0).

5.3.1.4. Unidentified Organic Chemicals

The potential emission rate for unidentified organic chemicals will be based on environmental performance demonstration estimates of total organic emissions (TOE). The TOE results will be used to estimate a TOE factor as shown below:

$$F_{TOE} = (TOE_C/\Sigma_i C_i) \times (TOC_{waste}/TOC_{PTF})$$

where

F_{TOE} = total organic emission factor (unitless)
TOE_C = total organic emission concentration (mg/m^3)
C_i = stack concentration of organic $COPC_i$ (mg/m^3)
TOC_{waste} = total organic carbon concentration in waste feed (g/L)
TOC_{PTF} = total organic carbon concentration in performance demonstration feed (g/L).

The equation is from (EPA 1998a, p. 2-10) with a correction factor to account for the use of surrogate feed in the environmental performance demonstration. The TOE factor is corrected for the difference in organic carbon concentration between the actual waste feed and the performance demonstration feed used in the environmental performance demonstration. The TOE factor will be calculated from emission concentration data in the FRA because environmental performance demonstration data will be available at that time. TOC will be an analyte for the test burn. The $\Sigma_i C_i$ includes all compounds not detected at the same concentration assumed for emission rate estimates of these compounds as described above (that is, detection limit, 1/2 detection limit, or zero) and will include any TICs included with the COPCs.

5.3.2. Process Upset Conditions

The potential impact of upset conditions on emission rates will be addressed by using an upset factor as described in section 5.2.2. The upset factors used for the PRA will be reevaluated for the FRA based on any changes in the design of the waste treatment plant process made since the PRA was conducted or additional data than becomes available for similar facilities.

5.3.3. Fugitive Emissions

The potential sources and magnitude of fugitive emissions identified for the PRA (section 5.2.3) will be re-evaluated for the FRA based on the following:

- Changes in the design of the waste treatment plant process made since the PRA was conducted
- Observations during operation of the waste treatment plant during the operational testing period and environmental performance demonstration

Revised fugitive emissions factors will be determined based on the above evaluation.

5.4. Uncertainties in Estimating Emission Rates

The estimation of emissions from the waste treatment plant is an important initial step in the risk assessment. Uncertainties associated with this step will affect the results of the human health and ecological risk assessments.

5.4.1. Uncertainties in Estimating Emission Rates for the Preliminary Risk Assessment

The PRA will be conducted prior to the environmental performance demonstration and is based on the current facility design. This early PRA will result in a high level of uncertainty in the emission rate estimates. This uncertainty will be addressed two ways: first, conservative assumptions will be used in an attempt to ensure that the uncertainty will result in overestimating rather than underestimating emissions; and second, many of the assumptions used will be re-evaluated following construction of the waste treatment plant and environmental performance demonstration. The primary sources of uncertainty in estimating stack and fugitive emissions are described below.

5.4.1.1. Identification of COPCs/ROPCs

The COPC/ROPC list for the SLRA includes all chemicals known or suspected to be present in the tank waste as well as all chemicals known or suspected to be emitted from a wide variety of hazardous waste incinerators. Note that many of the COPCs/ROPCS included in this list will not be emitted from the waste treatment plant.

5.4.1.2. Estimated Concentration of COPCs and ROPCs in Waste Feed

Emission rates will be estimated from the concentration of COPCs and ROPCs in waste feed, waste feed rate, and the DRE/SRE achieved by the treatment process. Emission estimates will be based on high-end estimates of the waste feed concentrations.

5.4.1.3. Waste Feed Rate

The waste treatment plant is assumed to operate at its maximum design throughput capacity for its design life. It will take several years for the plant to reach its full capacity.

5.4.1.4. DRE/SRE

The DRE/SRE of the process will be estimated from the process design, vendor specifications for various process equipment, and laboratory-scale testing of the technology. The use of these data sources may result in an overestimation or underestimation of the actual DRE/SRE capability of the process.

5.4.1.5. Estimated Concentrations of PCDDs/PCDFs and Other PICs

The emission rate for PCDDs/PCDFs assumes that the waste treatment plant will meet the likely MACT standard for these compounds. This standard is based on data from hazardous waste incinerators burning large quantities of chlorinated organic chemicals. The waste treatment plant emissions are expected to be below this standard because the RPP-WTP is much different from an incinerator (that is, the organics in the feed are much lower) and there has been historical restriction on the amount of chlorides introduced to the tank system due to the carbon-steel construction of the tanks.

Emission rates of other PICs will be based on data from surrogate testing, process design, and thermodynamic modeling and mass balance. These data could result in an over or under estimation of PIC emissions.

5.4.1.6. Process Upset Conditions

Process upset conditions include periods of process malfunction. Process upset conditions are generally assumed to result in greater than normal stack emissions during the short period of the upset. However, EPA 1998a has indicated that upsets generally are not expected to significantly increase stack emissions over the lifetime of a facility.

The potential for increased emissions during upset events will be addressed by applying an upset factor. This upset factor is based on the amount of time the waste treatment plant is expected to operate in an upset condition and the estimated magnitude of stack emissions during the upset condition relative to routine operating conditions. The EPA default upset factors are designed to provide a conservative estimate of potential emissions at a variety of hazardous waste incinerators (EPA 1998a). The waste feed and technology used by the RPP-WTP differ from a hazardous waste incinerator, and these default values are expected to overestimate the potential contribution to emissions from process upsets. Conservative upset factors derived from the process design and similar facilities will be used if possible and appropriate.

5.4.1.7. Fugitive Emissions

The potential sources and magnitude of fugitive emissions are estimated based on the waste treatment plant design and conservative assumptions regarding the type and concentration of volatile chemicals in the tank waste. The plant is designed to minimize potential fugitive emissions with most potential emission sources directed toward the stack. The potential impact of fugitive emissions on the uncertainty of the assessment is low.

5.4.2. Uncertainties in Estimating Emission Rates for the Final Risk Assessment

The FRA will be conducted following construction and environmental performance demonstration of the waste treatment plant and will reduce the level of uncertainty in the emission rate estimates. The impacts of the FRA on the primary sources of uncertainty in estimating stack and fugitive emissions are described below.

5.4.2.1. Identification of COPCs

The COPC list will be re-evaluated based on the results of the PRA and the environmental performance demonstration.

5.4.2.2. Estimated Concentration of COPCs and ROPCs in Waste Feed

Emission rates will be estimated from the concentration of COPCs and ROPCs in waste feed, waste feed rate, and the DRE/SRE achieved by the treatment process. The emission estimates will be based on high-end estimates of the waste feed concentrations for the PRA and FRA.

5.4.2.3. Waste Feed Rate

The waste treatment plant is assumed to operate at its maximum design throughput capacity for its design life for both the PRA and FRA unless additional information becomes available to make a more realistic assumption.

5.4.2.4. DRE/SRE

The DRE/SRE of the process will be estimated from the results of the environmental performance demonstration. This estimate will reduce the uncertainty in the assessment. The environmental performance demonstration will utilize worst-case operating conditions to minimize the measured DRE/SRE and maintain the conservative bias of the assessment.

5.4.2.5. Estimated Concentrations of PCDDs/PCDFs and Other PICs

The emission rates of PCDDs/PCDFs and other PICs will be measured during the environmental performance demonstration. The performance demonstration feed will maximize the concentrations of hard-to-destroy and chlorinated organic chemicals to maximize the potential formation of PICs. This process will result in an overestimation of PIC emissions.

5.4.2.6. Unidentified Organics

The FRA will utilize measured concentrations of organic chemicals in stack emissions rather than waste feed concentrations, thus reducing the uncertainty in estimating unidentified organics.

5.4.2.7. Process Upset Conditions

The upset factors used for the PRA will be reevaluated for the FRA based on any changes in the design of the waste treatment plant process, thus reducing the uncertainty in this parameter.

5.4.2.8. Fugitive Emissions

Availability of the completed design and operating information will reduce the uncertainty in this parameter.

5.5. Summary for Quantification of Emissions

The SLRA uses estimated emission rates of the COPCs and ROPCs to calculate exposure concentrations in air and other media (section 6). Estimated emission rates will include potential emissions from the facility stack(s) during normal (routine) operations as well as emissions resulting from nonroutine (upset) events and the few fugitive emissions that may escape from parts of the waste treatment plant other than the stack(s).

The PRA will be conducted prior to construction of the waste treatment plant, therefore, COPC/ROPC emission rates will be estimated based on waste feed data, process and design information, emission data from other facilities, laboratory studies, and default assumptions.

The FRA will be conducted following completion of the environmental performance demonstration. Emission rates for the FRA will be estimated based on the environmental performance demonstration results. The primary difference between the PRA and FRA is the estimation of emission rates.

Chapter 6

6. Environmental Modeling

Environmental modeling refers to four types of models that simulate the route of chemicals and radionuclides from the stack towards human and ecological receptors. Air dispersion modeling is defined first, followed by soil accumulation, biota uptake, and finally surface water and fish modeling.

6.1. Air Dispersion Modeling

Air dispersion modeling will be used to estimate the ambient air quality and deposition rates resulting from the emissions of chemicals and radionuclides during operations of the RPP-WTP. This section provides details of the approach that will be used in this task.

6.1.1. Model Selection

The Industrial Source Complex Short Term Model, Version 3 (ISCST3) (EPA 1995a and EPA 1995b) will be used to evaluate the air quality impacts in the vicinity of the RPP-WTP. This EPA-preferred model (*Guideline on Air Quality Models*, 40 *CFR* Part 51, Appendix W) is generally considered a conservative model for applications such as the SLRA. The model uses emissions source data and hourly meteorological data to estimate ambient air concentrations and deposition rates of gases and particles at locations (receptors) of interest in the vicinity of the facility (EPA 1995a, EPA 1995b, EPA 1998b). The most recent version of the ISCST3 (98226) will be used in this analysis and will be supplemented by EPA *Risk Assessment Guidelines* RAGs Part A and B models for radionuclides. This model has the capability of handling a large number of sources that could occur from a typical industrial source, including point sources (e.g., stacks) and area sources (e.g., fugitive emissions from an open area). However, it is expected that fugitive emissions will be so small that a qualitative evaluation of the near-field environment will suffice.

The ISCST3 model is capable of calculating ambient concentrations and deposition rates under variable terrain conditions. This capability is important in air modeling because the calculation of ambient air concentrations and deposition rates is greatly influenced by the height of the plume above local ground level. Terrain is defined as "complex" if the elevation of the surrounding terrain within the assessment area (up to 50 km for this risk assessment) is above the top of the stack, and "simple" if the terrain is at or below the stack height. EPA has developed specific guidance for use in complex terrain (to avoid the case where the source plume directly impacts elevated terrain), which was previously incorporated in the COMPLEX1 model. The ISCST3 model implements the algorithms from the COMPLEX1 air quality model when complex terrain occurs.

The ISCST3 model will be used to calculate ambient concentrations, and wet and dry deposition rates for COPCs and ROPCs at pre-determined exposure locations. The terrain elevation of each receptor will be included in the model input. Terrain elevations will be obtained from digitized maps of the Hanford Site for receptors located within the site or from U.S. Geological Survey digitized maps for receptors located outside of the site.

6.1.2. Model Parameters

This section discusses the modeling input parameters for the air dispersion and deposition modeling including: emissions data, meteorological data, exposure locations, calculations of deposition rates, and model variable settings.

6.1.2.1. Emissions Source Information

Identification of emission sources and quantification of emission rates for each specific COPC and ROPC was described in section 4.2, "Quantification of Emissions". Other data required for model execution, such as stack heights, stack diameters, stack gas flow velocities, and stack gas temperatures, will be provided in the PRA along with all model output data.

Unit Emission Rates. The ISCST3 model will be run with a unit (normalized) emission rate of 1.0 g/s, which is used as model input to preclude having to run the model with specific emissions for each COPC/ROPC. The relationship between the emission rate from a single source and the air parameter values (air concentrations and depositions) at a particular receptor is linear. Therefore, the normalized concentration and deposition outputs from ISCST3 can be adjusted to the COPC/ROPC-specific air concentrations and deposition rates by using COPC/ROPC-specific emission rates, as illustrated below:

$$COPC_{conc} = ISCST3_{conc} \times (COPC_{er}/Unit_{er})$$

where

$COPC_{conc}$ = COPC/ROPC-specific air concentration at a receptor ($\mu g/m^3$ for COPCs; pCi/m^3 for ROPCs)
$ISCST3_{conc}$ = modeled concentration based on the unit emission rate ($\mu g/m^3$ for COPCs; pCi/m^3 for ROPCs)
$COPC_{er}$ = COPC/ROPC-specific emission rate (g/sec)
$Unit_{er}$ = unit emission rate of 1 g/sec.

Both radiological and chemical decay will be accounted for by use of a decay term:

$$COPC_{conc(t)} = COPC_{conc(0)} \times e^{-\lambda t}$$

where:

COPCconc(t) = COPC/ROPC-specific air concentration at time t (μg/m3)
COPCconc(0) = initial COPC/ROPC-specific air concentration (μg/m3)
e = the base of the natural logarithm, approximately 2.71828
λ = radiological or chemical decay constant (day-1)
t = time elapsed in days since emission of the COPC/ROPC.

where

λ = 0.693/T1/2 and T1/2 is the half-life in days of chemical decay of COPCs (e.g., photooxidation) or radiological decay of ROPCs.

Analysis of Multiple Stacks. Based on the preliminary design of the RPP-WTP, there may be numerous separate stacks (LAW and HLW Vitrification System Stacks, Pretreatment Stack, and separate abated fugitive emissions stacks). If the stacks are located close together and have identical characteristics (stack heights, operating parameters, COPC/ROPC-specific emission rates), then a single model run may be used to represent the stacks. However, it is expected that each stack will need to be modeled separately using the ISCST3 model, because the COPC/ROPC-specific emission rates are likely to vary between stacks, and the stacks may have different elevations or emission characteristics. Thus, at a given receptor, one stack may be the main contributor of ambient concentrations and deposition rates of some COPCs/ROPCs, while another stack would be the primary contributor of other COPCs/ROPCs.

Assuming that the RPP-WTP has more than one stack, each source will be modeled separately using the ISCST3 model. The contribution from each source to the total COPC/ROPC-specific concentration and deposition rate at a receptor will be combined in a spreadsheet to determine the total COPC/ROPC-specific ambient concentration and deposition rate at each exposure location.

6.1.2.2. Meteorological Data

The ISCST3 model uses hourly meteorological data, along with the emissions data, as one of the two primary input data sets. Five years of comprehensive Hanford Site surface meteorological data collected by the Hanford Site Meteorological Station during the period 1992 to 1997 will be used as input into the model. The Hanford Meteorological Monitoring Network includes a station located at the 200-E area, within 1 mile of the location of the proposed RPP-WTP facility. The air-dispersion modeling uses wind speed, wind direction, and temperature data from that station. Other, less site-specific parameters used by the model, such as precipitation and solar radiation, are collected at the main Hanford Meteorological Station, located approximately 5 miles west-northwest of the RPP-WTP site. The terrain in the vicinity of the RPP-WPP site is relatively flat, with no major topographic features. The close proximity of the monitoring stations to the proposed facility and the lack of terrain obstacles ensure that the collected meteorological data are representative of the site.

The meteorological monitoring station at the 200-E area (near the site of the proposed BNFL facility) is part of the 30-station Hanford Meteorological Monitoring Network, operated by Pacific Northwest National Laboratory (PNNL) for the Department of Energy. The 200-E Station consists of a 10-meter tower, with wind speed and wind direction data collected at the standard 10-meter height and ambient temperature monitored at 2 meters. An on-site data logger collects the data for each parameter, computes 15-minute averages, and transmits these averages to the main Hanford Meteorological Station, where the data are permanently archived. Other data that are less site-specific, such as barometric pressure, precipitation, and solar radiation, are monitored at the main 410-foot Hanford Meteorological Station.

PNNL operates the stations on a daily basis and maintains a comprehensive quality assurance program to ensure the quality of the data collected in the Hanford Meteorological Monitoring Network. Because the risk assessment will be conducted on the concentrations and deposition rates calculated by using the meteorological data from the worst-case year, the ISCST3 model will be run independently with each year of meteorological data.

In addition to the surface meteorological data, upper air data collected during the same period are required to run the ISCST3 model. The upper air data, typically collected twice-daily at selected National Weather Surface (NWS) stations, are used to provide an estimate of the morning and afternoon mixing heights as an input to the model. Although mixing heights computed from -Hanford Site meteorological data would be desirable, the nearest valid upper air data are collected at Spokane, Washington, approximately 125 miles to the northeast of the Hanford Site. The Spokane upper air data should be representative of the Hanford Site, because Spokane is in the same regional climatic area as the Hanford Site. The upper air data are available from the National Climatic Data Center in Asheville, North Carolina, USA.

The screening-level risk assessment will use ISCST3 air quality model to determine the ambient concentrations and deposition rates of COPCs due to the emissions from the RPP-WTP. This model only allows the input of meteorological data from one station, which may result in some uncertainty in the results due to wind direction variations across a large area such as the Hanford Site. This limitation is one of the shortcomings of the ISCST3 model.

However, this is a screening level risk assessment, and EPA has approved the use of ISCST3 as the default model in similar applications. If the results of this risk assessment produce results that are near unacceptable risk levels, then it may be warranted to use a more comprehensive model such as CALPUFF, that allows the use of multiple meteorological data sets.

The *Hanford Site Climatological Data Summary 1997, With Historical Data* (PNNL-11794 UC-603) summarizes the precipitation data collected over the period of record for the Hanford meteorological monitoring stations. The document lists the average number of days per year with precipitation of a specified amount. These data are presented below.

- **Average annual number of days with 0.10 inch of precipitation or more: 23 days**
  [12 of these days (approximately 50 percent) occurred during the months of November through February, in which the precipitation is likely to be in the form of snow]

- **Average annual number of days with 0.25 inch of precipitation or more: 7 days**
  [4 of these days (approximately 50 percent) occurred during the months of November through February, in which the precipitation is likely to be in the form of snow]

- **Average annual number of days with 0.50 inch of precipitation or more: 1 day**

Thus, the extremely dry climate at the Hanford Site (average precipitation is just over 6 inches per year), means that there are very few days in which there is a potential for entrainment of soil due to rainwater splash. Investigation of this mechanism therefore does not appear to be appropriate for this screening level risk assessment.

The ISCST3 model requires the use of additional computer programs, referred to as "preprocessing" programs to format the meteorological data and other input variables into a file that can be used by ISCST3. The two preprocessing programs to be used for this modeling effort are described below.

The MPRM Preprocessing Program. A meteorological preprocessor program must be used to prepare the meteorological data for input into the ISCST3 program. For on-site data, the Meteorological Processor for Regulatory Models (MPRM) is recommended by EPA, and will be used in this risk assessment (EPA 1996a). This model performs the required meteorological formatting, and meshes the Hanford Site data with the NWS upper air data.

In addition to formatting the meteorological data, the MPRM model requires an additional series of input parameters, which are representative of the application site. These are site-specific parameters that can influence the calculated deposition rates, and include:

- Monin-Obukhov length (a measure of atmospheric stability)

- Surface roughness height (a measure of the height of obstacles to wind flow, used to determine how close a particle must be above the ground before it is subject to deposition)

- Noon-time albedo (the fraction of incoming solar radiation that is reflected from the ground at noon, which affects the hourly net heat balance)

- Bowen ratio (a measure of the amount of moisture at the surface, which affects the heat balance)

- Anthropogenic heat flux (surface heating caused by human activity)

- Fraction of net radiation absorbed at the ground (the final component of the radioactive heat balance)

EPA has provided guidance for estimating values for these parameters in the user guides for the MPRM meteorological preprocessing program and the ISCST3 air quality model (EPA 1996a and EPA 1995a and EPA 1995b). Estimated values are provided in these user guides for different land use categories or different vegetative types, depending on the parameter. Values also vary for some parameters by season. The most appropriate value for each parameter by season will be entered into the model input file.

The ISCST3 model requires that the meteorological data set contain no missing records. Any missing data will be substituted using EPA-recommended procedures (Atkinson and Lee 1992).

Building Profile Input Program (BPIP) Preprocessing Program. Building wake effects can have a significant impact on the dispersion of emissions near a stack. The turbulence induced by buildings produces a phenomenon, known as building downwash, in which a stack plume can be brought downward toward the ground much sooner than if the buildings were not there, resulting in localized areas of high emission concentrations.

Consequently, the ISCST3 model contains algorithms for evaluating the potential for downwash. Following EPA guidance (EPA 1998a), all nearby structures with heights of at least 40% of the height of the shortest stack to be modeled will be evaluated for building downwash. The BPIP calculates the maximum crosswind widths of the buildings, which are then input into the ISCST3 model to estimate building wake effects on air dispersion. The required building dimensions (length, height, and width) will be obtained from engineering drawings and used as input in the BPIP preprocessor. The BPIP output file is formatted for direct input into the ISCST3 model.

6.1.2.3. Receptor Data

The impact assessment area, for which COPC/ROPC-specific concentrations and deposition rates will be calculated, will extend out to 50 km in all directions from the RPP-WTP.

Receptor Grid. The ISCST3 model will be run using a Cartesian grid of exposure locations extending out to 50 km from the center of the RPP-WTP. The receptor grid points will be identified using universal transverse mercator coordinates. Receptor grid spacing will be established at 100-m intervals from the RPP-WTP up to a distance of 3 km, at 500-m intervals from 3 to 10 km, at 2-km intervals from 10 to 30 km, and at 4-km intervals from 30 to 50 km (Figure 6-1). As needed, additional modeling runs will be made with a finer grid resolution (50 m) to more precisely identify the locations of maximum impacts.

Discrete Receptors. Additional exposure locations will be evaluated at specific locations identified as potentially sensitive receptors in the human health and ecological risk assessments.

Receptor Elevations. The elevation for each exposure location will be used as input into the ISCST3 model. Elevations for all exposure locations within the Hanford Site will be obtained from digitized maps of the area. Elevations for exposure locations outside the site are available in digital form from the U.S. Geological Survey.

6.1.2.4. Calculation of Deposition Rates

The determination of deposition rates is an important input into the human health and ecological risk assessments being conducted for the RPP-WTP. The ISCST3 model will be used to calculate both wet and dry deposition rates, in addition to ambient concentrations, at each exposure location.

Dry deposition occurs in the absence of precipitation, while wet deposition is influenced by precipitation type and rate. The two types of deposition result from different physical processes and, therefore, must be considered separately.

Dry Deposition. The dry deposition flux, F_d, is calculated as follows:

$$F_d = \chi_d \times v_d$$

where

F_d = dry deposition flux ($\mu g/m^2$-sec)
χ_d = ambient concentration value calculated in ISCST3 ($\mu g/m^3$)
V_d = deposition velocity (m/sec).

The ISCST3 model calculates the deposition velocity from particle diameter, mass fraction, and particle density, which are the data input into the model for each particle size fraction. The calculation of deposition velocities within the ISCST3 model includes the effects of Brownian motion, inertial impaction, and gravitational settling. Particularly for the larger particles, the key parameter governing the rate of dry deposition is the terminal settling velocity. The terminal velocity, in turn, is affected primarily by the particle size and density: large particles have the highest terminal velocities (and therefore the highest deposition rates), and small particles have lower terminal velocities.

It is important to note that particles have a positive terminal settling velocity and, therefore, are subject to dry deposition. The revised (May 15, 1999) ISCST3 model issued by EPA in June 1999 now includes a gas dry deposition algorithm, and consequently the analysis of dry deposition will be extended to gasses through the application of the enhanced ISCST3 model. Solar radiation is a required parameter in the gas dry deposition algorithm and will be obtained from on-site data sets collected by the Hanford Meteorological Monitoring Network.

Wet Deposition. The wet deposition flux, F_w, is calculated by using a scavenging ratio to model the wet removal of particles and gases in the atmosphere. The flux of material to the surface through wet deposition is the product of a scavenging ratio times the ambient air concentration, integrated through the vertical:

$$F_w(x, y) = \int_0^\infty \Lambda \, \chi(x, y, z) \, dz$$

where

F_w = wet deposition flux ($\mu g/m^2$-s)
Λ = scavenging ratio (S^{-1})
χ = concentration ($\mu g/m^3$)

The scavenging ratio is calculated by the following equation:

$$\Lambda = \lambda \times R$$

where

Λ = scavenging ratio (S^{-1})
λ = scavenging coefficient (hr/s-mm)
R = precipitation rate (mm/hr)

The scavenging coefficient appears to depend on a complex combination of the characteristics of the COPC/ROPC (e.g., solubility and reactivity for gases, size distribution for particles) as well as the nature of the precipitation (e.g., liquid or frozen). However, the ISCST3 User's Guide (EPA 1995a) reports that the best fit to the data is a function of particle size. Particle size estimates for emissions through HEPA filters will be used. The two HEPA filters are designed to trap 99.97% of all particulates $\geq$ 0.3 microns (as well as many smaller particles). It will be assumed that particle size is 1 micron. The user guides also provide a figure with the scavenging coefficient, which will be used as one of the wet deposition data inputs into the ISCST3 model. Following EPA guidance, the scavenging coefficient for gases will be based on the scavenging coefficient for the smallest category of particle sizes.

Deposition Rate Calculations. COPC/ROPC emissions can occur in either the vapor or particle phase, and COPCs/ROPCs in both phases are subject to wet and dry deposition utilizing the revised (May 1999) EPA ISCST3 model. Due to the limitations of the ISCST3 model, estimates of deposition rates for all COPCs/ROPCs cannot be made in a single computer run. Three ISCST3 runs must be made: one for vapor phase COPCs/ROPCs, one for particle phase COPCs/ROPCs, and one for particle-bound COPCs/ROPCs. The appropriate phase for each COPC/ROPC will be designated prior to the disposition modeling task.

Particle size is a primary influence on the calculation of both dry and wet deposition of COPCs/ROPCs in the particle phase, as discussed above. Therefore, distribution of particle sizes in the stack emissions at the RPP-WTP is an important input parameter in the ISCST3 model for determining deposition rates. The primary source for obtaining the particle size distributions of emissions will be consultation with the RPP-WTP design engineers and reference to published specifications from control equipment manufacturers. In addition, a review of data from other hazardous waste combustion facilities processes which have similar control equipment may be used to help refine particle size distribution estimates. A final source of particle size distribution data that will be used if necessary, is EPA's generalized particle size distribution for hazardous waste combustion facilities (EPA 1998a), or such information that can come from the HEPA filter literature; e.g., particles < 0.3 μm. It is now planned that a single particle size of $\leq$ one micron will be assumed to be representative for all particles released from the stacks because of the use of HEPA filtration.

6.1.2.5. Model Variable Settings

Model settings used to run the ISCST3 model will follow recommendations in the ISCST3 User's Guide (EPA 1995b), as well as guidance from EPA Region X and the Washington State Departments of Ecology and Health. The standard default regulatory options, unless other options are agreed to, as specified in the ISCST3 User's Guide will be used in the model execution.

Land use information is important to air dispersion modeling. The ISCST3 model has the option to use "rural dispersion coefficients" or "urban dispersion coefficients," depending on the land use categories within 3 km of the RPP-WTP. The Auer method specified in the *Guideline on Air Quality Models* (40 *CFR* Part 51, Appendix W) is used to define local land use for purposes of specifying the appropriate dispersion model coefficients in ISCST3. The land use category for the RPP-WTP PRA will be "rural."

6.1.2.6. Resuspension of Particulate Matter

Wind erosion may cause the resuspension of particulate matter into the atmosphere, which could result in increased inhalation exposure at the site. The methodology used to address this potential pathway was first described in *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination*

Sites, EPA Office of Health and Environmental Assessment, by C. Cowherd, Jr., G. Muleski, P. Englehart, and D. Gillette (1985, EPA/600/8-85/002) and further discussed in *Soil Screening Guidance: Technical Background Document,* EPA Office of Solid Waste and Emergency Response (1996, EPA/540/R95/128).

The technical approach to address the resuspension of particulate matter requires three steps: (1) the estimation of emissions from the site, (2) the estimation of ambient concentrations of resuspended particulate matter, and (3) the estimation of exposure. The estimation of exposure is addressed elsewhere in this work plan; the following outlines the technical approach used to conduct the first two steps.

1 The Estimation of Emissions Resulting from the Resuspension of Particulate Matter

The approach suggested by Cowherd et. al. (1985) assumes that the soil surface at a site is characterized by a large number ("unlimited reservoir") of erodible particles. These surfaces tend to have a relatively low wind speed threshold for wind erosion. Field experiments of erodible soils have shown that the magnitude of particulate emissions was most sensitive to wind speed and surface soil characteristics. The best fit to the experimental data was a function of the cube of the mean annual wind speed, divided by the threshold friction velocity, which is the wind velocity necessary to initiate soil erosion. The threshold friction velocity depends upon characteristics of the local soil, such as the presence of a surface crust, soil moisture content, size distribution of the exposed material, and the presence of nonerodible elements (e.g., vegetation, rocks).

Particulate emissions per square meter due to resuspension are calculated by determining a representative mean wind speed and threshold friction velocity for that site, following guidance provided in the two references cited above. Total emissions due to resuspension at the site are determined by multiplying the emissions per unit area by the total exposed area.

2 The Estimation of Ambient Particulate Concentrations Resulting from the Resuspension of Particulate Matter.

The particulate emissions rate will be used as input into the ISCST3 model to determine the dispersion of resuspended particulate. The areas with emissions will be treated as area sources in the model.

6.1.3. Model Output

The modeled output from ISCST3 will be combined from each source (stack), if available, at each exposure location, so total emissions from the RPP-WTP will be presented at each exposure location. Tables of the results will be provided for use in the risk assessment, both in tabular and electronic form. In addition, plots will be used to graphically represent the concentrations and deposition rates of emissions from the RPP-WTP.

6.1.3.1. Chronic Output

Chronic output from the RPP-WTP, to be evaluated in the risk assessment, will be based on the annual average ambient air concentrations and deposition rates for each COPC/ROPC at each exposure location, as calculated by the ISCST3 model. Five complete sets of annual average concentrations and deposition rates will be calculated, one for each of the five years of meteorological data used as input into the ISCST3 model. The worst-case year, with the highest concentration and deposition, will be used in the risk assessment.

6.1.3.2. Acute Output

The acute output from the RPP-WTP, to be evaluated in the risk assessment, will be based on the highest 1-hour average air concentrations as required by EPA guidance (EPA 1998a) for each COPC/ROPC at each exposure location, as calculated by the ISCST3 model. The use of 1-hour average air concentrations is to support the analysis of worst-case acute effects in the risk assessment. An acute inhalation scenario is recommended in EPA guidance because it is possible for air concentrations of COPCs/ROPCs to significantly exceed the annual average concentration for a brief time and, thus, result in acute effects to receptor populations via inhalation. Because the acute effects are only due to direct inhalation, deposition rates are not important in determining the acute risk. Concentrations in soil and other media reflect long-term deposition of COPCs/ROPCs. The long-term cumulative concentration in these media will be greater than the concentration resulting from any single acute event. Therefore, the acute exposure scenario is only applicable to the inhalation pathway.

The highest 1-hour average concentration will be calculated for the worst-case year. Acute emissions estimates include process upset and fugitive emissions in addition to normal stack emissions as described in section 4.2.1. Acute emission modeling does not include accidental (i.e., catastrophic) releases. Accident scenarios are included in the risk management program under the Clean Air Act.

6.1.3.3. Exposure Point Concentrations

Exposure point concentrations used for estimating dose of COPCs and ROPCs depends on the location of the receptor. The location of the various receptor populations identified for the quantitative risk assessment will correspond to the receptor grid nodes defined during air dispersion modeling (section 6.1.2.3). In keeping with the protective approach used in this risk assessment, the location with the maximum concentration of COPCs/ROPCs will be used in estimating exposure point concentrations. Because the point of maximum concentration may be different for airborne COPCs/ROPCs and COPCs/ROPCs deposited via wet and dry deposition mechanisms, EPA 1998a recommends the following method for selecting the point of maximum concentration. Within each area to be evaluated, receptor grid nodes or exposure locations with the highest modeled unitized value will be identified for each of the following parameters:

- Vapor phase air concentration
- Vapor phase wet deposition rate
- Particle phase air concentration
- Particle phase wet deposition rate
- Particle phase dry deposition rate
- Particle-bound phase air concentration
- Particle-bound phase wet deposition rate
- Particle-bound phase dry deposition rate

The parameters are chosen because COPCs/ROPCs occur in three phases: vapor phase, particle phase, and particle-bound phase. Vapor phase COPCs/ROPCs are transported in the atmosphere as gases, particle phase COPCs/ROPCs are transported as particles, and particle-bound COPCs/ROPCs are transported primarily with the COPC/ROPC condensed (or adsorbed) on the surface of particles.

If all eight of these maxima occur at the same receptor grid node, the receptor will be evaluated at this location. If all eight of these parameters are not at the maxima at the same location, a receptor will be evaluated at the location where each maximum occurs. This could lead to the evaluation of each receptor at eight different locations. However, it is anticipated that all eight parameters will be maximized at three

grid locations or less because the location of highest air concentration and deposition generally occur at the same receptor grid. In summary, if all eight parameters are not at their maxima at the same receptor grid node or exposure location, multiple exposure locations will be evaluated. A single receptor will not be evaluated for concentration maxima occurring at different locations.

6.2. Soil Accumulation Modeling

COPC/ROPC concentrations in soil will be calculated by summing the vapor phase and particle phase of COPCs/ROPCs to the soil (Figure 6-2). Both wet and dry deposition of particles and deposition of vapors will be considered. The calculation of soil concentration also incorporates a term that accounts for loss of COPCs/ROPCs by several mechanisms, including leaching, erosion, runoff, degradation (biotic and abiotic), radiological decay, and volatilization. Loss of COPCs/ROPCs from the soil will be modeled using rates that depend on the physical and chemical characteristics of the soil, such as pH, structure, organic matter content, and moisture content. Equations presented in this section are based on those presented in EPA 1998a. Values for the equation variables are presented in Appendix B-1.

Because soil concentrations may require many years to reach steady state, the equations used to calculate the average soil concentration over the period of deposition are derived by integrating the instantaneous soil concentration equation over the period of deposition. The following equations are the basis for calculating the cumulative soil concentration for carcinogenic COPCs and ROPCs:

For exposure durations that are less than the operating life of the RPP-WTP ($T_x \leq tD$)

$$Cs = \frac{Ds}{ks \times (tD - T_1)} \times \left[\left(tD + \frac{\exp(-ks \times tD)}{ks}\right) - \left(T_1 + \frac{\exp(-ks \times T_1)}{ks}\right)\right]$$

For exposure durations longer than the operating life of the RPP-WTP ($T_1 < tD < T_2$)

$$Cs = \frac{\left(\frac{Ds \times tD - Cs_{tD}}{ks}\right) + \left(\frac{Cs_{tD}}{ks}\right) \times \left(1 - \exp[-ks \times (T_2 - tD)]\right)}{(T_2 - T_1)}$$

The following equation is the basis for calculating the cumulative soil concentration for noncarcinogenic COPCs/ROPCs:

$$Cs = \frac{Ds \times [1 - \exp(-ks \times tD)]}{ks}$$

where

- Cs = Average soil concentration over exposure duration (mass COPC/kg soil)
- Ds = Deposition term (mass COPC/kg soil/yr)
- T_1 = Time period at the beginning of combustion (yr)
- ks = COPC soil loss constant due to all processes (1/yr)
- tD = Time period over which deposition occurs or time period of combustion (yr)
- Cs_{tD} = Soil concentration at time tD (mass COPC/kg soil)
- T_2 = Length of exposure duration (yr).

Calculating the COPC/ROPC soil loss constant (ks) includes consideration of several removal processes that may not occur simultaneously. The constant (ks) will be determined by using the soil's physical, chemical, radiological, and biological characteristics to consider the loss resulting from the following:

- Leaching
- Runoff
- Erosion
- Biotic and abiotic degradation
- Radiological decay
- Volatilization.

The following equation will be used to calculate the soil loss constant ks:

$$ks = ksg + kse + ksr + ksl + kdecay + ksv$$

where

ks	=	COPC/ROPC soil loss constant due to all processes (1/yr)
ksg	=	COPC/ROPC soil loss constant due to biotic and abiotic degradation (1/yr)
kse	=	COPC/ROPC soil loss constant due to soil erosion (1/yr)
ksr	=	COPC/ROPC soil loss constant due to surface runoff (1/yr)
ksl	=	COPC/ROPT soil loss constant due to leaching (1/yr)
kdecay	=	ROPC radiological decay constant (1/yr)
ksv	=	COPC/ROPC soil loss constant due to volatilization (1/yr).

The soil loss constants listed above will be compiled from available sources for each COPC and ROPC. In some cases, the soil loss constant must be calculated based on additional parameters. The equations that describe these processes are presented in Appendix B-2.

The soil loss processes will be considered in the calculation of soil concentrations. A number of soil loss parameters are dependent on the available water, calculated as ($P+I-RO-E_v$), which is related to precipitation (P), irrigation (I), surface runoff (RO), and evapotranspiration (E_v) in the Hanford Site area. Climate in the region results in greater evapotranspiration than precipitation. Therefore, water added to the system to irrigate crops would not generally be available to generate surface runoff or leachate. Because little water is available for soil erosion, surface runoff, and leaching, these processes will have a negligible effect on the concentration of COPCs/ROPCs in soils. Exclusion of these processes is consistent with the conservative screening level approach being used.

The COPC/ROPC loss constant due to volatilization (ksv) will be assumed to be equal to zero as recommended by EPA 1998a. Any volatile COPCs sorbed to particulates would volatilize prior to deposition onto soil. Soil loss constant due to biotic and abiotic degradation (ksg) is presented for a number of COPCs in EPA 1998a and repeated in Appendix B. Where no value is presented in EPA 1998a, additional sources will be consulted prior to release of the final Work Plan. If no value can be obtained for this parameter, it will conservatively be assumed to be equal to zero. See Appendix B-1 for soil loss values for COPCs and ROPCs.

As described previously, soil erosion, surface runoff, leaching, volatilization, and chemical (biotic and abiotic) degradation are not expected to contribute significantly to chemical loss from soil at this site. The primary loss process at this site is radiological decay.

The deposition term (Ds) for the preceding equations will be calculated from the results of the dispersion modeling using the following equation:

$$Ds = \left[\frac{100 \cdot Q}{Z_s \cdot BD}\right] \times \left[F_v \times (315.36 \times Vdv \times Cyv + Dywv) + (Dydp + Dywp) \times (1 - F_v)\right]$$

where

Ds	=	Deposition term (mg COPC/kg soil/yr)
100	=	Units conversion factor (mg-m^2/kg-cm^2)
Q	=	COPC/ROPC emission rate (g/s)
Z_s	=	Soil mixing zone depth (cm)
BD	=	Soil bulk density (g soil/cm^3 soil),
F_v	=	Fraction of COPC air concentration in vapor phase (unitless)
315.36	=	Units conversion factor (m-g-s/cm-mg-yr)
Vdv	=	Dry deposition velocity (cm/s)
Cyv	=	Unitized yearly average air concentration from vapor phase (mg-s/g-m^3)
Dywv	=	Unitized yearly average wet deposition from vapor phase (s/m^2-yr)
Dydp	=	Unitized yearly average dry deposition from particle phase (s/m^2-yr)
Dywp	=	Unitized yearly average wet deposition from particle phase (s/m^2-yr).

In the equations presented above, a number of parameters require additional calculations, which are presented in Appendix B-2. The dry deposition velocity (Vdv) and COPC/ROPC emission rate (Q) will be provided by the air dispersion modeling. Site-specific factors such as soil mixing depth, soil bulk density, available water, and volumetric water content will have values as described below.

The soil mixing depth typically used in the calculations are:

- 1 cm for untilled soil
- 20 cm for tilled soil

These values are consistent with those presented in EPA 1998a. For this risk assessment, the soil mixing depth will conservatively be assumed to be 1 cm.

The soil dry bulk density (SD) used in the calculations will be the value of 1.5 g/cm^3 as recommended in EPA 1998a. Alternatively, if a Hanford Site-specific value can be determined using ASTM Method D2937 (ASTM 1994) and Method D2215 (ASTM 1998) by May 2000, the site-specific value will be used.

The values of the soil volumetric water content (θ_{sw}) will be 0.2 mL/cm^3 recommended by EPA 1998a. Alternatively, if a site-specific value can be determined by May 2000, the site-specific value will be used.

6.3. Terrestrial Plant and Animal Modeling

The modeled concentrations of contaminants in plants consumed by both humans and non-human receptors will be convergent. This is based upon previous stakeholder and tribal nations requests. This is not to say that receptors that ingest whole organisms will be exposed to the same contaminant concentration as receptors that eat only particular organs or tissues of the organism. Whole-body tissue concentrations will be calculated in the human health and ecological risk assessments using identical bioaccumulation factors, ingestion rates, and other parameters, and identical model equations. The

ecological risk assessment will use modeled whole-body concentrations to estimate doses to wildlife receptors.

6.3.1. Plants

The discussion in this section applies to plants for human consumption such as vegetables, as well as plants for animal consumption such as forage (including native plants consumed by browsing animals) and silage plants.

COPC and ROPC concentrations in plants will be estimated for aboveground produce as well as belowground produce. Aboveground produce will be exposed to particulate deposition and vapor phase contamination, as well as root uptake from soil and subsequent transfer to aboveground foliage (Figure 6-3). Aboveground plant parts are categorized as protected (i.e., the plant structure prevents accumulation of contaminants through the deposition and air-to-plant pathways) and unprotected. For example, corn kernels are protected by the husk. Protected plant parts will be limited to grain used as animal feed in this evaluation. All other plant parts for human and animal consumption will be considered unprotected; i.e., not physically shielded from deposition. Belowground produce will only be exposed to contaminants from root uptake.

Concentrations of COPCs/ROPCs in plants will be estimated using the equations presented below as recommended by EPA 1998a. Values for the chemical-specific parameters are presented in Appendix B-1.

6.3.1.1. Aboveground Plants/Direct Deposition

Concentrations of COPCs/ROPCs in aboveground produce due to direct deposition will be calculated using the following equation:

$$Pd = \frac{1{,}000 \times Q \times (1 - F_v) \times [Dydp + (Fw \times Dywp)] \times Rp \times [1 - \exp(-kp \times Tp)]}{Yp \times kp}$$

where

- Pd = Aboveground produce concentration due to wet and dry direct deposition (mass COPC/kg DW)
- 1,000 = Units conversion factor (mg/g)
- Q = COPC/ROPC emission rate (g/s)
- F_v = Fraction of COPC/ROPC in air concentration in vapor phase (unitless)
- Dydp = Unitized yearly average dry deposition from particle phase (s/m^2-yr)
- Fw = Fraction of COPC/ROPC wet deposition that adheres to plant surfaces (unitless)
- Dywp = Unitized yearly wet deposition from particle phase (s/m^2-yr)
- Rp = Interception fraction of the edible portion of plant (unitless)
- kp = Plant surface loss coefficient (1/yr)
- Tp = Length of plant exposure to deposition per harvest or growing season of the edible portion of the ith plant group (yr)
- Yp = Yield or standing crop biomass of the edible portion of the plant (kg DW/m^2).

Parameters representing the interception fraction (Rp), plant surface loss (kp), length of plant exposure (Tp), and crop yield (Yp) may require additional calculations. Values that will be used for each of these parameters are described below and are shown in Table 6-1.

Interception fraction (Rp) depends on the type and productivity of the plant being modeled. EPA 1998a reports interception fractions ranging from 0.053 for exposed fruits to 0.982 for exposed vegetables. The Rp is set to a value of 0.39 as recommended by EPA 1998a for fruits and vegetables consumed by human receptors. This value represents a weighted average Rp based on the relative ingestion rates of fruits and vegetables. Interception fractions of 0.499 for forage (including wild plants consumed by browsing animals) and 0.459 for silage were calculated from the correlation between Rp and productivity provided in EPA 1998a using the parameters below:

	Rp Interception Fraction	γ Constant	Yp Standing Biomass
Forage	0.499	2.88	0.24
Silage	0.459	0.769	0.8

These Rp values are used for estimating deposition onto forage and silage plants.

For chemical COPCs, EPA 1998a recommended value for the surface loss coefficient of 18 (1/yr) will be used in the calculations for chemicals. For radionuclides the surface loss coefficient will be calculated using the following equation:

$$kp = \left(\frac{\ln 2}{t_{1/2}}\right) \times CF$$

where

kp = Plant surface loss coefficient (1/yr)
$t_{1/2}$ = Half-life (days)
CF = Conversion factor of 365 (days/yr)

The value used for the length of edible plant exposure to deposition per harvest (Tp) will be 0.164 yr (60 days) as recommended by EPA 1998a. The EPA 1998a recommended value of 2.24-kg DW/m^2 for the standing crop biomass (Yp) will be used. Alternatively, if a Hanford site-specific length value for edible plant exposure to deposition can be determined by May 2000, the site-specific value will be used.

6.3.1.2. Aboveground Plants/Air-to-Plant Transfer

The concentration of COPCs/ROPCs in aboveground plants due to air-to-plant transfer will be calculated based on the following equation:

$$Pv = Q \times F_v \times \frac{Cyv \times Bv_{ag} \times VG_{ag}}{\rho_a}$$

where

Pv = Concentration of COPC/ROPC in the plant resulting from air-to-plant transfer (μg COPC/g DW)
Q = COPC/ROPC emission rate (g/s)
F_v = Fraction of COPC/ROPC air concentration in vapor phase (unitless)
Cyv = Unitized yearly average air concentration from vapor phase (μg-s/g-m^3)

Bv_{ag} = COPC/ROPC air-to-plant biotransfer factor [(mg COPC/g DW plant)/(mg COPC/g air)]
VG_{ag} = Empirical correction factor for aboveground produce (unitless)
ρ_a = Density of air (g/m^3).

6.3.1.3. Root Uptake

The concentration of COPCs/ROPCs in plants due to uptake from the soil will be calculated for aboveground and belowground plants. Concentrations in aboveground plants will be calculated using the following equation:

$$Pr = Cs \times Br$$

where

Pr = Concentration of COPC\ROPC in produce due to root uptake (mg/kg)
Cs = Average soil concentration over exposure duration (mg COPC/kg soil)
Br = Plant-soil bioconcentration factor for produce (unitless) from EPA 1998a and repeated in Appendix B

For concentrations in belowground plants the following equation will be used:

$$Pr = \frac{Cs \times RCF \times VG_{rootveg}}{Kd_s \times 1}$$

where

Pr = Concentration of COPC/ROPC in produce due to root uptake (mg/kg)
Cs = Average soil concentration over exposure duration (mg COPC/kg soil)
RCF = Root concentration to soil water concentration factor (unitless)
$VG_{rootveg}$ = Empirical correction factor for belowground produce (unitless)
Kd_s = Soil-water partition coefficient (L/kg)
1 = Conversion factor (kg/L)

6.3.2. Animal Tissue, Eggs, and Milk

The concentration of chemical and radiological COPCs/ROPCs in animal tissue (including beef, pork, poultry, and game animals), eggs, and milk products are estimated based on the amount of COPCs/ROPCs that each animal is assumed to consume through its diet from the following sources:

- Forage (primarily pasture grass and hay for domestic animals wild plants for game animals)
- Silage (forage that has been stored and fermented)
- Grain
- Incidental soil ingestion associated with grazing and browsing

The feed items are assumed to be contaminated through the following pathways:

- Direct deposition of particles – wet and dry deposition of particle phase COPCs/ROPCs onto forage, silage, and soil

- Vapor transfer – uptake of vapor phase COPCs/ROPCs in forage and silage

- Root uptake – root uptake of COPCs/ROPCs deposited in soil and subsequent transfer to aboveground plant portions of forage, silage, and grain

Figure 6-4, Figure 6-5 and Figure 6-6 present conceptual models of the sources and pathways that result in animal product contamination.

Concentrations of chemical and radiological COPCs/ROPCs in beef, pork, poultry, eggs, and milk will be estimated using the equations presented below as recommended by EPA 1998a. Values for the chemical-specific parameters are presented in Appendix B-1. Concentrations of COPCs/ROPCs in game animals will be estimated using the equations presented in section 8.2.2.1.

The concentration of COPCs in animal products, except wild game, will be estimated using the following equation:

$$A_j = \left(\sum\left(F_i \times Qp_i \times P_i\right) + Qs \times Cs \times Bs\right) \times Ba_j \times MF$$

where

A_j = Concentration of COPC/ROPC in animal product *j* (mass COPC/kg FW tissue)
F_i = Fraction of plant type *i* grown on contaminated soil and ingested by the animal (unitless)
Qp_i = Quantity of plant type *i* eaten by the animal per day (kg DW plant/day)
P_i = Concentration of COPC/ROPC in each plant type *i* eaten by the animal (mg/kg DW)
Qs = Quantity of soil eaten by the animal each day (kg/day)
Cs = Average soil concentration over exposure duration (mass COPC/kg soil)
Bs = Soil bioavailability factor (unitless)
Ba_j = COPC/ROPC biotransfer factor for animal product *j* (day/kg FW tissue)
MF = Metabolism factor (unitless).

The fraction of each plant type grown on contaminated soil and ingested by the animal (F_i) will be 1.0 (100%), as recommended by EPA 1998a. Values for P_i and C*s* in the above equation will be calculated, using appropriate equations as previously discussed. Biotransfer factors (Ba) from EPA 1998a will be used. Values for Qp, Qs, Bs, and MF are shown in Table 6-2; these values are from EPA 1998a.

Animal products include tissue (beef, pork, poultry, game), dairy products, and eggs. The biotransfer factors used to estimate COPC/ROPC concentrations in meat (fat and muscle) generally do not include transfer to other organ tissues. Chemical-specific biotransfer factors are provided by EPA 1998a. Other parameters are summarized in Table 6-2.

The metabolism factor (MF) represents the estimated amount of COPC that remains in fat and muscle tissue. The MF only affects the concentration of bis(2-ethylhexyl)phthalate since evidence indicates this chemical is more readily metabolized and excreted by mammals than other COPCs. The MF does not apply to poultry or eggs.

6.4. Surface Water and Fish Bioaccumulation Modeling

Estimating the intake of COPCs/ROPCs due to bioaccumulation in fish from surface water contaminants will involve several steps (Figure 6-7). First, the concentration of COPCs/ROPCs in surface water is calculated based on the following:

- Direct deposition into surface water
- Runoff from impervious surfaces within the watershed
- Runoff from pervious surfaces within the watershed
- Soil erosion from the watershed
- Direct diffusion of vapor phase COPCs/ROPCs into the surface water
- Chemical, biological, or radiological transformation of compounds within the surface water body

COPCs/ROPCs in surface water and fish will be estimated using the equations presented below as recommended by EPA 1998a. Values for the chemical-specific parameters are presented in Appendix B-1. It should be noted that the Hanford Surface Environmental Surveillance Program collects and analyzes fish tissues in the Hanford Reach of the Columbia River. However, the SLRA will be conducted prior to release of emissions from the RPP-WTP; therefore, the data collected could not represent contamination contributed for the RPP-WTP and cannot be used to calibrate the fish model.

Finally, ROPCs will be evaluated using similar equations to those presented for COPCs.

The equation used to quantify the total COPC/ROPC load to the surface water body is as follows:

$$L_T = L_{dep} + L_{dif} + L_{ri} + L_{rp} + L_e + L_{transform}$$

where

L_T	=	Total COPC/ROPC load to the water body, including deposition, runoff, and erosion (g/yr)
L_{dep}	=	Total wet and dry particulate deposition and wet vapor deposition of COPC directly to water body (g/yr)
L_{dif}	=	Vapor phase COPC diffusion (dry deposition) load to water body (g/yr)
L_{ri}	=	Runoff load from impervious surfaces (g/yr)
L_{rp}	=	Runoff load from pervious surfaces (g/yr)
L_e	=	Load due to soil erosion (g/yr)
$L_{transform}$	=	Load due to biological, chemical, and/or radiological transformation within the water body (g/yr).

As discussed previously in section 6.2, evapotranspiration exceeds precipitation in the Hanford Site area, resulting in insufficient water available to cause significant erosion or runoff of COPCs/ROPCs. Therefore, the terms for runoff from pervious (L_{rp}), impervious surfaces (L_{ri}), and erosion (L_e) will not be quantified in the above equation. It should be noted that exclusion of these minor processes from the surface water calculations does not result in loss of contaminated material. This material is accounted for in the soil calculations where it is assumed no chemicals are lost due to erosion or runoff. Due to limited data and uncertainty associated with the chemical or biological internal transfer of compounds into daughter products, $L_{transform}$ will be assigned the default value of zero, as recommended by EPA 1998a. Therefore, the only terms quantified are L_{dep} and L_{dif}.

Total wet and dry particulate deposition and wet vapor deposition of COPCs/ROPCs directly to the waterbody (L_{dep}) will be calculated with the following equation:

$$L_{dep} = Q \times [F_v \times Dywwv + (1 - F_v) \times Dytwp] \times A_w$$

where

L_{dep} = Total (wet and dry) particle phase and wet vapor phase COPC/ROPC direct deposition load to water body (g/yr)
Q = COPC/ROPC emission rate (g/s)
F_v = Fraction of COPC/ROPC air concentration in vapor phase (unitless)
Dywwv = Unitized yearly (water body) average wet deposition from vapor phase (s/m^2-yr)
Dytwp = Unitized yearly (water body) average total (wet and dry) deposition from particle phase (s/m^2-yr)
A_w = Water body surface area (m^2).

Emission rates are modeled (see section 4.2); F_v is chemical-specific; A_w is site-specific; and Dywwv and Dytwp are modeled air parameters.

The vapor phase COPC/ROPC diffusion (dry deposition) load to the water body (L_{dif}) will be calculated with the following equation:

$$L_{dif} = \frac{K_v \times Q \times F_v \times Cywv \times A_w \times CF}{\frac{H}{R \times T_{wk}}}$$

where

L_{dif} = Vapor phase COPC/ROPC diffusion (dry deposition) load to water body (g/yr)
K_v = Overall COPC/ROPC transfer coefficient (m/yr)
Q = COPC/ROPC emission rate (g/s)
F_v = Fraction of COPC/ROPC air concentration in vapor phase (unitless)
Cywv = Unitized yearly (water body) average air concentration from vapor phase (μg-s/g-m^3)
A_w = Water body surface area (m^2)
CF = Conversion factor of 1×10^{-6} (g/μg)
H = Henry's Law constant (atm-m^3/mol)
R = Universal gas constant (atm-m^3/mol-K)
T_{wk} = Water body temperature (K).

Emission rates (Q) and Cywv are modeled values; A_w is site-specific; F_v, H, and R are chemical-specific values; and EPA 1998a recommends a value of 298°K for T_{wk}.

Total water body COPC/ROPC concentration (C_{wtot}) will be calculated with the following equation:

$$C_{wtot} = \frac{L_T}{Vf_x \times f_{wc} + k_{wt} \times A_W \times (d_{wc} + d_{bs})}$$

where

C_{wtot} = Total water body of COPC/ROPC concentration in g COPC/m^3 water body
L_T = Total COPC/ROPC load to the water body (g/yr)
Vf_x = Average volumetric flow rate through the water body (m^3/yr)
f_{wc} = Fraction of total water body COPC/ROPC concentration in the water column (unitless)
k_{wt} = Overall total water body COPC/ROPC dissipation rate constant (1/yr)
A_W = Water body surface area (m^2)

d_{wc} = Depth of water column (m)
d_{bs} = Depth of upper benthic sediment layer (m).

The total load to the water body (L_T) is calculated (see previous equation); and Vf_x, A_W, and d_{wc} are site-specific; d_{bs} will be 0.03, as recommended by EPA 1998a; equations for f_{wc} and k_{wt} appear in Appendix B-2.

Total COPC/ROPC concentration in the water column (C_{wctot}) will be calculated with the following equation:

$$C_{wctot} = f_{wc} \times C_{wtot} \times \frac{d_{wc} + d_{bs}}{d_{wc}}$$

where

C_{wctot} = Total COPC/ROPC concentration in water column (mg COPC/L water column)
f_{wc} = Fraction of total water body COPC/ROPC concentration, in the water column (unitless)
C_{wtot} = Total water body COPC/ROPC concentration including water column and bed sediment (mg COPC/L water body)
d_{wc} = Depth of water column (m)
d_{bs} = Depth of upper benthic sediment layer (m).

Equations for f_{wc} are found in Appendix B-2; C_{wtot} is calculated (see previous equation); d_{wc} is site-specific; and d_{bs} is 0.03 as recommended by EPA 1998a.

The dissolved phase COPC/ROPC water concentration (C_{dw}) will be calculated with the following equation:

$$C_{dw} = \frac{C_{wctot}}{1 + Kd_{sw} \times TSS \times CF}$$

where

C_{dw} = Dissolved phase water concentration (mg COPC/L water)
C_{wctot} = Total COPC/ROPC concentration in water column (mg COPC/Lwater column)
Kd_{sw} = Suspended sediment/surface water partition coefficient (L water/kg suspended sediment)
TSS = Total suspended sediment concentration (mg/L)
CF = Conversion factor of 1×10^{-6} (kg/mg).

C_{wctot} is calculated (see previous equation); Kd_{sw} is chemical-specific; and TSS is site-specific (see Appendix B-2 if measured data are not available).

The COPC/ROPC concentration sorbed to bed sediment (C_{sb}) will be calculated with the following equation:

$$C_{sb} = f_{bs} \times C_{wtot} \times \left(\frac{Kd_{bs}}{\theta_{bs} + Kd_{bs} \times C_{BS}} \right) \times \left(\frac{d_{wc} + d_{bs}}{d_{bs}} \right)$$

where

C_{sb} = COPC/ROPC concentration sorbed to bed sediment (mg COPC/kg sediment)
f_{bs} = Fraction of total water body COPC/ROPC concentration in benthic sediment (unitless)
C_{wtot} = Total water body COPC/ROPC concentration, including water column and bed sediment (mg COPC/L water body)
Kd_{bs} = Bed sediment/sediment pore water partition coefficient (L COPC/kg water body)
θ_{bs} = Bed sediment porosity (Lpore water/Lsediment)
C_{BS} = Bed sediment concentration (g/cm^3)
d_{wc} = Depth of water column (m)
d_{bs} = Depth of upper benthic layer.

The equation for f_{bs} and θ_{bs} are found in Appendix B-2; C_{wtot} is calculated (see previous equation); Kd_{bs} is chemical-specific; C_{BS} and d_{wc} are site-specific; and d_{bs} is 0.3, as recommended by EPA 1998a.

After calculating COPC/ROPC concentrations in the water column and benthic sediments, the concentration in fish tissue will be calculated. The fish concentration due to dissolved phase water concentrations will be calculated using bioconcentration factors (BCF) for COPCs with a log K_{ow} less than 4:

$$C_{fish} = C_{dw} \times BCF_{fish}$$

where

C_{fish} = Concentration of COPC in fish (mg COPC/kg FW tissue)
C_{dw} = Dissolved phase water concentration (mg COPC/L)
BCF_{fish} = Bioconcentration factor for COPC in fish (L/kg).

With the exception of extremely hydrophobic compounds such as dioxins, furans, and PCBs, fish tissue concentrations of COPCs with log K_{ow} greater than 4 will be calculated using bioaccumulation factors (BAF):

$$C_{fish} = C_{dw} \times BAF_{fish}$$

where

C_{fish} = Concentration of COPC in fish (mg COPC/kg FW tissue)
C_{dw} = Dissolved phase water concentration (mg COPC/L)
BAF_{fish} = Bioaccumulation factor for COPC in fish (L/kg FW tissue).

Extremely hydrophobic compounds such as dioxins, furans, and PCBs are expected to be sorbed to bed sediments but not suspended particulate and will bioaccumulate from the benthic sediment layer into fish tissue. The following equation will be used to estimate fish tissue concentrations (C_{fish}) for hydrophobic compounds:

$$C_{fish} = \frac{C_{sb} \times f_{lipid} \times BSAF}{OC_{sed}}$$

where

C_{fish} = Concentration of COPC in fish (mg COPC/kg FW tissue)
C_{sb} = Concentration of COPC sorbed to bed sediment (mg COPC/kg bed sediment)
f_{lipid} = Fish lipid content (unitless)
BSAF = Biota-to-sediment accumulation factors (kg sediment organic carbon/kg fish lipid) (unitless)
OC_{sed} = Fraction of organic carbon in bottom sediment (unitless)

Although there is no explicit guidance for ERAs or how to estimate fish-tissue concentrations from water concentrations (EPA 1992a, 1997c, 1998a; Wentzel et al. 1994), whole-body concentrations in fish also may be calculated using total water-column concentrations (C_{wctot}) and BCFs because fish are exposed to contaminants associated with suspended particulates, as well as dissolved contaminants. The use of whole water concentrations can be justified on procedural and technical grounds. Procedurally, screening-level risk assessments should be conservative. Technically, some BCFs are based on exposures to whole-water contaminant levels. Although dissolved contaminant is more available for uptake by fish than particle-bound contaminant, some uptake from ingestion of contaminated particulates is likely. Furthermore, some published BCFs are likely derived from field data. Field data for fish-tissue COPC concentrations include the transfer from ingested particles to fish. Therefore, calculating fish-tissue concentrations by multiplying the BCF by the whole water concentration gives a more accurate estimate in some cases, as well as a conservative estimate in all cases, as is appropriate to a screening-level risk assessment. Calculating fish tissue concentrations for fish consumed by ecological receptors is presented in section 8.2.3 and the BAFs and BCFs are discussed in section 8.2.4.

6.5. Uncertainties

Uncertainties will be presented in the risk assessment for each aspect of the environmental modeling. This includes air dispersion modeling, soil accumulation modeling, biota modeling, and surface water and fish bioaccumulation modeling. The uncertainty assessment will be presented in the form of both text and tables summarizing the primary contributors and potential magnitude of uncertainties.

A variety of conservative assumptions are used throughout the modeling process to compensate for uncertainties. One limitation of the air dispersion and deposition modeling will result in the overestimation of COPC/ROPC concentrations in all media. This is the double counting of COPCs/ROPCs in air and deposited on soil, plants, and surface water. Air dispersion and deposition components of the modeling are conducted separately. Therefore, when estimating ambient air concentrations for inhalation exposure, the model assumes no loss due to deposition. When estimating deposition, the deposition rate at each point on the receptor grid assumes no loss of COPCs/ROPCs in the air due to deposition at any other grid or receptor location.

6.5.1. Uncertainty in Air Dispersion Modeling

A number of sources of uncertainty exist in the air dispersion modeling, such as:

- input values, such as stack emission characteristics
- meteorological data

Some of these uncertainties are based on the limited data available, such as estimates of the emissions data. Other uncertainties become larger when the model is used at the limits of its normal application, for instance, in very complex terrain or at distances near 50 km.

Uncertainties in the application of the model are reduced when the model is used to calculate longer-term averages (annual averages), and when several years of meteorological data are available to use in the model.

6.5.2. Uncertainty in Soil Accumulation Modeling

Estimating soil concentrations incorporates numerous uncertainties, which are inherent in the assumptions that are the basis for the calculations. Examples of uncertainty in the parameters would be soil mixing depth, soil bulk density, and volumetric water content, which are assigned a single value, but may vary widely over a relatively small area. The concentration of COPCs/ROPCs in soil will be subject to loss due to biotic and abiotic degradation; however, transformation and subsequent increase of secondary COPCs are not considered in the assessment. Transformation of ROPCs and formation of daughter products is included in this assessment through the use of toxicity values that include daughter products.

6.5.3. Uncertainty in Terrestrial Plant and Animal Modeling

Calculation of COPC/ROPC concentration in biota incorporates the uncertainties inherent in calculation of soil concentrations because the soil is one of the sources of COPCs/ROPCs in biota. Uncertainties also arise from the assumption that the location of maximum soil concentration is the location of exposure to biota over a multiple-year period. Additionally, although COPCs/ROPCs are incorporated into plants and animal tissue, it is assumed that the COPC/ROPC concentration in soil does not decrease due to these processes. Assumptions of the animal feed ingestion rates introduces additional uncertainty because they are based on average rates.

Additional pathways such as fugitive dust emission or entrainment of soil in rainwater splash may contribute to COPC/ROPC concentrations in biota. However, no equations are available to quantify these pathways, and this contribution is considered negligible compared to direct deposition and uptake. In addition, the chemical transport through inedible portions of plants (e.g., corn husks) may contribute to COPC/ROPC concentrations in edible portions of plants (e.g., corn kernel). Transfer factors for this type of chemical transport are not available; however, if transfer does occur, it is likely to be negligible.

6.5.4. Uncertainty in Surface Water and Fish Modeling

Uncertainty in the estimation of surface water and fish concentrations of COPCs/ROPCs results from the assumptions used in the calculations. The equations assume the water body reaches a steady-state condition; however, for application to the Columbia River and any other surface water, this is extremely conservative. Additionally, many of the equations used to model the fate of COPCs/ROPCs deposited into the water body greatly simplify the mechanisms occurring within such a dynamic system and may overestimate or underestimate the concentration of COPCs/ROPCs in the surface water. It is also assumed that the maximum deposition of COPCs/ROPCs occurs over the entire depositional area of the water body which is a source of additional uncertainty and conservatism.

The calculation of fish tissue concentrations incorporates the uncertainty inherent in the calculation of surface water concentrations, as well as the following sources. It is assumed that steady-state bioconcentration factors (BCF) for transfer of COPCs/ROPCs from contaminated surface water to fish tissue apply to the Columbia River and any other surface water. Additionally, generic BCF values will be used in the calculations that do not account for variability among specific fish species associated with specific surface water systems. There is uncertainty in assigning COPCs exclusively to either water column or bed sediment for purposes of estimating fish-tissue concentrations as described in the EPA guidance for human health (EPA 1998a). The problem is that this approach to partitioning COPCs in the

aquatic environment may not reflect the multiple pathways by which different kinds of fish are potentially exposed to any given contaminant. The EPA approach estimates fish-tissue concentrations using BCFs and dissolved water concentrations for COPCs with low K_{ow}s; BAFs and whole-water concentrations for COPCs with moderate K_{ow}s; and BAFs and bed-sediment concentrations for COPCs with high K_{ow}s. The uncertainty lies in the source and meaning of the different biotransfer factors used for the different media.

If the EPA (1998a) biotransfer factors do not incorporate all the pathways to all fish from the single medium where each COPC is assumed to predominate, then the exposure will be underestimated. It is unlikely that the EPA transfer factors account for all pathways relevant to all fish. Fish take up contaminants into their tissue via the water in contact with their gills and via the ingestion of water, abiotic particulates, and biota. Some fish will be exposed by primarily one pathway, while others will be exposed over multiple pathways. Dissolved contaminants are primarily taken up across the gill membrane, thus, all fish living in the water column will be exposed to dissolved contaminants. Filter-feeding fish, which usually live in the water column, will also be exposed to contaminants bound to suspended particulates that they filter out of the water and ingest. Sediment-ingesting fish that live in the water column will also be exposed to sediment contaminants by direct ingestion. Predatory fish, which are also water-column dwellers, will also be exposed to dissolved, particulate-bound, and sediment contaminants by ingesting prey that were so exposed, as well as by direct uptake from the water column and ingestion of suspended particulates. In fact, there are probably few fish that are exposed to only dissolved contaminants; perhaps only those that live in the water column and selectively feed on planktonic animals to the exclusion of abiotic particulates. Therefore, assigning each contaminant to a particular class of media (dissolved water, whole water, and bed sediment), based on its tendency to adsorb to particles or organic carbon, potentially neglects pathways from other media. Further discussion of uncertainty related to these pathways is presented in the ecological section.

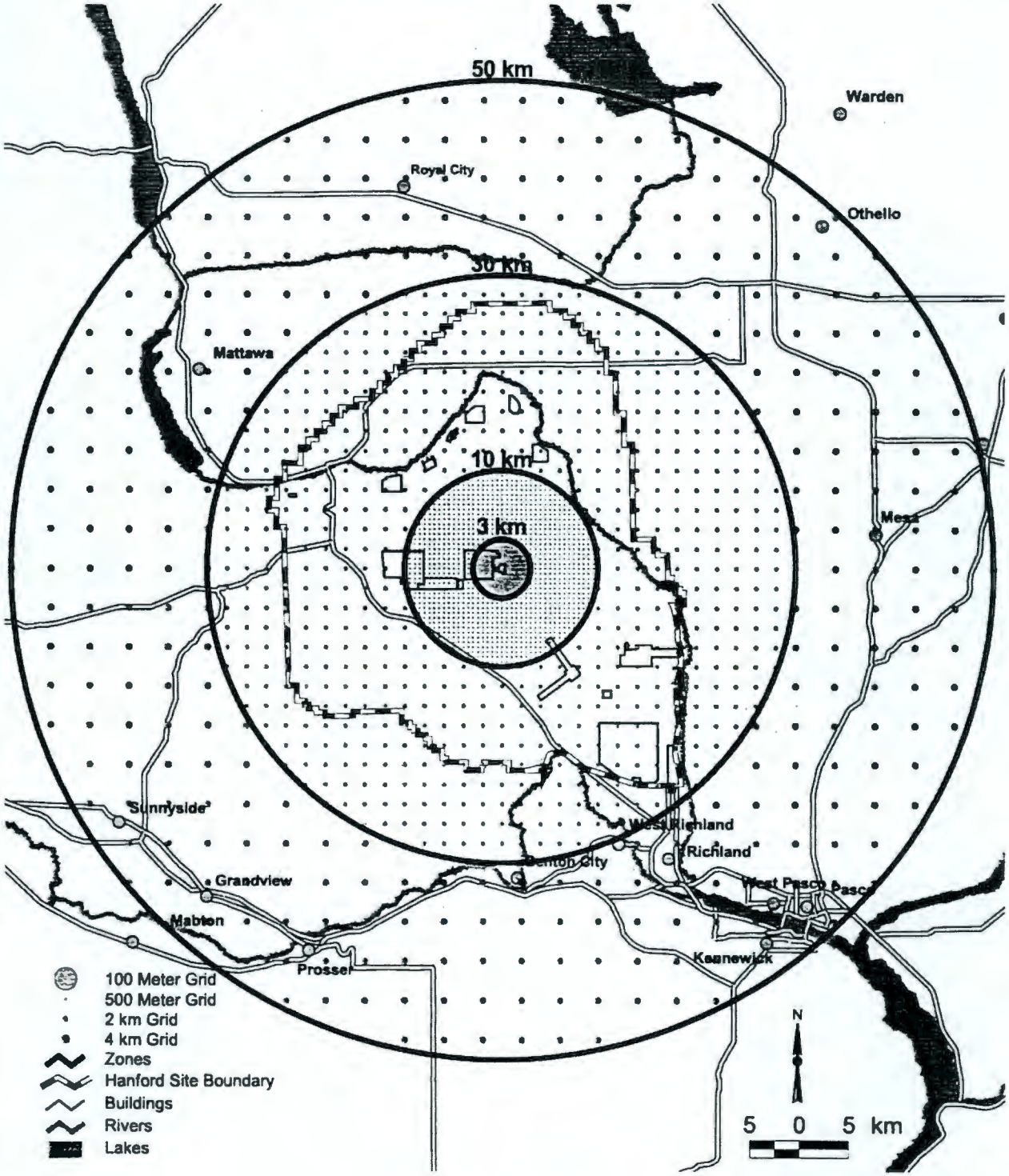
6.6. Summary for Environmental Modeling

Air dispersion modeling will be used to determine COPC/ROPC-specific concentrations and deposition rates resulting from emissions of the RPP-WTP. The assessment area will extend out to 50 km. These results will be used as input into the human health and ecological risk assessments.

The ISCST3 will be used for the air quality modeling task. The RPP-WTP emissions, as determined by the design engineers, and 5 years of Hanford Site meteorological data collected by the Hanford Site Meteorological Station will be used as input into the model. COPC/ROPC-specific concentrations and deposition rates will be calculated at a gridded network of receptors and at specific sensitive receptors identified by the risk assessment analysts.

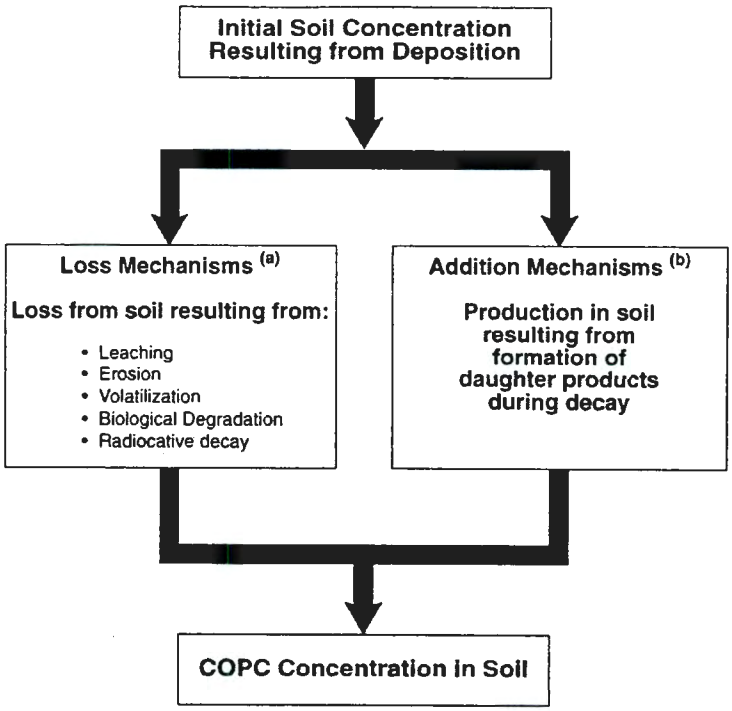
Fate and transport modeling will be used to estimate COPC/ROPC concentrations in various exposure media (air, surface water, fish tissue, soil, animal tissue, eggs, milk, and plants). This modeling effort will utilize assumed emission rates with a combination of default and site-specific parameters to describe the movement of COPCs/ROPCs through the environment. This modeling is predictive and cannot be confirmed by sampling environmental media since the emissions source does not yet exist. The high level of uncertainty associated with this predictive modeling is addressed through the use of conservative assumptions whenever possible. Estimated media concentrations resulting from this modeling effort will be used in the exposure assessment for the Human Health (Chapter 7) and Ecological (Chapter 8) risk assessments. Environmental modeling will be the same for the PRA and FRA with the possible inclusion of additional site-specific modeling parameters in the FRA.

Figure 6-1. Exposure Grids in Each concentric Zone



Hanford ERA - 004a

Figure 6-2. Sources of COPC and ROPC Concentrations in Soil

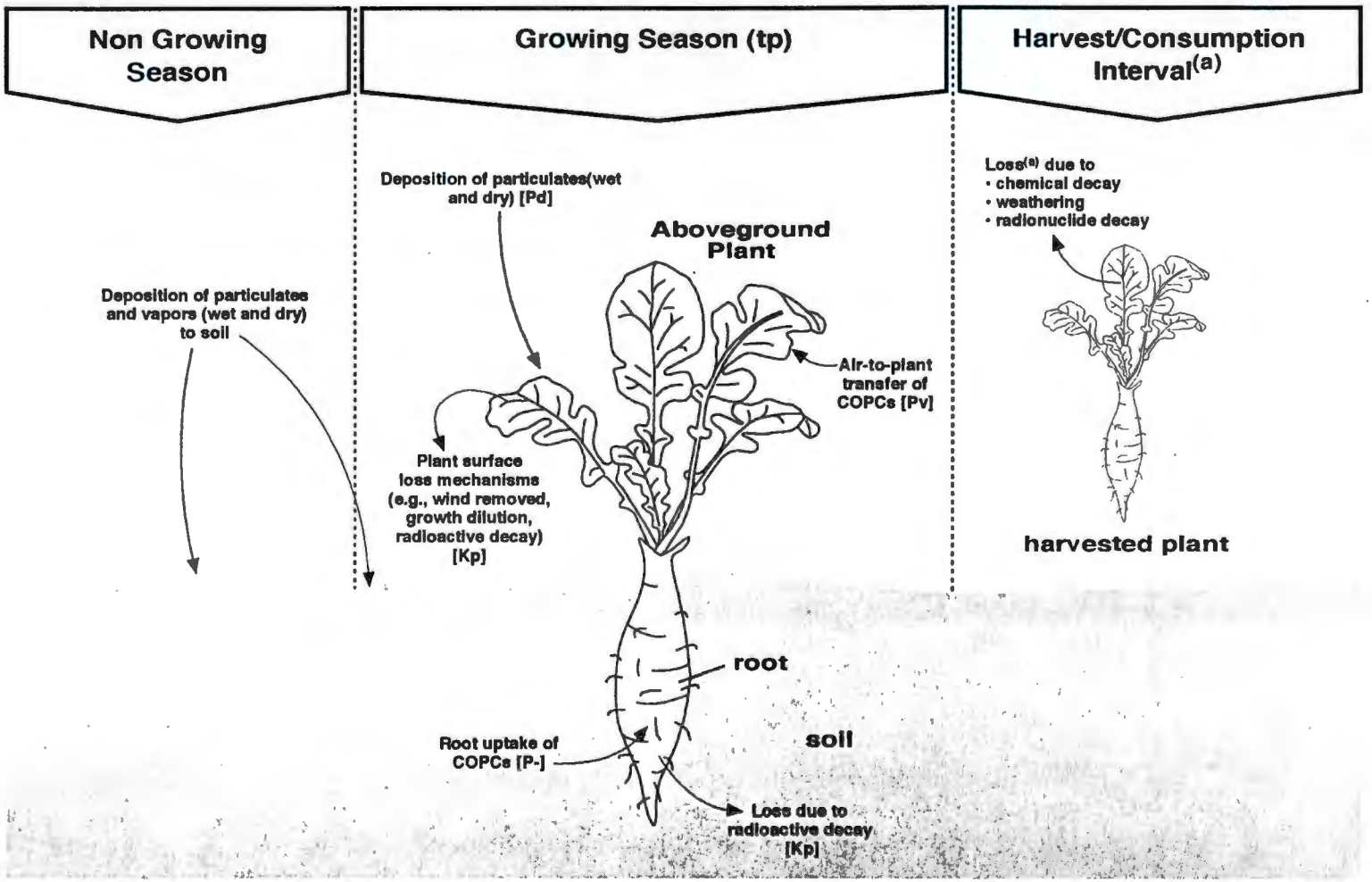


(a) The only loss mechanism to be quantified for this conservative screening level analysis is radioactive decay.

(b) Production of daughter products will be evaluated through the use of toxicity values (+D) that include all potential daughter products at equalibrium with the parent radionuclide.

Hanford TWRS-P: 08

Figure 6-3. Sources of Constituents of Potential Concern Concentration in Plants



Loss mechanisms not included in the PRA

(a) The conservative screening level risk assessment does not account for loss between harvest and consumption

Hanford ERA - 005

Figure 6-4. Generic Sources of Constituents of Potential Concern Concentrations in Animal Tissue, Eggs, and Dairy Products

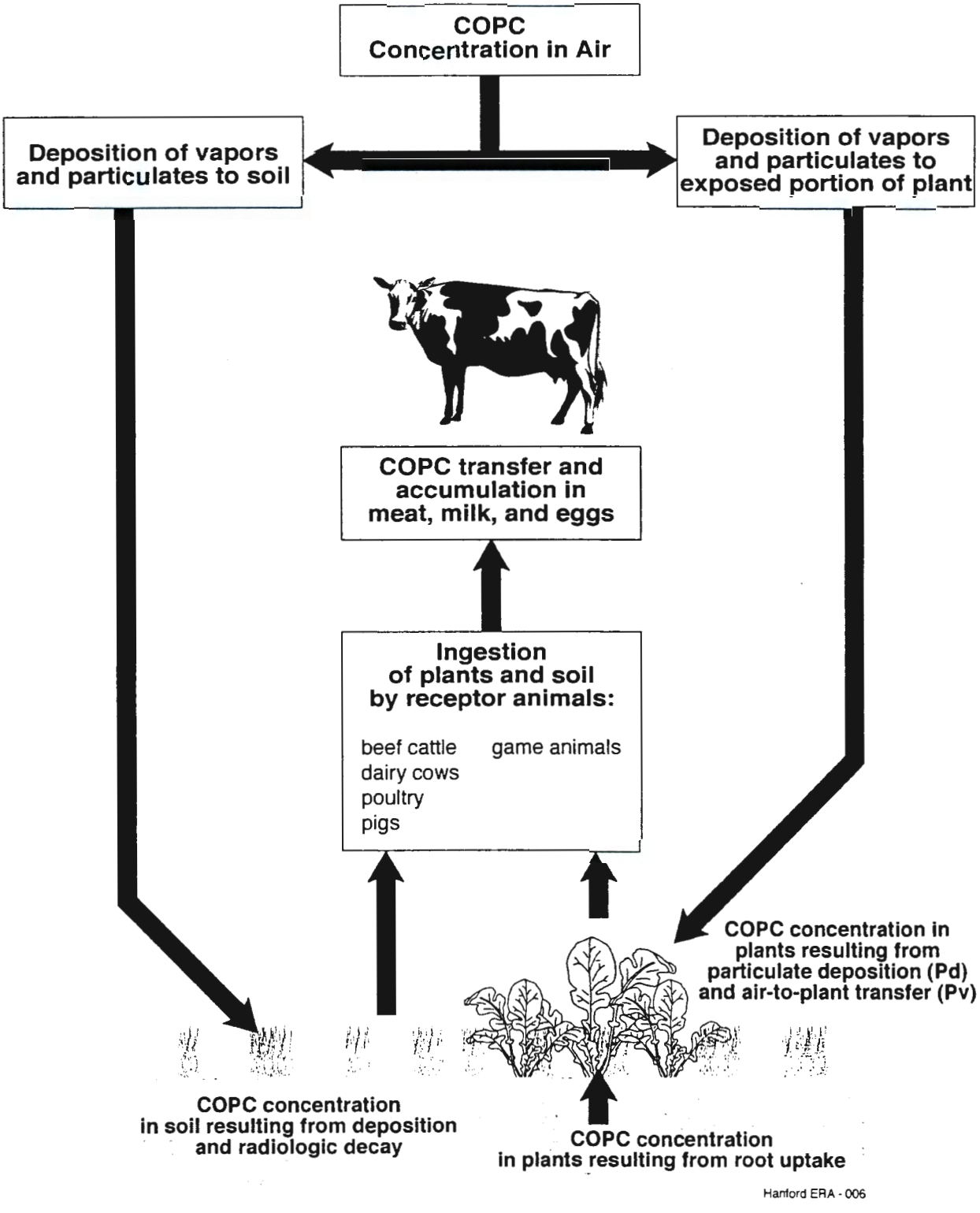


Figure 6-5. Sources of Constituents of Potential Concern Concentrations in Tissue, Eggs, and Dairy Products of Domestic Farm Animals

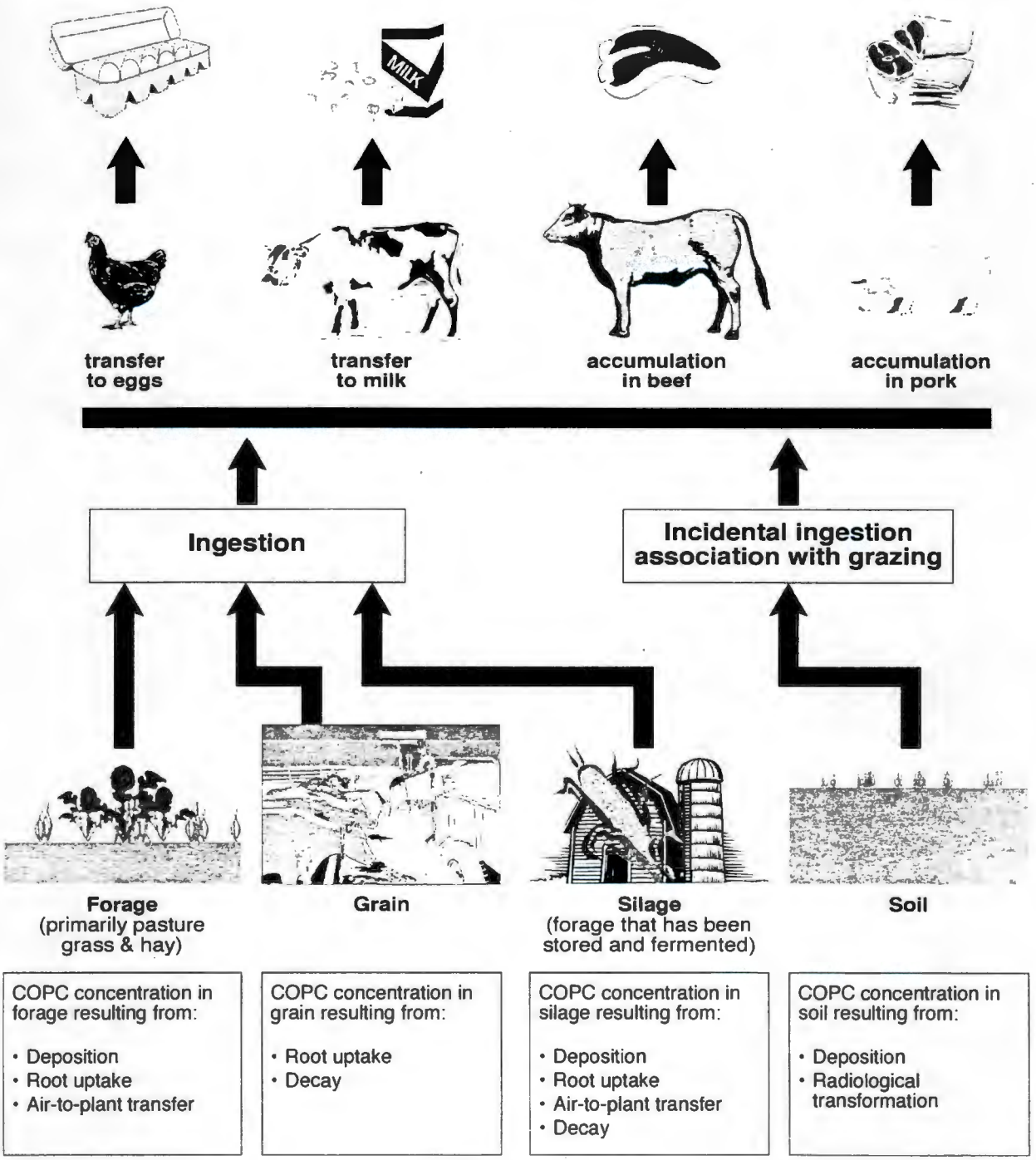


Figure 6-6. Sources of Constituents of Potential Concern Concentrations in Tissue of Game Animals

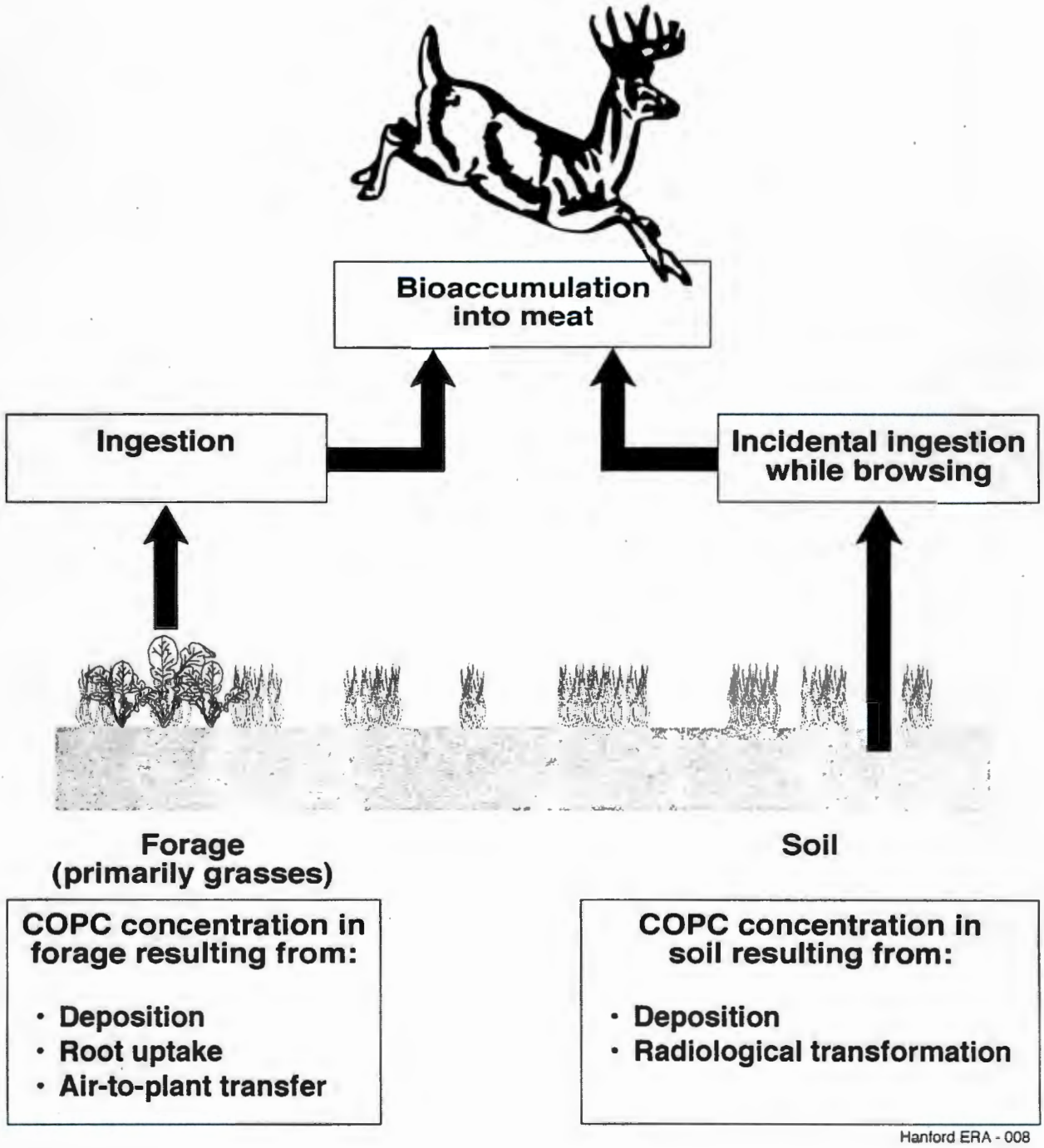
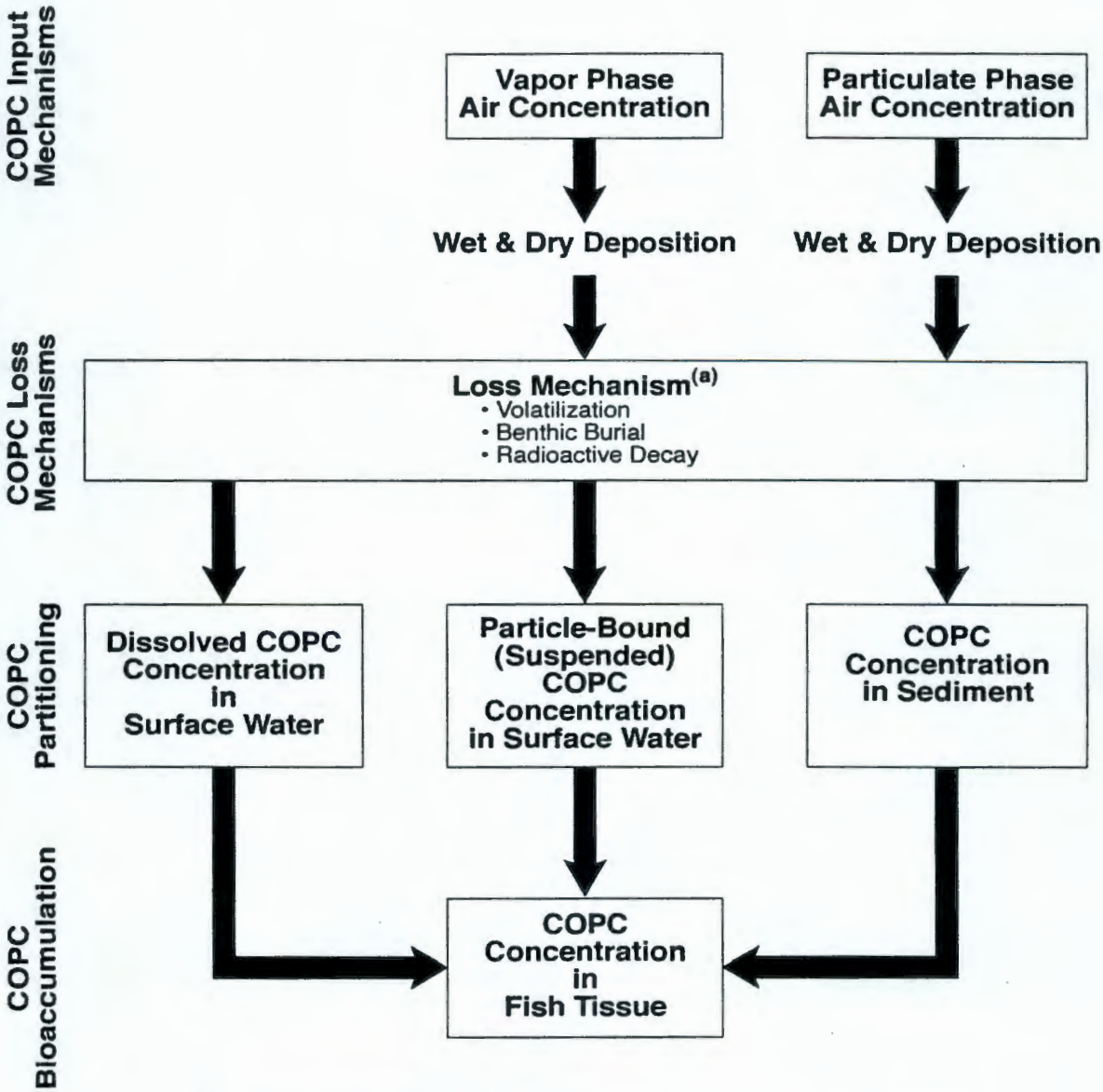


Figure 6-7. Sources of Constituents of Potential Concern Concentrations in Fish



(a) The only loss mechanism to be quantified for this conservative screening level analysis is radioactive decay.

Hanford ERA - 009

Table 6-1. Specific Variables for Plant Uptake Modeling[1]

Parameter	Plant Type	Value	Units
Interception Fraction (Rp)	Fruits	0.053	—
	Vegetables	0.932	—
	Fruits and Vegetables (weighted average)	0.39	—
	Forage	0.5	—
	Silage	0.46	—
Plant Surface Loss Coefficient (kp)	All (default)	18.0	1/yr
	All (calculated)	Applies to radionuclides	1/yr
Length of Plant Exposure (Tp)	Fruits and Vegetables	0.164	yr
	Forage	0.12	yr
	Silage	0.16	yr
Standing Crop Biomass (Yp)	Fruits	0.25	(kg DW/m^2)
	Vegetables	5.66	(kg DW/m^2)
	Fruits and Vegetables (weighted average)	2.24	(kg DW/m^2)
	Forage	0.24	(kg DW/m^2)
	Silage	0.8	(kg DW/m^2)
Empirical Correction Factor (VG_{ag})	Produce Log K_{ow} >4	0.01	—
	Produce Log K_{ow} <4	1.0	—
	Forage	1.0	—
	Silage	0.5	—

[1] All values from *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* EPA 1998a. See document for justification of values. All values presented are default values; for radionuclides, plant surface loss (kp) includes radiological decay.

— = unitless

Table 6-2. Specific Variables of Uptake into Animal Products[a]

Parameter	Beef Cattle	Pork	Poultry	Dairy Cattle	Deer
Forage Ingestion Rate (kg DW/day) (Qp forage)	8.8	0.0	0.0	13.2	1.463[b]
Silage Ingestion Rate (kg DW/day) (Qp silage)	2.5	1.4	0.0	4.1	0.0
Grain Ingestion Rate (kg DW/day) (Qp grain)	0.47	3.3	0.2	3.0	0.0
Soil Ingestion Rate (kg/day) (Qs)	0.5	0.37	0.022	0.4	0.0
Soil Bioavailability (unitless) (Bs)	1.0	1.0	1.0	1.0	1.0
Metabolism Factor for Bis(2-ethylhexyl)phthalate (MF)	0.01	0.01	NA	0.01	0.01
Metabolism Factor all other COPCs (MF)	1.0	1.0	NA	1.0	1.0

[a] Parameter values are from *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA 1998a), except where noted. See document for range and justification of values.

[b] Forage ingestion rate for deer is from Anderson, et al. 1974 and Allredge, et al. 1974, both presented in Higley and Kuperman 1996. Value presented has been calculated based on the body weight of 66.5 kg and an ingestion rate of 0.022 kg/kg BW/day.

NA = not applicable

Chapter 7

7. Screening Human Health Risk Assessment

This section presents four fundamental components of the human health risk assessment (HHRA) process: (1) data evaluation (2) exposure assessment, (3) toxicity assessment, and (4) risk characterization. The data evaluation step includes the selection of COPCs/ROPCs (section 4) and the quantification of emissions (section 5). Each of the remaining three components is discussed below.

7.1. Exposure Assessment

Exposure assessment is the process of estimating the magnitude, frequency, duration, and type of potential exposures to COPCs/ROPCs. This section presents the exposure scenarios and approach for conducting the quantitative exposure assessment.

A human health conceptual exposure model has been developed that identifies potential receptors and potentially complete exposure pathways (i.e., exposure scenarios). The conceptual exposure model is shown as Figure 7-1. The end product of the conceptual model is identifying exposure scenarios that are defined by potentially exposed populations and exposure pathways. The conceptual model was developed from information obtained from and the *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment* (DOE-RL 1998). The Native American scenario is taken from Harris and Harper 1997. The specific scenario contained in Harris and Harper 1997 represents a scenario developed for the Confederated Tribes of the Umatilla Indian Reservation. Exposure scenarios for other tribes may be different.

The conceptual exposure model focuses on identifying complete exposure pathways for potentially exposed populations. An exposure pathway is the means through which an individual may come in contact with a chemical in the environment. Exposure pathways are determined by environmental conditions (e.g., location of groundwater, vegetative cover, wind speed/direction), the potential for chemical migration among media (e.g., soil, surface water, or air), and by the lifestyles and work activities of potentially exposed populations. Although several potential pathways may exist, not all may be complete. For a pathway to be complete, the following four factors must exist:

- Source of COPC/ROPC release into the environment
- Release and transport mechanism (e.g., deposition to soil) that moves the COPC/ROPC from the source to other locations
- Point of contact with the affected medium
- Exposure route such as breathing vapors or ingesting affected media

These four factors were considered in the conceptual exposure model. The sources of COPC/ROPC release are the stack and any fugitive emissions from the RPP-WTP (see section 5). Transport processes, potential points of contact, and complete exposure pathways are identified to formulate exposure scenarios that will be the focus of the quantitative risk assessment. This process is summarized in the following section.

7.1.1. Characterization of Exposure Setting

Characterizing the exposure setting is the first step in identifying potentially exposed populations. This characterization includes identifying the location of human populations within the study area, and types of activities that can be expected under current and reasonable potential future land use.

The brief site characterization provided in this section is adequate to identify most possible receptors, especially the most significantly exposed receptors. A more detailed site characterization will be supplied in the PRA to describe all the populations evaluated.

The study area is defined as the area within a 50-kilometer radius of the RPP-WTP (Figure 7-2). This is considered to be the limit of the ISCST3 air-dispersion model. While it is possible for human populations to be exposed beyond this 50-km radius, the concentration of airborne and deposited emissions will be orders of magnitude less than those within the study area; essentially approaching zero. EPA 1998a reports that the most significant deposition of airborne emissions has been observed within a 3-km radius of a source (Figure 7-3). The Hanford Site boundary extends approximately 9 to 28 kilometers from the RPP-WTP. The Columbia River is located approximately 8 to more than 20 kilometers from the RPP-WTP. Therefore the potential for offsite impacts is likely to be minimal. Because of the importance of the Columbia River as a potable water and recreational resource, it will be included in the quantitative risk assessment despite its distance from the RPP-WTP. Currently, no residential receptors are present on the Hanford Site, nor are there likely to be any in the near future. Game animals that browse on Hanford Site property and plants that grow on Hanford Site property may be harvested by Native Americans living offsite.

Characterization of the exposure setting includes the following:

- Characterization of the physical setting – Including location of important physical features such as Gable Mountain, surface water bodies, and watersheds.

- Characterization of potentially exposed populations – Including identifying the location and activity patterns of current populations relative to the facility, determining plausible future land use, and identifying subpopulations of potential concern.

Characterization will concentrate on the areas potentially most impacted by emissions based on the results of the air-dispersion modeling.

<u>Current Land Use</u>

Current land use within the 50-km study area is characterized based on aerial photographs, zoning maps, land development plans, and information presented in:

- *Hanford Site Risk Assessment Methodology* (DOE-RL 1995)

- *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment* (DOE-RL 1998)

- *The Future for Hanford: Uses and Cleanup* (DOE 1992)

- *Draft Hanford Remedial Action Environment Impact Study and Comprehensive Land Use Plan* (DOE 1996a).

Representatives of the Nez Perce Tribe, Yakama Nation, and Confederated Tribes of the Umatilla Indian Reservation are also being consulted in evaluating current land use in the study area.

Future Land Use

Plausible future land use is characterized based on land development plans, and information presented in:

- *Hanford Site Risk Assessment Methodology* (DOE-RL 1995)
- *Screening Assessment and Requirements for Comprehensive Assessment: Columbia River Comprehensive Impact Assessment* (DOE-RL 1998)
- *The Future for Hanford: Uses and Cleanup* (DOE 1992)
- *Draft Hanford Remedial Action Environmental Impact Study and Comprehensive Land Use Plan* (DOE 1996)

Representatives of the Nez Perce Tribe, Yakama Nation, and Confederated Tribes of the Umatilla Indian Reservation are also being consulted in evaluating plausible future land use in the study area. Worst-case future land use will be based on the assumption that the exposure locations could be used for any purpose regardless of development plans, or the actual potential for such use to occur.

7.1.2. Identification of Exposure Scenarios

EPA 1998a recommends the following exposure scenarios for evaluating potential risks from combustion facilities:

- Resident - Adult
- Resident - Child
- Subsistence Farmer - Adult
- Subsistence Farmer - Child
- Subsistence Fisher - Adult
- Subsistence Fisher - Child
- Nursing Infant
- Acute Risk

The subsistence farmer – adult and child, and subsistence fisher – adult and child, represent worst case scenarios.

The nursing infant scenario is recommended by EPA guidance (EPA 1998a) to address specific concerns regarding exposure to PCDDs and PCDFs. EPA guidance recommends inclusion of the nursing infant only for PCDDs/PCDFs; however, both coplanar and non-coplanar PCBs will also be evaluated for this pathway in the SLRA. Because radionuclides are the primary component of the waste to be treated at the facility, ROPCs will also be evaluated for this pathway. The ROPCs strontium (Sr-90), iodine (I-129), and cesium (Cs-134 and Cs-137) will be evaluated for the nursing infant scenario. These radionuclides are potentially present in the waste and are judged to have the highest potential for accumulation in milk and toxicity (EPA 1999d). No other COPCs/ROPCs will be evaluated for this scenario, which will be evaluated based on intakes for both the resident adult and the Native American resident adult.

In addition to the recommended exposure scenarios listed above, EPA recommends evaluation of special subpopulations by identifying their locations, and determining whether they are located in areas that are particularly conducive to impacts from RPP-WTP emissions. Special subpopulations are defined as human receptors or segments in the population that potentially may be at higher risk due to receptor sensitivity to COPCs. As noted by the EPA, the risk assessment approach used is designed to protect human health, including special subpopulations (e.g., through the use of RfDs developed to account for toxicity to sensitive receptors). However, to address actual characteristics of the exposure setting and potential community concerns, the following additional exposure scenarios will be evaluated: Hanford Site industrial worker, and Native American subsistence resident.

Workers employed at the RPP-WTP will not be included in the risk assessment because other regulations exist for occupational exposures within the RPP-WTP boundary (e.g., Occupational Safety and Health Administration or Department of Energy (DOE)-equivalent standard). However, because of its location within the Hanford Site, the closest and most likely receptors are other Hanford Site workers located outside the RPP-WTP boundary. Therefore, a Hanford Site industrial worker scenario will be included in the risk assessment.

Native American tribes (Yakama Nation, Confederated Tribes of Umatilla Reservation, Nez Perce Tribe) ceded the land currently occupied by the US Government's Hanford Site. However, these tribes claim retained rights to use resources on this land. A wide range of possible Native American activities related to traditional life styles exists. The Native American scenarios will address a variety of potential exposures associated with food gathering (including hunting and fishing), as well as cultural and social activities.

7.1.3. Description of Land Use Scenarios

Exposure scenarios to be addressed by the risk assessment are described in more detail below and summarized in Table 7-1. The scenarios to be carried through the quantitative risk assessment will be determined based on the results of the air-dispersion modeling. For example, if air-dispersion modeling indicates that significant emissions will not reach the Columbia River, the subsistence fisher scenario will not be evaluated in the quantitative risk assessment. Because the location of sacred sites is confidential within the tribes, representatives of the three tribes will be consulted following completion of the air-dispersion modeling to determine potential impacts to sacred sites.

Four types of exposure scenarios will be quantified: plausible current, plausible future, worst-case future, and acute exposure. By examining these four types of exposure scenarios, a range of possible exposures will be provided, giving the permit and risk managers additional information on which to base decisions. Using this approach, it will not be necessary to rely solely on worst-case assumptions.

The primary difference between plausible and worst-case scenarios is the assumed location of receptor populations. For the plausible scenarios, potential receptors are assumed to be located in areas where similar receptors currently exist or may reasonably be expected to exist some time in the future. For the worst-case scenarios, receptor populations are assumed to be located at the point of maximum concentration regardless of the likelihood of this occurring. For example, no residential development is expected within 10 kilometers (Figure 7-2 and Figure 7-3) of the RPP-WTP; however, if the point of maximum concentration falls within this area, a residential receptor will be evaluated at this location. The four types of exposure scenarios are defined below.

7.1.3.1. Plausible Current Land Use Scenarios

The area within a 10-km radius of the RPP-WTP is completely within the current boundaries of the Hanford Site. Current activities in this area are associated with waste management, environmental restoration, and industrial and commercial land use (Figure 7-4). The potentially exposed population in this area is limited to Hanford Site industrial workers. The 50-km study area extends beyond the Hanford Site boundary and includes areas that are, or can be used, for residential development. Although Native American residents do not live within the site boundaries, they may engage in food gathering (plant gathering, hunting, fishing) and cultural activities on Hanford Site land.

Based on this information, the plausible current exposure scenarios are as follows:

- Hanford Site industrial worker
- Residential adult and child at the Hanford Site boundary
- Native American resident adult and child hunter/gatherer living at the Hanford Site boundary and conducting some food gathering on the Hanford Site
- Native American resident adult and child fisher living at the Hanford Site boundary and fishing the Columbia River

7.1.3.2. Plausible Future Land Use Scenarios

Plausible future land use includes continued use of the area for industrial and commercial purposes and residential development beyond the Hanford Site boundary (Figure 7-5). Although Native American residents do not live within the site boundaries, they may engage in food gathering (i.e., plant gathering, hunting, fishing) and cultural activities on Hanford Site land. Based on this information the plausible future exposure scenarios are as follows:

- Hanford Site industrial worker
- Residential adult and child at the Hanford Site boundary
- Native American resident adult and child hunter/gatherer living at the Hanford Site boundary and conducting some food gathering on the Hanford Site
- Native American resident adult and child fisher living at the Hanford Site boundary and fishing the Columbia River

Plausible current and future land use scenarios are very similar and may be the same for some receptors.

7.1.3.3. Worst-Case Future Land Use Scenarios

EPA 1998a recommended exposure scenarios (resident adult and child, subsistence farmer adult and child, subsistence fisher adult and child, and nursing infant) will be evaluated at the point of maximum concentration identified by air-dispersion modeling to provide a worst-case estimate of exposure and risk.

In addition to these EPA-recommended scenarios, resident subsistence Native American scenarios (including a nursing infant) will be evaluated for unrestricted land-use. Based on this information, worst-case future exposure scenarios are as follows:

- Resident adult and child (on-site)
- Subsistence farmer adult and child (on-site)
- Subsistence fisher adult and child (off-site, at the Columbia River)
- Nursing infant (on-site)

- Native American subsistence resident adult and child hunter/gatherer (on-site)
- Native American subsistence resident adult and child fisher (offsite, at the Columbia River)
- Native American nursing infant (on-site)

7.1.3.4. Acute Exposure

EPA 1998a recommends evaluating potential acute exposures in addition to the chronic exposures evaluated by previously described exposure scenarios. The acute exposure scenario includes direct inhalation of airborne emissions at the estimated maximum 1-hour concentration. The receptor for the acute exposure scenario is located at the point of maximum 1-hour concentration and is independent of land- use. Because the acute exposure scenario is based on the maximum-modeled concentration and assumes that a receptor will be present at the location of that maximum during the hour in which it occurs, this is considered a worst-case scenario.

7.1.4. Exposure Pathways

Exposure pathways to be evaluated for each of these exposure scenarios are summarized in Table 7-1 and the conceptual exposure model (Figure 7-1). Both direct and indirect pathways will be evaluated. Direct exposure pathways to be included in the quantitative risk assessment are as follows:

- COPCs and ROPCs
  - direct inhalation of emissions

- ROPCs only
  - external exposure to radionuclides in air.

Indirect exposure pathways to be included in the quantitative risk assessment are as follows:

- COPCs and ROPCs
  - ingestion of soil
  - inhalation of resuspended soil
  - ingestion of homegrown or wild gathered produce
  - ingestion of homegrown beef, milk, chicken, eggs, and pork
  - ingestion of drinking water
  - ingestion of fish
  - ingestion of wild game (including fowl and eggs)

- COPCs only
  - dermal absorption in the sweat lodge

- ROPCs only
  - external exposure to radionuclides in soil

- PCDDs/PCDFs, PCBs, and selected ROPCs (Sr-90, I-129, Cs-137, and Cs-137) only
  - ingestion of breast milk

- VOCs, SVOCs, and volatile ROPCs only
  - inhalation of vapors in the sweat lodge

External radiation exposure will be quantitatively evaluated for radionuclides in air and soil. External radiation exposure is not expected to be significant for surface water because of the following:

- Distance to the Columbia River will result in extremely low concentrations of ROPCs via deposition
- ROPC concentrations in air near the facility and in soil following deposition and accumulation will far exceed surface water concentrations
- Exposure to air and soil are continuous while potential exposure to surface water is intermittent

Thus, external radiation exposure is not expected to be significant for surface water because the distance to the Columbia River will result in extremely low concentrations of ROPCs via deposition. Thus, ROPC concentrations in air near the facility, and in soil following deposition and accumulation, are expected to far exceed far away surface water concentrations.

EPA 1998a has identified three exposure pathways that are generally insignificant contributors to risk at thermal treatment facilities; they are as follows:

- Groundwater pathways
- Resuspended dust
- Dermal contact

Groundwater pathways are generally not significant contributors to risk from airborne emissions because exposure concentrations in groundwater following air dispersion, deposition, leaching, and groundwater dispersion are much less than concentrations in air, soil, and other media. Conditions at the Hanford Site (i.e., very low precipitation) will make the contribution to groundwater even less than at other sites. Therefore, exposure to groundwater will not be included in the quantitative risk assessment. However, surface water concentrations will be used to evaluate the ingestion of drinking water, as well as inhalation of VOCs/SVOCs and dermal absorption for the Native American sweat lodge scenario.

Inhalation of resuspended dust can be an important exposure pathway at contaminated sites where the contaminant source is at the surface or in the soil. This was explained in the air dispersion modeling section (6). At these sites, dust resuspension generally represents the only source of inhalation exposure (unless significant volatiles are present). At sites such as the RPP-WTP where the source of COPCs/ROPCs is airborne emissions, direct, continuous inhalation of these emissions is a much more important exposure pathway than periodic inhalation of fugitive dust. However, because of the dry, dusty conditions at the Hanford Site, inhalation of resuspended dust will be evaluated in the PRA.

Dermal exposure pathways (to soil, surface water, or air) will not be included in the PRA with the exception of the Native American sweat lodge scenario. This is a non-conservative assumption, because dermal contact will occur when direct contact with soil or surface water is a potentially complete pathway, along with incidental ingestion. However, dermal exposure pathways have been identified as insignificant contributors to risk in numerous risk assessments prepared and/or reviewed by EPA for airborne emissions from thermal treatment facilities. If initial PRA results indicate that the ingestion pathway results in risks that are borderline for any plausible receptor, then the dermal exposure pathway may be included in the PRA. A discussion of the potential impact associated with exclusion of this minor pathway from the quantitative risk assessment will be included in the uncertainty assessment.

7.1.5. Quantification of Exposure

The following section provides the calculation algorithms that will be used to quantify intake (or dose) for each COPC and ROPC. Estimates of the lifetime average daily doses (LADDs) and average daily doses (ADDs) will be quantified. The LADD defines a dose level that is distributed (averaged) over an entire lifetime, rather than a specific incremental exposure period. Unlike the LADD, the ADD is not averaged over an entire lifetime.

The equations that will be used to quantify each of the exposure pathways are given below and are based on those presented in Appendix C of EPA 1998a; these equations are subject to change as the guidance is modified.

7.1.5.1. Inhalation of Vapor Phase and Particulate Emissions

Inhalation of vapor phase and particulate emissions will be quantified with the following equations:

COPCs:
$$I_{avg} = \frac{C_a \times IR \times ET \times EF \times ED \times 0.001}{BW \times AT \times 365}$$

ROPCs:
$$I_{avg} = C_a \times IR \times ET \times EF \times ED$$

where

I_{avg} = average daily COPC/ROPC intake via inhalation (mg COPC/kg-day for chemicals; pCi ROPC for radionuclides)
C_a = total COPC concentration in air ($\mu g/m^3$ for chemicals; pCi/m^3 for radionuclides)
IR = inhalation rate (m^3/hour)
ET = exposure time (hour/day)
EF = exposure frequency (day/year)
ED = exposure duration (year)
0.001 = conversion factor (mg/µg)
BW = body weight (kg)
AT = averaging time (year)
365 = conversion factor (day/year)

7.1.5.2. Ingestion of Soil

Ingestion of COPCs/ROPCs in soil will be quantified with the following equations:

COPCs:
$$I_{soil} = \frac{Cs \times CR_{soil} \times F_{soil} \times EF \times ED}{BW \times AT \times 365}$$

ROPCs:
$$I_{soil} = Cs \times CR_{soil} \times F_{soil} \times EF \times ED \times 1000$$

where

I_{soil} = daily intake of COPC/ROPC due to soil ingestion (mg/kg-day for chemicals; pCi for radionuclides)
Cs = average soil concentration of COPC/ROPC over exposure duration (mg COPC/kg soil for chemicals; pCi ROPC/g soil for radionuclides)

CR_{soil} = consumption rate of soil (kg/day)
F_{soil} = fraction of ingested soil that is contaminated (unitless)
EF = exposure frequency (day/year)
ED = exposure duration (year)
BW = body weight of receptor (kg)
AT = averaging time (year)
365 = conversion factor (day/year)
1000 = conversion factor (g/kg)

7.1.5.3. Ingestion of Produce

Ingestion of COPCs/ROPCs in homegrown or wild gathered produce will be quantified with the following equations:

COPCs:

$$I_{ag} = \frac{\{[(Pd + Pv + Pr) \times CR_{ag}] + (Pr \times CR_{pp}) + (Pr_{bg} \times CR_{bg})\} \times F_{ag} \times EF \times ED}{AT \times 365}$$

ROPCs:

$$I_{ag} = \{[(Pd + Pv + Pr) \times CR_{ag}] + (Pr \times CR_{pp}) + (Pr \times CR_{bg})\} \times F_{ag} \times EF \times ED \times 1000 \times BW$$

where

I_{ag} = daily intake of COPC/ROPC from produce (mg/kg-day for chemicals; pCi for radionuclides)
Pd = COPC/ROPC concentration in aboveground produce due to direct deposition onto plant surfaces (mg/kg for chemicals; pCi/g for radionuclides)
Pv = COPC/ROPC concentration in aboveground produce due to air-to-plant transfer (mg/kg for chemicals; pCi/g for radionuclides)
Pr = COPC/ROPC concentration in aboveground produce due to root uptake (mg/kg for chemicals; pCi/g for radionuclides)
CR_{ag} = consumption rate of aboveground unprotected produce (kg/kg-day DW or dry weight)
CR_{pp} = consumption rate of aboveground protected produce (kg/kg-day DW or dry weight)
Pr_{bg} = COPC/ROPC concentration in belowground produce due to root uptake (mg/kg for chemicals; pCi/g for radionuclides)
CR_{bg} = consumption rate of belowground produce (kg/kg-day DW or dry weight)
F_{ag} = fraction of ingested produce that is contaminated (unitless)
EF = exposure frequency (day/year)
ED = exposure duration (year)
AT = averaging time (year)
365 = conversion factor (day/year)
1000 = conversion factor (g/kg)
BW = body weight (kg)

7.1.5.4. Ingestion of Beef, Milk, Pork, Poultry, Eggs, and Wild Game

Ingestion of COPCs/ROPCs in homegrown beef, milk, pork, poultry, eggs and wild game will be quantified with the following equations.

$$\text{COPCs:}\quad I_i = \frac{A_j \times CR_j \times F_j \times EF \times ED}{AT \times 365}$$

$$\text{ROPCs:}\quad I_i = A_j \times CR_j \times F_j \times EF \times ED \times 1000 \times BW$$

where

I_i = daily intake of COPC/ROPC *i* from animal *j* (mg/kg-day for chemicals; pCi for radionuclides)
A_j = concentration of COPC/ROPC i in animal *j* (mg/kg FW or fresh (wet) weight for chemicals; pCi/g for radionuclides)
CR_j = consumption rate of animal *j* (kg/kg-day FW or fresh (wet) weight)
F_j = fraction of ingested animal tissue *j* that is contaminated (unitless)
EF = exposure frequency (day/year)
ED = exposure duration (year)
AT = averaging time (year)
365 = conversion factor (day/year)
1000= conversion factor (g/kg)
BW = body weight (kg)

For the metals mercury, selenium, and cadmium, the concentrations in beef, milk, and pork as well as the consumption rate are in kg DW per day and must be adjusted using wet weight to dry weight conversion factors.

7.1.5.5. Ingestion of Fish

Ingestion of COPCs/ROPCs in fish (e.g., chinook salmon, bass) will be quantified using the following equations:

$$\text{COPCs:}\quad I_{fish} = \frac{C_{fish} \text{ x } (CR_{fish} + CR_{organs}) \text{ x } F_{fish} \text{ x } EF \text{ x } ED}{AT \text{ x } 365}$$

$$\text{ROPCs:}\quad I_{fish} = C_{fish} \text{ x } (CR_{fish} + CR_{organs}) \text{ x } F_{fish} \text{ x } EF \text{ x } ED \text{ x } 1000 \text{ x } BW$$

where

I_{fish} = daily intake of COPC/ROPC from fish (mg/kg-day for chemicals; pCi for radionuclides)
C_{fish} = concentration of COPC/ROPC in fish (mg/kg for chemicals; pCi/g for radionuclides)
CR_{fish} = consumption rate of fish (fillets) (kg/kg-day FW)
CR_{organs} = consumption rate of fish parts (e.g., head, fins, etc.) (kg/kg-day FW)
F_{fish} = fraction of ingested fish that are contaminated (unitless)
EF = exposure frequency (day/year)
ED = exposure duration (year)
AT = averaging time (year)
365 = conversion factor (day/year)
1000 = conversion factor (g/kg)
BW = body weight (kg)

7.1.5.6. Ingestion of Water

Ingestion of COPCs/ROPCs in drinking water will be quantified using the following equation:

$$\text{COPCs: } I_{dw} = \frac{C_{dw} \times CR_{dw} \times F_{dw} \times EF \times ED}{BW \times AT \times 365}$$

$$\text{ROPCs: } I_{dw} = C_{dw} \times CR_{dw} \times F_{dw} \times EF \times ED$$

where

I_{dw}	=	daily intake of COPC/ROPC in drinking water (mg/kg-day for chemicals, pCi for radionuclides)
C_{dw}	=	dissolved phase COPC/ROPC water concentration (mg/L for chemicals; pCi/L for radionuclides)
CR_{dw}	=	drinking water consumption rate (L/day)
F_{dw}	=	fraction of ingested drinking water that is contaminated (unitless)
EF	=	exposure frequency (day/year)
ED	=	exposure duration (year)
BW	=	body weight (kg)
AT	=	averaging time (year)
365	=	conversion factor (day/year)

7.1.5.7. Infant Ingestion of Breast Milk

The infants ingestion of COPCs/ROPCs in breast milk will be quantified for dioxins/furans, coplanar dioxin-like PCBs and selected radionuclides (Sr-90, I-129, Cs-134, and Cs-137) based on the following equations:

$$\text{COPCs: } I_{infant} = \frac{\frac{m \times CF \times h \times f_1}{0.693 \times f_2} \times f_3 \times f_4 \times IR_{milk} \times ED}{BW_{infant} \times AT}$$

$$\text{ROPCs: } I_{infant} = \frac{m \times h \times f_1}{0.693 \times f_2} \times f_3 \times f_4 \times IR_{milk} \times ED \times EFI$$

where

I_{infant}	=	average infant intake of COPC/ROPC (pg/kg-day for chemicals; pCi for radionuclides)
m	=	average maternal intake of COPC/ROPC across all adult ingestion scenarios (mg/kg BW-day for chemicals; pCi/kg BW-day for radionuclides)
CF	=	conversion factor of 1×10^9 (pg/mg)
h	=	half-life of COPC/ROPC in adults (days)
f_1	=	fraction of ingested COPC/ROPC that is stored in fat (unitless)
f_2	=	fraction of mother's weight that is fat (unitless)
f_3	=	fraction of mother's breast milk that is fat (unitless)
f_4	=	fraction of ingested COPC/ROPC that is absorbed (unitless)
IR_{milk}	=	ingestion rate of breast milk by infant (kg/day)

ED = exposure duration (year)
BW_{infant} = body weight of infant (kg)
AT = averaging time (year)
EF = exposure frequency (day/year)

This equation is expected to overestimate chemical concentrations in the lipid portion of breast milk because it does not consider the time required to reach steady state or contaminant losses from breast feeding as described below EPA (1998a):

- Chemical concentrations in milkfat may be overestimated by a factor of 10 or more if the half-life of the chemical is large compared to the exposure duration (i.e., near steady state conditions are not reached).

- Contaminant losses can be significant. EPA (1998a) reports that the highest concentrations of PCDDs/PCDFs are excreted in breast milk within the first few weeks after delivery. After 1 year of breast feeding, PCDD/PCDF concentrations are about 30-50% of initial levels.

For dixoins/furans, as recommended in EPA 1998a, I_{infant} will be compared to an average infant intake target level of 60 pg/kg-day of 2,3,7,8-TCDD TEQ. As recommended by EPA Region X, for coplanar (dioxin-like) PCBs, I_{infant} will be compared to an average infant intake target level of 13 pg/kg-day of 2,3,7,8-TCDD TEQ. Cancer risks will be quantified for ROPCs, based on I_{infant}.

7.1.5.8. External Exposure to Radionuclides in Soil

External exposure to ionizing radiation in soil from ROPCs will be quantified using the following equation:

$$\text{ROPCs: } I_{irs} = Cs \times (1\text{-}Se) \times Te \times EF \times ED \times (1/365)$$

where

I_{irs} = intake of ROPC due to external exposure to ionizing radiation in soil [(pCi-year)/g]
Cs = average soil concentration of ROPC (pCi/g)
Se = shielding factor (unitless)
Te = exposure time factor (unitless)
EF = exposure frequency (day/year)
ED = exposure duration (year)
1/365 = conversion factor (year/day)

7.1.5.9. External Exposure to Radionuclides in Air

External exposure to ionizing radiation in air from ROPCs will be quantified using the following equation:

$$\text{ROPCs: } I_{ira} = Ca \times EF \times ED \times 86400 \times AF \times 0.037$$

where

I_{ira} = intake of ROPC due to external exposure to ionizing radiation in air [(Bq-secs)/m^3]

Ca = concentration of ROPC in air (pCi/m^3)
EF = exposure frequency (day/year)
ED = exposure duration (year)
86400 = conversion factor (secs/day)
AF = age factor of 1 for adults and 1.3 for children (unitless) (Saito, et al. 1998)
0.037 = conversion factor (Bq/pCi)

7.1.5.10. Inhalation of Vapors in Sweat Lodge Scenario

The inhalation of volatile and semivolatile organic compounds for Native American adults inside the sweat lodge will be quantified with the following equation which assumes a hemisphere with a 2 m diameter:

VOCs and SVOCs that are COPCs: $$I_{inh} = \frac{Cw \times \left(\frac{VW}{\frac{2}{3}\pi r^3}\right) \times IR \times EF \times ED \times ET \times \frac{1}{24}}{BW \times AT \times 365}$$

Volatile ROPCs: $$I_{inh} = Cw \text{ x } \left(\frac{VW}{\frac{2}{3}\pi r^3}\right) \text{ x } IR \text{ x } EF \text{ x } ED \text{ x } ET \text{ x } \frac{1}{24}$$

where

I_{inh} = average daily intake of VOCs/SVOCs that are COPCs/ROPCs, from adult inhalation within the sweat lodge (mg COPC/kg-day for chemicals; pCi for radionuclides)
Cw = average surface water concentration (mg/L for chemicals; pCi/L for radionuclides)
VW = volume of water used in sweat lodge (L)
r = radius of sweat lodge (m)
IR = inhalation rate (m^3/day)
EF = exposure frequency (day/year)
ED = exposure duration (year)
ET = exposure time (hour/day)
$\frac{1}{24}$ = conversion factor (day/hour)
BW = body weight (kg)
AT = averaging time (year)
365 = conversion factor (day/year)

7.1.5.11. Dermal Absorption in Sweat Lodge Scenario

The dermal absorption of water for Native American adults inside the sweat lodge (a hemisphere with a 2 m diamter) will be quantified with the following equation:

COPCs: $$I_d = \frac{Cw \times SA \times Kp \times ET \times EF \times ED \times 10}{BW \times AT \times 365}$$

where

I_d	=	average daily intake of COPCs, from adult dermal absorption within the sweat lodge (mg COPC/kg-day)
Cw	=	average surface water concentration (mg/L)
SA	=	body surface area available for contact (m^2)
Kp	=	permeability constant (COPC-specific) (cm/hour)
ET	=	exposure time (hour/day)
EF	=	exposure frequency (day/year)
ED	=	exposure duration (year)
10	=	conversion factor $\left[\left(\frac{L}{m^3}\right)\times\left(\frac{m}{cm}\right), \text{or}\left(\frac{L}{m^2-cm}\right)\right]$
BW	=	body weight (kg)
AT	=	averaging time (year)
365	=	conversion factor (day/year)

7.1.5.12. Inhalation of Resuspended Soil

The inhalation of resuspended soil will be quantified with the equation shown below. See section 6.1.2.6 for information regarding the estimation of air concentrations of resuspended dust.

$$\text{COPCs: } I_{inhsoil} = \frac{Ca_{soil} \times IR \times ET \times EF \times ED \times 0.001}{BW \times AT \times 365}$$

$$\text{ROPCs: } I_{inhsoil} = Ca_{soil} \times IR \times ET \times EF \times ED$$

where

$I_{inhsoil}$	=	average daily COPC/ROPC intake via inhalation of resuspended soil (mg/kg-day for chemicals; pCi for radionuclides)
Ca_{soil}	=	average air concentration of COPC/ROPC from resuspended soil (µg COPC/m^3 for chemicals; pCi ROPC/m^3 for radionuclides)
IR	=	inhalation rate (m^3/hour)
ET	=	exposure time (hour/day)
EF	=	exposure frequency (day/year)
ED	=	exposure duration (year)
0.001	=	conversion factor (mg/µg)
BW	=	body weight (kg)
AT	=	averaging time (year)
365	=	conversion factor (day/year)
1000	=	conversion factor (g/kg)

7.1.6. Exposure Parameters

The equations presented above are the basis for quantifying the exposure to COPCs/ROPCs experienced by a potential receptor. The values that will be used for each parameter identified in the equations are provided in Tables 7-2, 7-3, and 7-4. For residential scenarios in Table 7-2, exposure values were predominantly taken from the *Human Health Risk Assessment Protocol for Hazardous Waste Combustion*

Facilities (EPA 1998a). For Native American subsistence scenarios in Table 7-3, exposure values were predominantly taken from Harris and Harper 1997. For the Hanford Site worker scenario in Table 7-4, exposure values were predominantly taken from the *Hanford Site Risk Assessment Methodology* (DOE-RL 1995).

7.1.7. Exposure Point Concentrations

The exposure point concentrations used for estimating dose of both COPCs and ROPCs are dependent on the location of the receptor. The location of the various receptor populations identified for the quantitative risk assessment will correspond to the receptor grid nodes defined during air-dispersion modeling (section 6). In keeping with the protective approach used in this risk assessment, the location with the maximum concentration of COPCs/ROPCs will be used in estimating exposure point concentrations. Because the point of maximum concentration may be different for airborne COPCs/ROPCs and COPCs/ROPCs deposited via wet and dry deposition mechanisms, EPA 1998a recommends the following method for selecting the point of maximum concentration. Within each area to be evaluated, receptor grid nodes or exposure locations with the highest modeled unitized value will be identified for each of the following parameters:

- Vapor phase air concentration
- Vapor phase wet deposition rate
- Particle phase air concentration
- Particle phase wet deposition rate
- Particle phase dry deposition rate
- Particle-bound phase air concentration
- Particle-bound phase wet deposition rate
- Particle-bound phase dry deposition rate

At each of the unique locations, air concentrations from vapor, particle phase, and particle bound fractions will be summed, and concentrations of deposited materials will be summed to determine the point of maximum exposure. Air concentrations and deposition rates will not be summed together.

7.1.7.1. Exposure Point Concentrations for Plausible Exposure Scenarios

For the plausible current and future exposure scenarios, exposure point concentrations will be estimated at actual or likely exposure locations using models presented in section 6. Locations to be used in estimating exposure point concentrations are described below and summarized in Table 7-1.

Residential Scenarios. Residential use of the Hanford Site is prohibited. Therefore, the nearest potential residential receptor would be at the Hanford Site boundary. Current and future residential adult and child scenarios will be located at the point(s) of maximum concentration (as defined above) at the property boundary.

Hanford Site Industrial Worker Scenario. The Hanford Site industrial worker will be located at the point(s) of maximum concentration as identified by the air-dispersion modeling unless access to this location is and will remain restricted.

Native American Scenarios. The plausible current and future location of activities will be determined with input from the three tribes after completion of the air-dispersion modeling. Locations selected will represent the maximally impacted location at the minimum distance from the RPP-WTP for each activity.

7.1.7.2. Exposure Point Concentrations for Worst-case Exposure Scenarios

For the worst-case future land use scenarios, exposure will be evaluated at the point(s) of maximum concentration regardless of actual land use patterns.

Residential Scenarios. Residential scenarios, including resident adult and child, subsistence farmer adult and child, nursing infant, and the residential portion of the subsistence fisher adult and child will be evaluated at the point(s) of maximum concentration as identified by the air-dispersion modeling unless physical factors would prevent a residence at this location. COPC/ROPC concentrations in drinking water will be estimated from the point(s) of maximum concentration at the Columbia River.

Subsistence Fisher Scenario. The adult and child subsistence fisher will obtain fish from the point(s) of maximum concentration at the Columbia River.

Native American Scenarios. The potential future location of activities will be determined with input from the three tribes after completing the air-dispersion modeling. The locations selected will represent the maximally impacted location at the minimum distance from the RPP-WTP for each activity.

7.2. Toxicity Assessment

This section of the SLRA will present the chemical specific dose-response information to be used in the risk assessment. The toxicity assessment will be performed in accordance with EPA 1998a guidance. Chronic toxicity data will be obtained according to the following hierarchy:

1 **Integrated Risk Information System (IRIS)** EPA 1998c or most current. IRIS is an on-line database that provides toxicity values for chronic oral and inhalation exposures. All data contained in IRIS are verified by an EPA work group. As such, IRIS serves as the primary source of toxicity values for the risk assessment.

2 **Health Effects Assessment Summary Tables (HEAST)** (EPA 1995d and EPA 1997a or most current). HEAST is an EPA document that supplements IRIS by providing nonverified toxicity values, as well as values for evaluating the potential for noncancer effects following subchronic exposures. Information in HEAST (EPA 1997a) is used as a secondary source for chemicals when information is not available from IRIS. HEAST (EPA 1995d) is the source for all carcinogenic toxicity values (slope factors) for radionuclides. Ingrowth of radioactive daughters will be accounted for by using the +D (plus daughters) slope factors. This is a conservative approach since use of the +D assumes secular equilibrium.

3 **Provisional Values**. In the absence of established values from IRIS or HEAST, provisional toxicity values are used and are available from several sources (i.e., NCEA's Superfund Technical Support Center, EPA Regional Toxicologists, ATSDR Toxicological Profiles).

4 **Surrogate Values**. When toxicity values for a chemical are not available from the sources listed above, the use of a surrogate value may be necessary. This process involves applying a toxicity value established for one chemical to another chemical for which no value has been established. The application of surrogate values is based on similarities in structure, mechanism of action, and toxicity. The surrogate values will be identified in the SLRA when their need is identified

The same approach will be used for the toxicity assessment in both the PRA and FRA. Any new toxicity values that become available prior to development of the FRA will be incorporated in the final assessment.

7.2.1. Noncarcinogenic Health Effects

Potential noncarcinogenic health effects associated with exposure to COPCs will be evaluated using acceptable daily intake levels (i.e., reference doses and concentrations) established by EPA 1997a and EPA 1998c or as described above.

It is widely accepted that most biological effects of chemicals occur only after a threshold dose is exceeded (Klaassen et al. 1996 and Paustenbach 1989). For purposes of establishing noncarcinogenic health criteria, this threshold dose is usually estimated from the no-observed adverse effect level (NOAEL) or lowest-observed adverse effect level (LOAEL) determined in animal or human studies. NOAEL is defined as the exposure level at which no statistically or biologically significant increases are present in the frequency or severity of adverse effects (EPA 1989b). The LOAEL is the lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of adverse effects (EPA 1989b). The LOAEL or NOAEL from the most sensitive animal or human study is used by the EPA to establish long-term health criteria, termed reference doses (RfDs). A RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of the dose of a chemical (expressed in mg/kg-day) that is likely to be without an appreciable risk of deleterious effects during a lifetime (EPA 1989b). Similarly, a reference concentration (RfC) represents the concentration of a chemical in environmental media (expressed in μg/L for water or mg/m^3 for air) that is likely to be without an appreciable risk of deleterious effects during a lifetime (EPA 1989b). When deriving a RfD or RfC, a NOAEL value is used preferentially over a LOAEL value if both are available from the key study. EPA derives RfDs and RfCs by applying uncertainty factors to the NOAEL or LOAEL value to provide a margin of safety. The equation for deriving a RfD or RfC is shown below:

$$\text{RfD or RfC} = (\text{NOAEL or LOAEL}) / (\text{UF} \times \text{MF})$$

where

RfD = reference dose (mg/kg/day)
RfC = reference concentration (mg/m^3)
NOAEL = no-observed-adverse-effect-level
LOAEL = lowest-observed-adverse-effect-level
UF = uncertainty factor
MF = modifying factor.

Uncertainty factors can range from 1 to 10,000 and may include a factor of up to 10 to account for each of the following.

- Variation in sensitivity within human populations
- Extrapolation of effects observed in animals to humans
- Extrapolation from less-than-lifetime exposures in the critical study to lifetime exposures
- Extrapolation from a LOAEL to a NOAEL, if necessary

In some cases, a modifying factor [usually ranging from 1 to 10 or <1 for most essential nutrients (EPA 1989b)] also is applied to the NOAEL/LOAEL. This value reflects a qualitative professional assessment of additional uncertainties in the critical study and in the entire database for the chemical not explicitly addressed by the above uncertainty factors (EPA 1989b). RfDs and RfCs can be interconverted using default exposure assumptions (i.e., 70-kg body weight, 2 L/day water intake, and 20 m^3/day breathing

rate). EPA establishes RfDs and RfCs for evaluating both subchronic (less than 7 years) and chronic (7 years or more) exposures.

EPA generally reports only RfC values in IRIS and HEAST because the EPA observes that it is technically more accurate to base toxicity values directly on measured air concentrations than to make an estimate of the administered dose. Inhalation RfDs will be calculated from the corresponding RfC values when necessary using the following equation:

$$\text{Inhalation RfD} = (\text{Inhalation RfC}) \times (\text{Breathing Rate}) / (\text{Body Weight})$$

where

Inhalation RfD = chemical-specific inhalation reference dose in mg/(kg-day)
Inhalation RfC = chemical-specific inhalation reference concentration in mg/m^3
Breathing Rate = 20 m^3/day, default value for an adult
Body Weight = 70 kg, default value for an adult.

Uncertainties associated with this type of conversion include those surrounding deposition and absorption of the chemical in the lung, both of which depend on physico-chemical properties of the chemical, the phase of the chemical in air (i.e., vapor, particle, particle-bound), and characteristics of the exposed species. EPA recognizes the need for expressing toxicity values in terms of a dose (mg/kg-day) for risk assessment purposes and acknowledges that in many cases the conversion of a RfC to a dose does not add significant uncertainty to the risk assessment process (EPA 1997a). In addition, the appropriateness of this conversion depends on the toxicological endpoint observed in the key study. For example, it may be inappropriate to estimate an internal dose for compounds that act at the point of contact (i.e., sensitizers and irritants of the upper respiratory tract). In these cases, the toxicological endpoint depends only on the concentration of the chemical in air and not on the chemical dose expressed on a per body weight basis. For example, a chemical irritant will irritate nasal passages and lungs at a given concentration regardless of whether the exposed individual weighs 15 kg or 70 kg. In addition, this conversion might inappropriately imply effects to other organ systems or effects from other exposure routes.

Oral RfDs are adjusted for the evaluation of the dermal exposure pathway (EPA 1989c, 1996c). Most RfDs are expressed as the amount of substance administered per time and body weight; however, dermal exposure to chemicals in soil and water is expressed as absorbed dose.

For the dermal assessments in this risk assessment, the oral RfD for each COPC is adjusted by the percent gastrointestinal absorption efficiency (%GI) for that chemical. The %GI values have been obtained from the Risk Assessment Information System (RAIS), which is maintained by the Oak Ridge National Laboratory (ORNL 2000). The protocol used to obtain %GI values in the RAIS is based on guidance from EPA Region IV (EPA 1995e). This protocol involves obtaining %GI values from the literature, where available, and assigning default values for specific classes of chemicals where no literature values can be found. Specifically, the RAIS notes that measured %GIs are available for only a limited number of chemicals; for those chemicals for which no %GI is available in the literature, a value of 80 percent is used for VOCs, 50 percent for SVOCs, and 20 percent for inorganics. Wide ranges of %GI values can be found for some chemicals and, in the absence of chemical-specific absorption data, the values are often estimated from data for related chemical structures; most organic compounds are readily absorbed (i.e., %GI=100).

Adjustments, which favor conservatism, are made to the oral RfDs used in the dermal assessments. The dermal RfDs are calculated as follows:

Dermal (absorbed dose) RfD = (Oral RfD) x (%GI/100).

Oral RfDs, inhalation RfCs and RfDs, and dermal RfDs are provided in Tables 4-1 and 4-2.

Many constituents have oral or inhalation toxicity values available but not both. For these chemicals route-to-route extrapolation will be used to calculate toxicity values per USEPA (1998a). This conversion assumes that the toxicity of a constituent is equivalent over all routes of exposure and, therefore, introduces uncertainty into the risk assessment.

7.2.2. Carcinogenic Health Effects

Health risks from exposures to carcinogens are defined in terms of probabilities. These probabilities identify the likelihood of a carcinogenic response in an individual that receives a given dose of a particular compound. The slope factor, expressed in units of $(mg/kg\text{-}day)^{-1}$ multiplied by the lifetime ADD of the chemical, provides an estimate of the theoretical excess cancer risk. Slope factors represent an upper-bound estimate of the probability of developing cancer per unit dose (expressed as risk per mg/kg-day) of a chemical over a lifetime (EPA 1989b). Similarly, unit risks (URs) represent an upper-bound estimate of the probability of developing cancer per unit concentration [expressed as risk per (μg/L) for water; risk per ($\mu g/m^3$) for air] of a chemical over a lifetime. Slope factor and UR values can be interconverted using default exposure assumptions (i.e., 70-kg body weight, 2 L/day water intake, 20 m^3/day breathing rate).

The cancer weight-of-evidence classification is a qualitative descriptor that characterizes the quality and quantity of the data concerning the potential carcinogenicity of the chemicals. As defined by EPA 1989b, six weight-of-evidence groups exist to which a chemical may be assigned:

- Group A Human Carcinogen (sufficient evidence of carcinogenicity in humans)
- Group B1 Probable Human Carcinogen (limited evidence of carcinogenicity in humans)
- Group B2 Probable Human Carcinogen (sufficient evidence of carcinogenicity in animals, with inadequate or lack of evidence in humans)
- Group C Possible Human Carcinogen (limited evidence of carcinogenicity in animals, or lack of human data)
- Group D Not Classifiable as to Human Carcinogenicity (inadequate or no evidence)
- Group E Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)

Consistent with EPA guidelines (EPA 1989b), chemicals assigned a weight-of-evidence classification of A, B1, or B2 will be quantitatively evaluated for carcinogenic dose-response. All Group C carcinogens will also be quantitatively evaluated for carcinogenic effects.

In some cases, an oral SF must be calculated from the corresponding UR using the following equation:

$$\text{Oral SF} = (\text{Oral UR}) \times (\text{Body Weight}) \times (\text{Conversion Factor}) / (\text{Water Intake})$$

where

Oral SF	=	oral slope factor in $(mg/kg\text{-}day)^{-1}$
Oral UR	=	chemical-specific oral unit risk in $(\mu g/L)^{-1}$
Body Weight	=	70 kg, default value for an adult
Conversion Factor	=	1,000 μg/mg
Water Intake	=	2 L/day, default intake for an adult.

Expression of the UR in terms of a dose is necessary to evaluate cancer risk associated with exposure media other than drinking water (i.e., soil, sediment). EPA recognizes the need for expressing toxicity values in terms of a dose (mg/kg-day) for risk assessment purposes, and acknowledges that in many cases this conversion does not add significant uncertainty to the risk assessment process (EPA 1997b). However, it will be carried through to the discussion of uncertainties in the SLRA.

In some cases, an inhalation SF must be calculated from the corresponding UR using the following equation:

$$\text{Inhalation SF} = \frac{(\text{Inhalation UR}) \times (\text{Body Weight}) \times (\text{Conversion Factor})}{(\text{Breathing Rate})}$$

where

Inhalation SF	=	inhalation slope factor in $(mg/kg\text{-}day)^{-1}$
Inhalation UR	=	chemical-specific inhalation unit risk in $(\mu g/m^3)^{-1}$
Body Weight	=	70 kg, default for an adult
Conversion Factor	=	1000 μg/mg
Breathing Rate	=	20 m^3/day, default value for an adult.

The same uncertainties that apply to the conversion of inhalation RfC to RfD for noncarcinogens (see section 7.2.1) also apply to the conversion of inhalation unit risk (UR) to inhalation slope factor (SF) for carcinogens.

Oral slope factors are adjusted for the evaluation of the dermal exposure pathway (EPA 1989c, 1996c). Most slope factors are expressed as the amount of substance administered per time and body weight; however, dermal exposure to chemicals in soil and water is expressed as absorbed dose.

For the dermal assessments in this risk assessment, the oral slope factor for each COPC is adjusted by the percent gastrointestinal absorption efficiency (%GI) for that chemical. The source of %GI values used in this risk assessment has been described in section 7.2.1.

Adjustments, which favor conservatism, are made to the oral slope factors used in the dermal assessments. The dermal slope factors are calculated as follows:

Dermal (absorbed dose) Slope Factor = (Oral Slope Factor) / (%GI/100).

Oral, inhalation, and dermal SFs are provided in Tables 4-1 and 4-2. Many constituents have oral or inhalation slope factors available but not both. For these chemicals route-to-route extrapolation will be used to calculate slope factors. This conversion assumes that the carcinogenicity of a constituent is equivalent over all routes of exposure and, therefore, introduces uncertainty into the risk assessment.

7.2.3. Polychlorinated Dibenzo-p-dioxins and Polychlorinated Dibenzofurans

Chlorinated dioxins, chlorinated dibenzofurans, and chlorinated biphenyls are thought to act through a common mechanism of toxicity by binding to a protein known as the arylhydrocarbon receptor (AR) (for review see ATSDR 1997 or WHO 1998). The AR-ligand complex is responsible for the activation of genes that have a deleterious effect when they are not under proper regulation by the receptor's hormones. Interaction of dioxins and similar compounds with AR therefore can cause immunological, neurological, endocrine, embryotoxic, and many other effects.

The similarity in action of these compounds is thought to result from their structural similarity. Dioxin is composed of two benzene rings joined by two carbon-oxygen-carbon bonds on two adjacent carbons of each benzene ring. Dibenzofurans have two benzene rings joined by a carbon-oxygen-carbon bond and a carbon-carbon bond on two adjacent carbons of each benzene ring. Biphenyls consist of two benzene rings joined by a single carbon-carbon bond. To form the polychlorinated derivatives, chloro groups are attached at various locations, as designated in the names of the compounds. Benzene rings are planar, i.e., flat, in conformation. Because two adjacent carbons on each benzene ring are joined in dioxins and dibenzofurans, both benzene rings are held in the same plane, and the chloro groups are also in that plane. Therefore, these molecules are said to be coplanar. The coplanar structure appears to be essential for interaction with AR. The benzene rings in biphenyl can rotate relative to each other, unless there are added groups that interfere with rotation (such as 2,2',6,6'-chloro groups, which occupy the carbons immediately on both sides of the carbon-carbon bond joining the rings). PCB congeners that are able to form a coplanar molecule (and are called coplanar PCBs) can interact with AR when they are in that configuration. Therefore, coplanar PCBs are included among the COPCs with similar action to dioxins and dibenzofurans.

EPA 1998a recommends evaluating all polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) with chlorine molecules substituted in the 2,3,7, and 8 positions as carcinogens.

Because these contaminants have a common mechanism of action, it is assumed that their toxicity to biota is additive (WHO 1998, EPA 1998a). That is, the toxicity of all dioxins, dibenzofurans, and PCBs should be added. Furthermore, their relative potency as chronic toxins is assumed to be related to the degree of affinity for AR, which can be measured much more conveniently than chronic toxic effects. Toxicity equivalence factors (TEFs) have been proposed for several chlorinated dioxins, chlorinated dibenzofurans, and chlorinated biphenyls (WHO 1998, EPA 1998a), always using the toxicity of 3,4,7,8-tetrachlorodioxin (TCDD), the most potent chlorinated dioxin, as a TEF of 1.0.

Potential cancer risks associated with PCDDs/PCDFs will be evaluated using the toxicity equivalency approach. This approach assigns a relative toxicity to each of the seventeen 2,3,7,8-substituted PCDDs/PCDFs as compared to 2,3,7,8-TCDD. EPA 1998a recommends evaluating all polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) with chlorine molecules substituted in the 2, 3, 7, and 8 positions as carcinogens. Potential cancer risks associated with PCDDs/PCDFs will be evaluated using the toxicity equivalency approach. This approach assigns a relative toxicity, reported as a Toxicity Equivalency Factor (TEF), to each of the seventeen 2, 3, 7, 8-substituted PCDDs/PCDFs as compared to 2, 3, 7, 8-TCDD. Exposure concentrations are converted to equivalent concentrations of 2, 3, 7, 8-TCDD by multiplying the concentration by the appropriate TEF. This results in Toxicity Equivalent (TEQ) concentrations of each congener. The slope factor for 2,3,7,8-TCDD is used to evaluate risk from total TEQ concentration. TEFs are available from EPA (1989b) and the World Health Organization (WHO, 1997). Values from both agencies are listed below:

Dioxin /Furan Congener	TEF (unitless) USEPA	WHO
2,3,7,8-Tetrachlorodibenzo(p)dioxin	1.0	1.0
1,2,3,7,8-Pentachlorodibenzo(p)dioxin	0.5	1.0
1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin	0.1	0.1
1,2,3,6,7,8-Hexachlorodibenzo(p)dioxin	0.1	0.1
1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin	0.1	0.1
1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin	0.01	0.01
1,2,3,4,5,7,8,9-Octachlorodibenzo(p)dioxin	0.001	0.0001
2,3,7,8-Tetrachlorodibenzofuran	0.1	0.1
1,2,3,7,8-Pentachlorodibenzofuran	0.05	0.05
2,3,4,7,8-Pentachlorodibenzofuran	0.5	0.5
1,2,3,4,7,8-Hexachlorodibenzofuran	0.1	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	0.1	0.1
1,2,3,7,8,9-Hexchlorodibenzofuran	0.1	0.1
2,3,4,6,7,8-Hexachlorodibenzofuran	0.1	0.1
1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.01	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	0.01	0.01
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	0.001	0.0001

The TEFs published by these two agencies are very similar. The primary differences are:

- The WHO assigns 1,2,3,7,8-Pentachlorodibenzo(p)dioxin a toxicity equal to 2,3,7,8-TCDD, while the EPA assigns this congener a TEF of 0.5 or half the toxicity of 2,3,7,8-TCDD.

- The WHO assigns 1,2,3,4,5,7,8,9-octachlorodibenzo(p)dioxin and furan a TEF of 0.0001, while the EPA assigns these congeners a TEF of 0.001.

At the direction of EPA Region 10 (1999e) potential cancer risks associated with PCDD/PCDF emissions will be estimated using both WHO and EPA TEFs. This evaluation will be presented as follows:

- WHO TEFs will be used to estimate potential cancer risks in the SLRA.

- WHO TEFS will be used to develop risk-based emission limits for the facility.

- Potential cancer risks estimated using EPA TEFs will be presented as part of the uncertainty evaluation presented in the SLRA.

Exposure concentrations are converted to equivalent concentrations of 2,3,7,8-TCDD by multiplying the concentration by the appropriate TEF. This results in TEQ concentrations of each congener. The slope factor for 2,3,7,8-TCDD is used to evaluate risk from total TEQ concentration. The TEF approach will be used along with the SF for 2,3,7,8-TCDD to estimate potential cancer risks from all exposure pathways (including nursing infant) except acute inhalation.

Toxicity values are not available for evaluating noncancer effects of PCDDs/PCDFs. EPA 1998a recommends evaluating potential noncancer hazards using the national average background exposure levels. As recommended, national average background exposure levels of 1 to 3 pg/kg-day for adult and child receptors and 60 pg/kg-day for nursing infants will be used to estimate potential noncancer hazards for PCDDs/PCDFs.

7.2.4. Polycyclic Aromatic Hydrocarbons (PAHs)

The toxicity equivalency approach will also be used for evaluating potentially carcinogenic PAHs. Seven PAHs [benzo(*a*)pyrene, benzo(*a*)anthracene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, chrysene, dibenz(*a,h*)anthracene, indeno(1,2,3-*cd*)pyrene] are considered to be potentially carcinogenic. Adequate toxicity data are available to determine a cancer slope factor only for benzo(*a*)pyrene. Relative potency factors (RPFs) developed by EPA 1993a to be used in estimating cancer risks for all seven potentially carcinogenic PAHs are shown below:

Compound	RPF
Benzo(*a*)pyrene	1.0
Benzo(*a*)anthracene	0.1
Benzo(*b*)fluoranthene	0.1
Benzo(*k*)fluoranthene	0.01
Chrysene	0.001
Dibenz(*a,h*)anthracene	1.0
Indeno(1,2,3-*cd*)pyrene	0.1

This method will be applied to both oral and inhalation exposure pathways. RPFs are available from CalEPA for additional potentially carcinogenic PAHs and may be considered if PAHs are predicted to be a significant emission from the facility.

Noncancer effects will also be evaluated for PAHs that have available toxicity values. If PAHs are predicted to be a significant emission from the facility, surrogate toxicity values may be considered.

7.2.5. Polychlorinated Biphenyls (PCBs)

In addition to the TEFs for dioxin/furan congeners, EPA 1996b is implementing the use of TEFs for coplanar, dioxin-like PCBs. The same method of converting emissions for individual congeners to a 2,3,7,8-TCDD equivalent will be used for dioxin-like PCBs.

TEFs are available for coplanar PCBs from EPA (1998a) and WHO (1997). Values from both agencies are listed below:

	TEF (unitless)	
PCB Congener	EPA	WHO
3,4,4',5-Tetrachlorobiphenyl	--	0.0001
3,3',4,4'-Tetrachlorobiphenyl	0.0005	0.0001
2,3,3',4,4'-Pentachlorobiphenyl	0.001	0.0001
2,3,4,4',5-Pentachlorobiphenyl	0.0005	0.0005
2,3',4,4',5-Pentachlorobiphenyl	0.0001	0.0001
2',3,4,4',5-Pentachlorobiphenyl	0.001	0.0001
3,3',4,4',5-Pentachlorobiphenyl	0.1	0.1
2,3,3',4,4',5-Hexachlorobiphenyl	0.0005	0.0005
2,3,3',4,4',5'-Hexachlorobiphenyl	0.0005	0.0005
2,3',4,4',5,5'-Hexachlorobiphenyl	0.00001	0.00001

3,3',4,4',5,5'-Hexachlorobiphenyl	0.01	0.01
2,2',3,3',4,4',5-Heptachlorobiphenyl	0.0001	W
2,2',3,4,4',5,5'-Heptachlorobiphenyl	0.00001	W
2,3,3',4,4',5,5'-Heptachlorobiphenyl	0.0001	0.0001

-- no value W value withdrawn

The two sets of TEFs differ for six of the 14 coplanar PCBs. At the direction of EPA Region 10 (1999d) potential cancer risks associated with coplanar PCB emissions will be estimated using both WHO and EPA TEFs. This evaluation will be presented as follows:

- WHO TEFs will be used to estimate potential cancer risks in the SLRA.
- WHO TEFS will be used to develop risk-based emission limits for the facility.
- Potential cancer risks estimated using EPA TEFs will be presented as part of the uncertainty evaluation presented in the SLRA.

The TEF approach will be used along with the SF for 2,3,7,8-TCDD to estimate potential cancer risks from coplanar PCBs for all exposure pathways (including nursing infant) except acute inhalation.

Noncancer effects of coplanar PCBs will be evaluated for nursing infants using average background exposure concentrations. A reported range for the average background concentration of coplanar PCBs in human milk is 10-20 ng/L (higher levels have been measured) with a recommended point value of 13 ng/L (EPA 1999d).

Other PCBs will be evaluated using the most recent slope factor for PCBs. EPA 1996b recommends different slope factors for different exposure routes and chlorine contents. For this assessment, the most conservative toxicity values (slope factors from the high-risk persistence tier) will be used.

Noncancer effects will also be evaluated for PCBs according to EPA guidelines. Typically, the RfD for Aroclor 1254 will be used when congeners are > 4 chlorines comprise > 0.5% of total PCBs. Otherwise, the RfD for Aroclor 1016 will be used.

7.2.6. Chromium

Hexavalent chromium (Cr^{+6}) is the most toxic valence state of chromium and has been shown to be a human carcinogen via inhalation. Trivalent chromium (Cr^{+3}) has not been shown to be carcinogenic in either humans or laboratory animals. However, the mechanism of Cr^{+6} carcinogenically in the lung is believed to be its reduction to Cr^{+3} and its generation of reactive intermediates (Goyer 1996 in Klaassen et al. 1996). While chromium emitted from the melter is not likely to be in the hexavalent form, the PRA will conservatively assume that 100% of the facility emissions are hexavalent chromium (EPA 1998a).

For the FRA, chromium may be assumed to exist in the trivalent form. If this assumption is made in the FRA, the rationale will be provided at that time. Performance test data or design information may also be used to provide more realistic estimates of Cr^{+6}/Cr^{+3} emissions from the RPP-WTP.

7.2.7. Lead

The EPA has not derived a RfD/RfC or SF for lead. The potential for adverse health effects associated with exposure to lead will be characterized through comparison with the following media-specific health-based levels as recommended by EPA Region 6 (EPA 1998a).

Exposure Medium	EPA Region 6 Health-Based Target Level
Soil	100 mg/kg
Air	0.2 $\mu g/m^3$

The target level for soil is based on acceptable lead concentrations in blood. The EPA recommends that lead exposures be limited so that 95% of the sensitive subpopulation (children) will have blood lead concentrations below 10 μg/dL. Using the EPA (1994c) Integrated Exposure Uptake Biokinetic (IEUBK) Model to estimate lead levels in blood of children exposed to lead through diet, drinking water, air, and soil using standard default values, the model predicts that at least 95% of children exposed to a soil lead concentration of 400 mg/kg will have blood lead concentrations below 10 μg/dL. EPA Region 6 has incorporated a margin of safety by allowing only 25% of this 400 mg/kg threshold level as their recommended target level of 100 mg/kg.

The recommended target level of 0.2 $\mu g/m^3$ for air is 25% of the National Ambient Air Quality Standard (NAAQS) quarterly average air concentration of 1.5 $\mu g/m^3$ translated to an annual value of 0.9 $\mu g/m^3$.

7.2.8. Nickel

EPA (1998a) recommends that nickel be evaluated as an inhalation carcinogen because some forms of nickel, including nickel carbonyl, nickel subsulfide, and nickel refinery dust, are considered to be carcinogens. This is contrary to EPA's previous analysis of the toxicity of nickel emissions from hazardous waste combustion units because it was previously assumed that nickel can only be emitted as nickel oxide, which by itself, is not considered to be a carcinogen. Nickel oxide is a major component of nickel refinery dust (other major components include nickel subsulfide and nickel sulfate) which is identified as a potential human inhalation carcinogen. The components responsible for the carcinogenicity of nickel refinery dust have not been conclusively established. Therefore, nickel emissions will be evaluated as a potential carcinogen via the inhalation pathway using the inhalation unit risk factor for nickel refinery dust.

For exposure pathways other than inhalation, nickel has not been shown to be carcinogenic and will be evaluated as a noncarcinogen using the oral RfD for nickel soluble salts.

7.2.9. Particulate Assessment

Toxicity values are not available to quantitatively evaluate potential adverse health effects associated with inhaling particulates. Therefore, modeled annual average concentration of respirable particulates less than 10 microns in diameter (PM_{10}) will be compared to the average annual NAAQS for PM_{10} of 50 $\mu g/m^3$ (40 CFR 50.4-50.12). The 24-hour average PM_{10} concentrations will be compared with the NAAQS 24-hour level of 150 $\mu g/m^3$.

7.2.10. Radionuclide Assessment

HEAST (EPA 1995d) and EPA Federal Guidance Report 13 (EPA 1999b) are the sources for all carcinogenic toxicity values (slope factors) for radionuclides. Ingestion, inhalation, and external exposure slope factors for radionuclides are provided in Table 4-3. Risks will be calculated using slope factors that include the potential toxicity of daughter products.

7.2.11. Nursing Infant Assessment

Potential infant exposure to PCDD/PCDFs, coplanar PCBs, and selected radionuclides (Sr^{90}, I^{129}, Cs^{134}, Cs^{137}) in human breast milk will be evaluated in the SLRA. The interpretation of infant exposures is limited by the lack of infant dose-response data (EPA 1998a). Potential infant exposures will be evaluated in the SLRA two ways; by comparison to background exposures, and by the calculation of a cancer risk value.

7.2.11.1 Comparison to Background

Because the possible impact of a brief early life exposure to these chemicals is unknown, the most appropriate method for evaluating the potential for adverse health effects to exposed infants is through a comparison to average background exposures.

Polychlorinated Dibenzo-p-dioxins and Polychlorinated Dibenzofurans

EPA (1998d) recommends that risk assessments include a comparison of exposures to PCDDs and PCDFs with a national average background exposure level for infants of 60 pg TEQ/kg/day. This value is a modeled ADD based on a measured average concentration of 16 ppt 2,3,7,8-TCDD TEQ in the lipid portion of breast milk. This comparison to background will utilize EPA TEF (rather than WHO TEFs) because historic data available for background concentrations and exposures are based on the EPA TEF values.

Polychlorinated Biphenyls (PCBs)

Possible effects of coplanar PCBs will be evaluated for nursing infants using average background exposure concentrations. A reported range for the average background concentration of coplanar PCBs in human milk is 10-20 ng/L (higher levels have been measured) with a recommended point value of 13 ng/L (EPA 1999d).

Radionuclides

Background concentrations of the four radionuclides of interest are not currently available. If background values become available they will be included in the SLRA. Background data identified by September 2000 will be included in the draft PRA. Background data identified up to four weeks prior to subsequent submissions (e.g., final PRA, FRA) will be included in these later documents.

7.2.11.2 Estimated Cancer Risk

Incremental Lifetime Cancer Risks are generally estimated from the total lifetime exposure or dose of a chemical (LADD) and the cancer slope factor. Cancer slope factors represent an upper-bound estimate of the probability of developing cancer per unit dose of a chemical. The possible impact of a brief early life exposure alone to a potential carcinogen is unknown. Per EPA guidance (EPA 1998a), an infant

cancer risk will be calculated for a 1 year exposure (1 year ADD) to PCDDs/PCDFs, coplanar PCBs and the four potentially bioaccumulative ROPCs.

Polychlorinated Dibenzo-p-dioxins and Polychlorinated Dibenzofurans

Infant cancer risks will be estimated using the same TEF/TEQ approach described previously. Because PCDDs/PCDFs act as a cancer promoter rather than a cancer initiator, exposures early in life may not be as important as those that occur later (i.e., following initiation).

Polychlorinated Biphenyls (PCBs)

Infant cancer risks will be estimated using the same TEF/TEQ approach described for coplanar PCBs previously.

Radionuclides

Risks will be estimated using slope factors that include the potential toxicity of daughter products as described for adult exposures.

7.2.12. Acute Effects Assessment

In addition to chronic effects, direct inhalation of airborne COPCs and ROPCs (vapor and particulate) will be evaluated for potential acute effects. Modeled short-term, one-hour maximum air concentrations will be compared to acute inhalation exposure criteria (AIEC) to evaluate the potential for COPCs/ROPCs emitted from the RPP-WTP to pose an acute health hazard to potentially exposed receptors. Acute toxicity data for COPCs/ROPCs will be obtained according to the following hierarchy:

1 Values from NCEA (as provided by EPA Region X)

2 Acute exposure guideline levels (AEGL-1)

3 Emergency response planning guidelines (ERPG-1)

4 Acute reference exposure levels (ARELs) from California EPA

5 Temporary emergency exposure limits (TEEL-1)

6 Subcommittee on consequence assessment and protective actions (SCAPA) toxicity-based approach (DOE 1997)

The most up-to-date references currently available for items 2-5 above are:

- AEGL-1: (EPA Region X and 10-30-99 *Federal Register)*
- ERPG-1: http://www.scapa.bnl.gov/scapawl.htm
- AREL: http://oehha.ca.gov/scientific/relnums.htm
- TEEL-1: http://tis.eh.doe.gov/web/chem_safety/teel.html

Updated references will be used for these acute toxicity data when the references become available.

For acute exposures to ROPCs, derived air concentrations based on the ALI will be used. These derived air concentrations for acute exposure comparison will be the concentration of the radionuclide in air that,

under continuous exposure for a one-hour period, would produce a total effective dose equivalent of 50 millirem (0.5 millisievert).

Federal guidance for occupational radiation protection specifies the following primary guides for limiting occupational exposure (USEPA, 1988):

Receptor	Primary Guide for Limiting Exposure
Adults	5000 mrem/yr
Children under 18	500 mrem/yr
Pregnant Women	50 mrem/gestation period

7.3. Risk Characterization

This section of the Work Plan presents how the potential noncarcinogenic and carcinogenic health risks for the exposure scenarios identified in the exposure assessment (see section 7.1) will be characterized. Potential health risks will be characterized separately for noncarcinogenic and carcinogenic endpoints, and chemical (nonradiological) and radiological cancer risks will be evaluated and presented separately. These endpoints will be characterized by comparing calculated dose levels to maximum "acceptable" doses. Potential noncarcinogenic health risks will be determined using the hazard quotient (HQ)/HI approach that defines the relative hazard based on the ratio of the estimated lifetime ADD (LADD) to the acceptable intake level (i.e., the RfD). Potential carcinogenic health risks will be determined based on the probability that an individual may contract cancer in a lifetime from the estimated LADD. COPCs having both carcinogenic and noncarcinogenic health effects will be evaluated for both endpoints. ROPCs will be evaluated for carcinogenic health effects.

The term risk means the probability of harm. More precisely, risk is the excess rate of cancer. By contrast, hazard refers to adverse noncarcinogenic health effects. In many cases, in this Work Plan, the use of risk generically means carcinogenic and/or noncarcinogenic consequences. Methodologies that will be used to characterize potential risks for the RPP-WTP are presented below.

7.3.1. Noncarcinogenic Effects

Noncarcinogenic health risks are typically characterized using an "HQ" and "HI" approach (EPA 1989b). The HQ is the ratio of the calculated ADD to the maximally allowable "safe" dose (i.e., EPA reference levels such as the RfD or similar value). The equation used to calculate the HQ for a chemical is presented below.

$$HQ = \frac{ADD}{RfD}$$

where

HQ = hazard quotient (unitless)
ADD = average daily dose (mg COPC/kg-day)
RfD = reference dose (mg COPC/kg-day)

An HQ of 0.25 or less indicates that the chemical-specific ADD for a particular pathway is below the level associated with an adverse health effect.

EPA 1998a recommends an HQ goal of 0.25 for evaluating emission rates and this risk goal will be applied here. Additive noncarcinogenic health effects can be evaluated when exposure to more than one chemical occurs by using the HI approach (see section 7.2.1).

Additivity of Noncarcinogenic Effects

Multiple chemical exposures can result in synergism, antagonism, and/or additivity of biological responses when the chemicals act on similar target organs or when they are metabolized by the same enzymatic pathways. It is appropriate in risk assessment to evaluate the possible health effects associated with multiple chemical exposures at a site. EPA risk assessment guidelines (EPA 1989b) state that additivity of noncarcinogenic health effects should only be considered if the chemicals have the same toxicological endpoint (e.g., organ or enzyme systems). Note that the same toxicological endpoint also implies the same mechanism of action. Additivity for all chemicals will initially be assumed to occur regardless of the toxicological endpoint. This approach is likely to overestimate the true human health risks associated with exposure to the COPCs/ROPCs since many chemicals may act on different target organs. If the target hazard index (HI) is exceeded, a segregation of the HI by toxicological endpoint will be considered. In addition to multiple chemicals, receptors may be exposed via more than one pathway. As the EPA (1989b) notes:

"There are two steps required to determine whether risks or hazard indices for two or more pathways should be combined for a single exposed individual or group of individuals. The first is to identify reasonable exposure pathway combinations. The second is to examine whether it is likely that the same individuals would consistently face the "reasonable maximum exposure" for more than one pathway."

The simplified equation for calculating a generic HI is presented below.

$$\text{Hazard Index} = \frac{ADD_1}{RfD_1} + \frac{ADD_2}{RfD_2} + \ldots + \frac{ADD_n}{RfD_n}$$

An HI of 0.25 or less indicates that levels of exposure are acceptable. HI will be calculated for all COPCs and all pathways for a given receptor.

7.3.2. Carcinogenic Risks

Carcinogenic health risks are defined in terms of a probability that an individual may develop cancer as a result of exposure to a given chemical or radionuclide at a given concentration (EPA 1989b). The incremental probability of developing cancer (i.e., the excess cancer risk) is the additional risk above and beyond the cancer risk an individual would face in the absence of exposures characterized in this assessment. The excess cancer risk will be determined for each potentially carcinogenic COPC or ROPC using the total LADD from all pathways and cancer slope factors as described below.

Excess Cancer Risk = LADD x SF for all pathways except external exposure to air

Excess Cancer Risk = LADD x RF for external exposure to air,

where

LADD = Lifetime average daily dose, with units of

- (mg/kg-day) for COPCs
- pCi for ingestion and inhalation of ROPCs

- (pCi-yr/g) for external exposure to ionizing radiation in soil (for ROPCs)
- (Bq-secs/m^3) for external exposure to ionizing radiation in air (for ROPCs)

SF = Cancer slope factor, with units of

- $(mg/kg\text{-}day)^{-1}$ for COPCs
- $(pCi)^{-1}$ for ingestion and inhalation of ROPCs
- $(pCi\text{-}yr/g)^{-1}$ for external exposure to ionizing radiation in soil (for ROPCs)

RF = Cancer incidence risk factor $(Bq\text{-}secs/m^3)^{-1}$ for external exposure to ionizing radiation in air (for ROPCs) (EPA 1999c).

Oral and inhalation slope factors are provided in Table 4-1 (organic COPCs), Table 4-2 (inorganic COPCs), and Table 4-3 (ROPCs). The slope factors provided for radionuclides are taken from EPA (1995d) and include toxicity due to daughter products. Use of these "+D" slope factors for radionuclides is conservative because it assumes the daughter species are in equilibrium with the parent. For many radionuclides this equilibrium may require thousands of years.

The LADD and slope factor are multiplied, yielding a dimensionless value that represents the probability of developing cancer within a lifetime (70 years) due to the chemical or radiological dose (LADD) received by a person. For example, a theoretical risk value of 0.0001 or 1×10^{-4} is referred to as a probability of 1 in 10,000 of developing cancer. As with the HIs, the theoretical excess cancer risk will be presented for each scenario on a chemical/radiological-specific, pathway-specific, and total risk basis. In addition, chemical and radiological risks will be presented separately. The theoretical excess cancer risk may be compared to both the *de minimus* lifetime cancer risk rate of 1×10^{-6} (i.e., negligible risk) and the acceptable regulatory risk range of 1×10^{-6} to 1×10^{-4} (OSWER Directive 9355.0-30 EPA 1991a). The target risk goal for emissions from the RPP-WTP is 1×10^{-5}.

7.4. Uncertainty Assessment

Numerous sources of uncertainty inherent in the risk assessment process exist. Some degree of uncertainty is introduced into the assessment each time an assumption is made. Many assumptions have valid and strong scientific bases, whereas others are estimates usually represented by a range of values.

The purpose of the uncertainty analysis is to identify and discuss areas of uncertainty associated with the quantitative estimates of risk for COPCs and ROPCs. This discussion serves to place the risk estimates in proper perspective by fully specifying the assumptions and qualitatively evaluating the uncertainties of the assessment.

A table providing a qualitative summary of all potential sources of uncertainty and the potential effect of that uncertainty on the risk estimates will be included in the PRA. The key variables and assumptions that contribute most to uncertainty will be identified and further addressed in the FRA. A qualitative discussion of the uncertainties associated with each component of the risk assessment will be provided including:

- **Site Characterization**. The degree of confidence in the current and future land use assumptions will be addressed.

- **Exposure Assessment**. Uncertainties surrounding fate and transport modeling, and the assignment of exposure parameter values will be addressed, including any excluded pathways such as dermal contact with soil and the handling of plants.

- **Toxicity Assessment**. Uncertainties surrounding the toxicity values (RfDs and SFs), weight-of-evidence classifications, toxicity value data gaps, conversions of toxicity values from concentration to dose (e.g., UR to SF, RfC to inhalation RfD), and route-to-route extrapolations will be addressed.

- **Risk Characterization**. Uncertainties surrounding the practice of summing HIs and risks across chemicals and pathways. The uncertainties associated with the evaluation of chemical and radionuclide emissions will also be addressed.

The four sources of uncertainty listed are unique to the human health risk assessment. Uncertainties associated with COPC/ROPC selection, emission rates, and environmental modeling are provided in previous sections.

To aid in the process of moving the dangerous waste permit process forward, special attention will be given to uncertainties associated with estimated risk that exceeds risk goals.

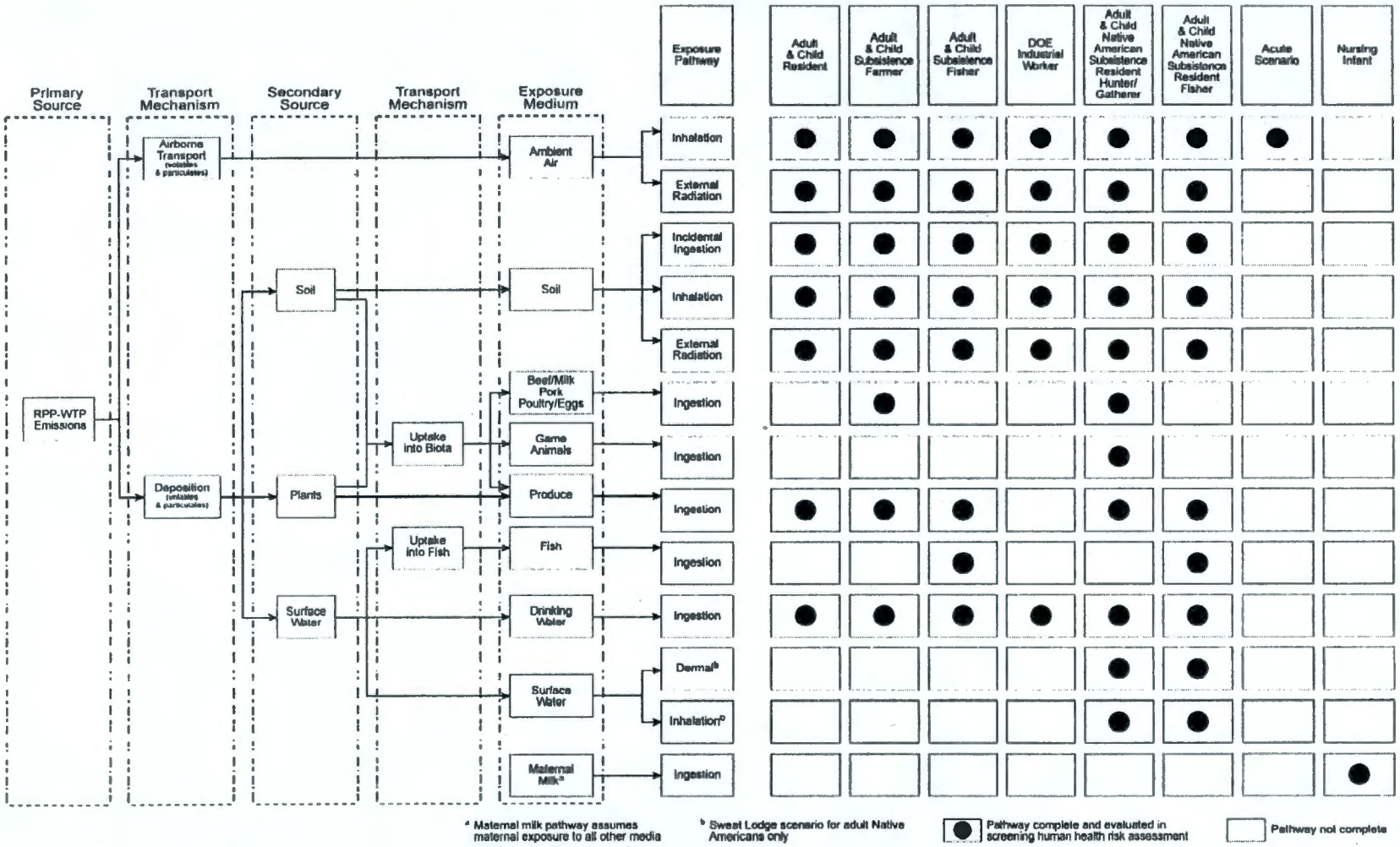
7.5. Summary for Screening Human Health Risk Assessment

Risks to human health from the potential emission of COPCs and ROPCs result from (1) exposure to the COPC/ROPC and (2) the toxicity of the COPC/ROPC. The screening HHRA utilizes the estimated emission rates (section 5) and results of fate and transport modeling (section 6) to calculate potential human exposure to COPCs and ROPCs. This exposure information is combined with toxicity data to estimate the potential for adverse effects to human populations in the vicinity of the RPP-WTP.

The PRA will use conservative exposure assumptions to compensate for the high level of uncertainty associated with conducting a risk assessment for a facility that is still in the design phase. The PRA will include a qualitative uncertainty analysis.

The FRA will focus on COPCs and ROPCs that exceed risk goals in the PRA and may utilize additional site-specific emission, fate and transport, and exposure data collected after completion of the PRA.

Figure 7-1. Human Health Conceptual Exposure Model



Hanford ERA - 014

Figure 7-2. Exposure Distances (Far-Field) from the RPP-WTP at the Hanford Site

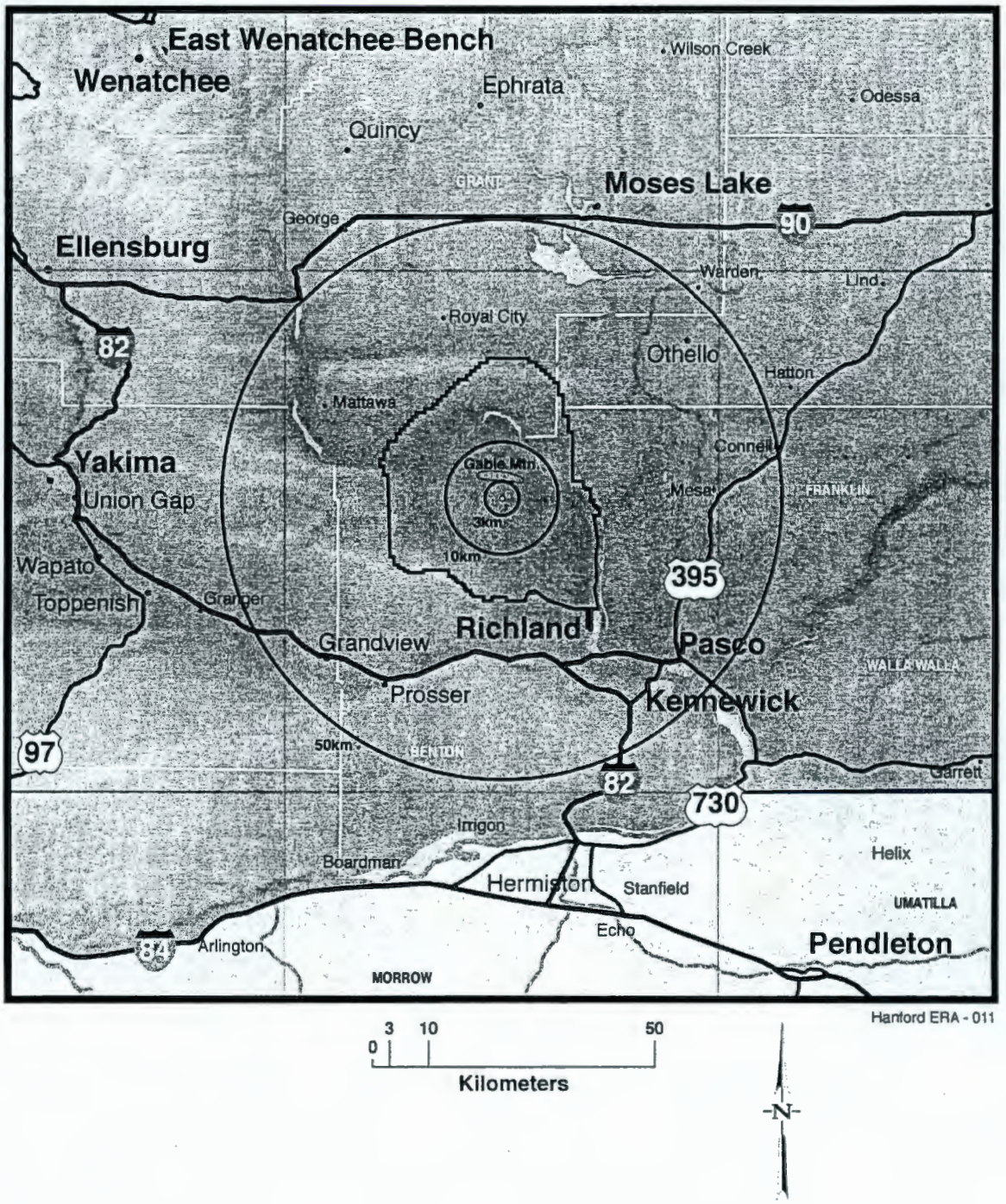


Figure 7-3. Exposure Distances (Near-Field) from the RPP-WTP at the Hanford Site

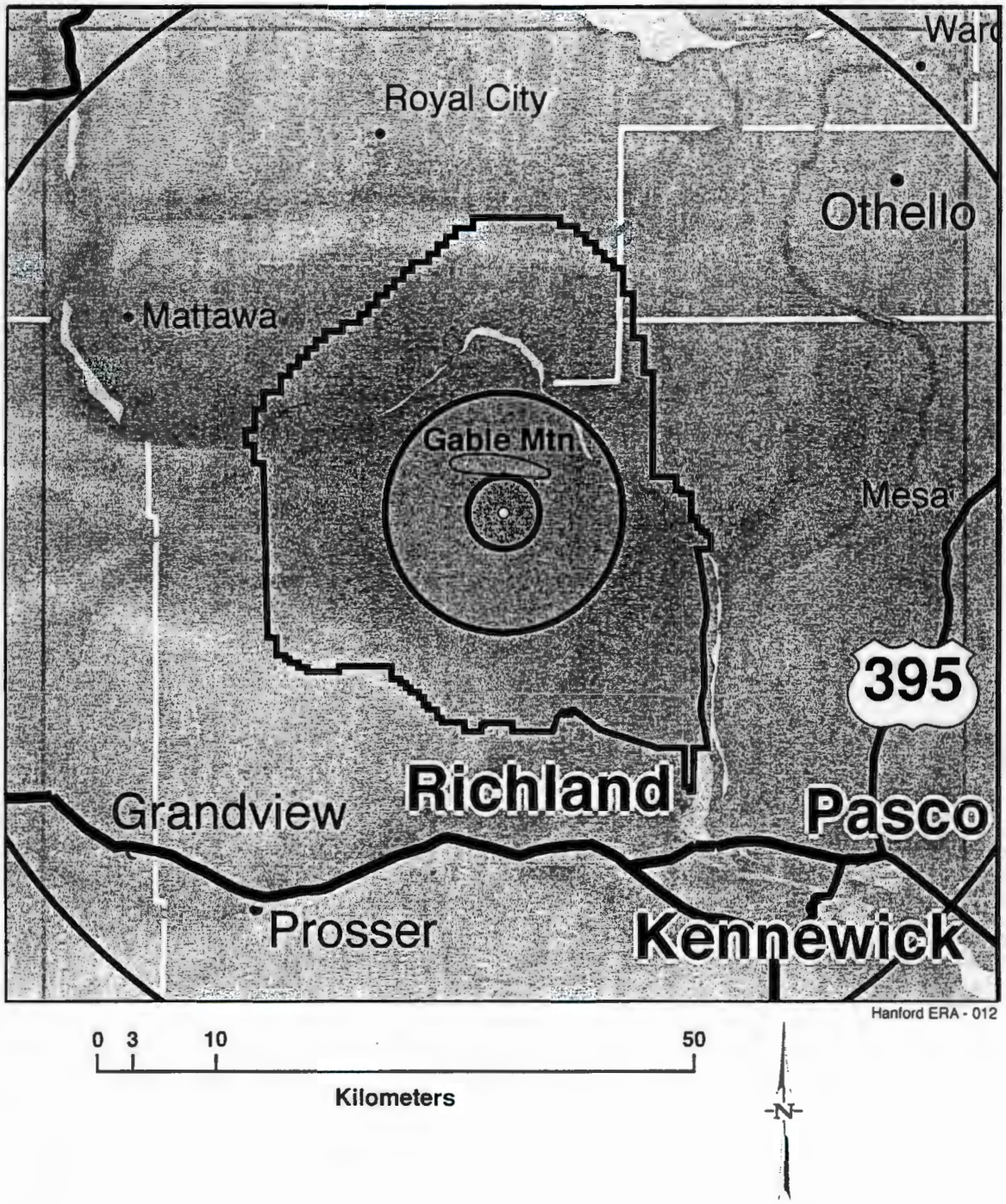
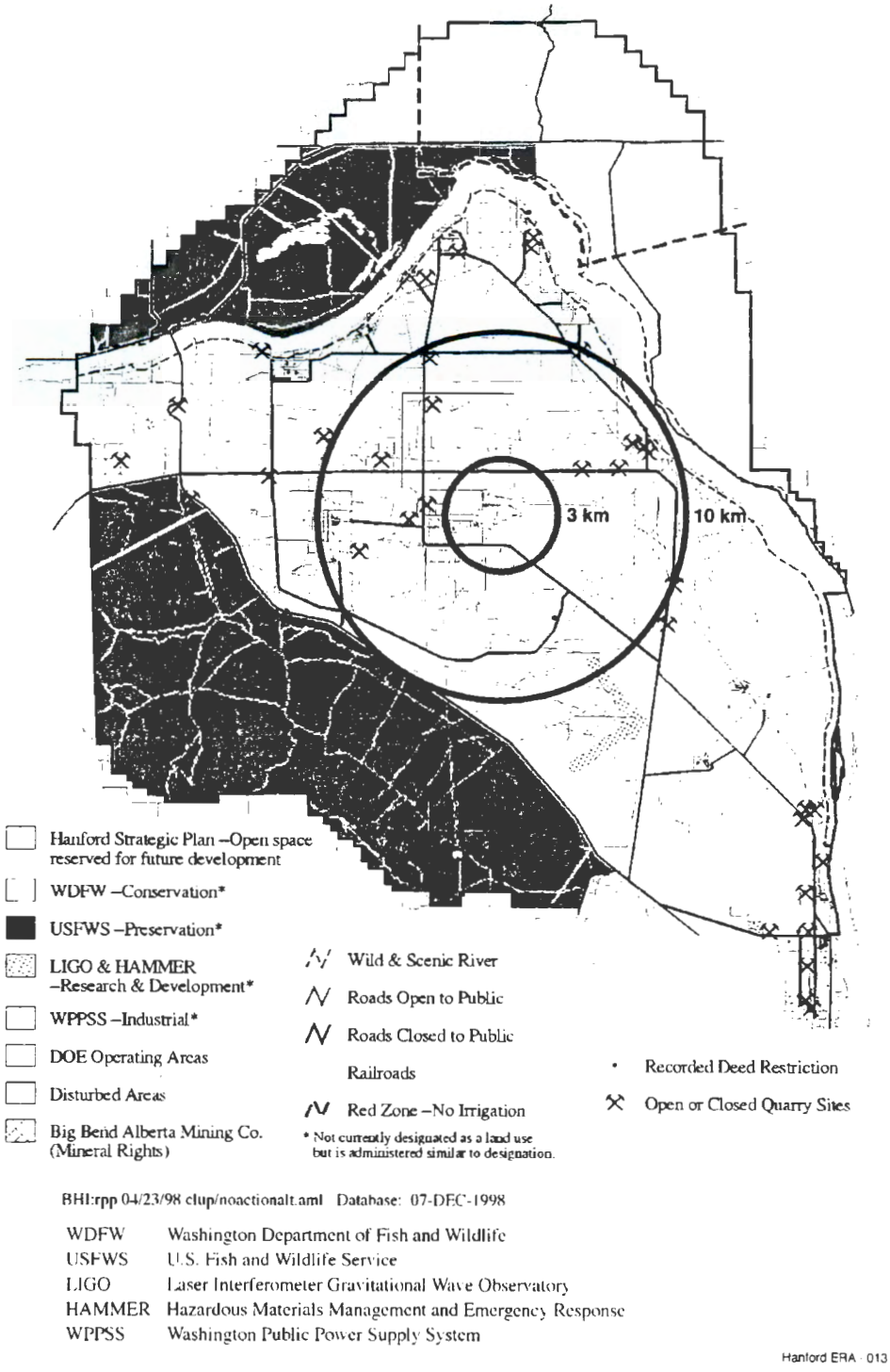


Figure 7-4 Hanford Site Existing Land Use Map – 1996



WDFW	Washington Department of Fish and Wildlife
USFWS	U.S. Fish and Wildlife Service
LIGO	Laser Interferometer Gravitational Wave Observatory
HAMMER	Hazardous Materials Management and Emergency Response
WPPSS	Washington Public Power Supply System

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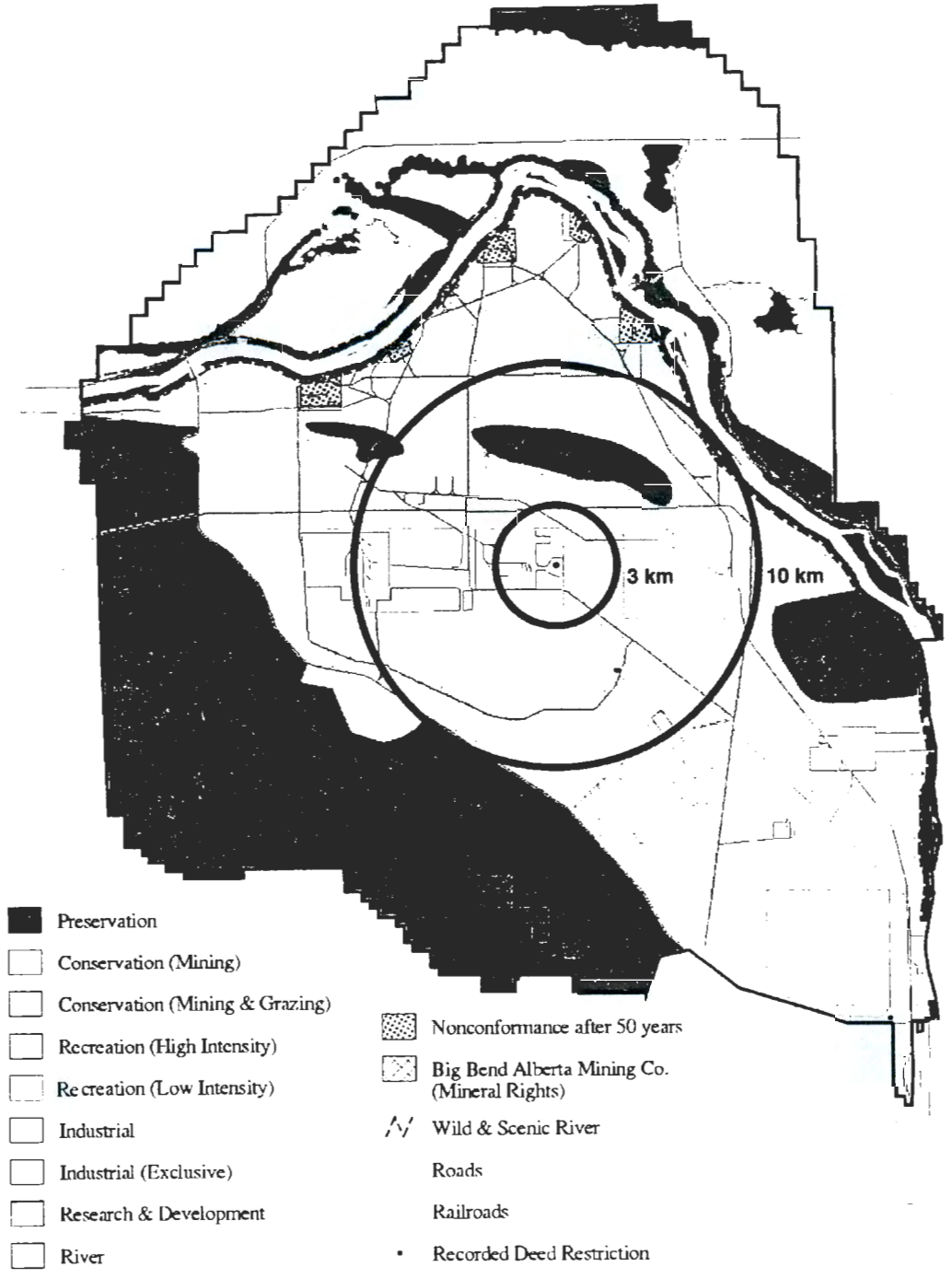
Figure 7-5 Hanford Site Projected Land Use Map - 2046



BHI:rpp 04/23/98 clup/prefalt.aml Database: 07-DEC-1998

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Table 7-1 Exposure Scenarios

Receptor	Receptor Location	Exposure Pathways	Reference Used to Define Exposures
Plausible Current Land Use Scenarios			
Hanford Site Industrial Worker[a]	Point of maximum exposure	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil	DOE-RL 1995
Resident Adult and Child	Point of maximum exposure at Hanford Site boundary	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown produce Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil	EPA 1998a
Native American Subsistence Hunter/Gatherer Adult and Child	Point of maximum exposure at Hanford Site boundary	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown/wild produce Ingestion of wild game Ingestion of wildfowl and eggs[d] Ingestion of milk Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil Inhalation of VOCs and SVOCs in sweat lodge[e] Dermal absorption in sweat lodge[e]	Harris and Harper 1997
Native American Subsistence Fisher Adult and Child	Point of maximum exposure at Hanford Site boundary	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown/wild produce Ingestion of fish (fillet and fish parts) Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil Inhalation of VOCs and SVOCs in sweat lodge[e] Dermal absorption in sweat lodge[e]	Harris and Harper 1997
Plausible Future Land Use Scenarios			
Hanford Site Industrial Worker[a]	Point of maximum exposure	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil	DOE-RL 1995

Table 7-1 Exposure Scenarios

Receptor	Receptor Location	Exposure Pathways	Reference Used to Define Exposures
Resident Adult and Child	Point of maximum exposure at Hanford Site boundary	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown produce Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil	EPA 1998a
Native American Subsistence Hunter/Gatherer Adult and Child	Point of maximum exposure	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown/wild produce Ingestion of wild game Ingestion of wildfowl and eggs[d] Ingestion of milk Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil Inhalation of VOCs and SVOCs in sweat lodge[e] Dermal absorption in sweat lodge[e]	Harris and Harper 1997
Native American Subsistence Fisher Adult and Child	Point of maximum exposure	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown/wild produce Ingestion of fish (fillet and fish parts) Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil Inhalation of VOCs and SVOCs in sweat lodge[e] Dermal absorption in sweat lodge[e]	Harris and Harper 1997
Worst-Case Future Land Use Scenarios			
Resident Adult and Child	Point of maximum exposure	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown produce Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil	EPA 1998a
Subsistence Farmer Adult and Child	Point of maximum exposure	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown produce Ingestion of homegrown beef and milk Ingestion of homegrown chicken and eggs Ingestion of homegrown pork Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil	EPA 1998a

Table 7-1 Exposure Scenarios

Receptor	Receptor Location	Exposure Pathways	Reference Used to Define Exposures
Subsistence Fisher Adult and Child	Point of maximum exposure at Columbia River	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown produce Ingestion of drinking water[c] Ingestion of fish External exposure to radionuclides in air External exposure to radionuclides in soil	EPA 1998a
Resident Nursing Infant[a]	Point of maximum exposure	Ingestion of breast milk	EPA 1998a
Native American Subsistence Hunter/Gatherer Adult and Child	Point of maximum exposure	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown/wild produce Ingestion of wild game Ingestion of wildfowl and eggs[d] Ingestion of milk Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil Inhalation of VOCs and SVOCs in sweat lodge[e] Dermal absorption in sweat lodge[e]	Harris and Harper 1997
Native American Subsistence Fisher Adult and Child	Point of maximum exposure	Inhalation of emissions[b] Ingestion of soil Inhalation of resuspended soil Ingestion of homegrown/wild produce Ingestion of fish (fillet and fish parts) Ingestion of drinking water[c] External exposure to radionuclides in air External exposure to radionuclides in soil Inhalation of VOCs and SVOCs in sweat lodge[e] Dermal absorption in sweat lodge[e]	Harris and Harper 1997
Native American Resident Nursing Infant[a]	Point of maximum exposure	Ingestion of breast milk	Harris and Harper 1997 and EPA 1998a
Acute Exposure Scenario			
Acute Exposure	Point of maximum short-term exposure	Inhalation of emissions[b]	EPA 1998a

[a] Special subpopulation to be evaluated.

[b] Includes direct inhalation of vapor phase and particulate emissions.

[c] Surface water concentrations will be used to evaluate the ingestion of drinking water pathway.

[d] Consumption rates for the ingestion of poultry and eggs for the Native American will be based on a partitioning of the consumption rate of wild fowl (which includes bird and eggs), as presented in Harris and Harper 1997.

[e] Inhalation and dermal absorption in the sweat lodge is evaluated for adult Native Americans only.

Table 7-2 Exposure Parameters for Residential Scenarios

Exposure Pathway	Parameter	Description	Units	Value[a]	Comment
Inhalation of particulates and vapors	IR	Inhalation rate of air	m^3/hr	0.63 0.3	Value for adults Value for children
	ET	Exposure Time	hr/day	24	Assumption
	EF	Exposure Frequency	day/year	350	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	year	40 30 6	Value for adult farmer Value for adult fisher/resident Value for child in all scenarios
	BW	Body Weight	kg	70 15	Value for adults Value for children
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects
Soil Ingestion	CR_{soil}	Consumption rate of soil	kg/day	0.0001[b] 0.0002[b]	Value for adults Value for children
	F_{soil}	Fraction of soil ingested that is contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	350	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	year	40 30 6	Value for adult farmer Value for adult fisher/resident Value for child in all scenarios
	BW	Body Weight	kg	70 15	Value for adults Value for children
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects

Table 7-2 Exposure Parameters for Residential Scenarios

Exposure Pathway	Parameter	Description	Units	Value[a]	Comment
Inhalation of Resuspended Soil	IR	Inhalation rate of air	m^3/hr	0.63 0.3	Value for adults Value for children
	ET	Exposure Time	hr/day	24	Assumption
	EF	Exposure Frequency	day/year	350	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	year	40 30 6	Value for adult farmer Value for adult fisher/resident Value for child in all scenarios
	BW	Body Weight	kg	70 15	Value for adults Value for children
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects
External Exposure to Ionizing Radiation in Soil	Se	Shielding Factor	unitless	0.2[c]	Assume 20% shielding
	Te	Exposure Time Factor	unitless	1.0[c]	Assumption (24 hours/24 hours)
	EF	Exposure Frequency	days/year	350	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	years	40 30 6	Value for adult farmer Value for adult fisher/resident Value for child in all scenarios
External Exposure to Ionizing Radiation in Air	EF	Exposure Frequency	day/year	350	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	year	40 30 6	Value for adult farmer Value for adult fisher/resident Value for child in all scenarios
	AF	Age Factor	unitless	1[d] 1.3[d]	No adjustment for adults Adjustment factor for child

Table 7-2 Exposure Parameters for Residential Scenarios

Exposure Pathway	Parameter	Description	Units	Value[a]	Comment
Produce Consumption	CR_{ag}	Consumption rate of unprotected aboveground produce	kg/kg-day DW	0.0003 0.00042	Value for adults Value for children
	CR_{pp}	Consumption rate of protected aboveground produce	kg/kg-day DW	0.00057 0.00077	Value for adults Value for children
	CR_{bg}	Consumption rate of below ground produce	kg/kg-day DW	0.00014 0.00022	Value for adults Value for children
	F_{ag}	Fraction of ingested produce that is contaminated	unitless	0.25 1.0 0.25	Value for resident Value for farmer Value for fisher
	EF	Exposure Frequency	day/year	350	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	year	40 30 6	Value for adult farmer Value for adult fisher/resident Value for child in all scenarios
	BW	Body Weight	kg	70 15	Value for adults Value for children
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects
Ingestion of beef, milk, poultry, eggs, and pork	CR_{beef}	Consumption rate of beef	kg/kg-day FW	0.00114 0.00051	Value for adults Value for children
	CR_{milk}	Consumption rate of milk	kg/kg-day FW	0.00842 0.01857	Value for adults Value for children
	$CR_{poultry}$	Consumption rate of poultry	kg/kg-day FW	0.00061 0.000425	Value for adults Value for children
	CR_{eggs}	Consumption rate of eggs	kg/kg-day FW	0.00062 0.000438	Value for adults Value for children
	CR_{pork}	Consumption rate of pork	kg/kg-day FW	0.00053 0.000398	Value for adults Value for children
	F	Fraction of ingested food item that is contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	350	Assumed 2 weeks away from contaminated area per year

Table 7-2 Exposure Parameters for Residential Scenarios

Exposure Pathway	Parameter	Description	Units	Value[a]	Comment
Ingestion of beef, milk, poultry, eggs, and pork (cont'd)	ED	Exposure Duration	year	40	Value for adult farmer
				30	Value for adult fisher/resident
				6	Value for child in all scenarios
	BW	Body Weight	kg	70	Value for adults
				15	Value for children
	AT	Averaging Time	year	70	Value for carcinogenic effects
				ED	Equal to exposure duration for noncarcinogenic effects
Ingestion of fish	CR_{fish}	Consumption rate of fish	kg/kg-day FW	0.00117	Value for adults
				0.000759	Value for children
	CR_{organs}	Consumption rate of fish parts (e.g., head, fins, tails, etc.)	kg/kg-day FW	0.0	No consumption of fish parts
	F_{fish}	Fraction of ingested fish that are contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	350	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	year	30	Value for adult fisher
				6	Value for child fisher
	BW	Body Weight	kg	70	Value for adults
				15	Value for children
	AT	Averaging Time	year	70	Value for carcinogenic effects
				ED	Equal to exposure duration for noncarcinogenic effects

Table 7-2 Exposure Parameters for Residential Scenarios

Exposure Pathway	Parameter	Description	Units	Value[a]	Comment
Ingestion of drinking water[e]	CR_{dw}	Consumption rate of drinking water	L/day	1.4 0.67	Value for adults Value for children
	F_{dw}	Fraction of ingested drinking water that is contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	350	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	year	40 30 6	Value for adult farmer Value for adult fisher/resident Value for child in all scenarios
	BW	Body Weight	kg	70 15	Value for adults Value for children
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects
Infant Ingesting Breast Milk[f]	h	Half-life of dioxin/furan/PCB or isotope in adult	day	2,555 isotope-specific	Upper bound of 5- to 7-year range is selected for dioxins Half-life of isotopes, in days
	f_1	Fraction of ingested COPC/ROPC that is stored in fat	unitless	0.9	EPA OSW recommendation
	f_2	Fraction of mother's weight that is fat	unitless	0.3	EPA OSW recommendation
	f_3	Fraction of mother's breast milk that is fat	unitless	0.04	EPA OSW recommendation
	f_4	Fraction of ingested COPC/ROPC that is absorbed	unitless	0.9	EPA OSW recommendation
	IR_{milk}	Ingestion rate of breast milk by infant	kg/day	0.8	Midpoint of range from 677 to 922 ml/day with assumed density >1 g/ml
	ED	Exposure duration	year	1.0	EPA OSW recommendation

Table 7-2 Exposure Parameters for Residential Scenarios

Exposure Pathway	Parameter	Description	Units	Value[a]	Comment
Infant Ingesting Breast Milk[f] (cont'd)	BW_{infant}	Body weight of infant	kg	10	Mean of 6 mo. to 1 year old infant's weight ranging from 9.1 to 11.3 kg
	AT	Averaging Time	year	1	EPA OSW recommendation acknowledging that this value may overestimate carcinogenic risks by a factor of 70
	EF	Exposure Frequency	day/year	365	Infant ingesting breast milk every day

[a] EPA default exposure parameters (EPA 1998a), unless otherwise noted.

[b] EPA Region X personal communication (EPA 1999e).

[c] RAGS, Part B (EPA 1991b).

[d] Saito, et al., 1998.

[e] Surface water concentrations will be used to evaluate the ingestion of drinking water pathway.

[f] Dioxins, furans, coplanar PCBs, and radionuclides are evaluated for the infant's ingestion of breast milk.

Table 7-3 Summary of Exposure Parameters for Native American Subsistence Scenarios[a]

Exposure Pathway	Parameter	Description	Units	Value[b]	Comment
Inhalation of particulates and vapors	IR	Inhalation rate of air	m^3/hr	0.833[c] 0.417[c]	Value for adults Value for children
	ET	Exposure Time	hr/day	24[c]	Assumption
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70 6[d]	Value for adults Value for children
	BW	Body Weight	kg	70 15[d]	Value for adults Value for children
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects
Soil Ingestion	CR_{soil}	Consumption rate of soil	kg/day	0.0002[e]	Value for adults and children
	F_{soil}	Fraction of soil ingested that is contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70 6[d]	Value for adults Value for children
	BW	Body Weight	kg	70 15[d]	Value for adults Value for children
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects

Table 7-3 Summary of Exposure Parameters for Native American Subsistence Scenarios[a]

Exposure Pathway	Parameter	Description	Units	Value[b]	Comment
Inhalation of Resuspended Soil	IR	Inhalation rate of air	m^3/hr	0.833[c]	Value for adults
				0.417[c]	Value for children
	ET	Exposure Time	hr/day	24[c]	Assumption
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70	Values for adults
				6[d]	Values for children
	BW	Body Weight	kg	70	Values for adults
				15[d]	Values for children
	AT	Averaging Time	year	70	Value for carcinogenic effects
				ED	Equal to exposure duration for noncarcinogenic effects
External Exposure to Ionizing Radiation in Soil	Se	Shielding Factor	unitless	0.2[f]	Assumed 20% shielding
	Te	Exposure Time Factor	unitless	1.0[f]	Exposure for 24 hr each day
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70	Value for adults
				6[d]	Value for children
External Exposure to Ionizing Radiation in Air	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70	Value for adults
				6[d]	Value for children
	AF	Age Factor	unitless	1[g]	No adjustment for adults
				1.3[g]	Adjustment factor for children
Produce Consumption	CR_{ag}	Consumption rate of unprotected aboveground produce	kg/kg-day DW	0.00575[h]	Value for hunter/gatherer adults, based on 402.5 g/day[h]
				0.02683[h]	Value for hunter/gatherer children, based on 402.5 g/day[h]
	CR_{pp}	Consumption rate of protected aboveground produce	kg/kg-day DW	0.0[i]	Value for hunter/gatherer adults and children[i]

Table 7-3 Summary of Exposure Parameters for Native American Subsistence Scenarios[a]

Exposure Pathway	Parameter	Description	Units	Value[b]	Comment
Produce Consumption (cont'd)	CR_{bg}	Consumption rate of belowground produce	kg/kg-day DW	0.00245[j]	Value for hunter/gatherer adults, based on 171.5 g/day[j]
				0.01143[j]	Value for hunter/gatherer children, based on 171.5 g/day[j]
	F_{ag}	Fraction of ingested produce that is contaminated	unitless	1.0	Assumed
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70	Value for hunter/gatherer adults
				6[d]	Value for hunter/gatherer children
	BW	Body Weight	kg	70	Value for hunter/gatherer adults
				15[d]	Value for hunter/gatherer children
	AT	Averaging Time	year	70	Value for carcinogenic effects
				ED	Equal to exposure duration for noncarcinogenic effects
Ingestion of game, milk, poultry, and eggs	CR_{game}	Consumption rate of beef, elk, and other game tissue	kg/kg-day FW	0.00357	Value for hunter/gatherer adults based on 250 g/day of meat
				0.01667	Value for hunter/gatherer children based on 250 g/day of meat
	CR_{milk}	Consumption rate of milk	kg/kg-day FW	0.00842[k]	Value for hunter/gatherer adults[k]
				0.01857[k]	Value for hunter/gatherer children[k]

Table 7-3 Summary of Exposure Parameters for Native American Subsistence Scenarios[a]

Exposure Pathway	Parameter	Description	Units	Value[b]	Comment
Ingestion of game, milk, poultry, and eggs (cont'd)	$CR_{poultry}$	Consumption rate of poultry	kg/kg-day FW	0.000329[l]	Value for hunter/gatherer adults, based on 23 g/day[j]
				0.001533[l]	Value for hunter/gatherer children, based on 23 g/day[j]
	CR_{eggs}	Consumption rate of eggs	kg/kg-day FW	0.0003[l]	Value for hunter/gatherer adults, based on 21 g/day[l]
				0.0014[l]	Value for hunter/gatherer children, based on 21 g/day[j]
	F	Fraction of ingested food item that is contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70	Value for hunter/gatherer adults
				6[d]	Value for hunter/gatherer children
	BW	Body Weight	kg	70	Value for hunter/gatherer adults
				15[d]	Value for hunter/gatherer children
	AT	Averaging Time	year	70	Value for carcinogenic effects
				ED	Equal to exposure duration for noncarcinogenic effects

Table 7-3 Summary of Exposure Parameters for Native American Subsistence Scenarios[a]

Exposure Pathway	Parameter	Description	Units	Value[b]	Comment
Ingestion of fish	CR_{fish}	Consumption rate of fish	kg/kg-day FW	0.00771	Value for fisher adults, based on 540 g/day. This same consumption rate is assumed for fisher children.[m]
	CR_{organs}	Consumption rate of fish parts (e.g., head, fins, tails, etc.)	kg/kg-day FW	0.000771	Value for fisher adults, based on 54 g/day. This same consumption rate is assumed for fisher children.[m]
	F_{fish}	Fraction of ingested fish that are contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70 6[d]	Value for fisher adults Value for fisher children
	BW	Body Weight	kg	70 15[d]	Value for fisher adults Value for fisher children
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects
Ingestion of drinking water[n]	CR_{dw}	Consumption rate of drinking water	L/day	3.0 1.5[o]	Value for adults Value for children
	F_{dw}	Fraction of ingested drinking water that is contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70 6[d]	Value for adults Value for children
Ingestion of drinking water[n]	BW	Body Weight	kg	70 15[d]	Value for adults Value for children
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects

Table 7-3 Summary of Exposure Parameters for Native American Subsistence Scenarios[a]

Exposure Pathway	Parameter	Description	Units	Value[b]	Comment
Inhalation of Volatile and Semi-Volatile Organic Compounds Inside the Sweat Lodge	VW	Volume of Water Used	L	4	Assumed value
	D	Diameter of Sweat Lodge	m	2	Hemisphere
	IR	Inhalation Rate	m^3/day	20	Assumed rate
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70	Assumed lifetime
	ET	Exposure Time	hr/day	1	1 hour of exposure each day
	BW	Body Weight	kg	70	Value for adults
	AT	Averaging Time	year	70	Assumed
Dermal Absorption Inside the Sweat Lodge	SA	Surface Area	m^2	2	Whole body for an adult
	ET	Exposure Time	hr/day	1	1 hour of exposure each day
	EF	Exposure Frequency	day/year	365	Exposure every day
	ED	Exposure Duration	year	70	Assumed lifetime
	BW	Body Weight	kg	70	Value for adults
	AT	Averaging Time	year	70	Assumed
Infant Ingesting Breast Milk[p]	h	Half-life of dioxin (and related compounds) or isotope in adult	day	2555[q] isotope-specific	Upper bound of 5 - to - 7 year range for dioxins Half-life of isotope in days
	f_1	Fraction of ingested dioxin or isotope that is stored in fat	unitless	0.9[q]	EPA OSW recommendation
	f_2	Fraction of mother's weight that is fat	unitless	0.3[q]	EPA OSW recommendation
	f_3	Fraction of mother's breast milk that is fat	unitless	0.04[q]	EPA OSW recommendation

Table 7-3 Summary of Exposure Parameters for Native American Subsistence Scenarios[a]

Exposure Pathway	Parameter	Description	Units	Value[b]	Comment
Infant Ingesting Breast Milk[p] (cont'd)	f_4	Fraction of ingested dioxin compounds or isotopes that are absorbed	unitless	0.9[q]	EPA OSW recommendation
	IR_{milk}	Ingestion rate of breast milk by infant	kg/day	0.742	Harris and Harper 1997
	ED	Exposure Duration	year	1.0[q]	EPA OSW recommendation
	BW_{infant}	Body Weight of Infant	kg	10[q]	Mean of 6 months to 1 year old infant's weight, ranging from 9.1 to 11.3 kg
	AT[i]	Averaging Time	year	1[q]	EPA OSW recommendation, acknowledging that this value may overestimate carcinogenic risks by a factor of 70
	EF	Exposure Frequency	day/year	365[q]	Infant ingesting breast milk every day

a The hunter/gatherer (child and adult) is not exposed to the ingestion of fish, but is exposed to all other non-infant pathways. The fisher (child and adult) is not exposed to the ingestion of produce, meat, game, milk, poultry, and eggs, but is exposed to all other non-infant pathways. Children are not exposed to the two sweat lodge scenarios (inhalation of VOCs/SVOCs and dermal absorption). The infant's ingestion of breast milk is based on the mother's total daily intake of COPCs/ROPCs via all indirect exposure pathways (i.e., ingestion of soil, produce, meat, game, milk, poultry, eggs, fish, and drinking water).

b Parameter values are from Harris and Harper 1997, unless otherwise noted.

c When the inhalation rate in m^3/hr is combined with the exposure time of 24 hr/day, the resulting inhalation rates are 20 m^3/day for adults and 10 m^3/day for children (EPA 1989b).

d BW and ED values for children are consistent with those found in EPA 1998a.

e Adult soil ingestion rate is from Harris and Harper 1997; this same rate (200 mg/day) is commonly used as a child's soil ingestion rate (EPA 1989c). Therefore, this same rate is used for the Native American child soil ingestion rate.

f RAGS Part B (EPA 1991b).

g Age modifying factors are from Saito, et al. 1998.

h Consumption rates for unprotected aboveground produce are based on the Native American intake rates of 3.3 g/kg-day (231 g/day for a 70 kg adult) for fruits and 4.9 g/kg-day (343 g/day for a 70 kg adult) for vegetables (Harris and Harper 1997), along with the following assumptions: (1) fruits are unprotected aboveground produce; (2) vegetables are a combination of unprotected aboveground produce and belowground produce; and (3) 50% of the vegetables are assumed to come from unprotected aboveground produce and 50% from belowground produce. Thus, the unprotected aboveground produce intake for a 70-kg adult is 231 g/day of fruits and 171.5 g/day of vegetables, for a total unprotected aboveground produce intake rate of 402.5 g/day. Adult and child consumption rates are calculated from the 402.5 g/day intake.

i Consumption rate for protected aboveground produce is 0.0 kg/kg-day, based on the assumption that neither fruits nor vegetables are protected aboveground produce. Also, see footnote h above.

j Consumption rates for belowground produce are based on the Native American intake rate of 4.9 g/kg-day (343 g/day for a 70 kg adult) for vegetables (Harris and Harper 1997), along with the following assumptions: (1) vegetables are a combination of unprotected aboveground produce and belowground produce; and (2) 50% of the vegetables are assumed to come from unprotected aboveground produce and 50% from belowground produce. Thus, 171.5 g/day of vegetables is used as the basis for belowground produce consumption rates for adults and children.

k Milk consumption rates for non-Native Americans; values used for Native Americans are consistent with those values used for non-Native Americans.

l Consumption rates for poultry and eggs are based on the Native American intake rate of 44 g/day of fowl, which includes both bird and eggs (Harris and Harper 1997). Based on the ratio of 0.54:0.491 for Native American intake of poultry to eggs (see Tables 11-5 and 11-7 in EPA 1997b), the fowl intake of 44 g/day is subdivided as 23 g/day of poultry and 21 g/day of eggs. These same intake rates are used to calculate consumption rates for hunter/gatherer adults and children.

m Personal communication (EPA 1999f).

n Surface water concentrations will be used to evaluate the ingestion of drinking water pathway.

o Value obtained from personal communication with 8. Harper (Harper 1999).

p Dioxins, furans, coplanar PCBs, and radionuclides are evaluated for the infant's ingestion of breast milk.

q Values from infant ingestion of breast milk scenario in EPA 1998a.

Table 7-4 Summary of Exposure Parameters for Hanford Site Worker Scenario

Exposure Pathway	Parameter	Description	Units	Value[a]	Comment
Inhalation of particulates and vapors	IR	Inhalation rate of air	m^3/hr	2.5[b]	Value for adult worker
	ET	Exposure Time	hr/day	8[b]	8-hour work day
	EF	Exposure Frequency	day/year	250	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	year	20	Value for adult worker
	BW	Body Weight	kg	70	Value for adult worker
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects
Soil Ingestion	CR_{soil}	Consumption rate of soil	kg/day	0.00005	Value for adult worker
	F_{soil}	Fraction of soil ingested that is contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	146	Derived from frequency of exposure (365 day/yr × 0.4)
	ED	Exposure Duration	year	20	Value for adult worker
	BW	Body Weight	kg	70	Value for adult worker
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects
Inhalation of Resuspended Soil	IR	Inhalation Rate of Air	m^3/hr	2.5[b]	Value for adult worker
	ET	Exposure Time	hr/day	8[b]	Assumption
	EF	Exposure Frequency	day/year	146	Derived from frequency of exposure (365 day/yr × 0.4)
	ED	Exposure Duration	year	20	Value for adult worker
	BW	Body Weight	kg	70	Value for adult worker
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects
External Exposure to Ionizing Radiation in Soil	Se	Shielding Factor	unitless	0.2	Assumed 20% shielding
	Te	Exposure Time Factor	unitless	8/24	8-hour workday
	EF	Exposure Frequency	days/year	146	Derived from frequency of exposure (365 day/yr × 0.4)

Table 7-4 Summary of Exposure Parameters for Hanford Site Worker Scenario

Exposure Pathway	Parameter	Description	Units	Value[a]	Comment
	ED	Exposure Duration	years	20	Value for adult worker
External Exposure to Ionizing Radiation in Air	EF	Exposure Frequency	day/year	146	Derived from frequency of exposure (365 day/yr x 0.4)
	ED	Exposure Duration	year	20	Value for adult worker
	AF	Age Factor	unitless	1[c]	No adjustment for adults
Ingestion of drinking water[d]	CR_{dw}	Consumption rate of drinking water	L/day	1	Value for adult worker
	F_{dw}	Fraction of ingested drinking water that is contaminated	unitless	1.0	Assumption
	EF	Exposure Frequency	day/year	250	Assumed 2 weeks away from contaminated area per year
	ED	Exposure Duration	year	20	Value for adult worker
	BW	Body Weight	kg	70	Value for adult worker
	AT	Averaging Time	year	70 ED	Value for carcinogenic effects Equal to exposure duration for noncarcinogenic effects

[a] Values are from DOE-RL 1995, unless otherwise noted.

[b] The combination of the inhalation rate, in m^3/hr, and the exposure time, in hr/day, produce the standard industrial inhalation rate of 20 m^3/day.

[c] Age modifying factor is from Saito, et al. 1998.

[d] Surface water concentrations will be used to evaluate the ingestion of drinking water pathway.

Chapter 8

8. Screening Ecological Risk Assessment

The screening ecological risk assessment incorporates four fundamental components of the ERA process: (1) problem formulation, (2) exposure assessment, (3) effects assessment, and (4) risk characterization. Selection of COPCs (section 4), quantification of emissions (section 5), and dispersion modeling (section 6) feed critical information to this process.

8.1. Problem Formulation

This section of the Work Plan focuses on the conceptual exposure model, ecological setting, ecological receptor identification, and assessment/measurement endpoints. Each is defined below.

8.1.1. Ecological Conceptual Exposure Model

A conceptual exposure model has been developed that identifies potential ecological receptors and potentially complete exposure pathways (that is, exposure scenarios). The conceptual model is shown as Figure 8-1. The end product of the conceptual model is the identification of exposure scenarios that are defined by potentially exposed populations and exposure pathways. The conceptual model was developed from information obtained from EPA (1998a) and *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment* (DOE-RL 1998).

The conceptual model focuses on identifying complete exposure pathways for potentially exposed receptor populations. An exposure pathway is the means through which an organism comes in contact with a chemical in the environment. Exposure pathways are determined by environmental conditions (e.g., location of habitat and home ranges and wind speed/direction), the potential for chemical migration among media (e.g., air, soil, or surface water), and by the behavior and diet of potentially exposed plant and animal populations. Although several potential pathways may exist, as was explained in the human health risk assessment, not all pathways may be complete. For a pathway to be complete, the following four factors must exist:

1. A source of COPC/ROPC release into the Hanford Site environment,

2. A release and transport mechanism (e.g., deposition to soil) that moves the COPC/ROPC from the source, such as stack, to other locations in the environment,

3. A point of contact with a contaminated medium, and

4. An exposure route to the receptor such as ingesting or inhaling affected media

These four factors were considered in the conceptual model. The sources of COPC and ROPC release are the stack and fugitive emissions from the RPP-WTP. Transport processes, potential points of contact, and complete exposure pathways are identified to formulate exposure scenarios that will be the focus of the quantitative risk assessment. The technical context for this is as follows.

8.1.2. Ecological Characterization

The Hanford Site and adjacent region are a shrub-steppe vegetation zone with a shrub overstory and an understory of grasses. Ecological resources at the Hanford Site are extensive, diverse, and important as explained in Neitzel et al. 1998. Because the Hanford Site has not been farmed or grazed for over

50 years, it has become a refuge for a variety of plant and animal species (Gray and Rickard 1989) containing one of the largest remaining undisturbed shrub-steppe ecosystems in Washington (see Appendix C-1 for a listing of plants and animals observed on the site). About 665 km^2 (257 mi^2) of undeveloped lands located on-site (almost half of the total area of the Hanford Site) have been designated as ecological study areas or refuges (Figure 8-2).

8.1.2.1. Physiographic Setting

The Hanford Site lies within the Intermountain Semidesert Province (USFS 1994). This province includes the plains and plateaus of the Columbia-Snake River Plateaus and the Wyoming Basin. The climate is cool, the average temperature being about 50°F, and semi-arid, with the average annual precipitation ranging from 10 to 20 inches across the province from west to east. At the Hanford Site, the average annual precipitation totals about six inches. This precipitation is evenly distributed throughout the fall, winter, and spring months, with little precipitation during the summer months.

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington and occupies an area of approximately 1,450 km^2 (560 mi^2) north of the confluence of the Yakima River with the Columbia River. The Pasco Basin lies within the southwest corner of the larger Columbia Basin. The Hanford Site occupies approximately one-third of the land area within the Pasco Basin. The Columbia River flows through the northern part of the Hanford Site and forms part of the Hanford Site's eastern boundary after turning south. The Yakima River runs near the southern boundary. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries of the Hanford Site. The Saddle Mountains form the northern boundary. Adjoining lands to the west, north, and east are principally range and agricultural land. The Hanford Site exhibits low relief, ranging from 120 m (390 ft) above mean sea level (MSL) at the Columbia River to 230 m (750 ft) MSL in the vicinity of the RPP-WTP sites.

The 200 Areas/RPP-WTP sites are located on the Central Plateau. The Central Plateau is characterized by generally low-relief hills with deeply incised river drainages. Gable Butte and Gable Mountain (small east–west ridges) are prominent features of the Central Plateau.

8.1.2.2. Regional Ecology

The region has been characterized as shrub-steppe. Shrub-steppe vegetation is dominated by a shrub overstory with an understory of grasses (Daubenmire 1970). Non-industrialized lands on the Hanford Site have not been farmed or grazed by livestock for over 50 years, allowing it to serve as a refuge for a variety of plant and animal species (Gray and Rickard 1989). As stated earlier, approximately 665 km^2 (257 mi^2) of undeveloped lands within the Hanford Site have been designated as refuges or ecological study areas. Shrub-steppe is considered a priority habitat by the State of Washington because of its importance to wildlife species of concern (Neitzel et al. 1998). The National Biological Service has identified native shrub and grassland steppes in Washington and Oregon as endangered ecosystems (DOE 1996).

Biodiversity on the Hanford Site is enhanced by the large, relatively undisturbed tract of native shrub-steppe habitat and by the Hanford Reach which is a stretch of the Columbia River below the Priest Rapids Dam (DOE 1996a). Additional factors influencing biodiversity include topographic features such as Rattlesnake Mountain, Gable Butte, Gable Mountain, and the presence of a variety of soils ranging from sand to silty and sandy loam. Unique terrestrial habitats include basalt outcrops, scarps (cliffs), scree slopes, and sand dunes. Aquatic habitats are mostly associated with the Columbia River and include open water habitat, wetlands, and riparian areas (Figure 8-3).

Cold Creek and a tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system that roughly parallel State Route 240 through the Hanford Site. Both streams drain areas to the west of Hanford Site. Surface flow, when it occurs, infiltrates and disappears into the surface sediments in the western portion of the Hanford Site. Rattlesnake Springs, located on the western portion of the Hanford Site, forms a small surface stream that flows for about 3 km (1.8 mi) before disappearing into the ground.

West Lake is located north of the 200 East Area and is recharged from groundwater (Neitzel et al. 1998). West Lake has not received direct effluent discharges from any Hanford Site facilities. This water body is created by an elevated water table within a low surface area south of Gable Mountain. This artificially elevated water table occurs under much of the Hanford Site, reflecting the augmented recharge from Hanford Site operations. Currently, West Lake has been reduced to a collection of small pools and mudflats (Neitzel et al. 1998).

Gable Mountain Pond (also to the north of 200 Area East but south of West Lake) and the B Pond System (immediately east of 200 Area East) received cooling water discharges from several facilities at the Hanford Site (Rogers and Rickard 1977). These artificial water bodies, formed by the waste water discharges from the operation of the separation facilities, were decommissioned and covered with soil.

Vegetation

The Hanford Site is a shrub-steppe ecosystem characterized by bunchgrasses and sagebrushes (Figure 8-3). This ecosystem is also referred to as high desert, northern desert shrub, or desert scrub (Franklin and Dyrness 1973). Prior to Western European settlement, the dominant plant in the area was big sagebrush (Artemisia tridentata) with an understory of perennial bunchgrasses, especially Sandberg's bluegrass (Poa sandbergii) and bluebunch wheatgrass (Agropyron spicatum). Following settlement in the early 1800s, grazing and agriculture disrupted the native vegetation and opened the way for invasive species such as Russian thistle (Salsola kali) and cheatgrass (Bromus tectorum). Cheatgrass is now dominant in fields that were cultivated prior to the establishment of the Hanford Site. Cheatgrass also is well established on rangelands at elevations less than 244 m (800 ft) (DOE and Ecology 1996). Establishment of the Hanford Site as a nuclear complex in 1943 resulted in the creation of a secured area of mostly undeveloped land with scattered, small industrial facilities. Consequently, the Hanford Site is one of a small number of remaining shrub-steppe tracts in Washington that is relatively undisturbed. Wildfire is a common occurrence and can significantly alter the shrub component of the vegetation. The most recent extensive fire on the Hanford Site was in 1984. Trees were planted and irrigated on most of the pre-1943 farms to provide windbreaks and shade. Some of these trees have persisted and serve as nesting platforms for several species of birds, (that is, hawks, owls, ravens, magpies, and great blue herons), and as night roosts for wintering bald eagles (DOE and Ecology 1996) (Figure 8-4).

The Central Plateau and surrounding areas have been identified as predominantly shrub-steppe (Neitzel et al. 1998 and Duranceau 1995). This designation includes communities dominated by big sagebrush and bitterbrush (*Purshia tridentata*) with an understory of cheatgrass or Sandberg's bluegrass. Over 100 plant species occur on the Central Plateau and vicinity. Common plant species include big sagebrush, rabbitbrush (*Chrysothamnus nauseous*), cheatgrass, and Sandberg's bluegrass.

The RPP-WTP sites in the 200 East Area and the immediately surrounding area are approximately 40% big sagebrush and rabbitbrush (Figure 8-3). Another 20% is dominated by Russian thistle, with the remainder being disturbed vegetation or bare gravel (PNL 1994). Other vegetation in the 200 Areas includes introduced perennial grasses planted to revegetate and stabilize disturbed areas such as waste burial grounds. Siberian wheatgrass (*Agropyron sibericum*) has been used extensively and has proven to be drought tolerant and better adapted to sandy soil than other species (Stegen 1993).

Wetland species such as cattail, reeds, and various trees, such as willow, cottonwood, and Russian olive, are established around some of the man-made ditches and ponds that are in the area. The decommissioning of some facilities have eliminated the supply of industrial water feeding some ponds. Without this water supply, the artificially supported wetland habitats have also been eliminated.

Almost 600 species of plants have been identified on the Hanford Site (Neitzel et al. 1998). The dominant plants are big sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass, with cheatgrass providing half of the total plant cover on much of the Hanford Site. Cheatgrass and Russian thistle that are annuals introduced to the United States from Eurasia in the late 1800's, invade disturbed areas. Big sagebrush and bitterbrush are widely spaced and usually provide less than 20% canopy cover. Bitterbrush provides important browse for the resident mule deer herd. The important understory plants are grasses, especially cheatgrass, Sandberg's bluegrass, Indian ricegrass, June grass, and needle-and-thread grass.

Central Plateau. More than 100 species of plants have been identified on the Central Plateau (Cushing 1992). Common species include sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass. Dominant vegetation type consists of big sagebrush with an understory of cheatgrass and Sandberg's bluegrass (Neitzel et al. 1998). Cheatgrass provides approximately 50% of the total plant cover. Cheatgrass also is common where native plant communities have been disturbed by wildfire or past construction activities. Three vegetation subtypes occurring in the vicinity of the 200 West Area of the Central Plateau are sagebrush and Sandberg's bluegrass, sagebrush and needle-and-thread grass, and spiny hopsage and Sandberg's bluegrass. Past wildfires in the Central Plateau have opened up some areas, creating a mosaic of shrub- and grass-dominated areas. Sandberg's bluegrass and cheatgrass are the most common grass species. Other vegetation includes riparian species associated with man-made ditches and ponds and introduced perennial grass planted to revegetate disturbed areas (DOE and Ecology 1996).

These riparian species include herbaceous species, such as cattail and reeds, and trees, such as willow, cottonwood, and Russian olive (Neitzel et al. 1998). Several of these ponds recently have been decommissioned, resulting in the elimination of wetland habitat as the supply of industrial waste water feeding the ponds was terminated. Introduced perennial grasses (that is, Siberian wheatgrass) have been used extensively in the Central Plateau to revegetate and stabilize waste burial grounds against wind and water erosion. Siberian wheatgrass has proven to be drought tolerant and better adapted to sandy soils than other cultivars used in Central Plateau revegetation efforts (WHC 1993).

Columbia River. The two major vegetation types occurring along the Hanford Reach of the Columbia River are riparian and upland (NPS 1994). Riparian habitats are found along the shoreline, slack water and slough areas, and on islands in the river. Riparian vegetation at these locations includes both woody and herbaceous species maintained by the high water table immediately adjacent to the river. Common plant species occurring in the riparian zone include black cottonwood, mulberry, willow, dogbane, and a variety of grasses and forbs (Neitzel et al. 1998). Sensitive habitats within the riparian zone include islands and cobbled shorelines occurring as a narrow band along the Hanford Reach. Plant species occurring in these areas include perennial summer-blooming forbs adapted to seasonal changes in water levels (NPS 1994). Upland habitats along the Hanford Reach are composed of shrub-steppe vegetation similar to that found on the Central Plateau (DOE and Ecology 1996).

In summary, special topographic features include Gable Butte and Gable Mountain north of the Central Plateau and an extensive series of active sand dunes in the southeast portion of the area. The dominant plant communities are cheatgrass, sagebrush-bitterbrush and Sandberg's bluegrass, sagebrush and cheatgrass, Sandberg's bluegrass, and riparian plant communities (Sackschewsky et al. 1992). Depending on the location, many of the terrestrial plants occurring in this area are the same as those found in the adjacent Columbia River and Central Plateau. Big sagebrush, bitterbrush, rabbitbrush, cheatgrass, and

Sandberg's bluegrass are common species in the 300 and 400 Areas (Neitzel et al. 1998). Common plants growing in riparian areas along the Columbia River include reed canarygrass, common witchgrass, large barnyard grass, summer-blooming forbs, sandbar willow, poplar, white mulberry, and Russian olive (NPS 1994). Vegetation occurring on scree slopes, outcrops, and scarps on Gable Butte and Gable Mountain is limited to scattered individuals or groups of plants. Plant species include squaw currant, bluebunch wheatgrass, rock buckwheat, and thyme buckwheat. Rigid sagebrush occurs, at the Hanford Site, only on Gable Mountain and Umtanum Ridge (Downs et al. 1993).

Wildlife

Almost 300 species of terrestrial vertebrates have been observed at the Hanford Site. This number includes 41 species of mammals, 246 species of birds, four species of amphibians, and nine species of reptiles (Neitzel et al. 1998).

Mammals. Large herbivorous mammal species that are found on the Hanford Site include mule deer, elk, and white-tailed deer. Mule deer, with an on-site herd of several hundred, occur just about everywhere on the Hanford Site but are most often found near the Columbia River. White-tailed deer and elk began to appear on the Hanford Site during the early 1970s. White-tailed deer tend to remain in the riparian habitats along the rivers, while elk generally are restricted to the Fitzner-Eberhardt Arid Lands Ecology Reserve (FEALE Reserve). Elk frequently move off the reserve to private lands to the north and west, particularly during late spring, summer, and early fall. This herd grew from an estimated eight animals in 1975 to almost 600 animals in 1997 (Neitzel et al. 1998).

Common mammalian predators are the coyote, bobcat, and badger. These carnivores feed primarily on the several species of small mammals found on the Hanford Site, including the Great Basin pocket mouse, Western harvest mouse, grasshopper mouse, deer mouse, house mouse, Townsend's ground squirrel, mountain and sagebrush voles, black-tailed jackrabbit, brushy-tailed woodrat, and Northern pocket gopher. Of these small mammals, the Great Basin pocket mouse is the most abundant. Coyotes have been a major predator of Canada goose nests on Columbia River islands, especially upstream from the abandoned Hanford townsite (DOE and Ecology 1996).

Black-tailed jackrabbits are common on the Hanford Site and are most often found in mature stands of sagebrush. Cottontail rabbits also are common but are more closely associated with the developed areas of the Hanford Site. Townsend's ground squirrels occur in colonies of various sizes scattered across the Hanford Site. The most abundant mammal inhabiting the site is the Great Basin pocket mouse. This mouse occurs all across the Columbia River plain and on the slopes of the surrounding ridges. Other small mammals include the deer mouse, harvest mouse, grasshopper mouse, mountain vole, vagrant shrew, and Merriam's shrew (DOE and Ecology 1996).

Up to 14 species of bats are known or have the potential to occur on the Hanford Site. They include the pallid bat, hoary bat, silver-haired bat, little brown bat, California brown bat, Yuma brown bat, and the Pacific western big-eared bat (Fitzner and Gray 1991). The pallid bat, which roosts in abandoned buildings, is considered to be most abundant. All of these bat species feed on insects.

Birds. Nearly 250 species of birds occur on or near the Hanford Site as year-round residents, seasonal residents, migrants, and accidentals (Neitzel et al. 1998).

Eleven raptors have been documented as nesting on the Hanford Site. These include the northern harrier (*Circus cyaneus*), red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*Buteo swainsoni*), golden eagle (*Aquila chrysaetos*), prairie falcon (*Falco mexicanus*), American kestrel (*Falco sparverius*), barn owl (*Tyto alba*), great horned owl (*Bubo virginianus*), long-eared owl (*Asio otus*), short-eared owl (*Asio*

flammeus), and burrowing owl (*Athene cunicularia*) (Fitzner and Gray 1991, Rickard et al. 1988). Raptors use a variety of habitats for nesting and foraging on the Hanford Site. Nesting habitats include outcrops, cliffs, trees, marshes, fields, and utility towers. Depending on raptor species, prey may include small mammals, birds, reptiles such as snakes, and insects.

A variety of songbird species occur in the shrub-steppe vegetation. These include the Western meadowlark (*Sturnella neglecta*), grasshopper sparrow (*Ammodramus savannarum*), horned lark (*Eremophila alpestris*), and sage thrasher (*Oreoscoptes montanus*) (Downs et al. 1993). The Western meadowlark and horned lark are the most abundant breeding bird species within the shrub-steppe habitat (Rickard and Poole 1989). These two species nest on the ground in the open, while other species e.g., sage sparrow, sage thrasher, and loggerhead shrike) require sagebrush or bitterbrush as nesting structures.

Common upland game bird species include the chukar partridge (*Alectoris chukar*), California quail (*Callipepla californicus*), and Chinese ring-necked pheasant (*Phasianus colchicus*). Sage grouse (*Centrocercus urophasianus*) and gray partridge (*Perdix perdix*) are less common and are rarely seen. Although once more common, sage grouse are now essentially absent from the Hanford Site, displaced after a major wildfire in 1984 (Brandt 1995). A 1997 inventory conducted by The Nature Conservancy did not record any sage grouse in the sagebrush-steppe habitat of the FEALE Reserve (Neitzel et al. 1998). None of the upland birds are native to the area except the sage grouse.

Reptiles and Amphibians. Nine species of reptiles and four species of amphibians are found at the Hanford Site (Neitzel et al. 1998). The most abundant reptile is the side-blotched lizard (*Uta stansburiana*) (Neitzel et al. 1998). The short-horned lizard (*Phrynosoma douglassii*) and northern sagebrush lizard (*Sceloporous graciosus*) are also common in mature sagebrush habitats with sandy soil. Commonly encountered snakes include the gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and Pacific rattlesnake (*Crotalus viridis*). Less common are striped whipsnakes (*Masticophis taeniatus*) and desert night snakes (*Hyspiglena torquata*). Amphibians on the Hanford Site are associated with riparian habitats located along permanent water bodies or the Columbia River (Fitzner and Gray 1991). Species include the Great Basin spadefoot toad (*Spea intermontana*), Woodhouses toad (*Bufo woodhouseii*), and the Pacific tree frog (*Hyla regilla*).

Insects. Grasshoppers and darkling beetles represent some of the more conspicuous insect groups. The populations of both of these species of insects are subject to seasonal changes and weather variations (Rogers and Rickard 1977). Fifty percent of the known insect species are of the order Coleoptera (beetles) (ERDA 1975). Many of the insect species are important in the food web of birds and mammals found on the Hanford Site. Species like the darkling beetle play an important role in the decomposition process by feeding on decaying plant material, animal feces, fungi, and live plant tissue (Weiss and Mitchell 1992).

The Nature Conservancy has identified nearly 1,500 species of insects on the Hanford Site (Hall 1998). The Nature Conservancy identified 41 new species of insects including six new species of bees, six new species of flies, five new species of leafhopper and planthopper insects, one new species of wasp, and one new species of beetle (Neitzel et al. 1998). The Nature Conservancy focused on the FEALE Reserve, the North Slope, and along the Columbia River. Consequently, none of these new species has been reported from the 200 Areas.

Central Plateau. A characterization study of small mammals performed south of the 200 East Area resulted in the following five species being trapped: the Great Basin pocket mouse, deer mouse, northern grasshopper mouse, sagebrush vole, and western harvest mouse (Rogers and Rickard 1977). The Great Basin pocket mouse represented more than 90% of the individuals caught. Medium- and large-size

mammals that may occur in the Central Plateau include rabbits, coyotes, badgers, and mule deer (Rogers and Rickard 1977). Some of these organisms will be receptors in the ecological risk assessment. Other mammals potentially using areas associated with ponds and ditches in the 200 Areas include muskrats, porcupines, and raccoons. Many common bird species, such as the western meadowlark and sage sparrow, are likely to occur on the Central Plateau where suitable habitats exist. Thirty-seven species of terrestrial birds were recorded during surveys conducted in the 200 Areas in 1986 (Schuler et al. 1993).

Unique habitats can be found on Gable Butte and Gable Mountain situated north of the Central Plateau. These unique habitats include basalt outcrops, scarps, and scree slopes. Birds likely to occur in these habitats are the prairie falcon, rock wren, poorwill, and chukar; small mammals include the yellow-bellied marmot and wood rat; reptiles include rattlesnakes, gopher snakes, and horned lizards (Downs et al. 1993).

Columbia River. Terrestrial wildlife species use both shoreline riparian and shrub-steppe habitats occurring along the Columbia River and on the islands. Wildlife reported to use the Hanford Reach include 184 species of birds, 36 species of mammals, 9 species of reptiles, and 4 species of amphibians (NPS 1994). The Canada goose uses islands along the Hanford Reach extensively for nesting. Monitoring of nesting geese that use the Hanford Site have been ongoing since 1950. These studies indicate that Canada geese nest more frequently on islands in the downstream reach because of heavy predation by coyotes further upstream (Neitzel et al. 1998). Mule deer use the islands and other riparian areas for fawning habitat. Wildlife occurring in shoreline habitat includes 46 species that use willow communities and 49 species that use grass areas (NPS 1994).

8.1.2.3. Aquatic Ecosystems

Washington State has classified the stretch of the Columbia River that includes the Hanford Reach as Class A, Excellent (Neitzel et al. 1998). Class A waters must be suitable for essentially all uses, including raw drinking water, recreation, and wildlife habitat. Water from the Columbia River is used for both irrigation and municipal water supplies. Federal and state drinking water quality standards apply to the Columbia River and are currently being met (Neitzel et al. 1998). Water samples from the Columbia River and three ponds on the Hanford Site are routinely collected and analyzed.

The Columbia River supports an ecosystem of plankton, benthic invertebrates, fish, and other communities. Algae are abundant in the river and provide food for herbivores, such as immature insects, which are then eaten by carnivorous species, such as bass.

Aquatic plants in the Hanford Reach include water milfoil, waterweed, pondweed, Columbia yellowcress, watercress, and duckweed. Water milfoil is an aggressive introduced aquatic plant and is becoming a nuisance in the river. Other aquatic species found in the Hanford Reach include a variety of microflora, zooplankton, and benthic invertebrates. Microflora include both sessile types (periphyton) and free-floating types (phytoplankton). Microflora species include diatoms, golden or yellow-brown algae, green algae, blue-green algae, red algae, and dinoflagellates. Dominant zooplankton taxa include *Bosmina*, *Diaptomus*, and *Cyclops*. Benthic invertebrate taxa occurring in the Hanford Reach include; insect larvae such as caddisflies, midge flies, black flies, also snails, freshwater sponges, limpets, and crayfish (Neitzel et al. 1998).

The Hanford Reach supports over 40 species of fish. The anadromous Chinook salmon, sockeye salmon, coho salmon, and steelhead trout use the river to migrate to and from upstream spawning areas. Chinook salmon and steelhead trout also spawn in the Hanford Reach in the fall (Figure 8-6). Shad may also spawn in this stretch of river. Mountain whitefish, white sturgeon, smallmouth bass, crappie, catfish,

walleye, and yellow perch are important gamefish to sport fisherman and Native Americans. A healthy rough fish population includes carp, redside shiner, suckers, and northern squawfish (Neitzel et al. 1998).

West Lake near the 200 Areas is created by a rise in the water table under the Central Plateau and is not fed by surface flow. This results in the pond being highly saline as well as alkaline and having a low species diversity (DOE and Ecology 1996). West Lake, located southwest of Gable Mountain, fluctuates in size with changes in the water table and is currently reduced to a collection of small pools and mudflats (Neitzel et al. 1998). Unlike other ponds on the Hanford Site, West Lake does not receive direct effluent discharges from Hanford Site facilities (PNL 1993). Wetland vegetation found at West Lake is limited to scattered patches of emergent macrophytes such as cattails and bulrushes.

Other wetland habitats found on the Hanford Site are associated with man-made ponds and ditches occurring on the Hanford Site, including the B Pond system located near the 200 East Area and a small cooling and wastewater pond in the 400 Area. The B Pond system was constructed in 1945 to receive cooling water from facilities in that area. Since that time, effluent flow to the B Pond has halted. One lobe of the pond received cooling water until recently; the rest of the B Pond system is slowly reverting to a shrub-steppe ecosystem. Gable Mountain Pond (also to the north of 200 East Area but south of West Lake) also received cooling water discharges from several facilities on the Hanford Site (PNNL 1997). These artificial water bodies, formed by the wastewater discharges from the operation of the separation facilities, were decommissioned and covered with soil.

8.1.2.4. Threatened and Endangered Species

Species of concern on the Hanford Site include federally-listed threatened and endangered species, state-listed threatened or endangered species, state candidate species, state plant species of concern, and species of ethnobiological concern to Native Americans.

No federally-listed threatened or endangered plant or mammal species is documented as occurring on the Hanford Site (Neitzel et al. 1998). Three birds on the federal list occur regularly or incidentally on the site; two federally-listed species of fish occur within the Hanford Reach. The threatened bald eagle (*Haliaeetus leucocephalus*) is found regularly along the Hanford Reach, while the threatened Aleutian Canada goose (*Branta canadensis leucopareia*) and the endangered peregrine falcon (*Falco peregrinus*) occur only as incidental visitors to the Hanford Site (Neitzel et al. 1998). The two fish species are the anadromous chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*). These species are regulated as Evolutionarily Significant Units (ESU) by the National Marine Fisheries Service based on historical geographic spawning areas. One ESU of the chinook salmon, the Upper Columbia River spring-run ESU, is listed as endangered (64 FR 14308). Two ESUs of the steelhead have been listed: the Upper Columbia River steelhead is listed as endangered (Neitzel et al. 1998) and the steelhead Middle Columbia River ESU is listed as threatened (64 FR 14517).

Washington State lists the peregrine falcon, Aleutian Canada goose, American white pelican (*Pelecanus erythrorhynchos*), sandhill crane (*Grus canadensis*), and pygmy rabbit (*Brachylagus idahoensis*) as endangered and the ferruginous hawk (*Buteo regalis*) and the bald eagle as threatened. The peregrine falcon is a casual migrant to the Hanford Site. The bald eagle is a regular winter resident along the Columbia River (Neitzel et al. 1998).

Eight species of plants listed by Washington State as threatened or endangered are found on the Hanford Site. Columbia milk-vetch (*Astragalus columbianus*), loeflingia (*Loeflingia squarrosa*), Hoover's desert parsley (*Lomatium tuberosum*), and dwarf evening primrose (*Oenothera pygmaea*), are designated as threatened. Columbia yellowcress (*Rorippa columbiae*), Umtanum desert buckwheat (*Erigonium codium*), and White Bluffs bladderpod (*Lesquerella tuplashensis*) are listed as endangered. Columbia

milkvetch occurs on upland terraces along the Columbia River and on Yakima Ridge within the FEALE Reserve. Dwarf evening primrose has been found north of Gable Mountain and on disturbed areas near the Wye Barricade. Umtanum desert buckwheat and White Bluffs bladderpod are indigenous to the Hanford Site (Neitzel et al. 1998).

Piper's daisy (*Erigeron piperianus*), a state sensitive species, has been found at B Pond near the 200 East Area and at Pit 30. Crouching milkvetch, stalked-pod milkvetch, and scilla onion, all state plant species of concern, are also found in the 200 East Area. Wildlife state candidate species observed or considered likely to be found on or near the Central Plateau include the sage sparrow (*Amphispiza belli*) and the loggerhead shrike (*Lanius ludovicianus*). Both of these birds commonly nest in undisturbed shrub-steppe habitat. The sage sparrow is one of the most common nesting birds on the Hanford Site (Downs et al. 1993). Other bird species of concern that may be found include the burrowing owl, ferruginous hawk, golden eagle, sage thrasher, and merlin (Neitzel et al. 1998). Another wildlife species of concern inhabiting the Central Plateau and vicinity is the striped whipsnake (*Mastocophis taeniatus*), a state candidate species.

Central Plateau. No federal or state listed threatened or endangered plant or animal species occur in the Central Plateau (DOE and Ecology 1996). Several state-listed plant species are found on the Central Plateau. Piper's daisy has been found at B Pond near the 200 East Area, and may occur in sagebrush-steppe habitat elsewhere on the Hanford Site (WHC 1992). Dwarf evening primrose has been found on disturbed areas near the Wye Barricade (Neitzel et al. 1998) and might also be found on the Central Plateau.

Wildlife species of state concern occurring in the 200 Areas include the loggerhead shrike and sage sparrow. Both species nest in undisturbed sagebrush habitat in the Central Plateau (PNL 1993). Other bird species of concern that may occur in shrub-steppe habitat in the Central Plateau are the burrowing owl, golden eagle, long-billed curlew, and Swainson's hawk. Reptile species of concern using the Central Plateau include the striped whipsnake (Rogers and Rickard 1977, Neitzel et al. 1998).

Columbia River. No federally listed threatened or endangered plant species occur on the Hanford Reach (DOE and Ecology 1996). State endangered plant species occurring along the Hanford Reach include the Columbia yellowcress. Preferred habitat for Columbia yellowcress is shoreline areas with gently sloping, cobbly, or sandy substrate (PNL 1993b). State plant species of concern that have been found along the shoreline and on islands of the Hanford Reach between the Vernita Bridge and the 300 Area include the southern mudwort, dense sedge, and shining flatsedge (WHC 1992, Neitzel et al. 1998).

Federally listed threatened and endangered birds include the Aleutian Canada goose, peregrine falcon, and bald eagle. The Aleutian Canada goose and the peregrine falcon are incidental migrants on the Hanford Site (Neitzel et al. 1998). State-listed bird species that occur along the Hanford Reach that are considered relatively common include the American white pelican (endangered), bald eagle (threatened), and sandhill crane (endangered). The common loon (*Gavia immer*), a state candidate species, is also found within the Hanford Reach.

8.1.2.5. Sensitive Environments

Sensitive habitats on the Hanford Site include wetlands and riparian habitats. Wetlands include those transitional lands occurring between terrestrial and aquatic ecosystems where the water table is usually close to the surface or where shallow water covers the surface (Cowardin et al. 1979). The primary wetlands found onsite occur along the Hanford Reach of the Columbia River and include the riparian habitats located along the river shoreline. Other wetland habitats found on the Hanford Site are associated with man-made ponds and ditches. These include B Pond and its associated ditches located

near the 200 East Area. The B Pond Complex was constructed in 1945 to receive cooling water from facilities in that area. Wetland plants occurring along the shoreline of B Pond include herbaceous species such as showy milkweed (*Asclepias speciosa*), western goldenrod (*Solidago occidentalis*), three square bulrush (*Scirpus americanus*), horsetails (*Equisetum* spp.), rushes (*Juncus* spp.), and common cattail (*Typha latifolia*), and woody species such as mulberry (*Morus alba*), silver poplar (*Populus alba*), black cottonwood (*Populus trichocarpa*), and willow (*Salix* spp.) (Sackschewsky et al. 1992). Wildlife species observed at B Pond include a variety of mammals and waterfowl species (Meinhardt and Frostenson 1979).

8.1.3. Receptor Identification

Food webs represent the transfer of matter among the components of an ecosystem. This transfer occurs through the uptake and absorption of substances from abiotic media or consumption of animal and plant tissue. In a contaminated environment, the transfer of contaminants may also occur during uptake or consumption of contaminated media.

The food web representing the terrestrial organisms of the Hanford Site and their trophic relationships is. The food web representing the aquatic organisms of the Hanford Site and their trophic relationships is shown in Figure 8-8.

8.1.3.1. Terrestrial Receptors

A simplified food web for selected terrestrial receptors is presented in Figure 8-9. The receptors selected for use in the ecological risk assessment are shown in bold in figure:

- Plants: cheatgrass, rabbitbrush
- Terrestrial Invertebrates: earthworms, darkling beetles
- Herbivorous Mammals: mule deer
- Omnivorous Mammals: Great Basin pocket mouse
- Omnivorous Birds: Western meadowlark
- Carnivorous Mammals: coyote
- Carnivorous Birds: burrowing owl, red-tailed hawk.

Species profiles are not required for plants (cheatgrass and rabbitbrush) and terrestrial invertebrates (earthworms and darkling beetles). Single-page species profiles for mammals and birds containing a short narrative and a table of receptor parameters are provided.

8.1.3.2. Aquatic Receptors

A simplified food web of selected aquatic receptors is presented in Figure 8-10. The receptors selected for use in the ecological risk assessment are shown in bold on the figure and are listed below:

- Benthic Invertebrates (sediment-dwelling organisms): clams, insects
- Aquatic Organisms, Fish, and Other: bass, salmon, channel catfish; water fleas, other invertebrates
- Waterfowl and Shorebirds: Canada goose, spotted sandpiper
- Piscivorous Terrestrial Carnivores: great blue heron, bald eagle, mink

Species profiles are not required for the very numerous benthic invertebrates (clams, insects, snails, and worms), the planktivorous fish and small invertebrates (small carp, small Northern squaw fish, small suckers, water fleas, and other invertebrates), and fish (bass, salmon, and channel catfish). Single-page

species profiles of birds and mammals containing a short narrative and a table of receptor parameters are provided.

8.1.4. Assessment and Measurement Endpoints

Environmental statutes govern the maintenance of ecological resources, including:

1 preservation and conservation of threatened and endangered organisms
2 maintenance and protection of terrestrial organism populations and ecosystems
3 maintenance and protection of aquatic organism populations and ecosystems

An assessment endpoint is defined by EPA as "an explicit expression of the environmental value that is to be protected" (EPA 1992a). This applies to ecological receptors (population, community, or individual in the case of a threatened or endangered species). Measures of effect are defined as a change in an attribute of an assessment endpoint or its surrogate in response to a stressor to which it is exposed. Decision criteria prescribe how the endpoints are evaluated.

Policy goals, assessment endpoints, measures of effect and exposure, and decision rules used for the ecological risk assessment are presented in Table 8-1.

Mule Deer (*Odocoileus hemionus*)

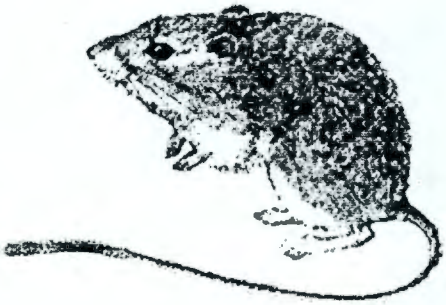
Mule deer, with an on-site herd of several hundred, occur just about everywhere on the Hanford Site, but are most often found near the Columbia River. Mule deer use the islands and other riparian areas as fawning habitat. Bitterbrush provides important browse for the resident mule deer herd. Summer browse is chiefly herbaceous plants and the young shoots of woody plants, while winter browse includes twigs of woody plants and trees, including cedar, yew, aspen, willow, dogwood, juniper, and sage. Coyotes are a major predator, along with bobcats to a lesser extent. Mule deer are most active in the mornings and evenings.

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	66.5	Average of males and females, north central Colorado (Anderson et al. 1974 in Higley and Kuperman 1996)
HR	Home range (ha)	285	Utah, Arizona, Montana (Harestad and Bunnell 1979 in Higley and Kuperman 1996)
TUF	Temporal use factor	1	Will be 1 unless specific value exists.
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.022	Colorado (Alldredge et al. 1974 in Higley and Kuperman 1996)
PF	Plant fraction	1	Estimated
AF	Animal fraction	0	Estimated
SF	Soil fraction	0.02	(Arthur-Alldredge 1979 in DOE and Ecology 1996)
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	44	(Bissell et al. 1955 in Higley and Kuperman 1996)
IR_i	Inhalation rate (m^3/day)	15.7	Allometric, 0.5458 $BW^{0.80}$ (EPA 1993b, Eq. 3-20)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.

Great Basin Pocket Mouse (*Perognathus parvus*)

The pocket mouse eats mostly seeds, but also eats insects (Fitzner and Gray 1991). It is the principal prey of the burrowing, great horned, long-eared, and barn owls at the Hanford Site (Downs et al. 1993) and serves as a vector for contaminant movement through the food chain from plants to mammalian and avian carnivores. The pocket mouse is a nocturnal, burrowing mammal, with most burrows being between 35 and 193 cm (1.2 and 6.3 ft deep) (Gano and Rickard 1982). The mouse has no requirement for drinking water, obtaining all its water from its food. Its small home range could cause it to spend all of its time within a contaminated area and obtain all of its food there (DOE and Ecology 1996).



Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.0235	Burt and Grossenheider 1976 in DOE and Ecology 1996
HR	Home range (ha)	0.209	O'Farrell et al. 1975 in DOE and Ecology 1996
TUF	Temporal use factor	1	DOE and Ecology 1996
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.285	Calder 1984 in DOE-RL 1995
PF	Plant fraction	0.62[b]	Annual average, Colorado, short-grass prairie (Flake 1973 in EPA 1993b)
AF	Animal fraction	0.38[b]	Annual average, Colorado, short-grass prairie (Flake 1973 in EPA 1993b)
SF	Soil fraction	0.262	Beyer et al. 1991 in DOE and Ecology 1996
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0.00	DOE and Ecology 1996
IR_i	Inhalation rate (m^3/day)	0.027	Allometric, 0.5458 $BW^{0.80}$ (EPA 1993b, Eq. 3-20)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.
[b] Values used for the Great Basin pocket mouse taken from values established for the deer mouse (*Peromyscus maniculatus*). (Cronin and Bradley 1988 in EPA 1993b)

Western meadowlark (*Sturnella neglecta*)

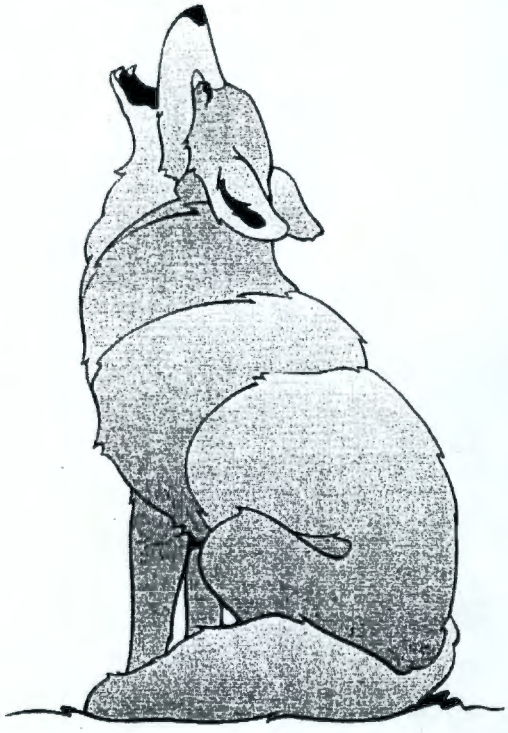
The Western meadowlark is a ground-nesting bird that nests in cheatgrass and sagebrush-bunchgrass communities (Rickard et al. 1988, Schuler et al. 1988). This species exhibits resistance to plant community structure changes resulting from grazing or wildfires (Rickard et al. 1988). The Western meadowlark is a common, omnivorous bird of open habitats in southeastern Washington and is abundant in the shrub-steppe ecosystem (Schuler et al. 1988). It feeds on a variety of items, which includes both insects and plant material, mostly seeds. One study (Bent 1958 in Sample et al. 1997) reports that the Western meadowlark's diet consists of roughly 70% insects and 30% plant material. Studies conducted in southeastern Washington indicate that it is the main bird prey item in the diets of the red-tailed, ferruginous, and Swainson's hawks (Rickard et al. 1988). Adult female Western meadowlarks average 94.2 grams in weight and lay three to seven eggs in dome-shaped nests concealed in the grass or weeds and constructed of the same materials.

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.094	Adult female
HR	Home range (ha)	0.42	Pitts 1984 in EPA 1993b; Bull and Farrand 1994
TUF	Temporal use factor	1	Will be 1 unless specific value exists
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.028	ATG 1998
PF	Plant fraction	0.30	Bent 1958 in Sample et al. 1997
AF	Animal fraction	0.70	Bent 1958 in Sample et al. 1997
SF	Soil fraction	0	No data
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0.186[b]	Estimated (EPA 1993b)
IR_i	Inhalation rate (m^3/day)	0.066	Allometric, 0.4089 $BW^{0.77}$ (EPA 1993b, Eq. 3-19)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.

Coyote (*Canis latrans*)

The coyote is the most common carnivore on the Hanford Site. They are nocturnal, but may be active at any time of day. Primarily carnivorous, coyotes feed mainly on birds and small mammals, but also feed on insects and fruits in season. The typical hunting range is 10 miles, but may extend to 100 miles, reflecting the coyote's variable home range. Being an upper-trophic-level receptor, the coyote could be particularly susceptible to chemicals that bioaccumulate. Coyotes living in the shrub-steppe feed on pocket mice, Northern pocket gopher, Nuttall's cottontail, and black-tailed jackrabbit. Favored den sites are riverbanks and the sides of canyons or gulches.



Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	12.75	Average of adult male and female (Bekoff 1977 in Higley and Kuperman 1996)
HR	Home range (ha)	11,300	Residents, southeast Colorado (Gese et al. 1988 in Higley and Kuperman 1996)
TUF	Temporal use factor	1	Will be 1 unless specific value exists
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.047	Adults (Gier 1975 in Higley and Kuperman 1996)
PF	Plant fraction	0.1	(Bekoff 1977 in Higley and Kuperman 1996)
AF	Animal fraction	0.9	(Bekoff 1977 in Higley and Kuperman 1996)
SF	Soil fraction	0	No data
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0.077	(Calder and Braun 1983 in Higley and Kuperman 1996)
IR_i	Inhalation rate (m^3/day)	4.2	Allometric, 0.5458 $BW^{0.80}$ (EPA 1993b, Eq. 3-20)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.

Burrowing Owl (*Athene cunicularia*)

The burrowing owl is the most abundant of the owls that nest on the Hanford Site. Burrowing owls nest in holes in the ground that are abandoned by burrowing mammals. Their diet consists of pocket mice, deer, pocket gophers, mountain voles, black-tailed jackrabbits, Nuttall's cottontail, rock doves, mallards, and American coots.

The burrowing owl is more diurnal than most owls. The female lays 5 to 7 eggs in a long, underground burrow lined with grasses, roots, and dung. The burrows are usually abandoned prairie dog or pocket gopher burrows, but burrowing owls are capable of digging their own.

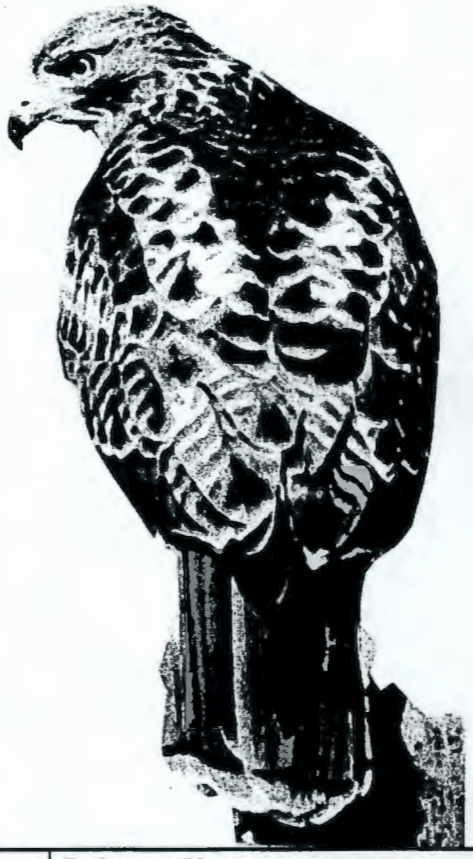
Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.15 [b]	Earhart and Johnson, 1970
HR	Home range (ha)	78.5 [b]	Estimated from Baumgartner 1939 in Higley and Kuperman 1996
TUF	Temporal use factor	1	Will be 1 unless specific value exists
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.092 [b]	Estimated from Craighead and Craighead 1956 in Higley and Kuperman 1996
PF	Plant fraction	0	Estimated
AF	Animal fraction	1	Estimated
SF	Soil fraction	0	No data
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0	No data
IR_I	Inhalation rate (m^3/day)	0.08	Allometric, 0.4089 $BW^{0.77}$ (EPA 1993b, Eq. 3-19)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.
[b] Values used for the Burrowing Owl are estimates calculated from values established for the Great Horned Owl (*Bubo virginianus*).

Red-tailed Hawk (*Buteo jamaicensis*)

The red-tailed hawk may be found on the Hanford Site year-round (Fitzner and Gray 1991). Forty-one nesting pairs of hawks (red-tailed, Swainson's and ferruginous) were observed on-site during the 1994 breeding season (Neitzel et al. 1998). Nests were constructed in trees, cliffs, basalt outcrops, and high-voltage transmission line towers (Neitzel et al. 1998).

The red-tailed hawk is a diurnal predator of rodents and other small mammals, including mice, shrews, voles, rabbits, and squirrels. Generally opportunistic, the red-tailed hawk feeds on whatever is most abundant and readily available. Red-tailed hawks maintain a territory year-round (Brown and Amadon 1968).



Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	1.055	Average of adult male and female, southwest Idaho (Steenhof 1983 in EPA 1993b)
HR	Home range (ha)	1,770	Adult, both , Colorado upland prairie (Andersen and Rongstad 1989 in EPA 1993b)
TUF	Temporal use factor	1	Will be 1 unless specific value exists
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.105	Average of adult male and female, Michigan, captive, outdoors (Craighead and Craighead 1956 in EPA 1993b)
PF	Plant fraction	0	Estimated
AF	Animal fraction	1	Estimated
SF	Soil fraction	0	No data
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0	No data
IR_i	Inhalation rate (m^3/day)	0.43	Allometric, 0.4089 $BW^{0.77}$ (EPA 1993b, Eq. 3-19)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.

Canada Goose (*Branta canadensis*)

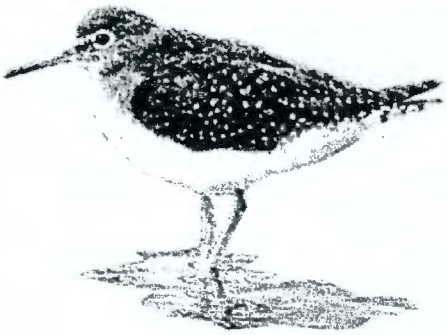
Canada geese forage primarily in open fields, feeding on grains, grass sprouts, and some aquatic vegetation. Breeding habitats includes tallgrass prairies and shortgrass prairies, marshes, ponds, and lakes. Most nesting sites are close to open water, often on islands (EPA 1993b). The Canada goose uses islands along the Hanford Reach extensively for nesting. Studies on the nesting habits of geese that use the Hanford Site have been ongoing since 1953. These studies indicate a general decline over the years in numbers of nests on islands in the Hanford Reach because of heavy predation by coyotes (Cushing et al. 1995).

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	2.620	Average of adult male and female, *B.c. parvipes* (Grieb 1970 in EPA 1993b)
HR	Home range (ha)	983+/- 822 SD	Adult female and brood, *B.c. mofitti*, river (Eberhardt et al. 1989a in EPA 1993b)
TUF	Temporal use factor	1	Will be 1 unless specific value exists
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.032	Average of adult male and female, winter and spring, *B.c. interior* (Joyner et al. 1984 in EPA 1993b)
PF	Plant fraction	1	Craven and Hunt 1984; Prevett et al. 1985 in EPA 1993b
AF	Animal fraction	0	< 1% invertebrates (Yelverton and Quay 1959; Prevett et al. 1985 in EPA 1993b)
SF	Soil fraction	0	No data
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0.044	Average of adult male and female, *B.c. mofitti*, estimated (EPA 1993b)
IR_I	Inhalation rate (m^3/day)	0.86	Allometric, 0.4089 $BW^{0.77}$ (EPA 1993b, Eq. 3-19)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.

Spotted Sandpiper (*Actitus macularia*)

The spotted sandpiper requires open water for drinking, semi-open habitat for nesting, and dense vegetation for breeding (Bent 1929 and Oring et al. 1983). The nest is a grassy scrape near water or in brush with a determinate clutch size of four eggs. Several clutches may be laid during a given breeding season. The diet of the spotted sandpiper consists mostly of terrestrial and aquatic insects (Bent 1929), with adult flying insects making up the bulk of the diet (Oring et al. 1983).



Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.0425	Maxson and Oring 1980 in EPA 1993b
HR	Home range (ha)	0.25	Territory, Maxson and Oring 1980 in EPA 1993b
TUF	Temporal use factor	0.4	Estimated, 5 months (May-September)
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	no data	Estimated metabolic rate of 448 kcal/kg-day (EPA 1993b)
PF	Plant fraction	0	Estimated
AF	Animal fraction	1	Estimated
SF	Soil fraction	0	No data yet; likely in excess of 0.2
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0.044	Average of adult male and female, *B.c. mofitti*, estimated (EPA 1993b)
IR_I	Inhalation rate (m^3/day)	0.036	Allometric, 0.4089 $BW^{0.77}$ (EPA 1993b, Eq. 3-19)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.

Great Blue Heron (*Ardea herodius*)

Great blue herons are year-round residents of the Hanford Reach. This bird is relatively common along the Hanford Reach (Fitzner and Gray 1991). Some of the trees planted on pre-1943 farms have persisted and serve as nesting platforms for several species of birds, including the great blue herons (DOE-RL 1995). Its nest is a platform of sticks lined with finer material and is sometimes found on the ground or in a reedbed. Principal prey items of the great blue heron are fish and frogs, although it will also feed on small mammals, reptiles, and occasionally birds.

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	2.39	Arithmetic mean, adult, both sexes, location not stated (EPA 1993b)
HR	Home range (km)	3.1	Foraging distance, mean, adults, both sexes, South Dakota, stream (EPA 1993b)
TUF	Temporal use factor	1	Will be 1 unless a specific value exists
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.18	EPA 1993b
PF	Plant fraction	0	None listed as dietary intake in EPA 1993b
AF	Animal fraction	1	98% aquatic vertebrates, a river in lower Michigan (EPA 1993b)
SF	Soil fraction	0	Not reported in EPA 1993b; assumed to be negligible
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0.045	Estimated (EPA 1993b)
IR_I	Inhalation rate (m^3/day)	0.080	Allometric, 0.4089 $BW^{0.77}$ (EPA 1993b, Eq. 3-19)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.

Bald Eagle (*Haliaetus leucocephalus*)

Bald eagles use trees during the day for perching and occasionally at night for communal roosts (DOE and Ecology 1996). The bald eagle is a common winter resident, usually arriving in October. These birds forage throughout the Hanford Reach. Wintering eagles tend to concentrate where food is abundant and with minimal human disturbance. The diet of bald eagles varies locally as well as seasonally. Food may vary from spawned salmon and waterfowl (often killed by other predators or disease) during the winter to fish, small mammals, carrion, and waterfowl during the breeding season (EPA 1993b). Although bald eagles exhibit nesting behavior at the Hanford Site, most leave before laying eggs (WHC 1994).

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	4.22	Adult average, male and female (Wiemeyer, pers. com., 1991 in EPA 1993b; Johnsgard 1990 in Higley and Kuperman 1996)
HR	Home range (ha)	1,880	Near Missouri Lake (Griffin and Baskett 1985 in Higley and Kuperman 1996)
TUF	Temporal use factor	1	Will be 1 unless specific value exists.
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.12	Adult, both sexes, Washington, free-flying (Stalmaster and Gessaman 1984 in EPA 1993b)
PF	Plant fraction	0	Estimated
AF	Animal fraction	1	Estimated
SF	Soil fraction	0	No data
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0.036	(Calder and Braun 1983 in Higley and Kuperman 1996)
IR_i	Inhalation rate (m^3/day)	1.24	Allometric, 0.4089 $BW^{0.77}$ (EPA 1993b, Eq. 3-19)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.

Mink (*Mustela vision*)

The mink is the most abundant and widespread carnivorous mammal in North America. The home range of mink encompasses both their foraging areas around waterways and their dens along the Columbia River. The mink is found in aquatic habitats of all kinds, including waterways such as rivers, streams, lakes, and ditches, as well as swamps, marshes, and backwater areas (Linscombe et al, 1982 in EPA 1993b). Mink are particularly sensitive to certain chemicals. Minks are predominantly nocturnal hunters, although they are sometimes active during the day. They can often be found along the Columbia River. Mammals are the mink's most important prey year-round in many parts of their range (Eagle and Whitman, 1987), but mink also hunt aquatic prey (e.g., fish, amphibians, and crustaceans) and other terrestrial prey (e.g., bird, reptiles, and insects) depending on the season (Linscombe et al, 1982 in EPA 1993b).

Parameter	Definition	Value	Reference/Notes
BW	Body weight (kg)	0.85	Average of adult male and female (summer and fall) (Mitchell, 1961 in EPA, 1993b)
HR	Home range (ha)	2.24	Foraging distance, mean, adults, both sexes, Sweden/stream (Gerell, 1970 in EPA, 1993b)
TUF	Temporal use factor	1	Will be 1 unless specific value exists.
IR_F	Food ingestion rate (g/g-d=kg/kgBW/day)[a]	0.14	Michigan (farm raised); (Bleavins and Aulerich, 1981 in EPA, 1993b)
PF	Plant fraction	0.02	Michigan/stream, river (%wet wt; stomach contents) (Alexander, 1977 in EPA, 1993b)
AF	Animal fraction	0.98	Michigan/stream, river (%wet wt; stomach contents) Alexander, 1977 in EPA, 1993b)
SF	Soil fraction	0	To be determined
IR_W	Water ingestion rate (g/g-d=L/kgBW/day)	0.11	Estimated in EPA (1993b)
IR_i	Inhalation rate (m^3/day)	0.48	Allimetric, 0.5458 $BW^{0.80}$ (EPA 1993b, Eq. 3-20)

[a] Food ingestion rate (g/g – d) reexpressed as kg/kg BW/day is assumed not to include ingested soil; therefore, PF + AF = 1.0.

8.2. Exposure Assessment

Estimation of the risk to ecological receptors from COPCs and ROPCs in environmental media at an exposure location requires an estimate of exposure and a toxicity reference value (TRV), that is, an exposure associated with little or no adverse effect. Exposure locations at the Hanford Site are areas within the deposition grid at which ecological receptors come into contact with COPCs and ROPCs in media contaminated by stack emissions. Contamination at a given location is represented by modeled concentrations of COPCs and ROPCs in environmental media. The ecological hazard quotient (HQ) is a risk estimate for the receptor at the exposure location and is calculated as the ratio of the estimated exposure and the TRV for a specific COPC or ROPC. The hazard index (HI) is the sum of the HQs for all COPCs with similar modes of toxicity. HQs and HIs exceeding the EPA specified threshold value (0.25) indicate that the receptor has an unacceptable probability of experiencing an adverse effect from exposure to the COPC(s).

The equations used to estimate exposure for terrestrial and aquatic receptors near the RPP-WTP at the Hanford Site are described below (section 8.2.2). Two types of exposure estimates are required. One, the exposure estimate for a wildlife receptor that does not live in a medium containing COPCs but is exposed by ingestion, inhalation, and other routes is the estimated average daily dose (ADD). The exposure equations for wildlife are variations of wildlife exposure equations from EPA (1998a, p. 68, Text Box 4-10) and implied in other sources (EPA 1997b). The equations for ecological receptors are functionally equivalent to the equations in section 7.1 that are used to quantify exposure of humans by ingestion of contaminated food (EPA 1998a). All these equations calculate the amount of contaminant ingested or inhaled per unit biomass per unit time by multiplying the concentration of the contaminant in the ingested medium (abiotic medium or food item) by the receptor's ingestion or inhalation rate for that medium and, explicitly or implicitly, by the fraction of time the receptor is exposed (TUF), dividing where necessary by the body weight of the receptor. The equations for specific wildlife receptors in the RPP-WTP work plan are different from the human health exposure equations (EPA 1998a) because they include a term for the fraction of contaminated space used by the receptor (AUF). The wildlife equations also allow for the contaminant concentration in a food item to be calculated as the product of the contaminant concentration in an ingested abiotic medium and the bioaccumulation (transfer) factor for the medium and the food item being ingested. Two, for receptors living immersed in a medium containing COPC/ROPCs (e.g., vegetation and soil invertebrates living in soil, fish and other aquatic life living in surface water, and sediment-dwelling organisms living in sediment), the exposure estimate is the concentration of COPC/ROPC in the medium.

The modeled whole-body concentrations of contaminants in plants and fish consumed by both humans and non-human receptors will be convergent. This is not to say that receptors that ingest whole organisms will be exposed to the same contaminant concentration as receptors that eat only particular organs or tissues of the organism. For instance, the whole-body concentration in a fish eaten by the great blue heron may not equal the concentration in the fillets of that fish eaten by humans. Whole-body tissue concentrations will be calculated in the human health and ecological risk assessments using identical bioaccumulation factors, ingestion rates, and other parameters, and identical model equations. The ecological risk assessment will use these modeled whole-body concentrations to estimate doses to wildlife receptors.

The exposure assessment will evaluate an exclusive diet and an equal diet in the PRA and a realistic diet in the FRA. An "exclusive diet" is a diet consisting of a single type of prey or food. An "equal diet" is a diet where the fractions of all types of prey or food reportedly eaten by the receptor are set equal to the average fraction reported for that receptor or a similar species. A "realistic diet" is a diet where the fractions of different types of prey or food eaten are more or less the fractions reported to actually occur in one or more cases for the receptor or similar species. The exclusive-diet scenario will be evaluated

when it is a worst-case scenario (that is, it gives the most conservative risk estimate). The realistic-diet scenario will be evaluated because it is realistic. An equal-diet scenario will be evaluated in the PRA because it provides a "standard" diet that does not require quantitative information on the diet of receptors and, therefore, can be easily implemented.

For a given receptor, there is no one exclusive diet for all COPC/ROPC that is the worst-case diet. The worst-case diet for a given COPC/ROPC is an exclusive diet of the prey type that has the highest expected body burden of that COPC/ROPC among all the receptor's potential prey or food types. Which prey or food type will have the highest expected body burden varies by COPC/ROPC as a function of the diets of the prey types, and the magnitudes of the BAFs for the different prey or food types. For example, a COPC/ROPC that bioaccumulates more in plants than in worms may result in mule deer being the worst-case diet for a coyote, whereas a COPC/ROPC that bioaccumulates more in worms than plants may result in the pocket mouse being the worst-case diet for the coyote. In general, the fractions of prey or food types in a given animal's diet, the body burdens in each prey or food type, and the animal's BAF for the COPC/ROPC determines the animal's body burden and, thus, the exposure to its predator. Assuming an exclusive diet, the dietary fractions are either 1 or 0, so the worst-case diet for a given receptor is determined by the product of the uptake and bioaccumulation factors along each possible food chain from the source medium to the receptor. To identify the worst-case diet for each COPC/ROPC for all receptors, the product of the uptake and bioaccumulation factors can be calculated for all food chains of all lengths leading to all receptors.

The equal diet gives a less-accurate exposure estimate than the realistic diet. The equal-diet scenario overestimates the exposure from those dietary items that are actually less than the average dietary fraction and underestimates the exposure from those dietary items that are actually more than the average dietary fraction. Thus, while easier to model because fewer data are required, the equal- proportions diet is less accurate than a realistic diet. The equal-diet scenario is also not consistently less conservative than the realistic-diet scenario and, therefore, does not serve with the worst-case scenario to bracket the range of possible exposures. An equal-proportion diet is an appropriate, unbiased model when no dietary fraction information is available. The equal-proportion diet will be evaluated in the PRA. Dietary fractions are expected to be available for all receptors to be evaluated in the risk assessment. Therefore, the realistic-diet scenario will be evaluated in the FRA.

Concentrations used to estimate exposure for ecological receptors, exposure equations for terrestrial and aquatic receptors, and the variables and parameters used in these equations to estimate exposures for ecological receptors are provided in the following sections.

8.2.1. Exposure Point Concentration

Exposure of ecological receptors to COPCs and ROPCs in the vicinity of the RPP-WTP will be estimated from the distribution of concentrations predicted by the aerial dispersion and other fate and transport models (section 6). Dispersion model output concentrations will be used to calculate exposure concentrations for surface soil (mg/kg, pCi/g), gases and particulates in air (mg/m^3, pCi/m^3), sediment (mg/kg, pCi/g) and surface water (µg/L, pCi/L). For any specified exposure location on the dispersion grid, the modeled concentration will be used to estimate the exposure to ecological receptors. Use of area-weighted modeled concentrations represents a conservative estimate of potential exposure due to the RPP-WTP.

Exposure point concentrations used to estimate doses of both COPCs and ROPCs are dependent on the location of the receptor. The location of the various receptor populations identified for the quantitative, screening risk assessment will correspond to the receptor grid nodes defined during air dispersion modeling (section 6). It is expected that two important places are Gable Mountain and the Hanford Site

boundary. Other places are those of maximum contaminant concentration. In keeping with the protective approach used in this risk assessment, the location with the maximum concentration of COPCs and ROPCs will be used in estimating exposure point concentrations. Because the point of maximum concentration may be different for airborne contaminants deposited via wet and dry deposition mechanisms, EPA 1998a recommends the following method for selecting the point of maximum concentration. Within each area to be evaluated, receptor grid nodes or exposure locations with the highest modeled unitized value will be identified for each of the following parameters:

- Vapor phase air concentration
- Vapor phase wet deposition rate
- Particle phase air concentration
- Particle phase wet deposition rate
- Particle phase dry deposition rate
- Particle-bound phase air concentration
- Particle-bound phase wet deposition rate
- Particle-bound phase dry deposition rate

At each of the unique locations, air concentrations from vapor, particle phase, and particle bound fractions will be summed, and concentrations of deposited materials will be summed to determine the point or location of area-weighted maximum exposure. Air concentrations and deposition rates will not be summed together.

8.2.2. Terrestrial Receptors

For receptors living in soil (e.g., vegetation and soil invertebrates), the HQ is calculated as the ratio of the concentration of COPC in soil and the TRV for the receptor and the COPC. That is:

$$HQ_{ijk} = C_{jk}/TRV_{ij.}$$

where

HQ_{ijk} = hazard quotient for receptor i at exposure location k for COPC j (unitless)
C_{jk} = concentration of COPC j in soil at exposure location k (mg/kg_{soil})
TRV_{ij} = toxicity reference value of receptor i for COPC j (mg/kg_{soil}).

The HQ for a wildlife receptor that does not live in the medium containing COPCs but is exposed by ingestion, inhalation, and other routes is calculated as the ratio of the ADD and the TRV. That is:

$$HQ_{ijk} = ADD_{ijk}/TRV_{ij}$$

where

ADD_{ijk} = average daily dose of COPC j to receptor i at exposure location k (mg/kg BW/day) calculated using concentration of COPC j at exposure location k (units vary)
TRV_{ij} = toxicity reference value of receptor i for COPC j (mg/kg BW/day).

The second equation is used to estimate risk for the wildlife receptors in the terrestrial food web: mule deer, Great Basin pocket mice, Western meadowlark, coyote, burrowing owl, and red-tailed hawk. The RME concentrations of COPCs/ROPCs in surface soil, plant and animal tissue, and air, ingestion and inhalation rates, body weights, and bioaccumulation factors (Appendix C-2) will be used to estimate the ADDs for receptors, as published in the receptor profiles and as described below.

8.2.2.1. Ingestion Exposure Calculations (Soil to Wildlife)

For wildlife receptors, such as mammals and birds, that are exposed to COPCs/ROPCs in soil by ingestion of soil, ingestion of terrestrial biota, or both, the ADD is calculated as follows:

Herbivores, Mid-level Predators, and Omnivores

$$ADD_{ijk} = AUF_{ik} \times TUF_{ik} \times [(Cr_{jk} \times IPr_i) + (Cv_{jk} \times IPv_i) + (Cd_{jk} \times IAd_i) + (C_{jk} \times IS_i \times AEs_j)]/BW_i$$
$$= AUF_{ik} \times TUF_{ik} \times C_{jk} \times [(IPr_i \times SPr_j) + (IPv_i \times SPv_j) + (IAd_i \times BAF\text{-}S_j) + (IS_i \times AEs_j)]/BW_i$$

where

AUF_{ik} = Area Use Factor for receptor i at exposure location k (unitless) =

$$\begin{cases} 1 & \text{if } A_k \geq HR_i \\ A_k / HR_i & \text{if } A_k < HR_i \end{cases}$$

where

A_k = Area of exposure location k (ha)
HR_i = Home range, foraging range, or territory size of receptor i (ha)
TUF_{ik} = Temporal Use Factor for receptor i at exposure location k (unitless) = 1 unless receptor-specific value is available
Cr_{jk} = Concentration of COPC j in plant reproductive tissue (fruit, nuts, flowers) at exposure location k (mg/kg-wet wt.) = RME tissue concentration, unless otherwise directed
IPr_i = Rate of ingestion of plant reproductive tissue by receptor i (kg/day)
Cv_{jk} = Concentration of COPC j in plant vegetative tissue (leaf, stem, root) at exposure location k (mg/kg-wet wt.) = RME tissue concentration, unless otherwise directed
IPv_i = Rate of ingestion of plant vegetative tissue of receptor i (kg/day)
Cd_{jk} = Concentration of COPC j in terrestrial invertebrate tissue at exposure location k (mg/kg-wet wt.) = RME tissue concentration, unless otherwise directed
IAd_i = Rate of ingestion of terrestrial invertebrate tissue by receptor i (kg/day)
C_{jk} = Concentration of COPC j in soil at exposure location k (mg/kg-dry wt.) = RME_{jk} soil concentration, unless otherwise directed
IS_i = Rate of soil ingestion (kg-dry wt./day) by receptor i = IF_i x SI_i, where IF_i is the total food ingestion rate (kg-dry wt./day) of receptor i and SI_i is the fraction of food ingested by receptor i that is soil, on a dry weight basis
AEs_j = Absorption efficiency factor for COPC j in ingested soil (unitless) = 1, unless chemical-specific value is available
BW_i = Body weight of receptor i (kg)
SPr_j = Soil-to-Plant transfer factor for reproductive tissue for COPC j (kg_{soil}-dry wt./kg_{tissue}-wet wt.)
SPv_j = Soil-to-Plant transfer factor for vegetative tissue for COPC j (kg_{soil}-dry wt./kg_{tissue}-wet wt.)
$BAF\text{-}S_j$ = Soil-to-soil invertebrate tissue transfer factor for COPC j (kg_{soil}-dry wt./kg_{tissue}-wet wt.)

For wildlife receptors that are exposed to COPCs/ROPCs in soil by ingestion of terrestrial biota, the ADD is calculated as follows:

Top Predators

$$ADD_{ijk} = AUF_{ik} \times TUF_{ik} \times [\Sigma_n(Cn_{jk} \times IAn_i) + (C_{jk} \times IS_i \times AEs_j)]/BW_i$$

where

$$Cn_{jk} = BAF\text{-}T_{nj} \times C_{jk} \times [(SPr_j \times FPr_n) + (SPv_j \times FPv_n) + (BAF\text{-}S_j \times FA_n) + (AEs_j \times FS_n)]$$

and

Cn_{jk}	=	Concentration of COPC *j* in animal tissue of prey type *n* at exposure location *k* (mg/kg-wet wt.) = RME tissue concentration, unless otherwise directed
IAn_i	=	Rate of ingestion of tissue of animal prey type *n* by receptor *i* (kg/day)
$BAF\text{-}T_{nj}$	=	Tissue-to-tissue transfer factor for prey type *n* for COPC *j* (kg_{tissue}-wet wt./kg)
FPr_n	=	Fraction of total daily ingestion by prey type *n* that is plant reproductive tissue (unitless) = IPr_n/IT_n
FPv_n	=	Fraction of total daily ingestion by prey type *n* that is plant vegetative tissue (unitless) = IPv_n/IT_n
FA_n	=	Fraction of total daily ingestion by prey type *n* that is terrestrial invertebrate tissue (unitless) = IAd_n/IT_n
FS_n	=	Fraction of total daily ingestion by prey type *n* that is soil (unitless) = IS_n/IT_n,

and

$$IT_n = IPr_n + IPv_n + IAd_n + IS_n$$

where

IT_n	=	the total daily ingestion by prey type *n* of receptor *i* (kg/day)
IPr_n	=	Rate of ingestion of plant reproductive tissue by prey type *n* of receptor *i* (kg/day)
IPv_n	=	Rate of ingestion of plant vegetative tissue by prey type *n* of receptor *i* (kg/day)
IAd_n	=	Rate of ingestion of terrestrial invertebrate tissue by prey type *n* of receptor *i* (kg/day)
IS_n	=	Rate of soil ingestion (kg-dry wt./day) by prey species *n* of receptor *i* = $IF_n \times SI_n$ where IF_n is the total food ingestion rate (kg-dry wt./day) of prey species *n* of receptor *i* and SI_n is the fraction of food ingested by prey species *n* that is soil, on a dry weight basis

Soil ingestion rates for Hanford receptors (Table 8-2) are required to calculate ADDs. Receptors are exposed to contaminants in soil by direct and indirect soil ingestion. Direct soil ingestion occurs during grooming, burrowing, and ingesting soil attached to the outside of the food. Indirect soil ingestion occurs during feeding on prey that contain soil in the gut. Soil ingestion fractions (direct and indirect soil ingestion) for two out of eleven Hanford receptors (Canada goose and mule deer) are documented in EPA (1993b). These values (Table 8-2) are derived from data in Beyer et al. (1994), EPA (1993), and Higley and Kuperman (1996). For three receptors (coyote, Great Basin pocket mouse, and spotted sandpiper), soil ingestion fractions for surrogate species documented in Beyer et al. (1994) are used to estimate direct and indirect soil ingestion. The indirect soil ingestion rates for the remaining six receptors without published values (bald eagle, red-tailed hawk, burrowing owl, western meadowlark, great blue heron, and mink) are estimated as described below. Direct soil ingestion is not estimated for these six receptors because direct soil ingestion is assumed to be a minor contribution compared to indirect soil ingestion.

Indirect soil ingestion rates for the six receptors without published values are calculated from the soil-to-body weight ratios (SBRs) of their prey and the proportions of different prey in their diets. The SBR of prey species with units kg_{soil}/kg is calculated as the product of the soil ingestion fraction (kg_{soil}/kg_{food}), the daily food ingestion rate per unit body weight ($kg_{food}/kg/d$) and the residence time (d) of soil in the prey gut (Table 8-3). To derive the indirect soil ingestion rate, a receptor's daily food ingestion rate per unit body weight is multiplied by the sum of the products of the dietary fraction and SBR of each prey type (Table 8-4). Indirect soil ingestion rates for the six Hanford receptors will also be calculated for the equal and exclusive diets evaluated in the PRA.

8.2.2.2. Inhalation Exposure Calculations (Air to Wildlife)

For wildlife receptors such as mammals and birds that are exposed to chemicals emitted from the stack(s) by inhalation of particulates and gases in air, the ADD is calculated as follows:

All Terrestrial Receptors

$$ADD_{ijk} = AUF_{ik} \times TUF_{ik} \times [(Dg_{jk} \times AEg_j) + (Dp_{jk} \times AEp_j)] \times IR_i / BW_i$$

where

AUF_{ik} = Area Use Factor for receptor i at exposure location k (unitless) =

$$\begin{cases} 1 & \text{if } A_k \geq HR_i \\ A_k / HR_i & \text{if } A_k < HR_i \end{cases}$$

where

A_k = Area of exposure location k (ha)
HR_i = Home range, foraging range, or territory size of receptor i (ha)
TUF_{ik} = Temporal Use Factor for receptor i at exposure location k (unitless) = 1, unless receptor-specific value is available
Dg_{jk} = Density of COPC j in air vapors or gases at exposure location k (mg/m^3)
Dp_{jk} = Density of COPC j in air particulates at exposure location k (mg/m^3)
AEg_j = Absorption efficiency factor for COPC j in inhaled gases or vapors (unitless) = 1, unless chemical-specific value is available
AEp_j = Absorption efficiency factor for COPC j in inhaled particulates (unitless) = 1, unless chemical-specific value is available
IR_i = Rate of inhalation of particulates and gases by receptor i (m^3/day).

EPA (1993) presents inhalation rates (m^3/d) for a few bird and mammal receptor species and regression equations to derive inhalation rates associated with standard metabolic rate from body weight. The inhalation rates used in the work plan are in the receptor parameter tables-profiles (Appendix Table C).

8.2.2.3. Radiological Exposure Equations

Ecological receptors are exposed internally and externally to ROPCs in terrestrial habitats within the deposition grid surrounding the RPP-WTP at the Hanford Site. The risk from exposure to ROPCs is calculated as the ratio of the estimated total-body dose rate (R_{ik}) and the TRV. That is:

$$HQ_{ik} = R_{ik}/TRV_i$$

where

HQ_{ik} = hazard quotient for receptor *i* at exposure location *k* for all ROPCs (unitless)
R_{ik} = total body dose rate to receptor *i* at exposure location *k* (rem/day)
TRV_i = toxicity reference value (dose rate) of receptor *i* for ROPCs (rem/day).

The total-body dose rate of terrestrial ecological receptors results from both internal and external exposures to all ROPCs, which are summed to estimate the combined exposure. That is:

$$R_{ik} = \Sigma_j\ [R_{ijk}(\text{internal}) + R_{ijk}(\text{external})].$$

where

R_{ijk} = total-body dose to receptor *i* from indicated exposure to ROPC *j* at location *k* (rem/day).

Internal and external dose rates for terrestrial receptors are calculated as described below.

8.2.2.4. Internal Exposure

The internal total-body dose rate to a terrestrial receptor from exposure to a single ROPC is

$$R_{ijk} = CFa \times [Co_{jk} \times (QF \times \Phi_\gamma E_\gamma n_\gamma + QF \times \Phi_\beta E_\beta n_\beta + QF \times \Phi_\alpha E_\alpha n_\alpha)]$$

where

R_{ijk} = total-body dose to receptor *i* from internal exposure to ROPC *j* at location *k* (rem/day)
CFa = unit conversion factor from pCi MeV/g disintegration to rad/day = 5.11×10^{-5} rad/day / (pCi MeV/g disintegration) [(3.70×10^{-2} dis/s /pCi) x (1.60×10^{-6} erg/MeV) x (1.00×10^{-7} Joule/erg) x (1.00×10^{2} rad x kg tissue/Joule) x (1.00×10^{3} g tissue / kg tissue) x (1 g soil/g tissue) x (8.64×10^{4} s/d)]
Co_{jk} = concentration of ROPC *j* in organism *i* at exposure location *k* (pCi/g wet weight)
QF = quality factor to account for relative effectiveness of radiation types: one rem/rad for β and γ and 20 rem/rad for α radiation
Φ_m = absorbed fraction of energy emitted by α, β, or γ radiation (unitless), where m = α, β, or γ
E_m = average effective energy emitted by α, β, or γ radiation (MeV per disintegration)
n_m = proportion of disintegrations producing α, β, or γ radiation (unitless).

It is assumed that n_m is contained along with E (as $E_\gamma n_\gamma$, $E_\beta n_\beta$, and $E_\alpha n_\alpha$) in the decay energy terms from Table A.1 of *External Exposure to Radionuclides in Air, Water, and Soil, Federal Guidance Report No. 12* (Eckerman and Ryman 1993). The values of Φ_β and Φ_γ come from *Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment* (Blaylock et al. 1993) or *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants* (Sample et al. 1997). The value of Φ_α is 1.0 for all radionuclides (Blaylock et al. 1993).

The internal concentration in a terrestrial plant or terrestrial invertebrate from exposure to a single ROPC is calculated by using soil-to-biota transfer factors and the radionuclide activity in soil. For plants,

Co_{jk} = SPr_j x C_{jk}

and for terrestrial invertebrates,

Co_{jk} = $BAF\text{-}S_j$ x C_{jk}

where

SPr_j = Soil-to-plant transfer factor for reproductive tissue for ROPC *j* (kg_{soil}-dry wt./kg_{tissue}-wet wt.)

$BAF\text{-}S_j$ = Soil-to-tissue transfer factor for terrestrial invertebrates for ROPC *j* (kg_{soil}-dry wt./kg_{tissue}-wet wt.)

The concentration of a radionuclide in a mammal or bird receptor results from the inhalation or ingestion of material that contains radionuclides and the uptake and effective bioaccumulation in the receptor. For ingestion:

$$Co_{jk} = Cm_{ijk} \times BAF\text{-}T_{ij} \times SIR_i$$

where

Cm_{ijk} = the average concentration of ROPC *j* in the matter ingested by receptor *i* at location *k* (pCi/g)

$BAF\text{-}T_{ij}$ = the bioaccumulation factor representing the retention of ROPC *j* in tissue of receptor *i* resulting from the ingestion rate of ROPC *j* by receptor *i* [pCi retained / (pCi ingested / day)].

SIR_i = specific ingestion rate or receptor *i* (kg matter/kg body weight/day) = $IT_I + IN_i$

Values of $BAF\text{-}T_{ij}$ (Appendix Table C-2-2) were derived from ingestion-to-beef uptake factors presented by Baes et al. (1984) [in units of (pCi retained/kg tissue)/(pCi ingested/day)]. The Baes et al. (1984) values were multiplied by an average beef body weight at slaughter of 550 kg to calculate a whole-body retention rate in units of pCi retained/pCi ingested/day (see Section 8.2.4.3). The same values (Appendix Table C-2-2) were used for both ingestion exposure and inhalation exposure.

The average concentration of a radionuclide in the material ingested or inhaled by a receptor (C_{jk}) is calculated using the equation for the receptor's ADD for that substance in its prey and in soil or other abiotic media ingested or inhaled, that is:

$$Cm_{jk} = ADD_{ijk} / SIR_i$$

where

ADD_{ijk} = average daily dose of ROPC *j* to receptor *i* at location *k* (pCi/g/day) by inhalation or ingestion

SIR_i = specific ingestion rate or receptor *i* (kg matter/kg body weight/day) = $IT_I + IN_i$

For inhalation, the contribution to body burden is given by:

$$Co_{jk(inhaled)} = AUF_{ik} \times TUF_{ik} \times Dp_{jk} \times AEp_j \times BAF\text{-}T_j \times IR_i / (BW_i \times 1000)$$

where

AUF_{ik} = Area Use Factor for receptor i at exposure location k (unitless) =
1 if A_k HR_i
A_k/HR_i if $A_k < HR_i$

where

A_k = Area of exposure location k (ha)
HR_i = Home range, foraging range, or territory size of receptor i (ha)

TUF_{ik} = Temporal Use Factor for receptor i at exposure location k (unitless) = 1, unless receptor-specific value is available
Dp_{jk} = Density of ROPC j in air particulates at exposure location k (pCi/m^3)
AEp_j = Absorption efficiency factor for ROPC j in inhaled particles (unitless) = 1, unless radionuclide-specific value is available
$BAF\text{-}T_j$ = Bioaccumulation factor representing the retention of ROPC j in tissue of receptor i resulting from the inhalation rate of ROPC j [pCi retained / (pCi inhaled/day)]
IR_i = Rate of inhalation of particulates in air by receptor i (m^3/day)
BW_i = Body weight of receptor i (kg)
1000 = Conversion factor, g/kg

The total body burden of ROPC j is found by adding body burdens from inhaled and ingested radionuclides:

$$Co_{ijk(total)} = Co_{ijk(ingested)} + Co_{ijk(inhaled)}$$

8.2.2.5. External Exposure

The external total-body dose rate to a terrestrial receptor, including plants, from aboveground exposure to a single ROPC is:

$$R_{ijk} = AUF_{ik} \times TUF_{ik} \times F_{above\,i} \times F_{rufk} \times CFb \times C_{jk} \times DCFs_j \times h_i$$

where

R_{ijk} = total-body dose to soil surface receptor i from external exposure to ROPC j in soil at location k (rem/day)
AUF_{ik} = Area Use Factor for receptor i at exposure location k (unitless) =
1 if $A_k >= HR_i$
A_k/HR_i if $A_k < HR_i$

A_k = Area of exposure location k (ha)
HR_i = Home range, foraging range, or territory size of receptor i (ha)
TUF_{ik} = Temporal Use Factor for receptor i at exposure location k (unitless) = 1 unless receptor-specific value is available
$F_{above\,i}$ = fraction of time receptor i spends on the ground surface (unitless)
F_{rufk} = dose rate reduction factor accounting for roughness of the ground surface at location k = 0.7 (unitless)
CFb = unit conversion factor from Sv/s per Bq/m^3 to rem/d per pCi/g = 5.12×10^{11} rem/day per pCi/g) / (Sv/s per Bq/m^3)
C_{jk} = concentration of ROPC j in soil at location k (pCi/g)

$DCFs_{jk}$ = dose coefficient for ROPC *j* in soil contaminated to a depth of 15 cm at location *k* (Sv/s per Bq/m^3) (Eckerman and Ryman 1993, Table III.6)

h_i = factor to adjust for height of receptor *i* above the ground surface (Appendix Table C-2-4)

The external DCF values from Eckerman and Ryan (1993) are based on exposures at a height of 1 m (3.28 ft), but Hanford Site receptors are exposed at varying distances from the soil. The height adjustment factor (h) is assumed to be 1 for receptors exposed at approximately 1 m above the ground surface (such as mule deer); h is assumed to be 2 for receptors on the ground surface (such as western meadowlark); and h is assumed to be 2 plants growing close to the ground (that is, cheatgrass).

The external total-body dose rate to a terrestrial receptor from belowground exposure to a single ROPC is:

$$R_{ijk} = AUF_{ik} \times TUF_{ik} \times 1.05 \times F_{below} \times CFa \times C_{jk} \times QF \times (\Phi_\beta \times E_\beta n_\beta + \Phi_\gamma \times E_\gamma n_\gamma)$$

where

R_{ijk} = total-body dose to subsurface receptor *i* from external exposure to ROPC *j* in soil at location *k* (rem/day)

AUF_{ik} = Area Use Factor for receptor *i* at exposure location *k* (unitless) =

$$1 \text{ if } A_k >= HR_i$$
$$A_k/HR_i \text{ if } A_k < HR_i$$

A_k = Area of exposure location *k* (ha)

HR_i = Home range, foraging range, or territory size of receptor *i* (ha)

TUF_{ik} = Temporal Use Factor for receptor *i* at exposure location *k* (unitless) = 1 unless receptor-specific value is available

1.05 = conversion factor to account for immersion in soil rather than water

F_{below} = fraction of time receptor *i* spends below ground in tunnels or burrows (unitless)

CFa = unit conversion factor from pCi/g x MeV/disintegration to rad/day = 5.11×10^{-5} rad/day/[(pCi MeV/(g soil x disintegration)]

C_{jk} = concentration of ROPC *j* in soil at location *k* (pCi/g)

QF = quality factor to account for relative effectiveness of radiation types: 1 rem/rad for β and γ radiation

Φ_m = absorbed fraction of energy emitted by β or γ radiation (unitless), where m = β or γ

E_m = average effective energy emitted by β or γ radiation (MeV/disintegration)

n_m = proportion of disintegrations producing β or γ radiation (unitless)

The dose rate for external radiation from radionuclides suspended in air will be calculated as described by Eckerman and Ryman (1993). The dose rate equation is:

$$R_{ijk} = AUF_{ik} \times TUF_{ik} \times Dp_{jk} \times DCFa_j \times CFc$$

where

R_{ijk} = total-body dose to terrestrial receptor *i* from external exposure to ROPC *j* in air at location *k* (rem/day)

AUF_{ik} = Area Use Factor for receptor *i* at exposure location *k* (unitless) =

$$1 \text{ if } A_k >= HR_i$$
$$A_k/HR_i \text{ if } A_k < HR_i$$

A_k = Area of exposure location k (ha)
HR_i = Home range, foraging range, or territory size of receptor i (ha)
TUF_{ik} = Temporal Use Factor for receptor i at exposure location k (unitless) = 1 unless receptor-specific value is available
Dp_{jk} = density of $ROPC_j$ in suspended particles at location k (pCi/m^3)
$DCFa_j$ = dose conversion factor for exposure to ROPC j by immersion in air (Sv/sec per Bq/m^3) (Eckerman and Ryman 1993, Table III.1)
CFc = unit conversion factor from Sv/sec per Bq/m^3 to rem/day per pCi/m^3 = 3.20 x 10^5 (rem/day per pCi/m^3) / (Sv/s per Bq/m^3)

Concentrations of ROPCs in air (pCi/m^3) derived by fate and transport modeling will be used for the concentration term Dp_{jk}.

The total-body dose from external exposure is added to the total-body dose from internal exposure to calculate the combined total-body dose, R_{ik}.

8.2.3. Aquatic Receptors

For receptors living in surface water or sediment (e.g., aquatic life and salmon and other fish living in surface water, and sediment-dwelling organisms living in sediment), the HQ is calculated as the ratio of the measured concentration of COPC in the medium and the TRV. That is:

$$HQ_{ijk} = C_{jk}/TRV_{ij}$$

where

HQ_{ijk} = hazard quotient for receptor i at exposure location k for COPC j (unitless)
C_{jk} = concentration of COPC j in water or sediment at exposure location k (µg/L or mg/kg)
TRV_{ij} = toxicity reference value of receptor i for COPC j (µg/L or mg/kg).

The HQ for a wildlife receptor that does not live in the surface water or sediment containing the COPCs but is exposed from aquatic food webs by ingestion, inhalation, and other routes is calculated as the ratio of the estimated ADD (mg/kg BW/day) and the TRV (mg/kg BW/day). That is:

$$HQ_{ijk} = ADD_{ijk}/TRV_{ij}$$

The above equation is used to estimate risk for the wildlife receptors in the aquatic food web: Canada goose, spotted sandpiper, great blue heron, bald eagle and mink. The concentrations of COPCs in sediment or surface water, estimated COPC concentrations in plant and animal tissue, ingestion rates, and bio-accumulation factors (Appendix C-2), will be used to estimate the ADDs for these receptors, as described below.

8.2.3.1. Ingestion Exposure Calculation (Sediment to Wildlife)

For animal receptors such as invertebrates and birds that are exposed to chemicals in sediment by ingestion of sediment, ingestion of sediment-associated biota, or both, the exposure is calculated as follows:

$$ADD_{ijk} = AUF_{ik} \times TUF_{ik} \times [(Cp_{jk} \times IP_i) + \Sigma_m(C_{mjk} \times IAm_i) + (Cs_{jk} \times IS_i \times AEs_j)]/BW_i$$
$$= AUF_{ik} \times TUF_{ik} \times Cs_{jk} \times [(IP_i \times SP_j) + \Sigma_m(IAm_i \times BSF_{mj}) + (IS_i \times AEs_j)]/BW_i$$

where

Cp_{jk}	=	Concentration of COPC *j* in aquatic plant tissue at exposure location *k* (mg/kg-wet wt.) = RME tissue concentration, unless otherwise directed
IP_i	=	Rate of ingestion of aquatic plant tissue by receptor *i* (kg/day)
Cm_{jk}	=	Concentration of COPC *j* in tissue of prey type *m* at exposure location k (mg/kg-wet wt.) = RME tissue concentration unless otherwise directed
IAm_i	=	Rate of ingestion of prey type *m* by receptor *i* (kg/day)
Cs_{jk}	=	Concentration of COPC *j* in sediment at exposure location *k* (mg/kg-dry wt.) = RME_{jk} sediment concentration
IS_i	=	Rate of ingestion of sediment by receptor *i* (kg/day)
AEs_j	=	Absorption efficiency factor for COPC *j* in ingested sediment (unitless) = 1, unless chemical-specific value is available
SP_j	=	Sediment-to-Plant transfer factor for aquatic plant tissue for COPC *j* ($kg_{sediment}$-dry wt./kg_{tissue}-wet wt.)
BSF_{mj}	=	Sediment-to-tissue transfer factor for prey *m* for COPC *j* ($kg_{sediment}$-dry wt./kg_{tissue}-wet wt.).

Note that BSF in the literature (also referred to as BSAF) is often provided as a ratio of lipid-normalized tissue chemical residue to organic carbon-normalized sediment chemical concentration so that a conversion may be needed to determine BSF_{mj}.

8.2.3.2. Ingestion Exposure Calculation (Surface Water to Animals and Wildlife)

For animal receptors such as mammals and birds that are exposed to chemicals in surface water by ingestion of surface water, ingestion of aquatic biota, or both, the exposure is calculated as follows:

$$ADD_{ik} = AUF_{ik} \times TUF_{ik} \times [(Cp_{jk} \times IP_i) + \Sigma_m(Cm_{jk} \times IAm_i) + (Cw_{jk} \times IW_i)]/BW_i$$
$$= AUF_{ik} \times TUF_{ik} \times Cw_{jk} \times [(IP_i \times WP_j) + \Sigma_m(IAm_i \times BCF_{mj}) + IW_i]/BW_i$$

where

Cw_{jk}	=	Concentration of COPC *j* in surface water at exposure location *k* (mg/L) = RME_{jk} water concentration, unless otherwise directed
WP_j	=	Water-to-plant transfer factor for aquatic plant tissue for COPC *j* (L/kg tissue wet wt., Table C-2-3)
IW_i	=	Rate of water ingestion by receptor *i* (L/day)
BCF_{mj}	=	Surface water-to-tissue transfer factor for prey type *m* for COPC *j* (L/kg_{tissue}-wet wt.).

8.2.3.3. Radiological Exposure Calculations

Ecological receptors are exposed internally and externally to ROPCs in aquatic habitats within the deposition grid surrounding the RPP-WTP at the Hanford Site. The risk from exposure to radionuclides is calculated as the ratio of the estimated total-body dose rate (R_{ik}) and the TRV. That is:

$$HQ_{ik} = R_{ik}/TRV_i$$

where

HQ_{ik} = hazard quotient for receptor *i* at exposure location *k* for all ROPCs (unitless)

R_{ik} = total body dose rate to receptor *i* at exposure location *k* (rem/day)
TRV_i = toxicity reference value (dose rate) of receptor *i* for ROPCs (rem/day).

The total-body dose rate of aquatic ecological receptors results from both internal and external exposure to all radionuclides, which are summed to estimate the combined exposure. That is:

$$R_{ik} = \Sigma_j \; [R_{ijk}(\text{internal}) + R_{ijk}(\text{external})]$$

Dose rates for aquatic receptors are calculated as in Blaylock et al. (1993).

8.2.3.4. Internal Exposure

The internal total-body dose rate to an aquatic receptor from exposure to a single ROPC is:

$$R_{ijk} = CFa \times [Co_{jk} \times (QF \times \Phi_\gamma E_\gamma n_\gamma + QF \times \Phi_\beta E_\beta n_\beta + QF \times \Phi_\alpha E_\alpha n_\alpha)]$$

where

R_{ijk} = internal total-body dose of ROPC *j* to receptor *i* at exposure location *k* (rem/day)
CFa = unit conversion factor from pCi/g x MeV/dis to rad/day, 5.11×10^{-5}
Co_{jk} = concentration of radionuclide ROPC *j* in organism *i* at exposure location *k* (pCi/g wet weight)
QF = quality factor to account for relative effectiveness of radiation types: 1 rem/rad for β and γ and 20 rem/rad for α radiation
Φ_m = absorbed fraction of each radiation-energy type *m* (dimensionless) where m = α, β , or γ
E_m = average effective energy emitted by α, β, or γ radiation (MeV per disintegration)
n_m = proportion of disintegrations producing α, β, or γ radiation.

According to Blaylock et al. (1993), internal beta radiation for large fish and internal alpha radiation for both small and large fish are completely absorbed (i.e., $\Phi = 1$).

8.2.3.5. External Exposure

The external total-body dose rate to a generic aquatic receptor from exposure to a single ROPC in aquatic habitat is calculated as in Blaylock et al. 1993, that is:

$$R_{ijk} = AUF_{ik} \times TUF_{ik} \times CFa \times [Cw_{jk} \times (1 - F_s - F_{in}) \times 1000 \text{ mL/L} / 1 \text{ g/mL} + Cs_{jk} \times (0.5F_s + F_{in})] \times QF \times [(1-\Phi_\gamma) \times E_\gamma n_\gamma + (1-\Phi_\beta) \times E_\beta n_\beta]$$

where

R_{ijk} = total-body dose to terrestrial receptor *i* from external exposure to ROPC *j* in surface water and sediment at location *k* (rem/day)
AUF_{ik} = Area Use Factor for receptor *i* at exposure location *k* (unitless) =
1 if $A_k >= HR_i$
A_k/HR_i if $A_k < HR_i$

A_k = Area of exposure location *k* (ha)
HR_i = Home range, foraging range, or territory size of receptor *i* (ha)
TUF_{ik} = Temporal Use Factor for receptor *i* at exposure location *k* (unitless) = 1 unless receptor-specific value is available

CFa = unit conversion factor from pCi/g x MeV/disintegration to rad/d = 5.11×10^{-5} rad/day/[pCi MeV/(g x disintegration)]
Cw_{jk} = concentration of ROPC *j* in water at location *k* (pCi/L)
F_s = fraction of time the receptor spends at the sediment-water interface (unitless) [exposure is assumed to be one-half as great at the interface as while immersed (Blaylock et al. 1993)]
F_{in} = fraction of time the receptor spends buried in sediment (unitless)
1000 mL/L = unit conversion factor for volume of water
1 g/mL = unit conversion factor for density of water
Cs_{jk} = concentration of ROPC *j* in sediment at location *k* (pCi/g)
QF = quality factor to account for relative effectiveness of radiation types: 1 rem/rad for β and γ radiation
Φ_m = absorbed fraction of energy emitted by β or γ radiation (unitless), where m = β or γ
E_m = average effective energy emitted by β or γ radiation (MeV/disintegration)
n_m = proportion of disintegrations producing β or γ radiation (unitless)

According to Blaylock et al. (1993), external beta radiation from water and sediment for large fish and external alpha radiation for both small and large fish from water and sediment are negligible.

Where ROPC concentrations are available for sediment but not surface water or surface water but not sediment, screening benchmarks presented by DOE (1998) will be used to screen exposures of fish and aquatic invertebrates.

Note that DOE (1998) has used the methods developed by, and TRUs published by, Blaylock et al (1993) to derive these sediment and surface water radiological benchmarks for aquatic biota.

8.2.4. Exposure Variables

The magnitude of exposure of ecological receptors to COPCs and ROPCs in environmental media depends on various parameters and variables in the above exposure equations. The exposure variables include factors correcting for the fraction of a receptor's total exposure originating at the exposure location, variables determining the rate of uptake into tissues and cells, and factors accounting for the accumulation in one medium of substances present in another medium. The exposure variables for ecological receptors are briefly discussed below.

8.2.4.1. Space and Time Factors for Exposure Calculations

For wildlife receptors that are exposed to COPCs and ROPCs by ingestion and inhalation, the calculation of exposure may require exposure factors that adjust for the fraction of a receptor's exposure obtained from the contaminated site. A receptor may obtain only a fraction of its exposure to a contaminant from the exposure location as a result of the receptor foraging over an area larger than the exposure location, spending only a fraction of its lifetime at the exposure location, or both. The rules for use and derivation of area-use and temporal-use factors follow.

Area-Use Factor

The area-use factor (AUF) estimates the fraction of a receptor's exposure that comes from the exposure location. The AUF is the smaller of 1 and the ratio of the area of the exposure location and the area in which a receptor lives or forages, whichever is more appropriate to the routes by which the receptor is exposed. The AUF is calculated as follows:

$$AUF_{ik} = 1, \text{ if } A_k \geq HR_i$$
$$= A_k/HR_i, \text{ if } A_k < HR_i$$

If the receptor has a home range large enough to comprise multiple exposure locations in the exposure grid, then the exposure location *k* can be an aggregate of smaller sites, in which case the AUF is calculated as above, using the area of the aggregate, which is the sum of the areas of the smaller units. Assuming that the receptor moves randomly over the exposure location, the area-weighted exposure concentrations of COPCs are used to calculate the average daily dose for that receptor that comes from the multiple nodes on the exposure grid.

Temporal-Use Factor

There are several approaches to dealing with the temporal aspect of exposure. The first approach is to assume conservatively, that receptors are exposed throughout their lifetime to COPCs and ROPCs present at the exposure location. The second approach is to estimate the temporal-use factor (TUF) as the fraction of time each year that a receptor is in the vicinity of the exposure location during which it forages or resides at the exposure location. The remaining time is assumed to be spent in either, one an area free of contamination, or two an area with 'background' levels of contaminants. The third approach is more complicated because it depends on receptor behavior and physiology, and the duration of the toxicity test on which the TRV is based. In general, the TUF is calculated as follows:

$$TUF_{ik} = (EF_{ik} \times ED_{ik})/AT_i$$

where

EF_{ik} = frequency of exposure of receptor *i* at exposure location *k* (days/year)
ED_{ik} = duration of exposure of receptor *i* at exposure location *k* (years)
AT_i = exposure averaging time for receptor *i* (days).

For the SLRA, the TUF will be assumed to be 1 for all receptors (unless explicitly stated otherwise). This is a reasonable assumption because the duration of toxicity tests is short compared to the duration of exposure of the receptor at the site.

8.2.4.2. Uptake Variables

The exposure equations for ecological receptors include parameters for the ingestion and inhalation of ecological receptors and the efficiency of absorption of COPCs and ROPCs from inhaled or ingested media.

Ingestion and Inhalation Rates

The magnitude of exposure of ecological receptors to COPCs and ROPCs in environmental media depends on the rate of intake of the contaminated media. For wildlife receptors exposed by ingestion and inhalation, receptor-specific ingestion and inhalation rates are required to estimate exposure. Published values for food ingestion (IP and IA), soil and sediment ingestion (IS), water ingestion (IW), and inhalation (IR) will be used to estimate exposure.

Absorption Efficiency

Substances ingested or inhaled by ecological receptors are absorbed and taken up into the receptors cells and organs to varying degrees. The efficiency of absorption depends on the relative affinity of the

substance for the environmental medium (soil, air, particulate, sediment, water, and tissue) and for the receptor's tissues. Published absorption values will be used for a COPC or ROPC when available. For both the PRA and the FRA, the absorption efficiency (AE) for inhaled and ingested media will be assumed to be the same or 100% of the actual absorption of the contaminant in the experiment or field observation used to derive the TRV. This is a conservative assumption for COPCs and ROPCs ingested as soil, sediment, or particulates in water, and inhaled as particulates.

8.2.4.3. Bioaccumulation Factors for Calculating Terrestrial Exposures

The calculation of exposure for ecological receptors may require one or more bioaccumulation and transfer factors. These factors are used to estimate the concentration in the tissue of an organism from the concentrations in the contaminated media to which it is exposed. Such factors are required to estimate exposure for wildlife receptors, such as mammals and birds, that are exposed to chemicals in soil by ingestion of plants, soil-dwelling invertebrates or other wildlife, when the concentration in the ingested organism is not measured directly. In each case, the numerator of the factor must have units corresponding to concentration in the medium taking up the substance (tissue) and the denominator the units of concentration in the 'source' medium (soil, tissue). The rules for use and derivation of bioaccumulation or transfer factors follow:

Soil-to-plant transfer factor

The soil-to-plant transfer factor (SP) is the ratio of the chemical concentration in plant tissue and in soil as follows: The SP is used to estimate the tissue concentration of plants exposed to chemicals in soil from the concentration of chemical in bulk soil. That is:

$$SP = [(mg/kg_{tissue}\text{-wet wt.})/(mg/kg_{soil}\text{-dry wt.})].$$

$$SPr_j = \text{Soil-to-Plant transfer factor for reproductive tissue for COPC } j = (kg_{soil}\text{-dry wt.}/kg_{tissue}\text{-wet wt.})$$

and

$$SPv_j = \text{Soil-to-Plant transfer factor for vegetative tissue for COPC } j = (kg_{soil}\text{-dry wt.}/kg_{tissue}\text{-wet wt.})$$

where reproductive tissues are flowers, seeds, and fruit, and vegetative tissues are leaf, stem, and root. Concentrations are estimated for plant tissues that are fed upon by wildlife receptors.

The first choice for terrestrial soil-to-plant (SP) transfer values will be EPA (1999) values. Per EPA (1999a), recommended SP values for inorganic elements are values published in Baes et al. (1984), and for those with no published field or laboratory data, the arithmetic average of the available SP values for the other inorganics will be used as the SP. EPA recommends using bioaccumulation equivalency factors (BEFs) to estimate the bioaccumulation of PCDD and PCDF congeners for which field or laboratory measurements are not available. The BEF is the predicted ratio of bioaccumulation of a PCDD or PCDF congener in soil to the bioaccumulation of TCDD (EPA 1999a). BEFs were used by EPA (1999a) to calculate the BAFs presented in Appendix C for PCDD and PCDF congeners. The EPA (1999a) recommended SP values for organic compounds with no field or laboratory data are estimated using the Travis and Arms (1988) regression on K_{ow}:

$$\log SP = 1.588 - (0.578 \log K_{ow})$$

For organic compounds, the same SP values are used for both SP_r and SP_v. Baes et al. (1984) and Travis and Arms (1988) values are reported in Appendix C-2, Table C-2-1. Where K_{ow} values are not available, SP_r and SP_v values for organic compounds will be values preferred and provided by the State of Washington. Where such values are not available, we will seek values from PNNL derived from Hanford site-specific data. Default SPs are 1 for COPCs/ROPCs without values from any of the above sources.

SP_r and SP_v values are also used for aboveground protected and unprotected plant parts for human health exposure (section 6.3.1).

Air-to-plant tissue transfer factor

The air-to-plant tissue transfer factor (AP*v*) is the ratio of the chemical concentration in aboveground vegetative tissue of a plant and the concentration in air [(mg/kg)/(mg/L or m^3)]. The AP*v* is used to estimate the tissue concentration of plants exposed to chemicals in air from the concentration of chemical in the air. That is,

$$APv_j = \text{air-to-plant tissue transfer factor for COPC } j \text{ (L or m}^3\text{/kg)}$$

Tissue concentrations are estimated for plants that are fed upon by wildlife receptors, such as mule deer, because plant-tissue concentrations are needed to estimate the daily dose to receptors.

The first choice for air-to-plant tissue transfer factors (AP*v*) will be EPA (1999a) values, where they are referred to as B*v*. EPA (1999a) calculates the AP*v* for organics (except PCDDs and PCDFs) using regressions on K_{ow} published by Bacci et al. (1990, 1992) and the calculated values are reduced by a factor of 100. For PCDDs and PCDFs, EPA (1999a) recommends the use of AP*v* values from Lorber and Pinsky (1999). For metals except mercuric chloride, EPA (1999a) assumes that AP*v* = 0. For mercuric chloride, EPA (1999a) recommended AP*v* values are obtained from EPA (1997d).

Where K_{ow} values are not available, AP*v* values for organic compounds will be values preferred and provided by the State of Washington. Where such values are not available, we will seek values from PNNL derived from site-specific field or laboratory data. Default AP*v* values are 1 for organic COPCs without values from any of the above sources.

Soil-to-soil invertebrate tissue transfer factor

The soil-to-soil invertebrate tissue transfer factor (BAF-S) is the ratio of the chemical concentration in soil invertebrate tissue and that in soil [(mg/kg_{tissue}-wet wt.)/(mg/kg_{soil}-dry wt.)]. The BAF-S is used to estimate the tissue concentration of terrestrial invertebrates exposed to chemicals in soil by all exposure routes (ingestion, direct contact, and inhalation) from the concentration of a chemical in bulk soil. That is:

$$BAF\text{-}S_{mj} = \text{Soil-to-soil invertebrate tissue transfer factor for prey type } m \text{ for COPC } j \text{ (kg}_{soil}\text{-dry wt./kg}_{tissue}\text{-wet wt.)}$$

where prey type *m* is a soil-dwelling invertebrate, such as the earthworm, which is an important diet item of many mid-level predators, such as shrews and robins. Tissue concentrations are estimated for terrestrial invertebrates that are fed upon by wildlife receptors.

The first choice for terrestrial soil-to-earthworm bioaccumulation (BAF-S) values will be field or laboratory values for earthworms in EPA (1999a). Per EPA (1999a), recommended BAF-S values for inorganic elements (except lead) with no published field or laboratory data are arithmetic averages of the

BAF-S values available for other inorganics. For organic compounds with no field or laboratory data. EPA (1999a) uses values derived from K_{ow}s for daphnids, an aquatic macroinvertebrate, exposed to PAHs (Southworth et al 1978). For organic compounds with no field or laboratory data available, we will seek values from the State of Washington and Pacific Northwest National Laboratory (PNNL) derived from Hanford site-specific data. If values are not available from either of these sources, published values from published sources (e.g. HAZWRAP 1994) will be used. The Southworth et al (1978) regression for daphnids is not recommended for earthworms. Where no appropriate published surrogate data are available, the default BAF-S for organic compounds will be 10.

The earthworm BAF-S for lead (Pb) is calculated from the site-specific concentrations of calcium and lead (Corp and Morgan 1991), as follows:

$$\text{BAF-S}_{worm,Pb,k} = 0.2 \times C_{worm,Pb,k}/C_{soil,Pb,k}$$

where

$$\log C_{worm,Pb,k} = 1.16 + (0.916 \times \log C_{soilPb,k}) - (0.326 \times \log C_{soil,Ca,k})$$

and

$C_{worm,Pb,k}$ = the concentration of lead in worm tissue at exposure location k (mg/kg$_{tissue}$-dry wt.)
$C_{soil,Pb,k}$ = the concentration of lead in soil at exposure location k (mg/kg$_{soil}$-dry wt.)
$C_{soil,Ca,k}$ = the concentration of calcium in soil at exposure location k (mg/kg$_{soil}$-dry wt.)

The concentration of lead in the worm tissue (mg/kg$_{tissue}$-dry wt.) is converted to wet weight by multiplying by 0.2, on the assumption that worms are 80% water. No other substance is known to have an equation for predicting site-specific BAFs that depends on the concentration of a different substance.

BAF-S values are listed in Appendix C2. Note that the earthworm data (of which there are several values) serve as proxy for the darkling beetle and other desert terrestrial invertebrates (Figure 8-9) for which there are no known BAF-S values.

Tissue-to-tissue transfer factor

The tissue-to-tissue transfer factor (BAF-T) is the ratio of the chemical concentrations in predator tissue and that in the tissue of its prey [(mg/kg/(mg)/kg$_{tissue}$-wet wt.)]. The BAF-T is used to estimate the tissue concentration of animals exposed to chemicals by ingestion of prey from the concentration of chemical in the prey. That is:

$$\text{BAF-T}_{nj} = \text{Tissue-to-tissue transfer factor for prey type } n \text{ for COPC } j \text{ (kg}_{tissue}\text{-wet wt./kg)}$$

where, for example, prey type n is a mid-level predator of soil-dwelling invertebrates such as a Western meadowlark or Great Basin pocket mouse and also a prey of top predators, such as coyotes or owls and receptors such as deer and rabbits, which are considered wild game in the human health risk assessment. Tissue concentrations are estimated for animals that are fed upon by wildlife receptors.

For medium-to-tissue accumulation factors for mammals and birds, EPA (1999a) proposes the use of Baes et al. (1984) and Travis and Arms (1988) Ba values (d/kg) multiplied by the receptor's absolute ingestion rate for the medium (kg-medium/d). The EPA approach holds that the ratio of the receptor's tissue concentration (mg/kg body weight) to the receptor' contaminant intake rate (mg/d) is invariant. In other words, a deer (56.5 kg body weight, 1.74 kg/d ingestion rate) would have a seven-fold higher body

burden than a cottontail (1.2 kg body weight, 0.237 kg/d ingestion rate) eating the same vegetation because of the deer's seven-fold larger food ingestion rate.

It is proposed to calculate BAF-Ts from published biotransfer factors (Ba), as follows:

$$BAF\text{-}T_{nj} = Ba_A \times BW_A \times SIR_n$$

where

$BAF\text{-}T_{nj}$ = animal-to-animal tissue transfer factor for prey species *n* and COPC *j* (kg_{tissue}-wet wt./kg)
Ba_A = biotransfer factor for animal *A* (d/kg)
BW_A = body weight of animal *A* (kg)
SIR_n = specific food ingestion rate of prey species *n* (kg_{tissue}-wet wt./kg/d)

This approach to estimating BAF-T assumes that the ratio of the amount of contaminant taken up per unit body weight and the amount of contaminant ingested per unit body weight per day (mg/kg / mg/kg/d) is constant among similar species, e.g., mammals.

The proposed approach can be derived from a simple model,

$$dC_{tissue}/dt = Z - \lambda C_{tissue},$$

where C_{tissue} (mg COPC/kg body weight) is the COPC-tissue concentration (amount of contaminant per unit tissue) at time t; Z is the amount of contaminant absorbed per unit tissue per unit time (mg COPC/ kgBW/day); and λ is the loss (depuration) rate constant (d^{-1}). A biouptake factor (BF) can be defined as the ratio of the equilibrium tissue concentration $[C_{tissue}(\bullet)]$ and the "input" of contaminant into the organism, that is,

$$BF = [C_{tissue}(\bullet)]/Z.$$

BF has units mg COPC/kgBW per mg COPC/kgBW/d, or more simply days (d). BF is equal to the inverse of the loss rate,

$$BF = [C_{tissue}(\bullet)]/Z = [Z/\lambda]\ /Z = 1/\lambda,$$

because $C_{tissue}(\bullet)$ can be shown to be equal to Z/λ.

It is likely that the depuration rate constant varies in nature, but possibly not as much as food ingestion rates. Metabolic scaling theory suggests that rate constants or frequencies ($time^{-1}$) vary as the inverse of the 0.25 power of body weight while rates with units of mass or volume per unit time (e.g., kg/d) vary approximately as the 0.75 power of body weight (Schmidt-Nielsen 1984). If depuration rate constants are less variable than ingestion rates, then BF will be more invariant across species and individuals than EPA.

Given that the amount of contaminant absorbed per unit tissue per unit time (Z) can be estimated as

$$Z = C_{ingested} \times AE \times SIR,$$

then the relationship of BF to the BAF-T required in the RPP-WTP is as follows:

$$BAF\text{-}T = C_{tissue}(\bullet)/C_{ingested}$$

$$= (Z/\lambda)/(C_{ingested})$$
$$= C_{ingested} \times AE \times SIR/(\lambda \times C_{ingested})$$
$$= (1/\lambda) \times AE \times SIR$$
$$= BF \times AE \times SIR,$$

where BAF has units (mgCOPC/kg-receptor tissue/mgCOPC/kg-medium ingested), AE is the absorption efficiency (mgCOPC-receptor tissue/mgCOPC-medium ingested), and the specific ingestion rate (SIR) has units kg-medium ingested/kg BW/d. Thus, BF isolates the storage component of the bioaccumulation process from the ingestion (SIR) and absorption (AE) components of the process.

The BAF will be relatively invariant with body weight if the BF, AE, and SIR vary as the 0.25, 0, and –0.25 powers of body weight, respectively. As stated above, the depuration constant likely varies as the inverse of the 0.25 power of body weight and BF is the inverse of the depuration constant, so it likely varies as the 0.25 power. To the extent that absorption is a tissue property, absorption efficiency should not vary with body weight (exponent = 0). If ingestion rate varies approximately as the 0.75 power of body weight (Schmidt-Nielsen 1984), then the body-weight specific ingestion rate will vary as approximately the –0.25 power of body weight ($W^{0.75}/W^{1} = W^{-0.25}$).

The proposed BAF values are calculated from Baes et al. (1984) and Travis and Arms (1988) Ba values because BF values are not available. Assuming that the ratio of the receptor-tissue concentration to specific ingestion rate of contaminant is invariant across species, that is,

$$BF_{cow} = BF_{receptor}$$

$$C_{cow}(\bullet)/(C_{ingested} \times AE_{cow} \times SIR_{cow}) = C_{receptor}(\bullet)/(C_{ingested} \times AE_{receptor} \times SIR_{receptor}),$$

the BAF for the receptor is calculated from the Ba value for the cow as described above.

Assuming that $AE_{receptor} = AE_{cow}$, it follows that,

$$BAF_{receptor} = C_{receptor}(\bullet)/C_{ingested}$$
$$= [C_{receptor}(\bullet)/(C_{ingested} \times AE_{receptor}/AE_{cow} \times SIR_{receptor})] \times SIR_{receptor}$$
$$= [C_{cow}(\bullet)/(C_{ingested} \times SIR_{cow})] \times SIR_{receptor}$$
$$= [C_{cow}(\bullet)/(C_{ingested} \times IR_{cow})] \times BW_{cow} \times SIR_{receptor}$$
$$= Ba_{cow} \times BW_{cow} \times SIR_{receptor},$$

because the biotransfer factor Ba (d/kg) is defined as follows (Baes et al. 1984):

$$Ba_{cow} = C_{cow}(\bullet)/(C_{ingested} \times IR_{cow}),$$

where IR_{cow} is the ingestion rate (kg/d) of the cow.

When published field or laboratory values are not available, the first choices for Ba values are those recommended by EPA (1999a). For mammals, EPA (1999a) recommends using the following regression on K_{ow} (Travis and Arms 1988) for organic compounds (except dioxins/furans):

$$\log Ba = -7.6 + \log K_{ow}$$

For dioxins/furans, EPA (1999a) recommends for mammals the use of the Ba values presented in EPA (1995). For mammals and inorganic elements (except mercury), the EPA (1999a) recommended values are those reported in Baes et al. (1984). For mercury, EPA (1999a) recommends for mammals the use of the Ba value for total mercury reported for cows in EPA (1997d) converted to a wet weight basis and partitioned into methylmercury and mercuric chloride forms in the ratio of 0.13:0.87. For all mammal receptors, the Ba values are multiplied by the ratio of the receptor fat to the beef cattle fat.

For birds, EPA (1999a) recommends using for organic compounds (except dioxins/furans) the Travis and Arms (1988) Ba values for mammals adjusted for the lower fat content of birds. Bird Ba values are derived by multiplying the mammal value by the ratio of bird fat to mammal fat (0.15/0.19). For dioxins/furans, EPA (1999a) recommends for birds using the Ba values for chickens derived in Stephens et al. (1995). For birds and cadmium, selenium, and zinc, the EPA (1999a) recommended values are those reported in EPA (1992). For mercury, EPA (1999a) recommends for birds the use of the Ba value for total mercury for poultry reported in EPA (1997d) converted to a wet weight basis and partitioned into methylmercury and mercuric chloride forms in the ratio of 0.13:0.87.

The second choice for tissue-to-tissue bioaccumulation (BAF-T) values will be values preferred and provided by the State of Washington. Where such values are not available, we will seek values from PNNL derived from Hanford site-specific data. If values are not available from these sources, we will use values published in Baes et al. (1984) for elements and from published studies that have been compiled by HAZWRAP (1994). These values are found in Appendix C-2.

Default BAFs for mammals and birds are 1 for inorganic and 10 for organic COPCs.

Published BAF-Ts are listed in Appendix C2. Unless Hanford site-specific BAF-Ts become available, these and other BAF values will be used.

Abiotic medium-to-vertebrate tissue transfer factor

The abiotic medium-to-vertebrate animal tissue transfer factor (BAF-T) is the ratio of the chemical concentration in vertebrate animal tissue and the concentration in soil, drinking water or air (mg/kg/ mg/kg_{soil}-dry wt. or L or m^3). The BAF-T is used to estimate the tissue concentration of vertebrates exposed to chemicals by soil ingestion (direct or indirect), water ingestion, or inhalation from the concentration of chemical in the abiotic medium. That is,

$BAF\text{-}T_{nj}$ = abiotic medium-to-vertebrate animal tissue transfer factor for prey species n and COPC j (kg_{soil}-dry wt. or L or m^3/kg)

where, prey type n is a mid-level predator, such as the Western meadowlark or Great Basin pocket mouse, that feeds upon plants or soil-dwelling invertebrates. Tissue concentrations are estimated for mid-level predators that are fed upon by wildlife receptors, such as coyotes and burrowing owls, because prey-tissue concentrations are needed to estimate the daily dose to receptors.

The BAF-Ts for vertebrates ingesting soil, drinking water or inhaling air are the same as the BAF-Ts for tissue-to-tissue uptake. As with BAF-Ts for tissue-to-tissue uptake, BAF-Ts for uptake from abiotic media are calculated from published biotransfer factors (Ba), the beef cattle body weight (200 kg), and the prey's specific ingestion or inhalation rate for the abiotic medium. The Ba values used to calculate BAF-Ts for abiotic medium-to-tissue uptake are the same as the Ba values used to calculate BAF-Ts for tissue-to-tissue uptake. The default BAF-T values for abiotic media are the same as the default BAF-Ts for tissue.

Default bioaccumulation values

When a bioaccumulation factor for terrestrial receptors is not available, a default value will be used. Default values are conservative, order of magnitude estimates, based on an evaluation of available published values (HAZWRAP 1994). Default values are selected to be larger than most published values.

The default SP for terrestrial plants is 1 for all contaminants without published values. Default AP value for organic compounds is 1. Default BAF-S values are 1 for inorganic and 10 for organic contaminants without published values. Default BAF-Ts for terrestrial mammals and birds are 1 for inorganic and 10 for organic contaminants.

8.2.4.4. Bioaccumulation Factors for Calculating Aquatic Exposures

The calculation of exposure for ecological receptors may require one or more bioaccumulation or transfer factors that are used to estimate the concentration in the tissue of an organism from the concentrations in the contaminated media to which it is exposed (Figure 8-11). Such factors are required to estimate exposure for wildlife receptors, such as mammals and birds that are exposed to chemicals in sediment or surface water by ingestion of plants, sediment-dwelling invertebrates, or aquatic biota, when the concentration in the ingested organism is not measured directly. In each case, the numerator of the factor must have units corresponding to the units of the medium taking up the substance (tissue) and the denominator the units of the 'source' medium (sediment, water, tissue). The rules for use and derivation of these factors follow:

Water-to-plant transfer factor

The water-to-plant transfer factor (WP) is the ratio of the chemical concentration in aquatic plant tissue and that dissolved in water [(mg/kg$_{tissue}$-wet wt.)/(mg/L)]. The WP is used to estimate the tissue concentration of aquatic plants exposed to chemicals in sediment or surface water from the concentration of chemical dissolved in sediment pore water or surface water, respectively. That is:

WP_j = water-to-plant transfer factor for aquatic plant tissue for COPC j dissolved in water (L/kg$_{tissue}$-wet wt.).

Aquatic plants are assumed to be exposed only to the dissolved phase of contaminants in sediment pore water, or surface water, depending on the morphology of the particular type of aquatic plant (e.g., rooted, floating). Concentrations are estimated for aquatic plant tissues that are fed upon by terrestrial receptors (e.g., Canada goose).

If field-measured WPs at the Hanford Site are available, they are the first choice. Second choice are laboratory-measured WPs. The third choice is field or laboratory values in EPA (1999a). If no field or laboratory values are available, WPs will be calculated as the product of the SP and the Sediment Kd. We do not recommend that WP values for organic compounds be derived using the Southworth et al (1978) regression on K_{ow} for daphnids as described in EPA (1999a) because aquatic plants and aquatic microcrustacean invertebrate animals are expected to have different uptake and depuration. Default WPs are 1 for COPCs/ROPCs without more preferred values.

Sediment-to-plant transfer factor

The sediment-to-plant transfer factor (SP) is the ratio of the chemical concentration in aquatic plant tissue and that in sediment [(mg/kg$_{tissue}$-wet wt.)/(mg/kg$_{sediment}$-dry wt.)]. The SP is used to estimate the tissue concentration of aquatic plants exposed to chemicals in sediment. That is,

SP_j = Sediment-to-plant transfer factor for aquatic plant tissue for COPC j ($kg_{sediment}$-dry wt./kg_{tissue}-wet wt.)

Rooted aquatic plants are assumed to be exposed only to the dissolved phase of contaminants in sediment pore water. Therefore, if SP values are not available for a constituent, the SP can be estimated from the water-to-plant tissue transfer factor (WP) and the sediment Kd. That is,

$$SP_j = WP_j/Kd_j$$

where

WP_j = Water-to-plant transfer factor for aquatic plant tissue for COPC j (L/kg_{tissue}-wet wt.)
Kd_j = Soil-to-water partitioning coefficient for COPCj ($L/kg_{sediment}$-dry wt.)

This assumes equilibrium between sediment and sediment pore water.

The first choice for sediment-to-aquatic plant tissue (SP) values will be field or laboratory values preferred and provided by EPA (1999a). Where such values are not available, values will be obtained from the State of Washington or PNNL values derived from Hanford site-specific data. If values are not available from either of these sources, terrestrial soil-to-plant transfer values will be used for the vegetative parts of plants (SPv) published in Baes et al. (1984) for elements and values derived from regressions on K_{ow} (Travis and Arms 1998) for organics in accordance with EPA (1999a) (Appendix C.2). If SPv values are not available, calculate the SP as the ratio of the water-to-plant tissue value (WP) and soil-to-water partition coefficient (Kd), as described above. Default SP values are the same as the terrestrial SP_r, and SP_v values.

Surface water-to-aquatic invertebrate transfer factor

The surface water-to-aquatic invertebrate tissue transfer factor (BCF) is the ratio of the chemical concentrations in animal tissue and that in the surface water to which the animal is exposed [(mg/kg_{tissue}-wet wt.)/(mg/L)]. The BCF is used to estimate the tissue concentration of animals exposed to chemicals in surface water from the concentration of chemical in the surface water. The tissue concentration is estimated for animals that are fed upon by wildlife receptors. That is:

BCF_{invj} = Surface water-to-aquatic invertebrate tissue transfer factor for prey for COPC j (L/kg_{tissue}-wet wt.).

where m is an aquatic organism such as small fish and crustaceans, which are an important diet item of many terrestrial predators of aquatic biota, such as herons.

The first choice for BCFs for aquatic invertebrates are values preferred and provided by the State of Washington or EPA, including field or laboratory values reported in EPA (1999a). Where such values are not available, we will seek values from PNNL derived from site-specific field or laboratory data. If values are not available from either of these sources, we will use published values for surrogates derived from field or laboratory data and values for organics derived from regressions on K_{ow}.

If no more preferred values are available, BCFs for aquatic invertebrates are calculated per EPA (1999a) from the octanol water-partitioning coefficient (K_{ow}) using the regression equation of Southworth et al. (1978):

$$\log BCF_{inv,j} = 0.819 \times \log K_{ow,j} - 1.146$$

where

$BCF_{inv,j}$ = Surface water-to-tissue transfer factor for invertebrate aquatic biota for COPC *j* (L/kg_{tissue}-wet wt.).

$K_{ow,j}$ = Octanol-water partition coefficient of COPC *j* (Lyman et al.1982).

For BCFs derived from field data on tissue concentrations and total water column concentrations, modeled total COPC concentration in the water column (C_{wctot}) will be used to estimate aquatic invertebrate tissue concentrations. For BCFs derived from laboratory data or K_{ow} regressions, the modeled dissolved phase water concentration (C_{dw}) will be used to estimate the aquatic invertebrate tissue concentrations.

Published BCFs are listed in Appendix C2. The default BCFs are 500 for inorganics and 100,000 for VOCs, SVOCs, and pesticides/PCBs.

Water-to-fish tissue transfer factor

The water-to-fish tissue transfer factor (BCF) is the ratio of the chemical concentration in fish tissue and the concentration in water [(mg/kg_{tissue}-wet wt.)/(mg/L)]. The fish BCF is used to estimate the tissue concentration of fish from the concentration in the water to which the fish is exposed. That is,

$BCF_{fish,j}$ = Water-to-fish tissue transfer factor for COPC *j* (L/kg_{tissue}-wet wt.)

The fish tissue concentrations are estimated because fish are consumed by wildlife receptors, such as herons, bald eagles, and mink.

The first choice for BCFs for fish are values preferred and provided by the State of Washington or EPA, including field or laboratory values reported in EPA (1999a). Where such values are not available, we will seek values from PNNL derived from site-specific field or laboratory data. If values are not available from either of these sources, we will use published values for surrogates derived from field or laboratory data and values for organics derived from regressions on K_{ow}.

If preferred values are not available for organic compounds, BCFs for fish are calculated using the following regression on the K_{ow} (Bintein et al. 1993):

$$\log BCF_{fish} = 0.91 \times \log K_{ow} - 1.975 \times \log (6.8 \times 10^{-7} \times K_{ow} + 1.0) - 0.786$$

If preferred values are not available for inorganic COPCs and ROPCs, per EPA (1999a), the BCF will be estimated as the arithmetic average of available BCFs for other inorganics.

For BCFs derived from field data for fish-tissue concentrations, modeled total COPC concentrations in the water column (C_{wctot}) will be used to estimate fish-tissue concentrations. In this case, the BCF is equivalent to the BAF (EPA 1999a). For BCFs derived from laboratory data or K_{ow} regressions, the modeled dissolved phase water concentration (C_{dw}) will be multiplied by both BCFs and EPA (1995f) food-chain multipliers (FCMs) to estimate the fish-tissue concentrations (EPA 1999a). That is,

$$BAF = BCF_{fish} \times FCM,$$

where

BAF	=	Bioaccumulation factor (mg/kg$_{tissue}$-wet wt./ mg/L)
BCF$_{fish}$	=	Bioconcentration factor (mg/kg$_{tissue}$-wet wt./ mg/L)
FCM	=	trophic level food-chain multiplier (unitless)

EPA (1995) has calculated FCMs for log K_{ow} values ranging from 3.5 to 9.0.

Published BCFs for fish are listed in Appendix C-2, Table C-2-3. The default fish BCFs are 500 for inorganics and 100,000 for organic VOCs, SVOCs, and pesticides/PCBs.

Sediment-to-animal tissue transfer factor

The sediment-to-animal tissue transfer factor (BASF) is the ratio of the chemical concentrations in sediment-dwelling animal tissue and that in bulk sediment [(mg/kg$_{tissue}$-wet wt.)/(mg/kg$_{sediment}$-dry wt.)]. The BASF is used to estimate the tissue concentration of animals exposed to chemicals in sediment by all exposure routes (ingestion, direct contact) from the concentration of chemical in bulk sediment. The tissue concentration is estimated for animals that are fed upon by wildlife receptors. That is:

$$BASF_{mj} = \text{Sediment-to-animal tissue transfer factor for prey } m \text{ for COPC } j \; (kg_{sediment}\text{-dry wt./}kg_{tissue}\text{-wet wt.})$$

where prey type *m* is typically a sediment-dwelling invertebrate, such as a burrowing amphipod or chironomid, which are important diet items of predators, such as the spotted sandpiper or certain fishes but may also be a sediment-ingesting fish such as carp and catfish.

BASFs are available in the literature for only a few chemicals. The first choice for BASFs are field or laboratory values preferred and provided by the EPA (1999a). However, we do not recommend that the BCF_{inv} derived using the Southworth et al (1978) regression for daphnids be used directly for the BASF as described in EPA (1999a). Where such values are not available, values from the State of Washington or PNNL will be obtained which are derived from Hanford site-specific data. If values are not available from either of these sources, published soil-to-soil invertebrate tissue transfer factors (BAF-S) will be used for inorganics and water-to-aquatic invertebrate tissue transfer factors (BCFs) will be derived for organics. For organics, the BASF will be estimated from the BCF as follows:

$$BASF_{mj} = BCF_{mj}/Kd_{jk}$$

where

BCF_{mj}	=	Surface water-to-aquatic invertebrate transfer factor for prey type *m* for COPC *j* (L/kg$_{tissue}$-wet wt.),
Kd_{jk}	=	Sediment-water partitioning coefficient for COPC *j* at exposure location *k* (L/kg$_{sediment}$-dry wt.),

Note that BASF in the literature (also referred to as BSAF) is often provided as a ratio of lipid-normalized tissue chemical residue to organic carbon-normalized sediment chemical concentration, so that a conversion may be needed to determine BASF.

For organic compounds, the Kd is a function of the K_{oc} and the organic matter content of the sediment, that is:

$$Kd_{jk} = K_{oc,j} \times FOC_k$$

where

$K_{oc,j}$ = the carbon-water partitioning coefficient for COPC *j* ($L/kg_{sediment}$-dry wt.)
FOC_k = mass fraction of organic carbon content of the sediment at exposure location *k* (unitless).

Because the K_{oc} is available for few compounds, the K_{ow}, the octanol-water partitioning coefficient, is used to estimate K_{oc} (EPA 1993c).

To estimate animal tissue concentrations, the BASFs derived from both field data and from aquatic invertebrate BCFs will be multiplied by the modeled bed-sediment COPC concentration (C_{bs}). Using bed-sediment concentrations with BASFs derived from BCFs is equivalent to using dissolved phase water concentrations and BCFs.

Published BASF values are listed in Appendix C2. The default BASF values are the same as the default BAF-S values (1 for inorganics, 10 for organics).

Default bioaccumulation values

When a transfer factor for aquatic receptors is not available because it was not measured in a field or laboratory investigation, it has no suitable surrogate value, or it could not be calculated, then a default value will be used. Default values are conservative, order of magnitude estimates, based on an evaluation of available published values (e.g., HAZWRAP 1994) and professional judgement. Default values are selected to be larger than most published values.

The default WP and SP values for aquatic plants is 1 and is the same as the default SPv for terrestrial plants. Default BCFs for aquatic animals are 500 for inorganics and 100,000 for VOCs, SVOCs, and pesticides/PCBs. The default BASF values are the same as the default BAF-S values (1 for inorganics, 10 for organics). Default BAF-Ts for mammals and birds ingesting aquatic biota are 1 for inorganic and 10 for organic COPCs.

8.3. Effects Assessment Calculations

TRVs are concentrations or doses of constituents that are associated with a specified level of adverse effect on ecological receptors. TRVs are used as the denominator in hazard quotients, as shown in the HQ equations (section 8.4).

8.3.1. Toxicity Reference Values for Terrestrial Receptors

TRVs for receptors dwelling in and thus, exposed by direct contact to COPCs/ROPCs in soil (plants, earthworms) are typically values from published sources, if field observations or site-specific toxicity tests of these media are not available.

8.3.1.1. Single Chemical TRVs

TRVs for plants and soil-dwelling invertebrates are derived values based on a review of published single-chemical laboratory studies (Efroymson et al. 1997a and 1997b).

For wildlife receptors, TRVs are required for both the ingestion and inhalation exposure pathways. Ingestion TRVs (Section 8.3.1.1) will be used to calculate HQs for the ingestion exposure pathway. Inhalation TRVs (Section 8.3.1.2) will be used to calculate HQs for the inhalation exposure pathway.

Inhalation and ingestion HQs for a given COPC can be added to calculate a HI for the combined pathways. This can be understood as adding the pathway-specific exposures, each weighted by its pharmacokinetic efficiency factor for the COPC, and comparing this combined "normalized" dose to the pathway-independent TRV (TRV'). For example, if the COPC is blood labile, there is a blood concentration associated with a particular level of adverse effect. This blood level corresponds to potentially different inhaled or ingested doses due to different pharmacokinetics of ingestion and inhalation. The factor that relates the dose to the corresponding blood concentration, with units kgBW/d/L, can be used to normalize the inhaled and ingested exposure doses to blood concentration so that they can be added together and compared on a common basis to the threshold blood concentration. That is,

$$\begin{aligned} HI &= ADD_{inh}/TRV_a + ADD_{ing}/TRV \\ &= ADD_{inh}/(TRV'/AE_{inh}) + ADD_{ing}/(TRV'/AE_{ing}) \\ &= (ADD_{inh} \times AE_{inh})/TRV' + (ADD_{ing} \times AE_{ing})/TRV' \\ &= (ADD_{inh} \times AE_{inh} + ADD_{ing} \times AE_{ing})/TRV' \end{aligned}$$

where

ADD_{inh} = the average daily dose by inhalation
ADD_{ing} = the average daily dose by ingestion
TRV_a = the inhalation TRV
TRV = the ingestion TRV
AE_{inh} = the inhalation absorption efficiency
AE_{ing} = the ingestion absorption efficiency

8.3.1.2. Ingestion TRVs

Ingestion TRVs for wildlife receptors are derived values based on published single-chemical laboratory toxicity tests (Sample et al. 1996). The outputs from these tests are subchronic or chronic NOAEL or LOAEL doses (mg/kg BW/day) for the test species. If the NOAEL or LOAEL is from a subchronic study, then the benchmark is adjusted downward by a factor of 10 to estimate the chronic benchmark. If the benchmark is a LOAEL for a mortality or reproduction endpoint, it is adjusted downward by a factor of 10 to estimate the NOAEL. To adjust a subchronic LOAEL for mortality or reproductive effect to a chronic NOAEL, divide by a factor of 100. As an alternative or addition to the above adjustments, an uncertainty factor can be applied to a NOAEL for a test species to adjust for extrapolating from a test species to a receptor species. The effect on HQs of adjusting benchmarks and alternative benchmarks will be discussed in the uncertainty section of the risk characterization.

If the desired TRV is that corresponding to the NOAEL, then the endpoint observed in the study should be mortality or reproduction. Non-lethal or non-reproductive NOAELs are conservative, that is, lower than necessary to protect the receptor, but will be used if a NOAEL for mortality or reproduction is not available. If the TRV is a LOAEL, then the endpoint observed in the study should be non-lethal or a non-reproductive effect. If the observed LOAEL endpoint is mortality or reproduction, then the non-conservative nature of the TRV should be considered in the risk characterization.

8.3.1.3. Inhalation TRVs

Appropriate inhalation toxicity data are those from chronic studies with ecologically significant endpoints. For example, mortality, impaired reproduction, organ dysfunction, and, in some cases, reduced growth are potentially ecologically significant endpoints, where as cancer is not. Portal effects on the respiratory tract (e.g., irritation) that do not lead to systemic effects (e.g., death) under chronic exposure are also not likely to be ecologically significant effects. The use of such data to derive TRVs is extremely conservative, which may be appropriate in certain situations, e.g., as a NOAEL in a screening ERA.

Chronic studies are usually more appropriate than acute data. In the absence of chronic data and assuming the endpoint is appropriate for the ERA, an acute benchmark is the conservative choice for the TRV, if it is less than the oral benchmark. In some cases, it may be appropriate to further reduce the acute benchmark by an acute-to-chronic uncertainty factor. No cases are known of any common contaminant causing ecologically significant effects from acute inhalation exposure at a dose lower than the dose causing significant effects from chronic oral exposure.

There are inhalation toxicity data from laboratory experiments reported in IRIS, RTECS and other databases. Air concentrations associated with varying levels of effect are reported for one or more laboratory animals, most if not all of which are mammals. These TRVs are reported as concentrations (mg/m^3) with a specified exposure duration and period. Assuming that the test duration and period is appropriately long for natural conditions, then test data can be used to derive inhalation TRVs for wildlife receptors of the same vertebrate class (mammal to mammal, bird to bird) given certain crucial assumptions. These assumptions are discussed below in Section 8.3.1.3.

When converting from published threshold-air concentrations to threshold doses, we assume that the values of the test species inhalation rate and body weight used to make the conversions are equal to those in the published study. A similar approach is used to interconvert threshold doses for ingestion and threshold dietary concentrations (Sample et al. 1996). See Appendix C2 for data.

8.3.1.4. Body-weight Scaling of TRVs

The starting point for deriving TRVs for receptors is thus the TRVs for one or more test species. TRVs for receptors should be derived from TRVs for test species from a similar taxonomic group. TRVs for birds should be derived from the TRV for a bird test species, and those for mammals from a mammal test species. The following equation is used to derive the TRV dose for wildlife receptors for COPCs in ingested matter (e.g., soil, sediment, water, biota) or inhaled air from published TRVs for test species:

$$TRV_{ij} = TRV_{tj} \times (BW_t/BW_i)^{0.25}$$

where

TRV_{ij} = Toxicity Reference Value of receptor *i* for COPC *j* (mg/kg BW/day)
TRV_{tj} = Toxicity Reference Value of test species *t* for COPC *j* (mg/kg BW/day)
BW_i = Body weight of receptor *i* (kg)
BW_t = Body weight of test species *t* (kg)

For ingestion TRVs, the body-weight ratio scaling exponent is 0.25 based on the weight of theoretical and empirical evidence (Travis et al. 1998, EPA 1992b) as presented in Sample et al (1996). Although there is some evidence that the body-weight ratio scaling exponent for acute toxicity in birds is 0 (Sample et al. 1996, Sample 1999), acute toxicity data (i.e., LC_{50}) may not be appropriate to predict body-weight scaling of chronic toxicity (Sample 1999). Acute toxicity likely operates by different mechanisms

than does chronic toxicity. Chronic toxicity depends on the balance of absorption and depuration, which probably scale to body weight. Therefore, an exponent of 0.25 will be used for both mammal and bird receptors for ingestion and inhalation TRVs.

Applying this body-weight scaling to inhalation TRVs for wildlife receptors involves two assumptions. First, it assumes that the ¾ power metabolic scaling law invoked by Sample et al. (1996) for toxicity of ingested contaminant applies equally well to inhaled contaminant. Second, it assumes that the absorption of contaminant per unit air inhaled is a constant fraction of body weight. This means that the amount of contaminant absorbed into the blood per unit body weight given a unit of inhaled contaminant is constant across animals of a given type.

The first assumption (inhalation toxicity scaling as ingestion toxicity) is reasonable because the Sample et al. (1996) approach is based on the observation that toxicity scales to the ¾ power of body weight (Chappell 1992, USEPA 1992, Travis and White 1988). Sample et al. (1996) attribute the scaling of toxicity to body weight to size-dependent variation in detoxification (depuration rates). The depuration rate for a blood-labile substance should be the same irrespective of the place of absorption, because depuration occurs primarily in the kidney, not at the site of absorption. Allometric scaling works best for substances processed by the kidney (Chappell 1992). Therefore, the scaling of toxicity with body weight should apply equally to ingested and inhaled substances.

The second assumption (constant specific lung-absorption efficiency) is reasonable for animals given the observed "constancy" with body weight of several related lung parameters: tidal volume, vital capacity, diffusion capacity, and especially, oxygen removal fraction (Schmidt-Nielsen 1989). The second assumption is analogous to the assumption of constant specific gut-absorption efficiencies (amount absorbed per unit ingested per unit body weight) that is required to extrapolate ingestion TRVs for test species to wildlife receptors (Sample et al. 1996), and which is also based on metabolic scaling arguments. In summary, we are assuming that inhalation toxicity scales to the ¾ power of body weight, for the same reason as does ingestion toxicity.

Finally, to apply the body-weight scaled inhalation thresholds derived from laboratory data for test species, one must assume that lab and the field conditions (e.g., temperature) are insignificantly different with respect to toxicity and metabolic function. This assumption is also made for toxicity via ingestion. Therefore, the application of the Sample et al. (1996) approach to deriving ingestion-based TRVs for wildlife receptors to the problem of deriving inhalation TRVs is defensible, and laboratory inhalation-toxicity data for test species can be used to derive inhalation TRVs for wildlife receptors.

If there is no published benchmark for a COPC, the lowest benchmark for a compound having like properties can be used as a surrogate. Also, when TEFs are available for a class of COPCs, such as dioxins and furans, then TEFs can be used to derive TRVs (see section 7.2.3 and following sections).

Published TRVs for chemical COPCs for plants, soil-dwelling invertebrates, and wildlife receptors (mammals and birds) are listed in Appendix C-3.

8.3.1.5. Toxicity Equivalence Factors for Dioxins, Dibenzofurans, and PCBs

Chlorinated dioxins, chlorinated dibenzofurans, and chlorinated biphenyls are thought to act through a common mechanism of toxicity by binding to a protein known as the arylhydrocarbon receptor (AR) (for review see ATSDR 1997 or WHO 1998). The AR-ligand complex is responsible for the activation of genes that have a deleterious effect when they are not under proper regulation by the receptor's hormones. Interaction of dioxins and similar compounds with AR therefore can cause immunological, neurological, endocrine, embryotoxic, and many other effects.

The similarity in action of these compounds is thought to result from their structural similarity. Dioxin is composed of two benzene rings joined by two carbon-oxygen-carbon bonds on two adjacent carbons of each benzene ring. Dibenzofurans have two benzene rings joined by a carbon-oxygen-carbon bond and a carbon-carbon bond on two adjacent carbons of each benzene ring. Biphenyls consist of two benzene rings joined by a single carbon-carbon bond. To form the polychlorinated derivatives, chloro groups are attached at various locations, as designated in the names of the compounds. Benzene rings are planar, i.e., flat, in conformation. Because two adjacent carbons on each benzene ring are joined in dioxins and dibenzofurans, both benzene rings are held in the same plane, and the chloro groups are also in that plane. Therefore, these molecules are said to be coplanar. The coplanar structure appears to be essential for interaction with AR. The benzene rings in biphenyl can rotate relative to each other, unless there are added groups that interfere with rotation (such as 2,2',6,6'-chloro groups, which occupy the carbons immediately on both sides of the carbon-carbon bond joining the rings). PCB congeners that are able to form a coplanar molecule (and are called coplanar PCBs) can interact with AR when they are in that configuration. Therefore, coplanar PCBs are included among the COPCs with similar action to dioxins and dibenzofurans.

EPA has recommended that toxicity equivalence factors (TEFs) be used to evaluate the cumulative toxicity of chlorinated dioxins, chlorinated dibenzofurans, and chlorinated biphenyls. Because these contaminants have a common mechanism of action, it is assumed that their toxicity to biota is additive (WHO 1998, EPA 1999b). That is, the toxicity of all dioxins, dibenzofurans, and PCBs should be added. Furthermore, their relative potency as chronic toxins is assumed to be related to the degree of affinity for AR, which can be measured much more conveniently than chronic toxic effects. TEFs have been proposed for several chlorinated dioxins, chlorinated dibenzofurans, and chlorinated biphenyls (WHO 1998, EPA 1999b), always using the toxicity of 3,4,7,8-tetrachlorodioxin (TCDD), the most potent chlorinated dioxin, as a TEF of 1.0. Separate lists were developed for mammals, birds, and fish, and these lists are presented in Table 8-5.

TEFs are reported in Table 8-5 for individual PCB congeners (e.g., 2,3,3',4,4',5-hexachlorobiphenyl), but analytical values for individual congeners in the exposure media are sometimes not available. It is also possible to calculate TEFs for Aroclors, which are mixtures of PCB congeners, using the typical composition of Aroclor mixtures (Hutzinger, Safe, and Zitko 1983).

Using TEFs, HQs can be calculated for chlorinated dioxins, chlorinated dibenzofurans, and PCBs for which TRVs are not available. The concentration of the COPC is multiplied by its TEF to calculate an equivalent concentration of TCDD. The TRV for TCDD is then used to calculate the HQ for the COPC. Because the mechanism of action of these compounds is thought to be the same, the TCDD-equivalent concentrations are added to determine the composite equivalent concentration of TCDD. This value is the same as the hazard index for the individual COPCs.

8.3.1.6. Radionuclide Benchmarks

The benchmark values for radiation given by IAEA (1992) are 1 mGy/d (0.1 rad/d) for terrestrial mammals and birds and 10 mGy/d (1 rad/d) for plants, invertebrates, and aquatic biota. These benchmarks are confirmed in *Effects of Ionizing Radiation on Terrestrial Plants and Animals: A Workshop Report* (Barnthouse 1995) and DOE Order 5400.5 (1990). Alpha radiation has a much higher effect on biological tissue than beta and gamma radiation because of the large mass of the alpha particle. When internal exposure is being evaluated, it is particularly important to consider the relative effectiveness of the radiation (P.M. Achey, U. of Fla, personal communication to C. Hadden, 9/20/99). *Rad* and *gray* are units of absorbed radiation (alpha, beta, and gamma) that do not adjust for the biological effectiveness of the radiation. *Rem* and *sievert* are units of absorbed radiation that include a quality factor

(QF rem/rad or sievert/gray) for the greater damage done by alpha particles than by beta and gamma radiation, and QF was included in the dose calculations used by IAEA (1992) to evaluate the benchmark. Inclusion of QF results in the calculation of effective dose in rem/day rather than absorbed dose in rad/day. Therefore, for this evaluation, radiological benchmarks for biota have been restated in units of rem/day rather than rad/day.

8.3.2. Toxicity Reference Values for Aquatic Receptors

TRVs for receptors dwelling in and thus exposed by direct contact to COPCs in sediment (sediment-dwelling biota) or surface water (fish, aquatic biota) are typically values from published sources if field observations or site-specific toxicity tests of these media are not available. The units of these values vary by source and medium, e.g., µg/L for surface water and mg/kg-dry wt. for sediment. TRVs for sediment-dwelling biota are derived values from published studies and reports, including field measured concentration and effect co-occurrence data and laboratory bioassays (Jones et al. 1997). TRVs for aquatic biota are values such as chronic National Ambient Water Quality Criteria (NAWQC) and Tier II values and lowest chronic values derived from published studies (Suter and Tsao 1996). TRVs for wildlife receptors exposed by ingesting biota exposed to surface water or sediments are derived as for terrestrial wildlife receptors (section 8.3.1).

Published TRVs for COPCs for sediment-dwelling invertebrates, aquatic biota, and wildlife receptors (mammals and birds) are listed in Appendix C-3.

For all sediment and aquatic biota, the TRV for total-body radiological dose from combined internal and external exposure for all ROPCs combined is 1.0 rem/day (IAEA 1992). However, the TRV for aquatic wildlife receptors (that is, birds and mammals) is 0.1 rem/day.

8.4. Risk Equations

Risk estimates for a receptor at an exposure location is calculated as the HQ, which is the ratio of the estimated exposure and the TRV. That is:

$$HQ = \text{Estimated Exposure/TRV}.$$

The HQ equation takes different forms depending on how the receptor is exposed, which also determines how the TRV is expressed (section 8.2.2). In the ecological risk assessment for the RPP-WTP, the exposure to ecological receptors is either a media concentration (C_{jk}), an average daily dose of a COPC (ADD_{ijk}), or a daily total-body radiological dose (R_{ik}).

The HQ is an index of the total risk to the receptor from exposure to the COPC if the COPC does not occur in the 'background' environment or if the home range of the receptor is smaller than the area of the exposure location, that is, if the AUF =1.

The HI is an index of the combined risk from exposure to multiple COPCs that have similar modes of action. A preliminary classification of inorganic COPCs groups arsenic, antimony, selenium, and vanadium as respiratory inhibitors; lead, manganese, and mercury as central nervous system inhibitors; and aluminum, chromium, and nickel as deoxyribonucleic acid (DNA) and protein reactors. Organic COPCs are typically grouped by chemical structure: VOCs, PAHs, organochloride pesticides, and PCBs. These chemical groupings are based on professional judgement and experience. For the PRA all HQs, regardless of mode of actions, will be grouped and summed because such summing represents the most conservative case. When the HI exceeds 0.25, additional HIs by mode of action will be developed. Thus,

the HI for a receptor at an exposure location is calculated from the HQs for the individual COPCs as follows:

$$HI_{ik} = \Sigma_j HQ_{ijk}$$

where

HI_{ik} = Hazard Index for receptor i at exposure location k (unitless)
HQ_{ijk} = Hazard Quotient for receptor i at exposure location k for COPC j (unitless).

Calculating HI assumes an additive effect on receptors from COPCs of all classes.

The HQ equation for receptors exposed to ROPCs is equivalent to an HI because the dose from all radionuclides is summed to estimate the total-body dose from internal and external exposures.

The threshold value for HQs and HIs for COPCs will be 0.25, unless a similar mode of action can be demonstrated and approved by Ecology. HIs for COPCs and ROPCs will not be added together.

8.5. Reporting of Major Ecological Risk Findings

Risk characterization will be reported in such a way as to capture all the various elements of the work. The following outline of headings is proposed:

- Current Risk at Exposure Location 1,2,3…n
  - Terrestrial Conditions: Central Plateau
    - Plausible Scenario
      - Chemicals
      - Radiologicals
    - Worst-case Scenario
      - Chemicals
      - Radiologicals
  - Aquatic Conditions: Columbia River
    - Plausible Scenario
      - Chemicals
      - Radiologicals
    - Worst-case Scenario
      - Chemicals
      - Radiologicals

- Future Risk at Exposure Locations 1,2,3…n
  - Terrestrial Conditions
    - Plausible Scenario
      - Chemicals
      - Radiologicals
    - Worst-case Scenario
      - Chemicals
      - Radiologicals
  - Aquatic Conditions
    - Plausible Scenario
      - Chemicals

Radiologicals
- Worst-case Scenario
  Chemicals
  Radiologicals

This will be done for the PRA as well as the FRA within the SLRA.

8.6. Uncertainties in Ecological Risk Assessment

Evaluation of uncertainties is part of the ERA process (EPA 1998e). Uncertainties in each of the four inter-related steps of the EPA approach to the screening the ERA will be discussed as follows:

- problem formulation
- exposure assessment
- effects assessment
- and risk characterization

Uncertainties about the data will be evaluated in the exposure assessment and the effects assessment steps.

8.6.1. Problem Formulation

Environmental concentrations of contaminants deposited on the soil and water at exposure locations will be based on many predictions. A degree of uncertainty exists about the predicted spatial distribution of contaminants. Exposure concentrations could be overestimated or underestimated, depending on how good the model is in predicting contaminant distribution.

Because the conservative exposure parameters (section 8.6.2) will be used to calculate HQs, the estimates of risk from ecological COPCs/ROPCs are conservative (that is, protective). Using conservative exposure concentrations decreases the likelihood of underestimating the risk posed by each ecological COPC/ROPC and increases the likelihood of overestimating the risk. Note that for wildlife receptors not living in soil, sediment, or surface water, HQ is a function of chemical dose (ADD) or radiological dose (R), which in turn, depends on a number of exposure factors (in addition to contaminant exposure concentration). Thus, several factors determine how conservative a HQ might be (in addition to contaminant exposure concentration).

The distribution and abundance of organisms comprising the ecological receptors at exposure locations have not been quantified by field studies. The lack of quantitative data introduces uncertainties concerning whether, and to what extent, the risk characterization based on the selected receptor species underestimates, or overestimates, the risk to organisms that are not used in the risk computations but are found at exposure locations. Additional reconnaissance on the Hanford Site at and near the exposure locations of maximum deposition will establish the nature and quality of habitat and confirm the presence of vegetation types and active, visible animal species. This is especially needed regarding bodies of water. Observations made during this reconnaissance will validate assumptions about the presence of unobserved organisms that are essential to normal ecosystem functioning, such as soil-dwelling worms and arthropods and herbivorous insects.

One (or more) unobserved species at exposure locations possibly is more sensitive than those ecological receptors for which toxicity data were available for use in setting TRVs. It does not necessarily follow that

these unevaluated species are at significantly greater risk of harmful ecological effects than that estimated in the SLRA. The reconnaissance will focus on places of predicted maximum ground concentrations.

8.6.2. Exposure Assessment

Movement of contaminants from the exposure locations through direct and indirect pathways to ecological receptors will not be measured for this SLRA. This introduces uncertainties about the actual modes and pathways of exposure and the actual exposure concentrations of these contaminants to the ecological receptors. Exposure concentrations can differ from the predicted environmental concentrations as a result of physical and chemical processes during transport from source to receptor and as a result of biomagnification through the food web. These processes will not be predicted quantitatively in this SLRA. Although bioaccumulation will be estimated for those receptors ingesting food for which toxicity thresholds were available, exposure of top predators possibly is underestimated because the biomagnification of certain contaminants in their prey was not considered.

The modes and pathways used to characterize the exposure of ecological receptors are the most important ones for the relatively large and active species in terrestrial habitats. Soil-dwelling terrestrial animals may be exposed to contaminants in soil by way of inhalation. However, it is expected that concentrations of VOCs will be very small and that gaseous concentrations in soil interstices, cavities, and burrows will not be available. Therefore, the exposure to burrowing organisms at the site from contaminated soil, and interstitial water in the soil, may be underestimated if gas concentrations are larger than soil concentrations. Overestimating exposure by using conservative exposure concentrations is thought to oppose the underestimation of exposure that results from neglecting certain exposure modes and pathways of lesser importance. Additional uncertainties are inherent in ingestion rates and dietary fractions of plants and animals. Likewise, uncertainties with dermal exposure will be considered. Exposure concentrations are likely overestimated because of conservative exposure factors. Sources of conservatism in the exposure factors include using published bioaccumulation factors, irrespective of species and environmental conditions.

8.6.3. Effects Assessment

Toxicity thresholds are based on concentrations reported to have no or little effect on the test organism or estimated conservatively from published toxicity data. TRVs for wildlife receptors exposed to soils derived from NOAELs or LOAELs reduced by safety factors of 10 for chronic LOAEFs and subchronic NOAELs or 100 for subchronic LOAELs (Sample et al. 1996). These thresholds would underestimate the risks only to organisms at the exposure locations that are considerably more sensitive than the receptor organisms for the specific toxicological endpoint. The thresholds are more likely to overestimate the risk to organisms that are equally or less sensitive than the receptor organisms. The possibility remains that some thresholds are set at levels at or above which some harm would occur to organisms at the exposure locations because receptors may be more sensitive to other toxicological endpoints.

There are limited data for developing inhalation TRVs and very few for developing dermal TRVs. Little is known about the actual absorption across the dermal layer of wildlife receptors. There is also uncertainty about the extrapolation of TRVs for ingestion to inhalation. Ingestion TRVs will not be extrapolated to dermal contact. The uncertainties associated with neglecting dermal contact and estimating inhalation toxicity will be discussed.

The calculated risks to the ecological receptors at the exposure locations are the risks of individual contaminants. The risks from exposure to multiple contaminants depend on contaminant interactions; effects could be greater or less than those from a single chemical. This screening ERA provides findings for ecological COPC-specific risk estimates and assumes additivity when calculating HIs. An evaluation of risk

from chemical mixtures cannot be conducted without additional data and evaluation of alternative models of contaminant interactions.

TRVs are not available for some COPCs/ROPCs. This lack of TRVs is especially true for organic COPCs Compounds. This situation likely results in underestimated risks.

Additional uncertainty exists as to the pertinence of individual organism toxicity for characterizing the risk to individuals, populations, and ecosystems. Populations possibly may compensate for the loss of large numbers of juveniles or adults with increased survival or birth rates, and habitats or ecosystems may possess functionally redundant species that are less sensitive to contaminants. Although the desert habitat at the exposure locations likely possesses some buffering mechanisms, a conservative approach is still justified to risk assessment based on organismal toxicity thresholds (i.e., NOAELs).

8.6.4. Risk Characterization

The uncertainties described above ultimately produce uncertainty in the quantification of current and future risks to plants and animals at the exposure locations. Three additional areas of uncertainty in the risk characterization exist: off-site risk, background risk, and cumulative risk. Each is briefly described below.

8.6.4.1. Risk Outside the Modeled Study Area

It is unlikely that the receptors outside the 50 km study area would have lower toxicity thresholds for contaminants than the thresholds used for receptors within the study area. In addition, there is little reason to expect that contaminants migrating outside the study area would be concentrated above predicted concentrations at the exposure locations unless a contaminant bioconcentrates in organisms that move extensively on and off the study area. In general, the risk to receptors outside the study area is likely to be overestimated rather than underestimated by the risk estimate for receptors within the 50 km radius of the site. (Spromberg et al. 1998).

8.6.4.2. Background Risk

Another source of uncertainty is ecological risk relative to background or predepositional conditions. Only incremental risk due to facility emissions will be evaluated because the concentration terms are modeled concentrations resulting from RPP-WTP operations. The HI< 0.25 threshold specified by EPA (1994a, 1994b, and 1994c), as cited in ATG (1998), are designed to "buffer" the potential for background contributions to risk (EPA 1998a). The amount of loading of various chemicals will be discussed. Background concentrations for the Hanford Site and the incremental loading rates will help to determine the portion of total risk coming just from stack emissions.

8.6.4.3. Cumulative Risk

The SLRA will estimate the risk to populations of ecological receptors from individual contaminants. In nature, receptors are exposed simultaneously to mixtures of chemicals. Generally, the methods used are sufficiently conservative, resulting in individual risks that are overestimated.

A second type of cumulative risk is possible when several living plants and animals are affected simultaneously. Harmful effects in ecosystems (including effects on individual organisms) may cascade throughout the system and have indirect effects on the ability of a population to persist in the area even though individual organisms are not sensitive to the given contaminants in isolation.

In addition, cumulative risk more broadly includes risk from multiple sources at the Hanford Site. Therefore, the ecological risk characterization for exposure locations may underestimate actual risks to plants and animals from cumulative risks.

8.6.5. Summary of Uncertainties

The most important uncertainties in the ecological portion of the SLRA for exposure locations are those surrounding the estimates of the contaminant concentrations to which ecological receptors are actually exposed (exposure point concentrations) and the concentrations that present an acceptable level of risk or harmful effects (toxicity thresholds or reference values). These uncertainties arise from multiple sources, especially from the lack of site-specific data on contaminant transport and transformation processes, organismal toxicity, animal behavior and diet, population dynamics, and the response of arid land plant and animal populations to stressors in the Hanford Site environments. Despite these uncertainties, the modeled exposure concentrations and published exposure and effects information will allow risks to be characterized for various exposure locations according to exposure/effects scenarios.

8.7. Summary for Screening Ecological Risk Assessment

Risks to ecological receptors from the potential emission of COPCs and ROPCs result from exposure to and ecological toxicity of the COPC/ROPC. The screening ecological risk assessment utilizes the estimated emission rates (section 5) and results of fate and transport modeling (section 6) to calculate potential ecological receptor exposure to COPCs and ROPCs. This exposure information is combined with toxicity data to estimate the potential for adverse effects to terrestrial and aquatic organisms and populations in the vicinity of the RPP-WTP.

The PRA will use conservative exposure assumptions to compensate for the high level of uncertainty associated with conducting a risk assessment for a facility that is still in the final design phases. The PRA will include a qualitative uncertainty analysis. Monte Carlo analysis or other quantitative methods may be used to identify and evaluate the primary sources of uncertainty in the FRA that may drive risk estimates. The exact procedures that may be used will be determined at a later time.

The FRA will focus on ecological COPCs that exceed risk goals in the PRA and may utilize additional site-specific emissions, fate and transport, and exposure data collected after the completion of the PRA.

Figure 8-1. Ecological Conceptual Exposure Model

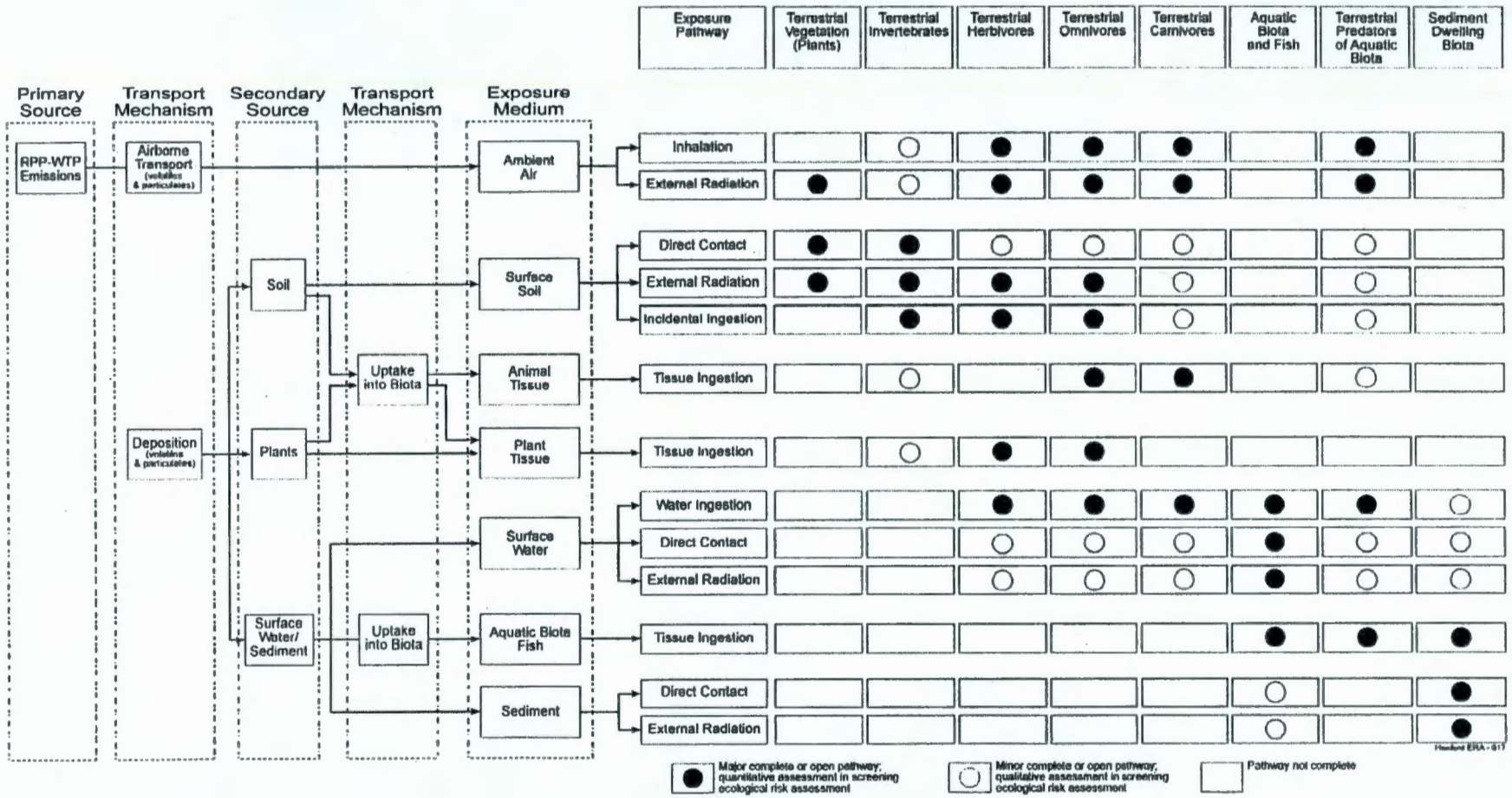


Figure 8-2. Recreation and Wildlife Areas and the Hanford Reach

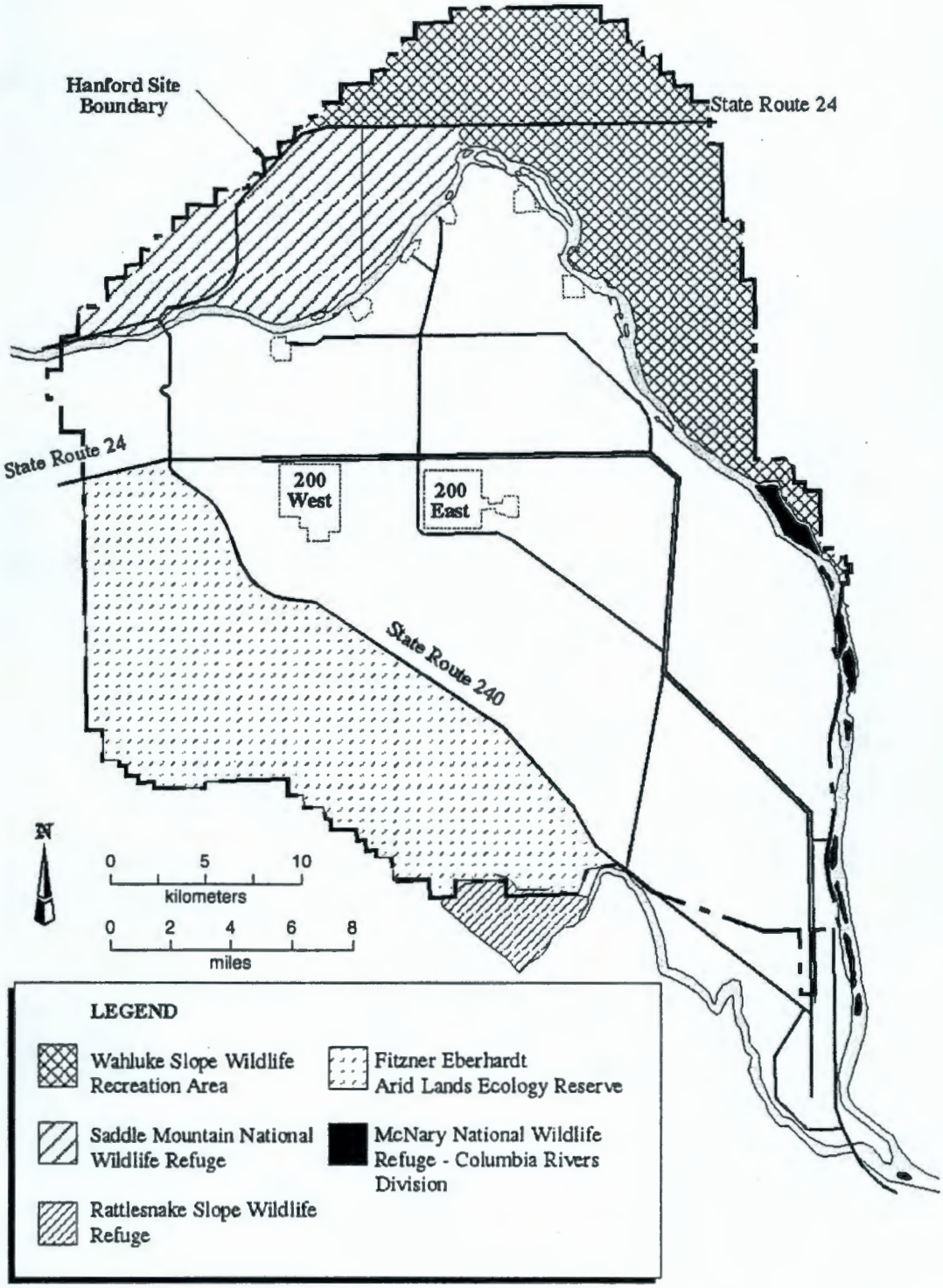


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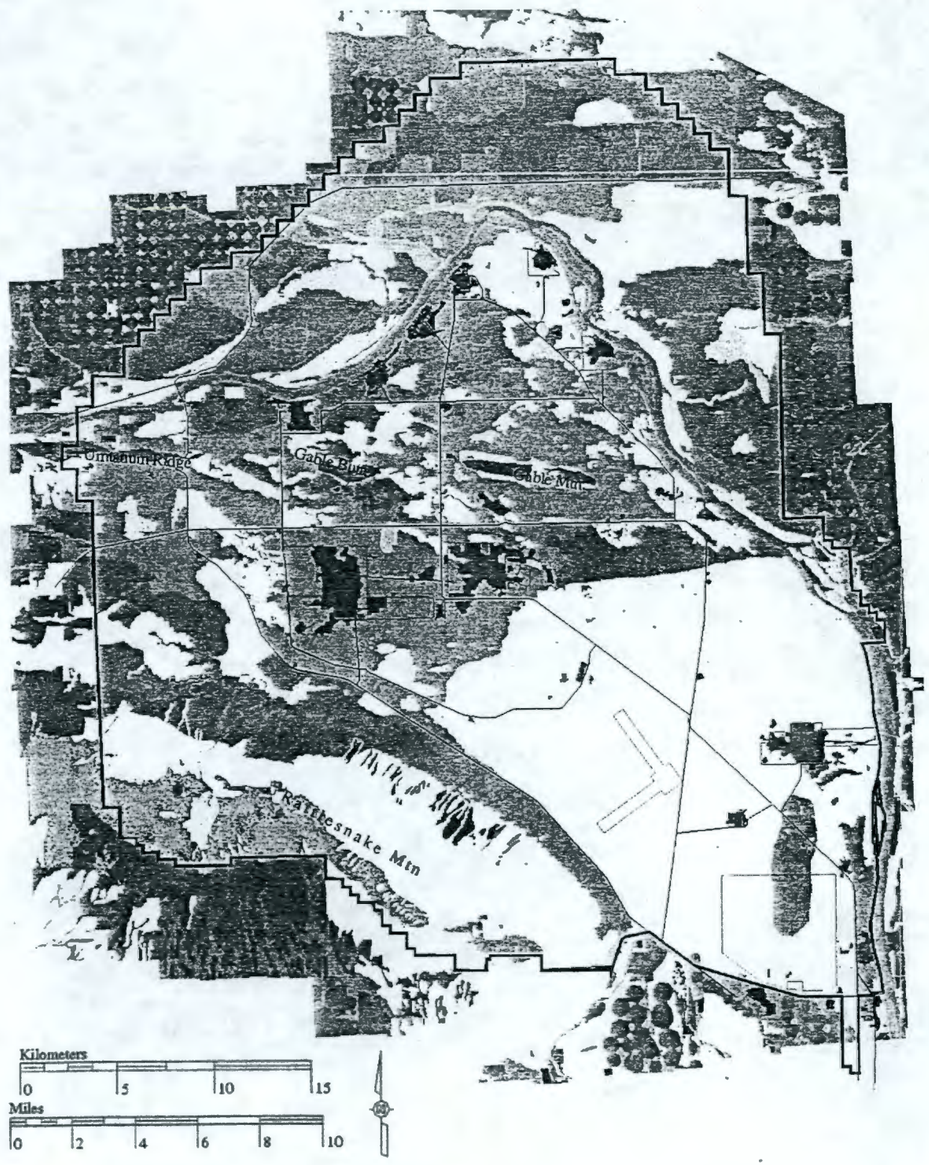
Figure 8-3. Vegetation Types of the Hanford Site

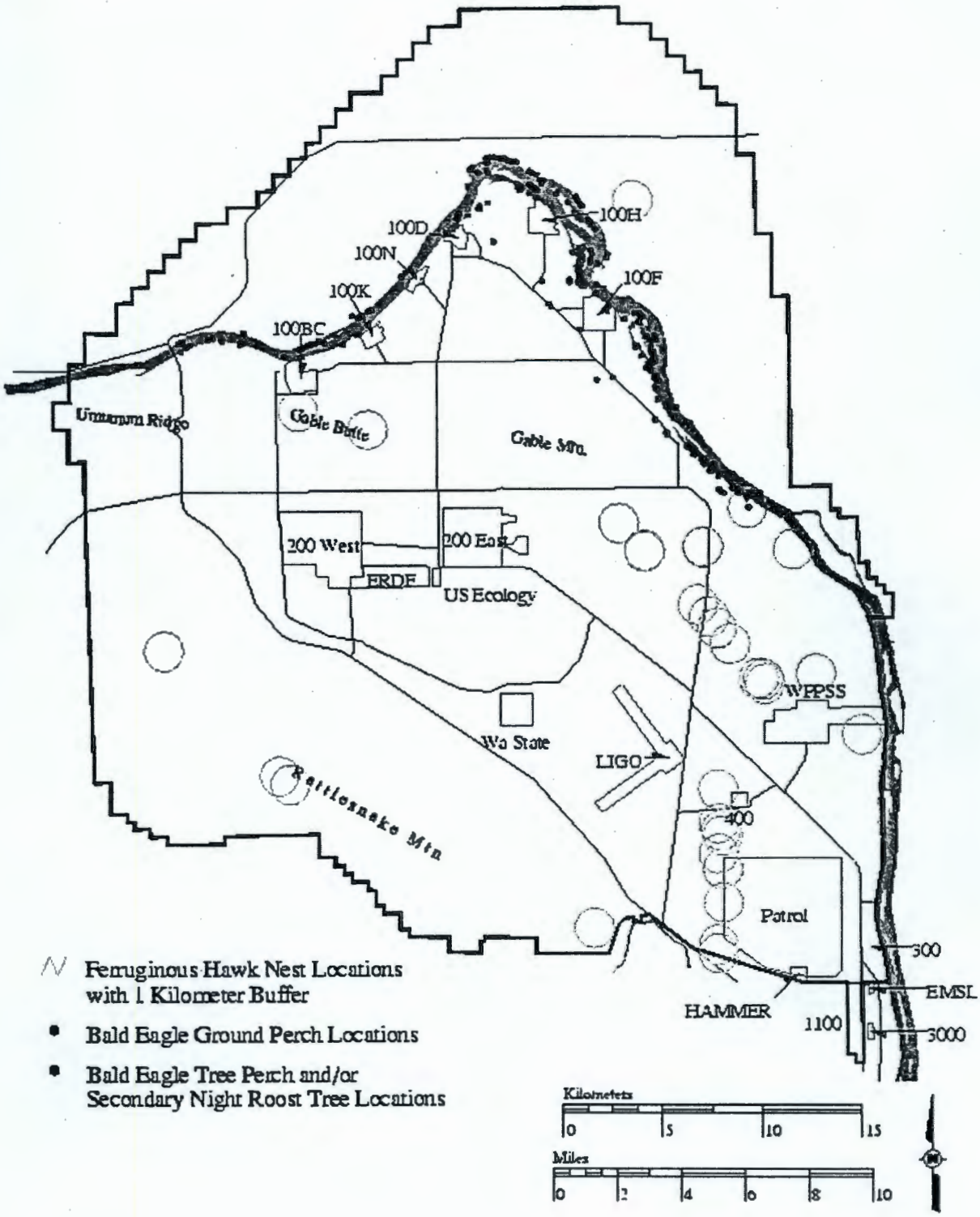


BHI:rpp 04-22/96 clup/brmap d02.aml Database: 07-DEC-1998

- Post-Fire Shrub-Steppe on the Columbia River Plain
- Rabbitbrush / Bunchgrasses
- Rabbitbrush / Cheatgrass
- Big Sagebrush / Bunchgrasses –Cheatgrass
- Big Sagebrush –Spiny Hopsage / Bunchgrasses –Cheatgrass
- Threetip Sagebrush / Bunchgrasses
- Spiny Hopsage / Bunchgrasses
- Spiny Hopsage / Cheatgrass
- Black Greasewood / Sandberg's Bluegrass
- Winterfat / Bunchgrasses
- Winterfat / Cheatgrass
- Snow Buckwheat / Indian Ricegrass
- Bunchgrasses
- Cheatgrass –Sandberg's Bluegrass
- Planted Non-native Grass
- Bitterbrush / Bunchgrasses Sand Dune Complex
- Bitterbrush / Cheatgrass
- Alkali Saltgrass –Cheatgrass
- Riparian
- Basalt Outcrops
- Agricultural Areas
- White Bluffs Cliffs
- Buildings / Parking Lots / Gravel Pits / Disturbed Areas
- Abandoned Old Fields and Farms
- Riverine Wetlands and Associated Deepwater Habitats
- Non-Riverine Wetlands and Associated Deepwater Habitats

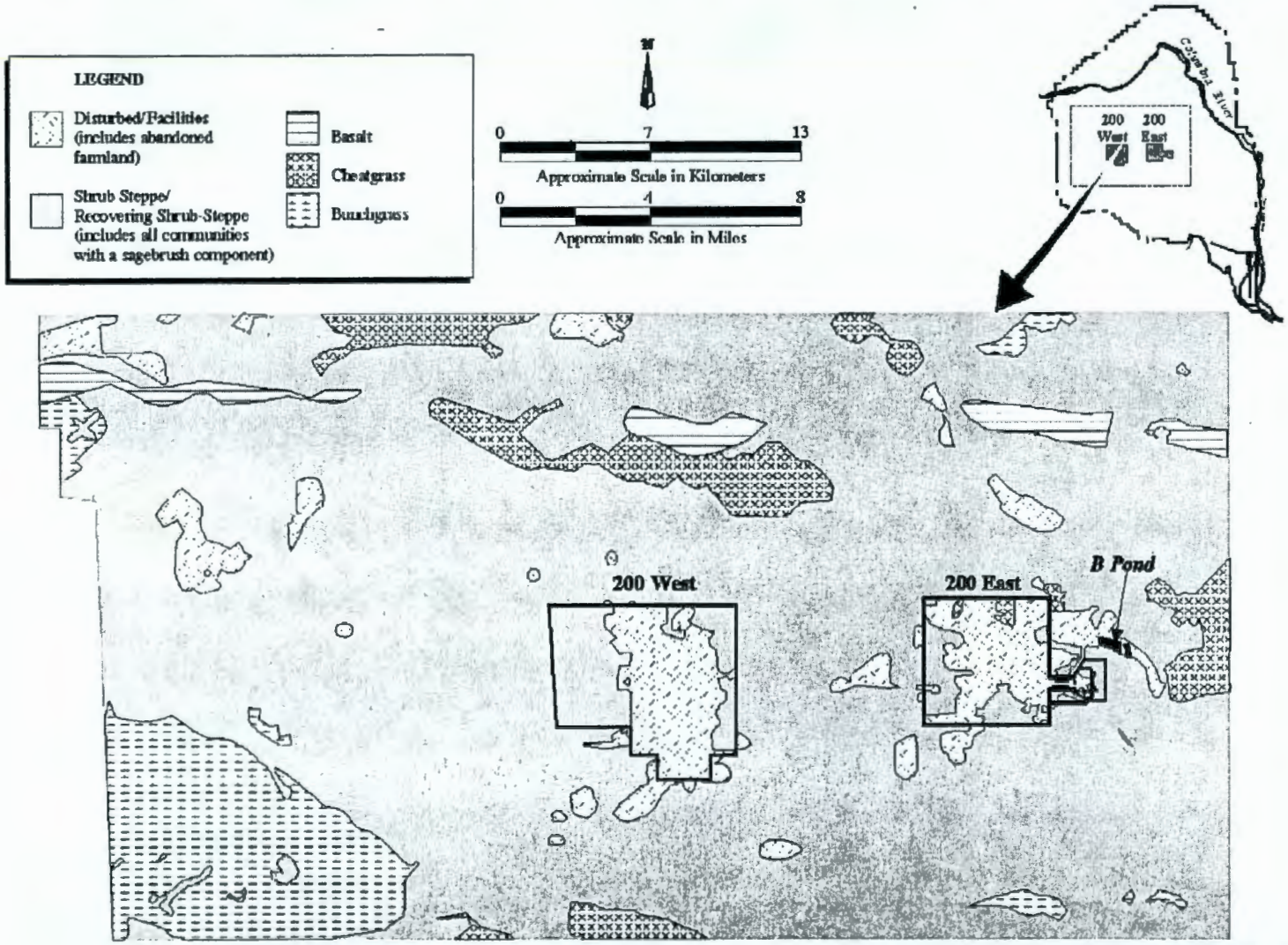
Hanford ERA - 017

Figure 8-4. Selected Raptor Nesting and Perching Locations on the Hanford Site



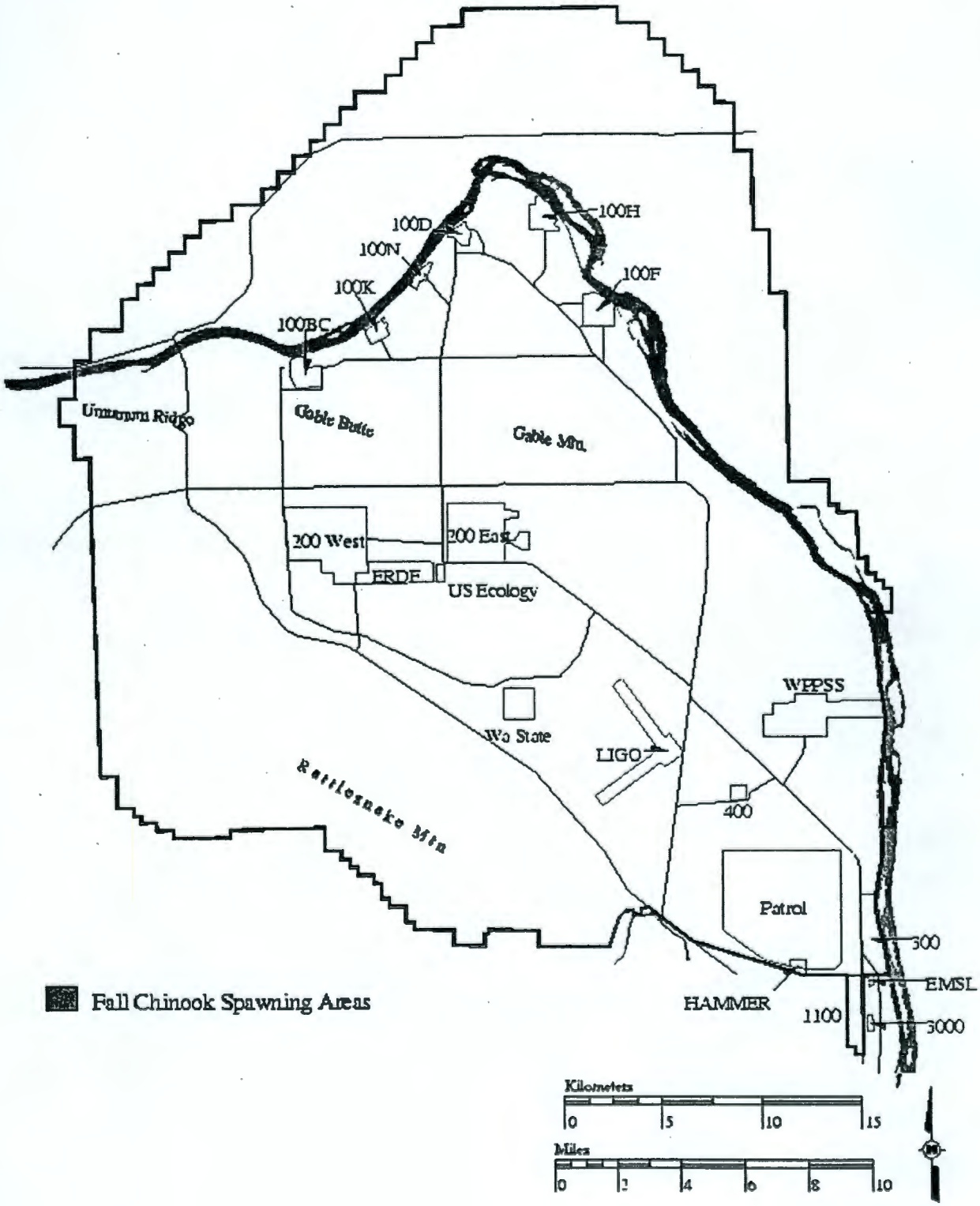
Hanford ERA - 018

Figure 8-5. RPP-WTP Areas Vegetation Types (Simplified)



Hanford ERA - 019

Figure 8-6. Fall Chinook Salmon Spawning Areas Along the Columbia River



Hanford ERA - 020

Figure 8-7. Trophic Levels and Receptor Species Considered in Development of the 200 Area and Vicinity Terrestrial Conceptual Exposure Model

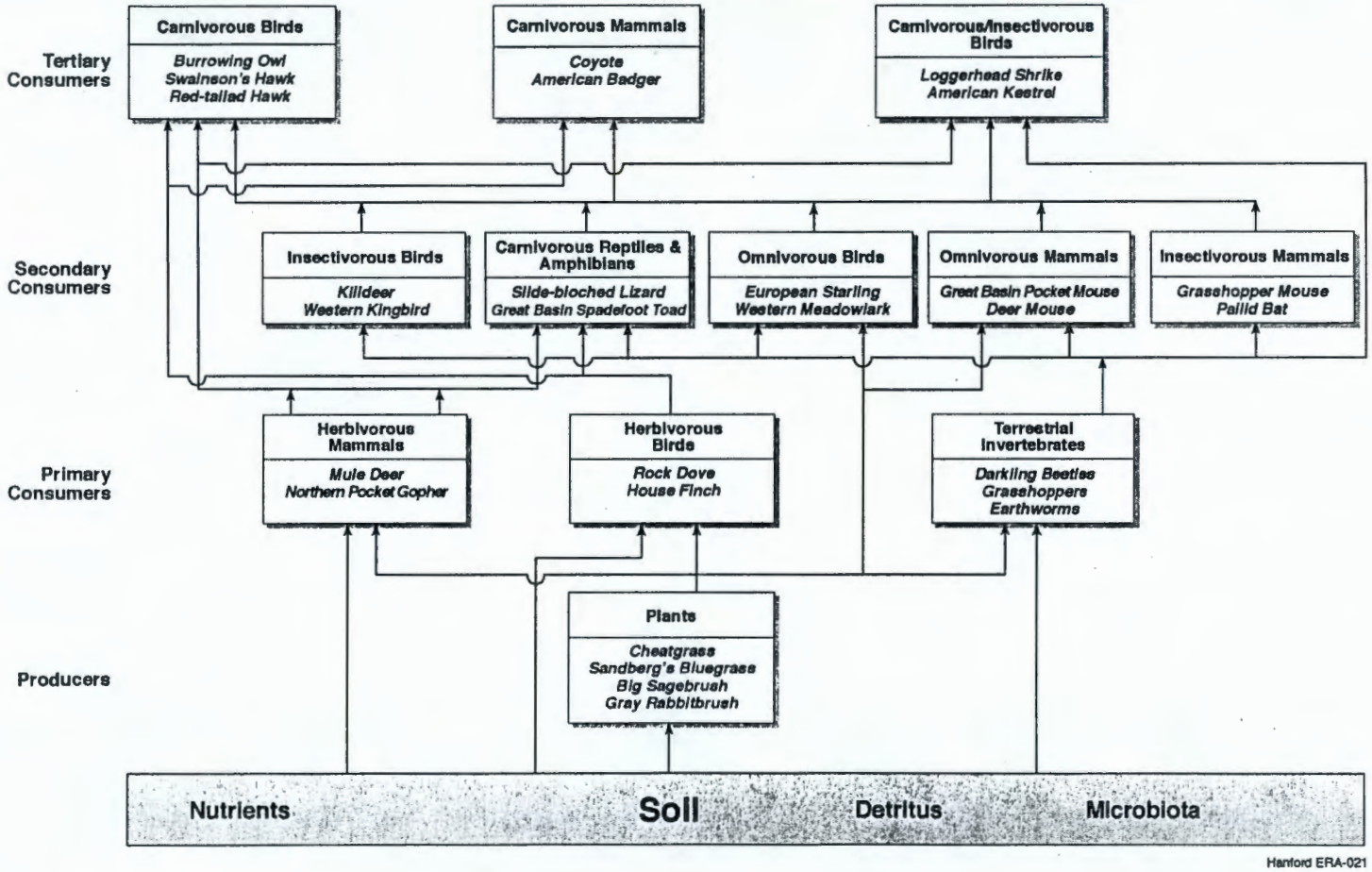


Figure 8-8. Trophic Levels and Receptor Species at the Columbia River Considered in Development of the 200 Area and Vicinity Aquatic Conceptual Exposure Model

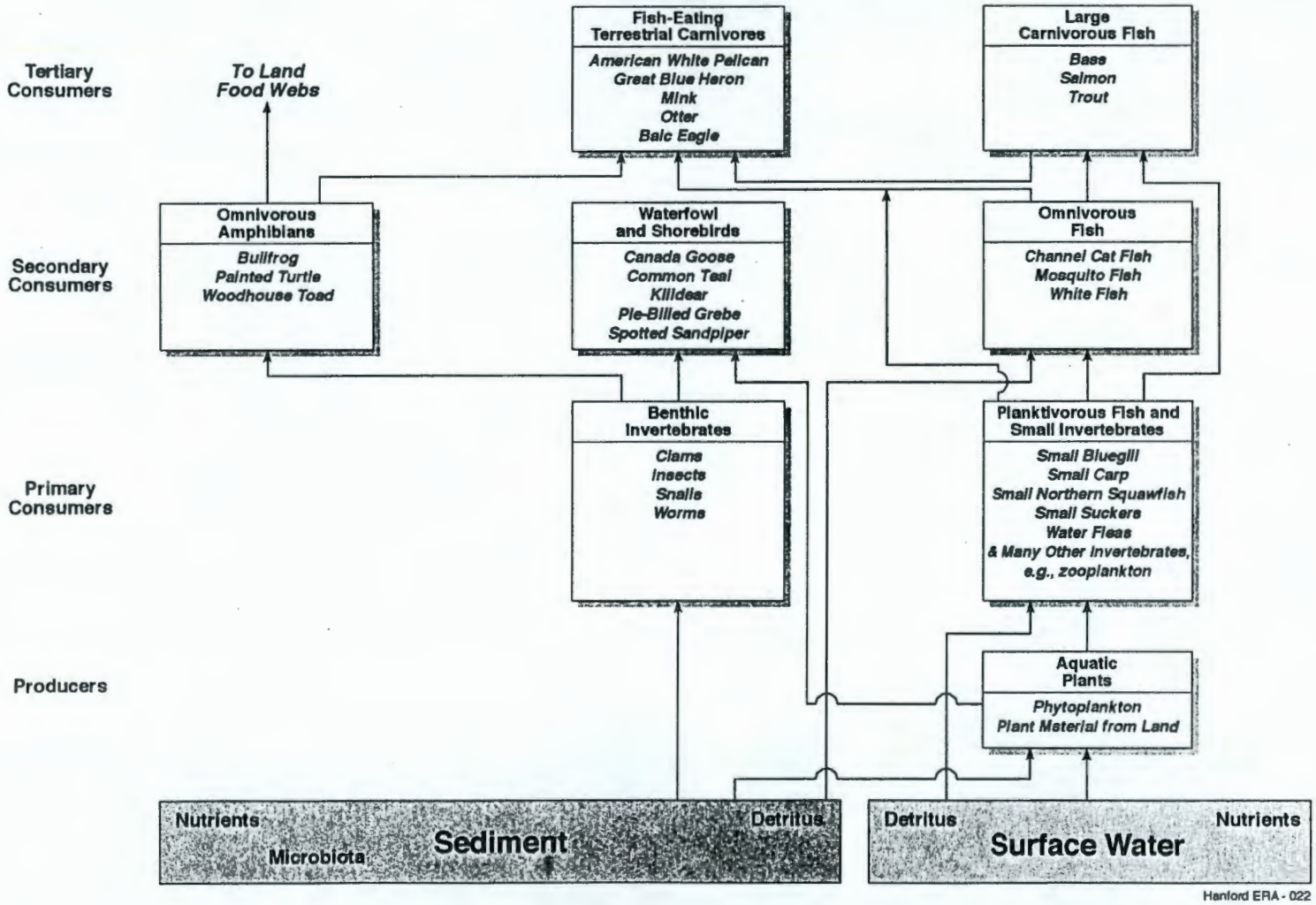
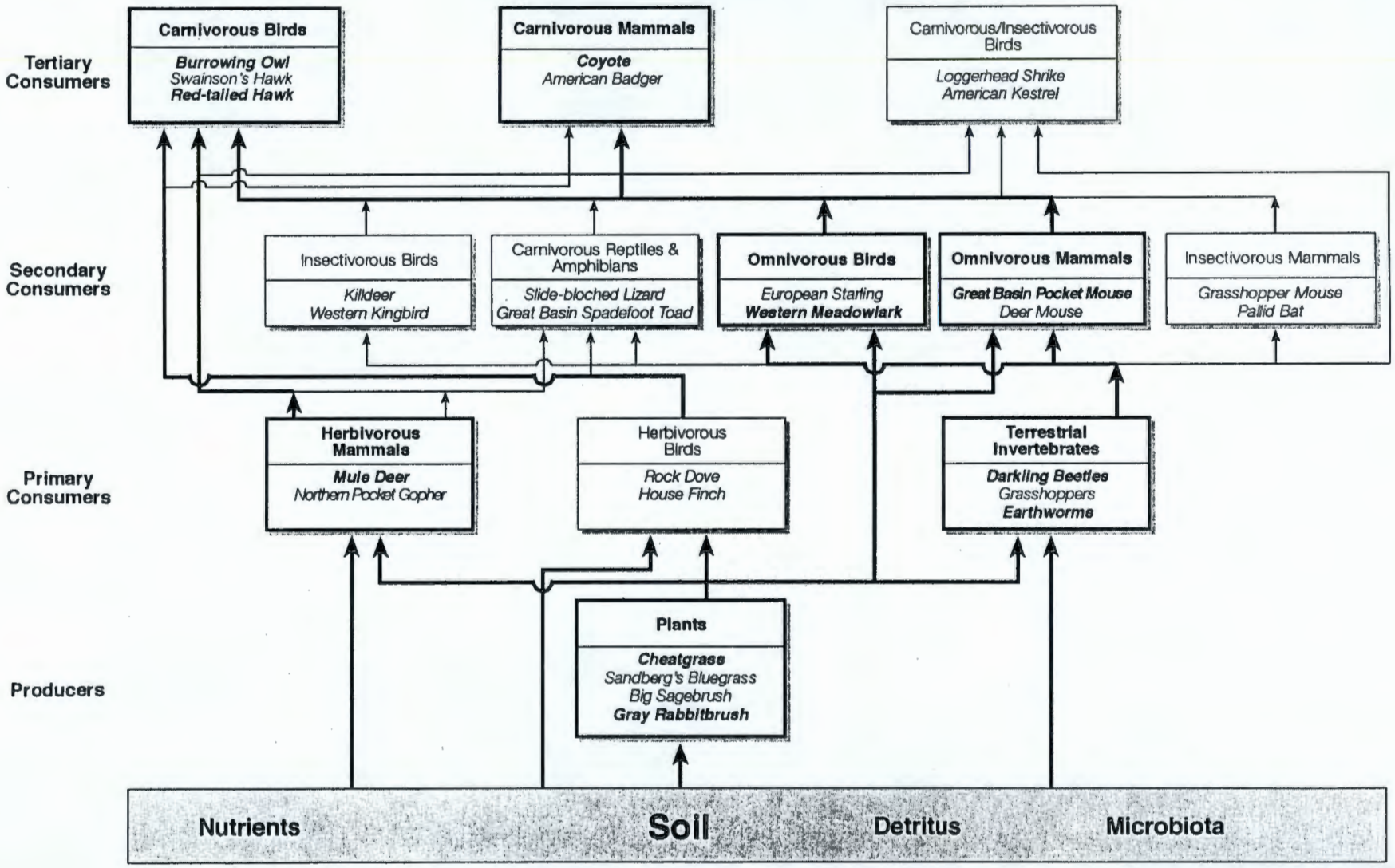


Figure 8-9. Trophic Levels and Selected Receptor Species (names in bold) from the 200 Area and Vicinity Terrestrial Conceptual Exposure Model



Hanford ERA-023

Figure 8-10. Trophic Levels and Selected Receptor Species (names in bold) at the Columbia River Considered in Development of the 200 Area and Vicinity Aquatic Conceptual Exposure Model

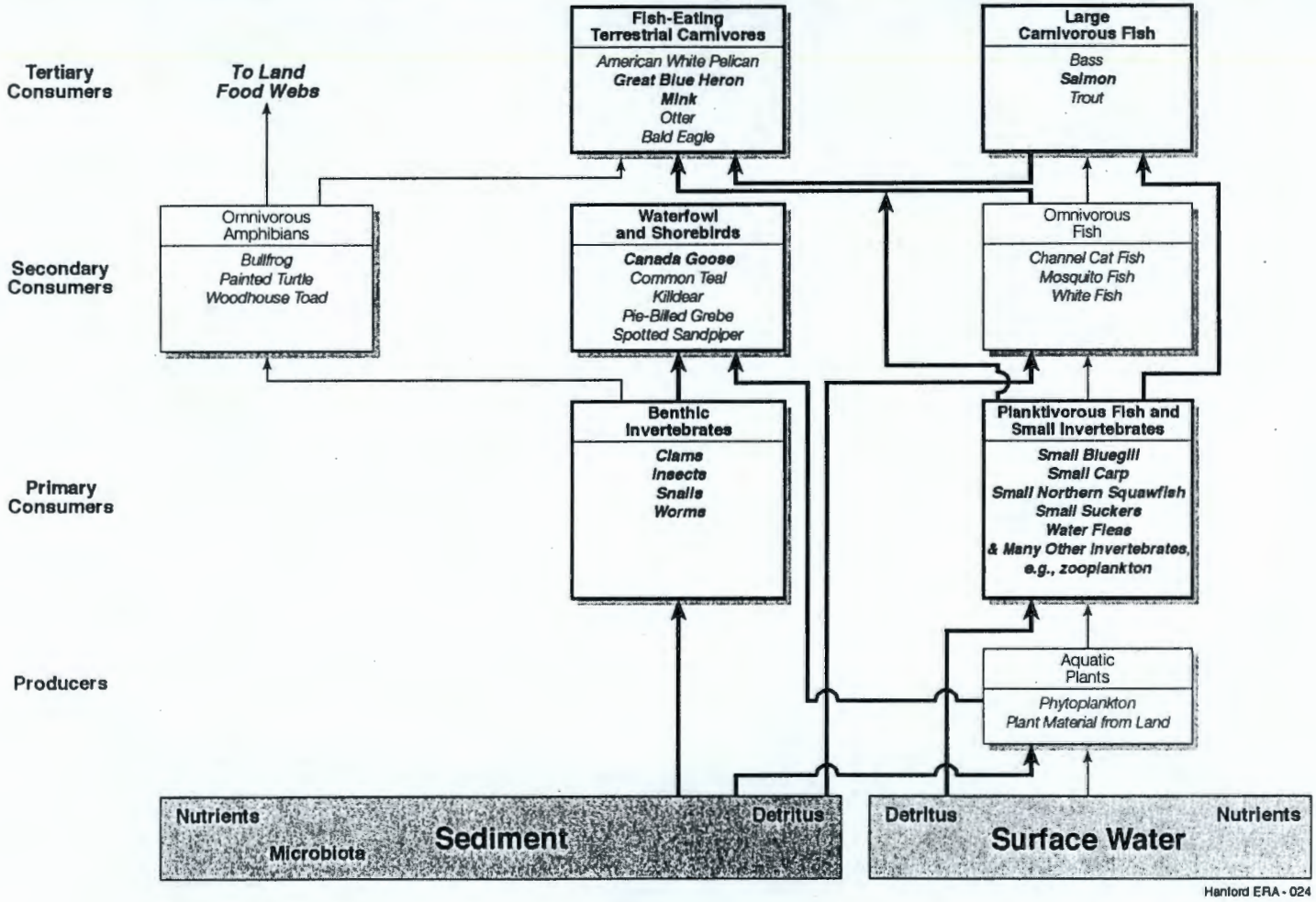


Figure 8-11. Relationship Between Sources and Biotransfer Factors for Calculating Terrestrial and Aquatic Exposures

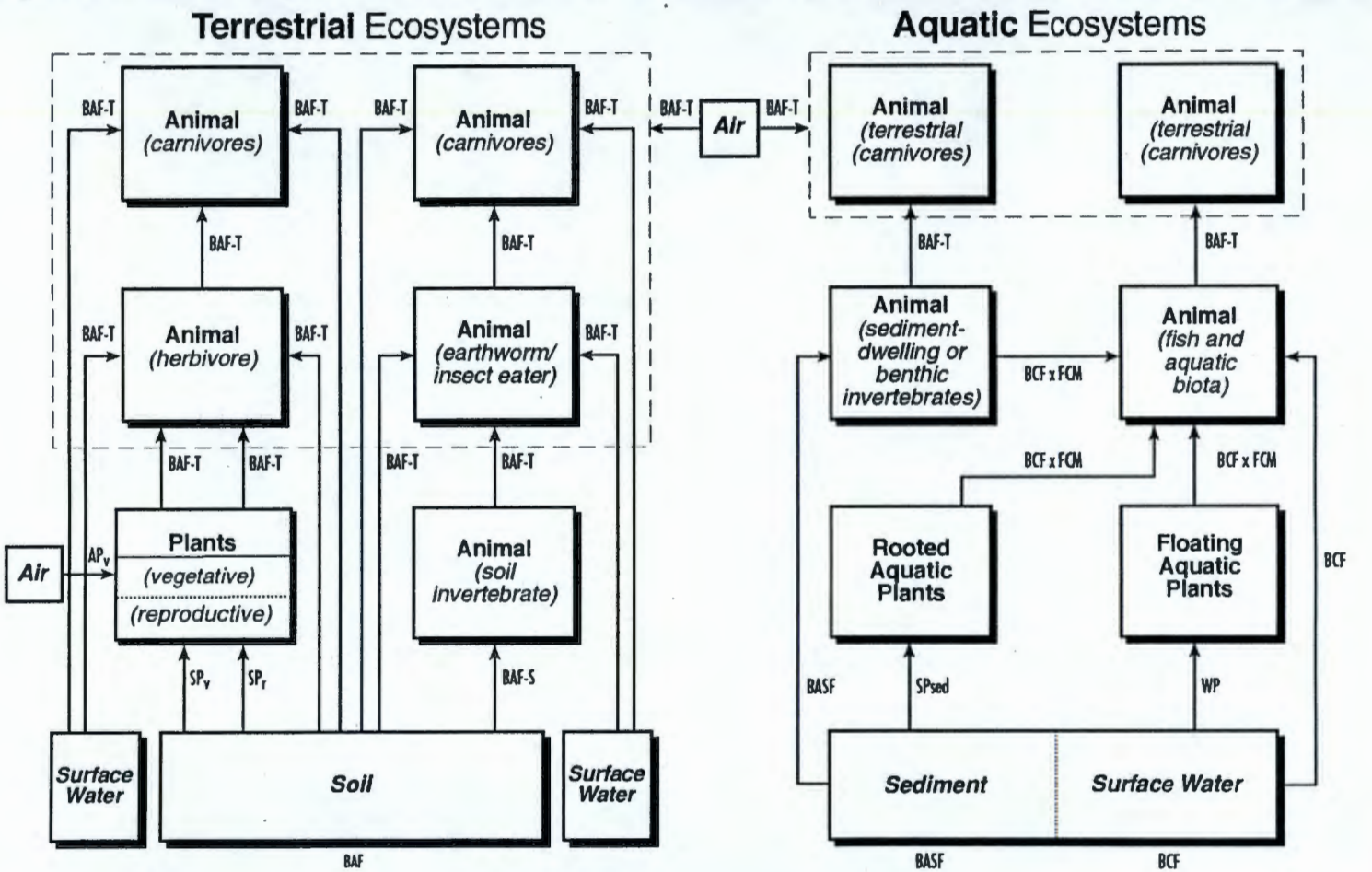


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Table 8-1. Policy Goals, Ecological Assessment Endpoints, Measures, and Decision Rules for 200 Areas and Surroundings

Policy Goals	Assessment Endpoint	Measures	Decision Rule
Policy Goal 1: The conservation of T&E species and their critical habitats.	**Assessment Endpoint 1:** Protection of individuals of state or federally designated threatened or endangered species. Endpoint Species: bald eagle and other species.	**Measure 1:** Modeled contaminant concentrations in prey (e.g., deer mouse, Western meadowlark, Great Basin pocket mouse, and house finch) based on modeled concentrations of vapors in air and particulates, depositions of contaminant particulates to soil, and measured concentrations of contaminants in abiotic media.	**Decision Rule for Assessment Endpoint 1:** If T&E species are not present, or RME concentrations in the media do not contribute to chronic NOAEL, possibly adjusted by a safety factor, exceedance (i.e., HQs <0.25), then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, the T&E species should be preserved. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
Policy Goal 2: The protection of terrestrial populations and ecosystems.	**Assessment Endpoint 2:** Stable plant community for erosion control and energy production. Endpoint Species: cheatgrass, rabbitbrush.	**Measure 2:** Modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil.	**Decision Rule for Assessment Endpoint 2:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, maintain the plant populations and communities. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 3: Stable soil-dwelling invertebrate community for nutrient and energy processing. Endpoint Species: earthworms and darkling beetles.	**Measure 3:** Modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil.	**Decision Rule for Assessment Endpoint 3:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, maintain the soil invertebrate community. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.

Table 8-1. Policy Goals, Ecological Assessment Endpoints, Measures, and Decision Rules for 200 Areas and Surroundings

Policy Goals	Assessment Endpoint	Measures	Decision Rule
	Assessment Endpoint 4: Stable populations of herbivorous animals. Endpoint Species: mammals - mule deer.	**Measure 4:** Modeled contaminant concentrations in food chain, e.g., plants, based on modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil.	**Decision Rule for Assessment Endpoint 4:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of the herbivores, e.g., Great basin pocket mice, mule deer, and house finch, are maintained. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 5: Stable populations of plant-eating and/or insectivorous animals (omnivores). Endpoint Species: bird-Western meadowlark.	**Measure 5:** Modeled contaminant concentrations in earthworms, plants, and other prey based on modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil.	**Decision Rule for Assessment Endpoint 5:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of omnivores, e.g., Western meadowlark, are maintained. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 6: Stable populations of terrestrial predators. Endpoint Species: mammal-coyote; bird-burrowing owl and red-tailed hawk.	**Measure 6:** Modeled contaminant concentrations in prey (e.g., Western meadowlark and Great Basin pocket mice) based on modeled concentrations of vapors in air and particulates and depositions of contaminant particulates to soil.	**Decision Rule for Assessment Endpoint 6:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of terrestrial predators are maintained. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.

Table 8-1. Policy Goals, Ecological Assessment Endpoints, Measures, and Decision Rules for 200 Areas and Surroundings

Policy Goals	Assessment Endpoint	Measures	Decision Rule
Policy Goal 3: The protection of aquatic populations and ecosystems.	**Assessment Endpoint 7:** Stable populations of sediment-dwelling organisms. Endpoint Species: Clams, insects, snails, and worms.	**Measure 7:** Modeled sediment contaminant concentrations from dispersion and deposition.	**Decision Rule for Assessment Endpoint 7:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of sediment-dwelling organisms are maintained. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 8: Stable planktivorous fish and small invertebrate populations. Endpoint Species: water fleas and other invertebrates.	**Measure 8:** Modeled surface water contaminant concentrations.	**Decision Rule for Assessment Endpoint 8:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of small invertebrates are maintained. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 9: Stable waterfowl and shorebird populations. Endpoint Species: Canada goose, spotted sandpiper	**Measure 9:** Modeled contaminant concentrations in benthic invertebrates or aquatic plants based on modeled contaminant concentrations in surface water or sediments from dispersion and deposition.	**Decision Rule for Assessment Endpoint 9:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of waterfowl and shorebirds are maintained. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.

Table 8-1. Policy Goals, Ecological Assessment Endpoints, Measures, and Decision Rules for 200 Areas and Surroundings

Policy Goals	Assessment Endpoint	Measures	Decision Rule
	Assessment Endpoint 10: Stable populations of large carnivorous fish population for regulation. Endpoint Species: salmon, bass, channel catfish	**Measure 10:** Modeled surface water and sediment contaminant concentrations.	**Decision Rule for Assessment Endpoint 10:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of large carnivorous fish are maintained. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.
	Assessment Endpoint 11: Stable fish-eating terrestrial predator populations for population regulation. Endpoint Species: great blue heron, bald eagle, mink	**Measure 11:** Modeled contaminant concentrations in large carnivorous fish and planktivorous fish and small invertebrates based on modeled surface water and sediment concentrations.	**Decision Rule for Assessment Endpoint 11:** If the HQ is <0.25, then it is indicated that the contaminant alone is unlikely to cause adverse ecological effects and, therefore, populations of fish-eating terrestrial predators are maintained. If the HQ >0.25, lines of evidence will be evaluated to determine the potential for ecological risk and the need for any additional measurements or calculations.

RME = Reasonable maximum exposure
T&E = Threatened and endangered
NOAEL = No observed adverse effects level
HQ = Hazard (risk) quotient

1

Table 8-2. Soil Ingestion Rates For Hanford Receptors

Receptors	Soil Ingestion (kg/kgBW/d)	Source
Reported (Direct and Indirect)		
Canada goose	0.00254	Reported Soil fraction, 8.2% (EPA 1993, Table 4-4) *x* reported Food Ingestion Rate 0.031 (g/g-d) average adult both sexes (EPA 1993, Pg. 2-25)
Mule deer	0.00044	Reported Soil Fraction for Mule deer, 2.0% (Beyer et al.1994) *x* reported Food Ingestion Rate, 0.022 kg/kgBW/d (Alldredge et al. 1974 in Higley and Kuperman 1996)
Surrogate (Direct and Indirect)		
Great Basin pocket mouse	0.0057	Reported Soil Fraction for white-footed mouse, 2.0% (EPA 1993, Table 4-4) *x* reported Food Ingestion Rate for the Great Basin pocket mouse, 0.285 kg/kgbw/d (Calder 1984 in DOE-RL 1995)
Spotted sandpiper	0.056	Calculated from EPA (1993) using equations 3-39, 3-40, 4-11, and 4-12; Soil fraction for Stilt sandpiper 0.17 (Table 4-4), Diet of 100% Crustacea; Crustacea gross energy = 1.1 kcal/g wet wt. (Table 4-1); Waterfowl assimilation efficiency = 77% (Table 4-3); Body weight = 42.5g (average adult both sexes)
Calculated (Indirect only)		
Bald eagle	0.0000003	Calculated from soil-to-body weight ratio of prey
Red-tailed hawk	0.0004	Calculated from soil-to-body weight ratio of prey
Burrowing owl	0.0133	Calculated from soil-to-body weight ratio of prey
Western meadowlark	0.0082	Calculated from soil-to-body weight ratio of prey
Great blue heron	0.000005	Calculated from soil-to-body weight ratio of prey
Mink	0.000044	Calculated from soil-to-body weight ratio of prey
Coyote	0.00011	Calculated from soil-to-body weight ratio of prey

2

Table 8-3. Derivation of Soil-to-Body Weight Ratios for Prey of Hanford Receptors

Prey Species	SF	IR_f (kg/kgBW/d)	Rt (d)	SBR (kg/kgBW) =SFxIR_fxRt
Pronghorns[a]	0.057	0.015	1	0.0009
Meadow vole	0.024	0.81	1	0.0194
Black-tailed Jackrabbit[b]	0.063	0.047	1	0.003
Great Basin Pocket Mouse[c]	0.02	0.285	1	0.0057
Bullfrog	ND	0.0002	1	0[d]
Mallard	0.02	0.00025	1	0.000005

SF = Soil Ingestion Fraction (kg soil ingested/kg food ingested); all values for EPA (1993b) unless noted
IR_f =Food Ingestion Rate = ratio of amount of food ingested daily (kg/d) to body weight (kg/Bw)
Rt =Residence times (days); value assumed to be 1 day
SBR = Soil-to-body weight ratio
ND = No data

[a]Soil ingestion fraction and food ingestion rates from Arthur and Gates (1988)
[b]Food ingestion rate from Arthur and Gates (1988)
[c] Values for the white-footed mouse (Calder 1984 in EOE-RL 1995)
[d]Assumed to be zero

1

Table 8-4. Derivation of Indirect Soil Ingestion Rate for Hanford Receptors

Receptor	Receptor IR_f (kg/kgBW/d)	Prey: Earthworm DF	Earthworm SBR[a]	Pronghorn[b] DF	Pronghorn SBR	Meadow vole DF	Meadow vole SBR	Black-tailed[c] jackrabbit DF	Black-tailed[c] jackrabbit SBR	Great Basin[d] pocket mouse DF	Great Basin[d] pocket mouse SBR	Bullfrog[e] DF	Bullfrog[e] SBR	Mallard[f] DF	Mallard[f] SBR	Receptor IS (kg/kgBW/d) $IS=IR_f x S_a(DF_a x SBR_a)$
Bald eagle[g]	0.12	0	0.53	0	0.0009	0	0.0194	0	0.003	0.0	0.0057	0	0	0.53	0.000005	0.0000003
Red-tailed hawk[h]	0.105	0	0.53	0	0.0009	0.024	0.0194	0.26	0.003	0.46	0.0057	0	0	0.26	0.000005	0.0004
Burrowing owl[i]	0.092	0.26	0.53	0	0.0009	0.31	0.0194	0	0.003	0.22	0.0057	0.21	0	0.00	0.000005	0.0133
Western meadowlark[j]	0.028	0.55	0.53	0	0.0009	0	0.0194	0	0.003	0	0.0057	0	0	0.00	0.000005	0.0082
Great blue heron	0.18	0	0.53	0	0.0009	0	0.0194	0	0.003	0.005	0.0057	0.04	0	0.005	0.000005	0.000005
Mink[k]	0.14	0	0.53	0	0.0009	0	0.0194	0	0.003	0.06	0.0057	0.05	0	0.06	0.000005	0.000044
Coyote[l]	0.047	0	0.53	0.52	0.0009	0	0.0194	0.21	0.003	0.21	0.0057	0	0	0.04	0.000005	0.00011

IR_f = Food Ingestion Rate; values taken from receptor parameter profiles
DF = Dietary fraction
SBR = Soil-to-Body weight ratio (see Table 8-3)
BW = body weight
IS = Indirect soil ingestion rate (kg/kgbw/d)

[a]Earthworm SBR values derived from soil concentrations and acid-insoluble residue data for earthworms (Stafford and McGrath 1986)
[b]Pronghorn includes deer and other ungulates
[c]Black-tailed jackrabbit include lagomorphs
[d]Great Basin pocket mouse includes mole, squirrel, porcupine, pocket gopher, deer mouse, and rat
[e]Bullfrog includes all herpetofauna; SBR assumed to be zero
[f]Mallard includes all birds
[g] Food ingestion rate and diets from EPA (1993b); values for the bald eagle (EPA 1993b); Washington, River; all birds assumed to be mallards
[h] Food ingestion rate and diets from EPA (1993b); summer, Alberta, Canada, farm and woodlands,
[i]Values for dietary fractions are values for the American Kestrel (EPA 1993b); California/hayfields, pasture plus; 0.925% added to each dietary fraction per prey represented
[j]Values for dietary fractions for the American Robin (EPA 1993b); Western United States % volume; stomach contents, average of all seasons; remainder dietary fraction 0.44 is fruit. We assume fruit SBR = 0
[k]Food ingestion rate and diets from EPA (1993b) pg 2-253; average all seasons; Michigan/stream, river year-round
[l]Food Ingestion Rate for Adults (Gier 1975 in Higley and Kuperman 1996), dietary fraction Table 1 in MacCracken (1984) Foods in the Black Hills, South Dakota (*J. Wildl. Manage.*48)
Herbivorous receptors such as mule deer and Canada goose are absent from table
Diets for bald eagle, great blue heron, and mink are exclusive of fish, therefore; we assume fish SBR = 0

Table 8-5 Toxicity Equivalence Factors for Chlorinated Dioxins, Chlorinated Dibenzofurans, and PCBs[a]

	Receptor		
Congener	**Mammals**	**Birds**	**Fish**
Dioxins[b]			
2,3,7,8-TCDD	1.0	1.0	1.0
1,2,3,7,8-PeCDD	1.0	1.0	1.0
1,2,3,4,7,8-HxCDD	0.1	0.05	0.5
1,2,3,6,7,8-HxCDD	0.1	0.01	0.01
1,2,3,7,8,9-HxCDD	0.1	0.1	0.01
1,2,3,4,6,7,8-HpCDD	0.01	<0.001	0.001
OCDD	0.0001	NA	NA
Dibenzofurans[c]			
2,3,7,8-TCDF	0.1	1.0	0.05
1,2,3,7,8-PeCDF	0.05	0.1	0.05
2,3,4,7,8-PeCDF	0.5	1.0	0.5
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01
OCDD	0.0001	0.0001	0.0001
PCBs[d]			
3,4,4',5-TCB	0.0001	0.1	0.0005
3,3',4,4'-TCB	0.0001	0.05	0.0001
3,3',4,4',5-PeCB	0.1	0.1	0.005
3,3',4,4',5,5'-HxCB	0.01	0.001	0.00005
2,3,3',4,4'-PeCB	0.0001	0.0001	<0.000005
2,3,4,4',5-PeCB	0.0005	0.0001	<0.000005
2,3',4,4',5-PeCB	0.0001	0.00001	<0.000005
2',3,4,4',5-PeCB	0.0001	0.00001	<0.000005
2,3,3',4,4',5-HxCB	0.0005	0.0001	<0.000005
2,3',4,4',5,5'-HxCB	0.00001	0.00001	<0.000005
2,3,3',4,4',5,5'-HpCB	0.0001	0.00001	<0.000005
2,2',3,3',4,4',5'-HpCB	NA	NA	NA
2,2',3,4,4',5,5'-HpCB	NA	NA	NA

T = tetra, Pe = penta, Hx = hexa, Hp = hepta, O = octa, NA = not available
[a] Values from WHO 1997
[b] CDD = chlorinated dibenzodioxin
[c] CDF = chlorinated dibenzofuran
[d] CB = chlorinated biphenyl

9. Risk-Based Emissions Criteria

Risk-based emission criteria will be developed, as needed, for protection of human and ecological resources. This will be done in the PRA and updated in the FRA. Risk-based emission criteria will be developed for plausible scenarios.

9.1. Human Health Risk-Based Emission Levels

During the PRA, any COPCs, which do not meet the target risk goals, will be evaluated further to determine the driving factors behind the risk and the potential uncertainty associated with them. Risk-based emission limits will be calculated for any COPC which exceeds risk goals in the PRA and these compounds will be further evaluated in the FRA. For example, additional site-specific information will be available for the FRA. Risk goals that are exceeded will be addressed to the satisfaction of Ecology and EPA prior to approval of the FRA.

Risk-based emission levels will be calculated using the same exposure scenarios, pathways, toxicity values, and equations used to calculate plausible risk estimates. The risk equations will be used to back-calculate acceptable COPC concentrations in various media based on the following risk goals: for carcinogens a target incremental lifetime cancer risk level of 1×10^{-5} and for noncarcinogens with a HQ of 0.25. Air dispersion modeling results will then be used to convert these media concentrations to risk-based emission limits.

9.2. Ecological Receptor-based Emissions Levels

During the PRA, chemicals with ecological HQs greater than 0.25 for a given receptor will need development of a risk-based emission level. This emission level will be developed by setting the HQ to 0.25 and back-calculating through the same TRVs and exposure values in the food web, and the same dispersion modeling to the stack emission for plausible scenarios. The result will be risk-based emissions for protection of ecological resources.

Chapter 10

10. Summary

A master summary will be provided in the SLRA that will capture the major points in each of the following areas:

- The SLRA approach, which includes identification of source COPCs
- The melter process, and quantification of chemical and radiological emissions
- Organization of environmental modeling to meet environmental requirements and to secure the dangerous waste permit from the State of Washington
- PRA and FRA human health risk assessment
- PRA and FRA ecological risk assessment
- Uncertainties
- Development of receptor-based emission levels

Chapter 11

11. References

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